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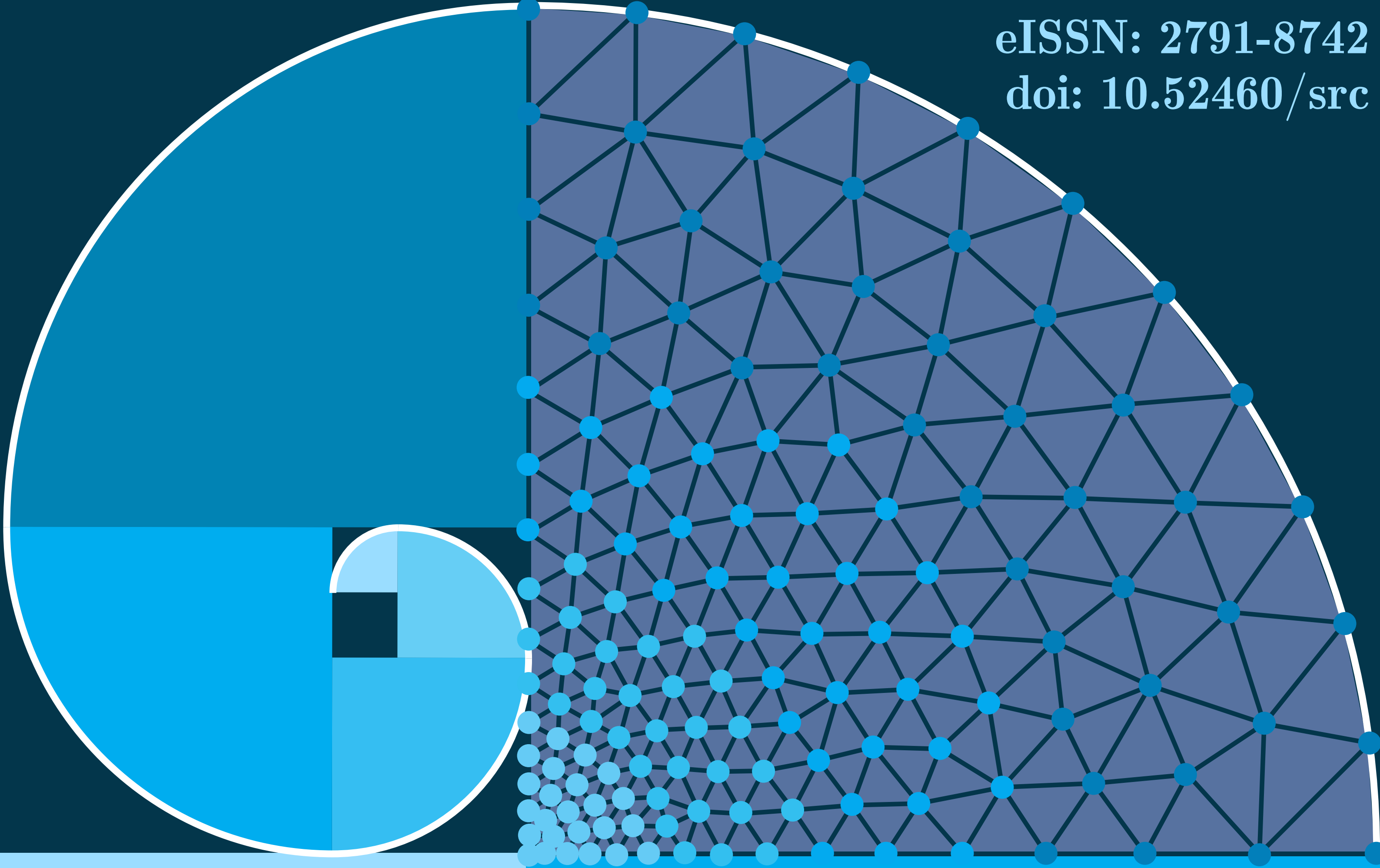

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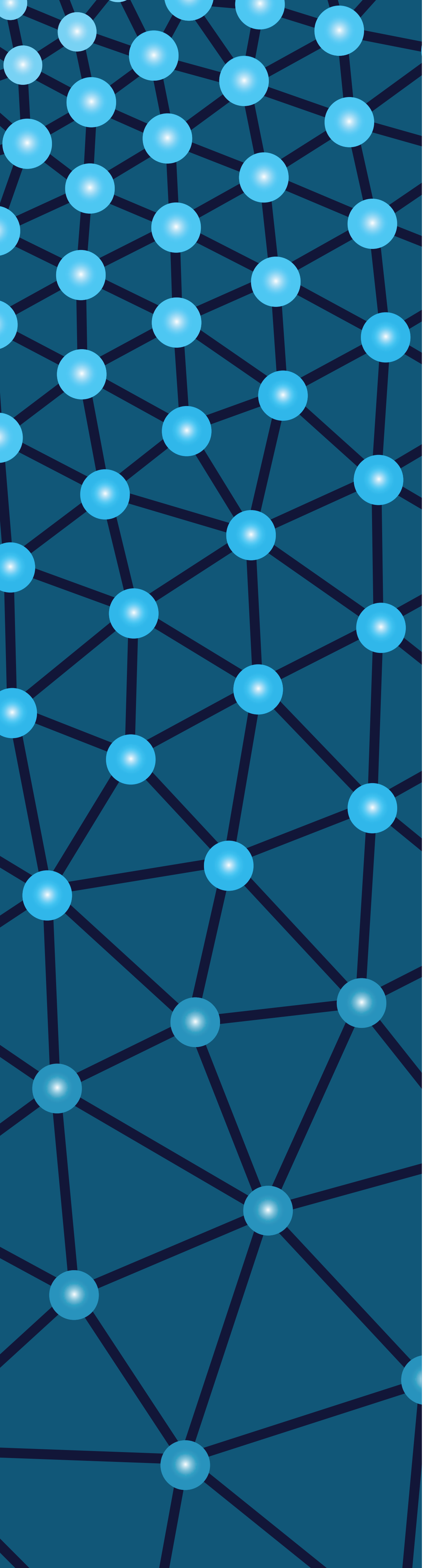

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Monthly Change of Some Climate Parameters and Biocomfort Status in Ordu Province

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Abstract

Biocomfort, which is shaped depending on the suitability of climate parameters, is an important criterion that affects people's comfort, peace, happiness and performance, as well as their health. Therefore, determining suitable areas in terms of biocomfort and using them as a base in the planning of residential areas is of great importance in terms of both human health and happiness and energy efficiency. In this study, suitable areas in terms of wind, temperature, relative humidity and biocomfort, which shape the biocomfort situation in Ordu, which is one of the largest cities in Turkey and whose population is constantly increasing, were determined on a monthly basis. As a result of the study, it has been determined that the wind speed, temperature and relative humidity parameters that are the subject of the study prevent the formation of biocomfort areas to a large extent. While the wind speed causes the formation of uncomfortable areas in January, February, March, April, October, November and December, there are areas where the temperature is below 15 °C in many months, and high humidity causes the formation of uncomfortable areas every month. Suitable areas in terms of biocomfort account for 0.4% of the surface area of Ordu in May, 1.36% in June, 1.45% in July, 1.77% in August, and 8.06% in September. In January, February, March, April, November and December, the entire province is within the scope of uncomfortable areas.

Keywords: Army; climate; biocomfort

1. Introduction

"Climate", which affects and shapes almost the whole life of people, is briefly defined as "average weather conditions in a large region, which remains the same over a long period of time" (Zeren Çetin and Şevik, 2020). Climate affects human life directly or indirectly in many different ways (Doğan et al., 2022). Because humans are warm-blooded creatures and they have to keep their body temperature within a certain range regardless of the ambient temperature (Dündar, 2015). The human body, which is a homeothermic creature, needs to be kept at an almost constant temperature in order to maintain its vital functions. This balance is mostly provided by clothes and buildings and air conditioning systems that minimize the effects of the external environment (Aker, 2016).

The suitability of the climatic conditions in the environment is called biocomfort or bioclimatic comfort in short (Adıgüzel et al., 2020). Biocomfort is also defined as the conditions in which a person can adapt to his environment by spending the least amount of energy, that is, the most appropriate value ranges in terms of body temperature (Çetin et al., 2010; Tağıl and Ersayın, 2015; Cantürk and Kulaç, 2021; Koç, 2022a; Koç, 2022b; Değerli and Çetin 2022a; Değerli and Çetin 2022b; Çevik Değerli and Çetin, 2023). Providing thermal comfort conditions in which people can feel comfortable, first of all, people can work efficiently, peace of mind and comfort with health (Kılıçoğlu et al., 2021; Zeren Çetin et al., 2023a; Zeren Çetin et al., 2023b).

Biocomfort also has a great impact and importance on energy consumption. While the building sector constitutes one third of the total energy consumption, a large part of this consumption is consumed by the heating, cooling and ventilation systems in the building (Aker, 2016). Therefore, climatic conditions have a great impact on energy consumption. It is estimated that worldwide energy consumption will increase by approximately 60% by 2030. This situation will cause the pressure on limited natural resources to increase even more (Bulut, 2018; Elhadar, 2020).

The increase in energy demand increases the use of natural resources and fossil fuels, and the increased use of fossil fuels brings with it many problems such as the increase in greenhouse effect, global climate change, and increase in air pollution (Şevik et al., 2019; Yayla et al., 2022; Kuzmina et al., 2023). Studies show that the highest level of air pollution in urban centers is reached during the winter months when the need for heating is at its highest (Elsunousi et al., 2021).

As a result, biocomfort is of great importance both in terms of people's comfort, peace, comfort and health, and in terms of energy efficiency, and therefore, urban settlements should be established in areas suitable for biocomfort. In this study, suitable areas in terms of biocomfort in Ordu, which is one of the biggest cities of Turkey and whose population is constantly increasing, were determined on a monthly basis.

2. Methodology

The study was carried out in Ordu, one of the largest cities in Turkey. Ordu province is located in the Eastern Black Sea Region in Turkey. To the north is the Black Sea. According to Greenwich, the city center is located between the 37° and 38° east meridians and the 41° north parallel. (URL-1, 2022).

Within the scope of the study, it is aimed to determine and compare some climatic parameters and bioclimatic comfort areas in Ordu province based on monthly and annual average data. For this purpose, wind speed, humidity and temperature data obtained from the meteorology station were processed on Arc GIS 10.5 software. Then, using the "Inverse Distance Weighted (IDW)" command in Arc map 10.5 software, climate maps were created with the Interpolation method.

Inverse Distance Weighted (IDW) technique is one of the most preferred techniques among interpolation and map generation methods. It is an interpolation technique used to determine the cell values of unsampled points with the help of the values of known sample points. The cell value is calculated by considering various points moving away from the relevant cell and depending on the increase in the distance. The predicted values are a function of the distance and size of the neighboring points, and as the distance increases, the importance and effect on the cell to be estimated decreases. The formula used in the calculations is given in Eq. (1) (Taylan and Damçayırı, 2016; Çetin et al., 2018; Çetin et al., 2023a; Çetin et al., 2023b).

$$z(x_0) = \frac{\sum_{i=1}^{n} z\,(x_i)\, d_{i0}^{-r}}{\sum_{i=1}^{n} d_{i0}^{-r}} \tag{1}$$

The location X_0 from which the estimations are made is a function of neighbor measurements n (z(X_{0i}) and i=1, 2, …, n); r is the exponent determining the assigned range of each of the observations, and d is the distance separating the observation location X_i from the prediction location X_0. The larger the exponent, the smaller the assigned weight of observations far from the forecast location. Increasing the exponent indicates that the estimates are very similar to the closest observations. The mathematical formulas were as described above, and the maps were produced in the ArcGIS environment, which is a GIS software. This method has been used in different studies before (Setianto et al., 2013; Qu et al., 2019; Golla et al., 2019).

Then, the climate maps were reclassified by using the Reclassify command in Arc map 10.5 software of the obtained climate maps for the production of the biocore map. Comfortable areas were determined by using the index formula on the classified climate maps obtained. As a biocomfort index, Çetin et al. (2020) is based on the index used. According to this index, a region is considered comfortable if the temperature is between 15-27 °C, the relative humidity is between 30-70% and the wind speed is below 5 m/s (Çetin et al., 2020).

Within the scope of the study, firstly topographic maps were created for Ordu and the land elevation classes map, aspect map and slope map of the province were created. These maps are intended to be used when interpreting climate data and biocomfort maps. Then, the wind speed map, humidity map, temperature map and precipitation map were created for the province in general and the appropriate areas in terms of biocomfort were determined using climate data and interpreted by transferring them to maps.

3. Results

Within the scope of the study, some climate data for Ordu and the biocomfort status depending on these data were evaluated on a monthly basis, and some topographic features were also determined in order to contribute to the interpretation of the change in climate data and biocomfort status. In this context, the land elevation classes map for Ordu is given in Figure 1.

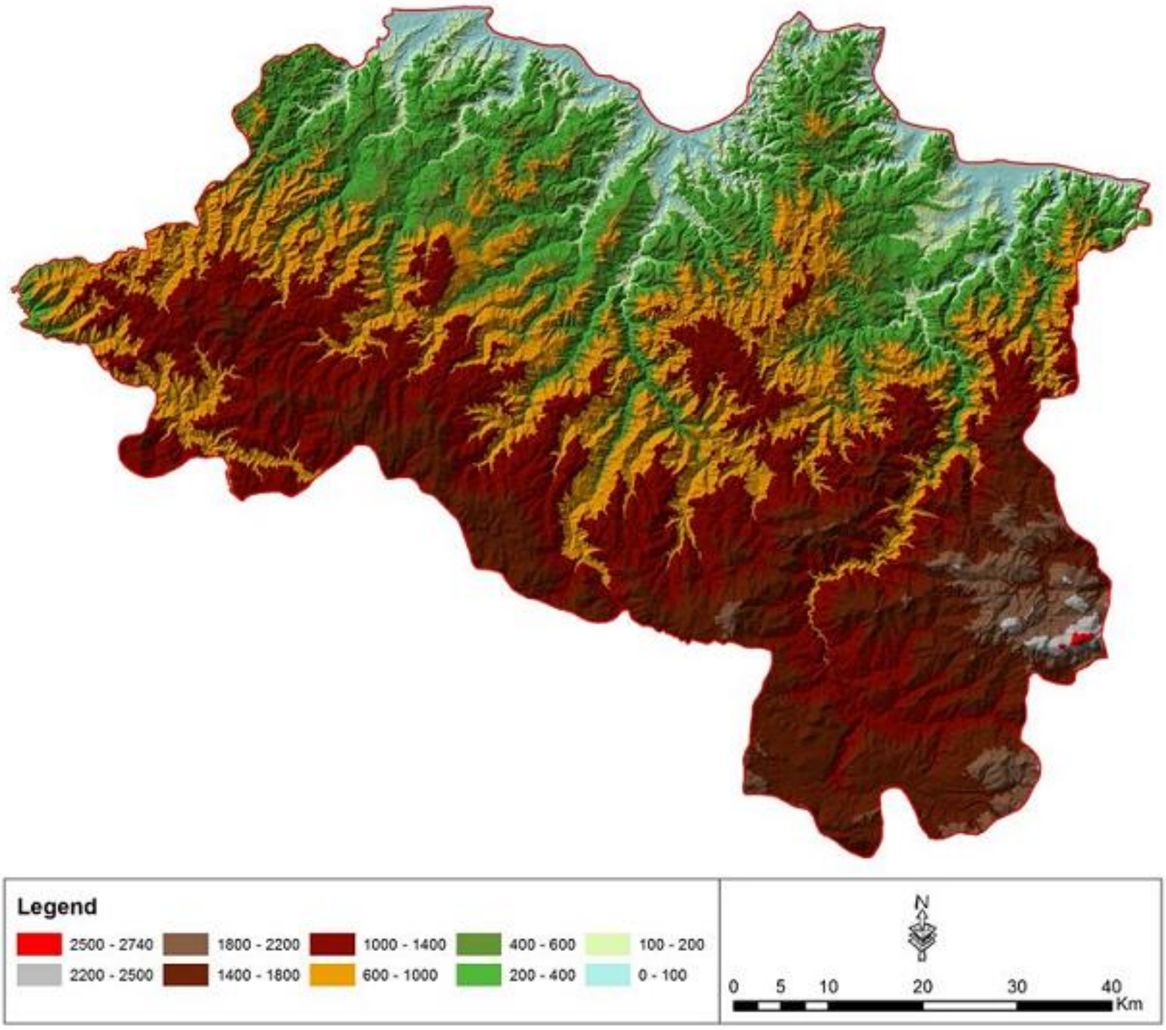

Figure 1. Ordu land elevation classes map

When the Ordu elevation classes map is examined, it is seen that the elevation of the southeastern parts of the province is quite high, and the elevation generally increases from the north to the south of the province. As you move away from the Black Sea in the north of the province, the altitude increases rapidly and reaches 1400 m above sea level, and even over 2500 m in the southeast of the province.

According to the calculations, approximately 4.16% of Ordu province is below 100 m, 5.38% of it has an altitude of 100-200 m, while 3.37% is at 1800-2200 m and 0.45% is at 2200 m. Apart from this, approximately 12,47% of the provincial area is 200-400 m, 11.82% is 400-600 m, 21.98% is 600-1000 m, 24.46% is 1000-1400 m and % 15.91 of them consist of areas with an altitude of 1400-1800 m.

As a result of the evaluations based on long-term meteorological data for Ordu, the wind speed, precipitation, temperature and humidity maps were prepared on a monthly basis and the monthly variation map of the wind speed is given in Figure 2.

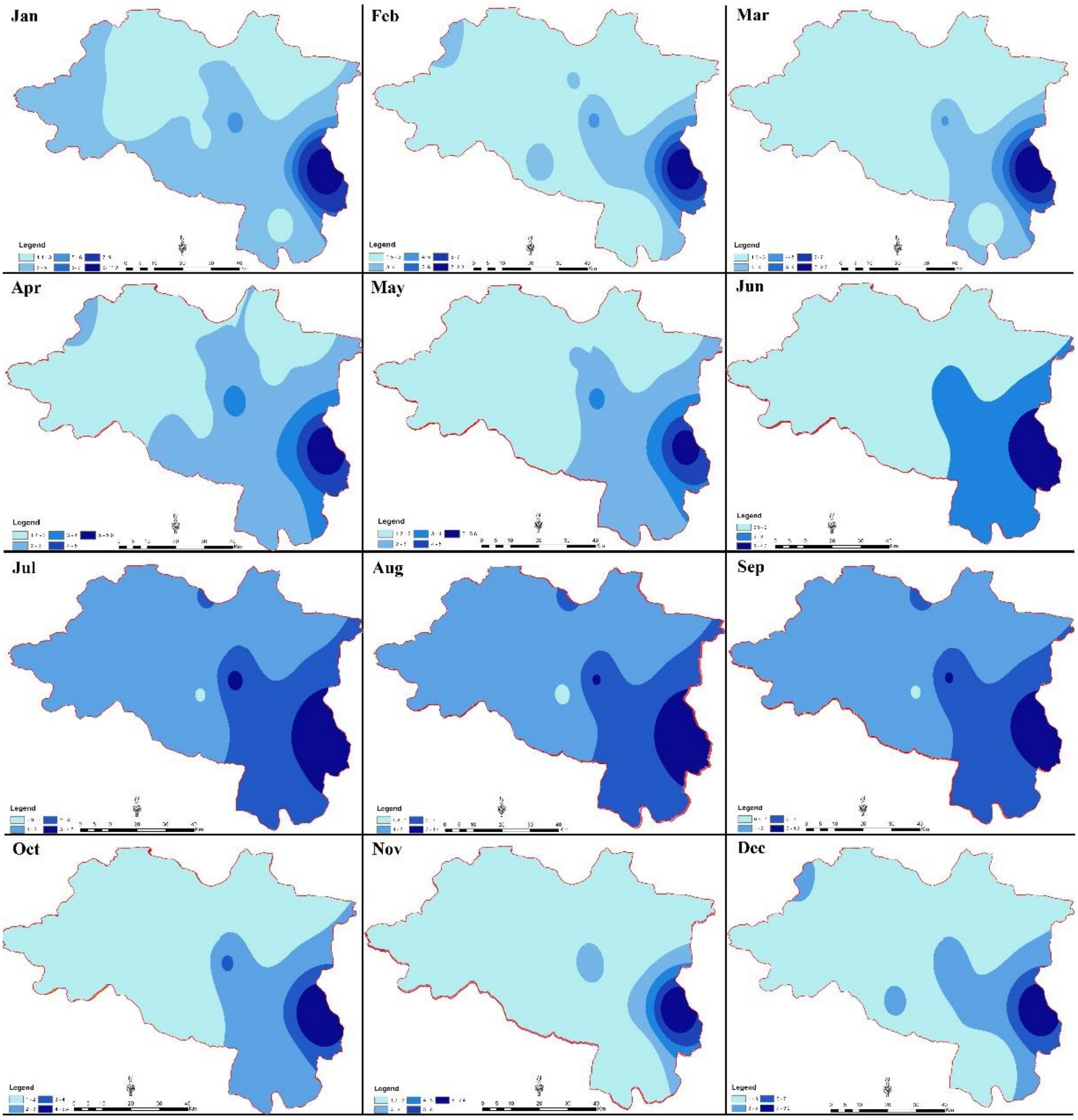

Figure 2. Ordu monthly wind speed map

When the Ordu wind speed map is examined, it is seen that the areas with the highest average wind speed are the southeast part of the province and the wind speed in this section exceeds 5 m/sec especially in winter and creates areas that are not suitable for comfort. The monthly humidity change map across Ordu is given in Figure 3.

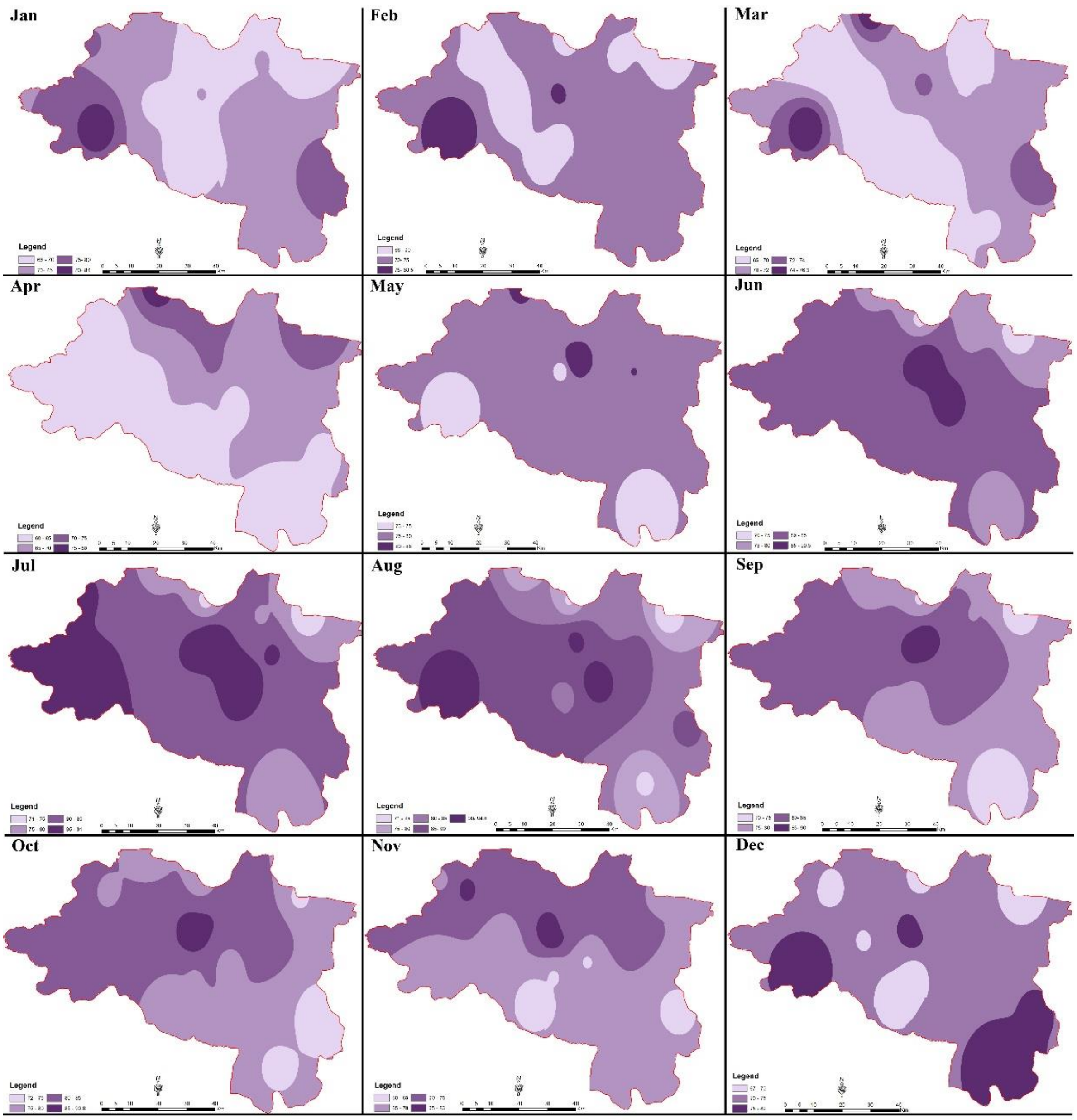

Figure 3. Ordu monthly humidity map

As seen in the monthly humidity change map of Ordu, the humidity rate throughout the province of Ordu is at a level that will cause the formation of uncomfortable areas to a large extent. The humidity rate, which is over 60% throughout most of the year, exceeds 90% in the summer months. Ordu monthly temperature change map is given in Figure 4.

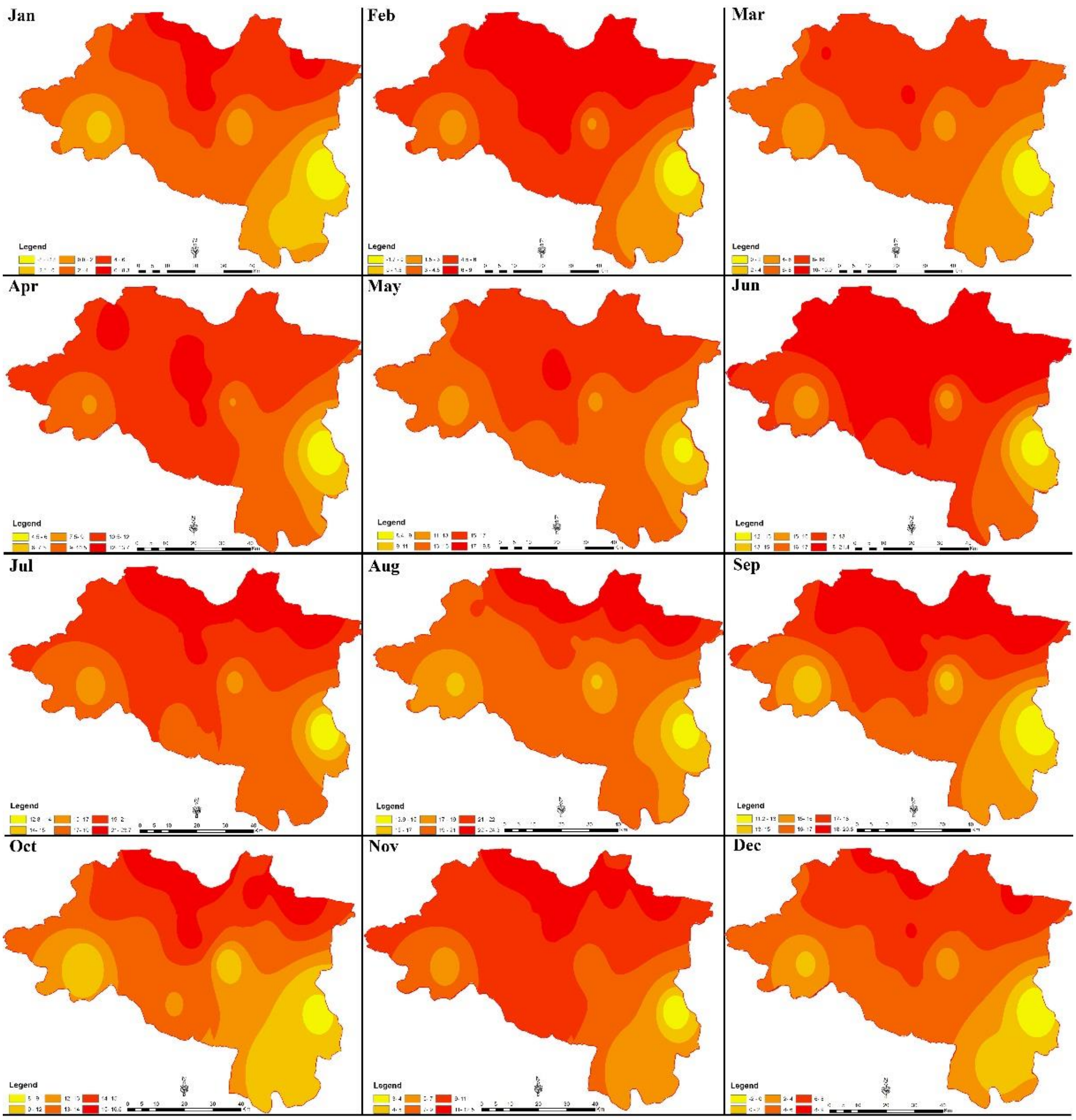

Figure 4. Ordu monthly temperature map

When the map is examined, it is seen that the areas with the highest temperature in Ordu are in the north of the province, and the average temperature values in the southeast and southwest of the province are quite low. The temperature, which goes up to 25 C in summer, drops down to -5 degrees in winter, causing uncomfortable areas to form. Based on the climate data in Ordu, suitable and unsuitable areas in terms of biocomfort were determined and according to the calculations, suitable areas in terms of biocomfort are given in Figure 5 on a monthly basis.

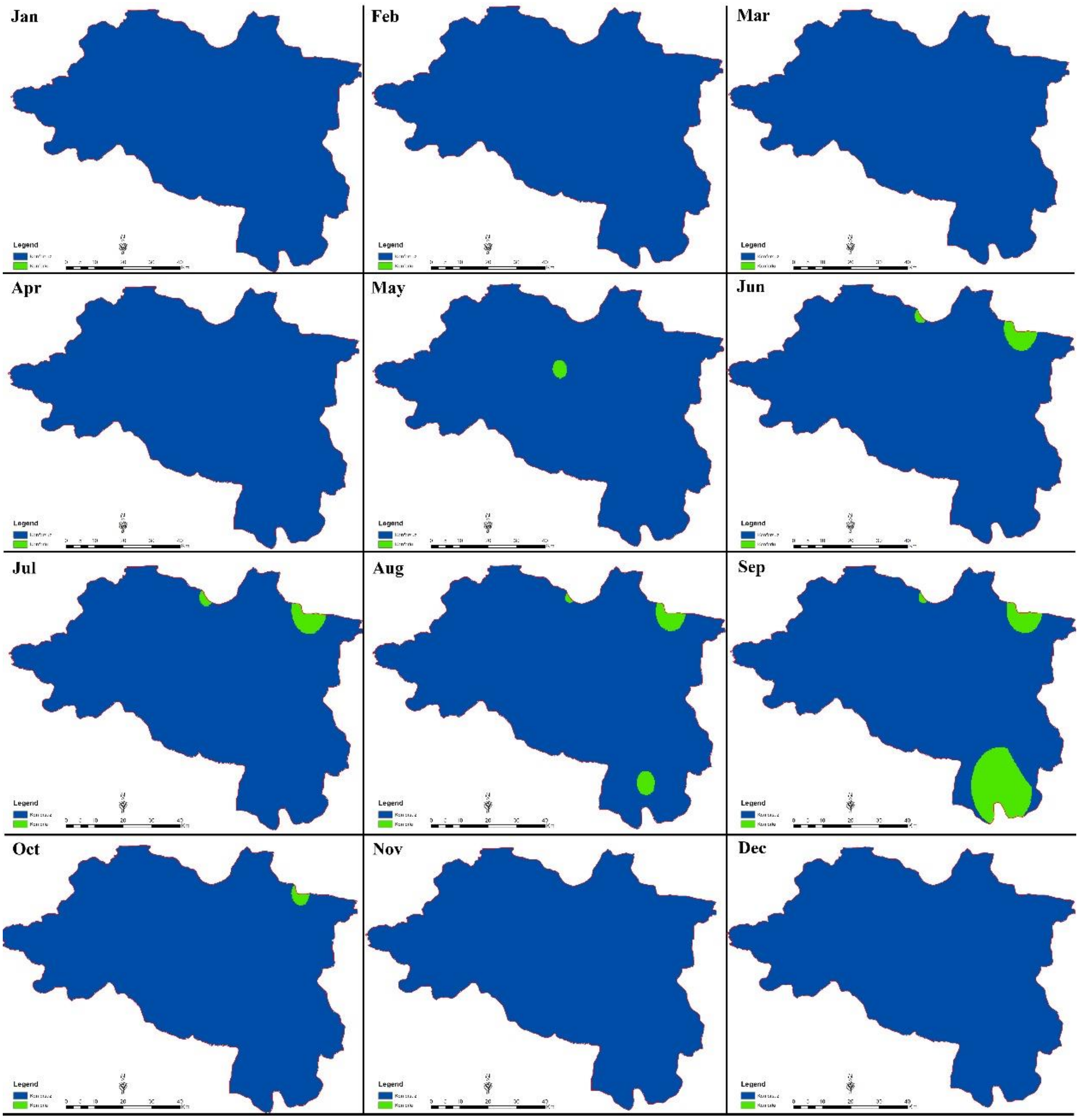

Figure 5. Ordu monthly biocomfort map

When the monthly biocomfort map of Ordu is examined, it is seen that the entire province is within the scope of uncomfortable areas in January, February, March, April, November and December. In other months, areas suitable for comfort cover a very small part of the province. It was determined that the area with the highest percentage of comfort occurred in September, but even in this month, it was calculated that the areas suitable for biocomfort cover only 8.06% of the province's surface area. In terms of biocomfort, suitable areas account for 0.4% of the surface area of Ordu in May, 1.36% in June, 1.45% in July, 1.77% in August, 8.06% in September and 0.37% in October.

4. Discussions

In Ordu, which was evaluated within the scope of the study, it can be said that all three parameters that are the subject of the study prevent the formation of biocomfort areas to a large extent. For example, in January, the wind speed reaches up to 11.2 m/s, the humidity is more than 70% in about 68% of the province, and the temperature rises to a maximum of

8.3 °C. While the wind in Ordu causes uncomfortable areas in January, February, March, April, October, November and December, there are areas where the temperature is below 15 °C in many months, and high humidity causes the formation of uncomfortable areas every month. Especially, high humidity stands out as the factor that most affects the formation of comfort areas, and it was determined that the humidity rate increased up to 94.6% in August.

Biocomfort is one of the issues that has come to the fore especially in recent years and has been studied extensively. One of the main reasons for this is people's desire for more comfort in the modern world. Humans are warm-blooded creatures and therefore they are significantly affected by external environmental conditions. If the outdoor conditions are not within certain ranges, that is, outside the comfort ranges, people feel uncomfortable in that environment and want to leave (Çetin et al., 2018; Yücedağ et al., 2021; Arıcak, 2020).

Many of the external factors that affect people's comfort; While factors such as noise, smell, and light are perceived by the five senses, there are also air pollution components such as the amount of CO_2, particulate matter, volatile organic compounds, and heavy metals that cannot be easily perceived by the five senses (Cesur et al., 2021; Sulhan et al., 2022). Some of these factors may pose a threat to human health when they exceed certain limits (Işınkaralar et al., 2022).

However, one of the most important conditions affecting the comfort of people is temperature and humidity. Ensuring the continuity of human life is possible, especially if the temperature is within certain intervals. If the temperature values are outside of human needs, people need clothes, heating or cooling equipment, etc. and temperature values within certain ranges (Kaya et al., 2019; Güngör et al., 2020; Ertuğrul et al., 2021). However, bringing the climatic conditions in the outdoor environment to the appropriate value ranges causes a significant amount of energy consumption. It is stated that around 40% of fossil resources worldwide are used to meet heating, cooling or lighting needs in buildings. Therefore, it is of great importance for people to establish their residential areas in areas with suitable value ranges in terms of comfort, in terms of reducing energy consumption and therefore the pressure on the natural resources of the world (Elahsadi, 2020).

Climate is a factor that affects not only humans but all living things. Survival of living things is possible if various external conditions are in suitable value ranges. The most effective factors in the development and spread of living things on the earth are especially climatic and edaphic factors (Ertuğrul et al., 2019; Kravkaz Kuşçu et al., 2018a; Erdem et al., 2023; Kravkaz Kuşçu et al., 2018b). Climatic factors significantly affect the morphological, anatomical and phenological characters of living things (Şevik et al., 2021; Yiğit et al., 2021).

As a result, the climate; It is a factor that affects people's health, happiness, psychology, life style, in short, their whole life, but also affects almost everything from the habitats of other living creatures to their morphological, anatomical and physiological characteristics (Varol et al., 2022a; Tekin et al., 2022; Özel et al., 2022). Since there are quite different climate types in our country, it is normal for the biocomfort situation to differ in areas where these climate types prevail.

Especially in recent years, climatic conditions have started to be one of the important factors in choosing the region where people will live. Therefore, studies on biocomfort have started to be among the criteria evaluated especially in the planning of residential areas (Kılıçoğlu et al., 2020; Doğan et al., 2022; Zeren Çetin et al., 2023a; Zeren Çetin et al., 2023b).

Another factor affecting the change of climatic parameters is climate change, which is effective on a global scale. While the world population was only around 717 million in the 1750s, it is estimated to exceed 7.7 billion in 2020 and to reach 8.5 billion in 2030 (Elsunousi et al., 2021).

Population growth around the world has brought along many problems. One of the most important of these problems is environmental pollution. The process has caused soil (Çetin et al., 2022a, Çetin et al., 2022b; Zeren Çetin et al., 2023a; Zeren Çetin et al., 2023b), water (Ucun Özel et al., 2020) and air (Key et al., 2022; Çobanoğlu et al., 2023) pollution. Industrial activities carried out in order to meet the demands and needs of the increasing world population have caused significant human-induced destruction in the ecosystem, the release of elements and fossil fuels used as raw materials in the industry from underground and released into the atmosphere, and the concentration of many pollution sources, especially CO_2, in the atmosphere (Varol et al., 2022b; Ghoma et al., 2022).

5. Conclusions

In addition to industrial activities, efforts to meet the shelter and food needs of the increasing world population have put a significant pressure on forest areas. Human activities such as deforestation, the use of fossil fuels, and agricultural activities, especially with the industrial revolution, have caused a significant increase in the emissions of natural greenhouse gases such as methane (CH_4), carbon dioxide (CO_2), nitrous oxide (N_2O). This increase in greenhouse gas emissions in the atmosphere has caused and continues to cause the deterioration of the natural greenhouse effect and warming of the atmosphere. The potential effect of this warming is climate change. It is certain that these changes that may occur in climate parameters as a result of global climate change will significantly change the comfort zones. However, few studies have been conducted on this subject. It is recommended that studies be continued by diversifying and expanding both to determine biocomfort areas and to determine how biocomfort areas will change with the effects of global climate change.

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Author Statement

The authors confirm contribution to the paper as follows: study conception and design: Osama, Mehmet; data collection: Mehmet; analysis and interpretation of results: Osama and Mehmet; draft manuscript preparation: Osama. All authors reviewed the results and approved the final version of the manuscript.

Conflict of Interest

The authors declare no conflict of interest.

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Determination of Boron for Indoor Architecture Plants Used in Indoor Architectural Designs

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Abstract

Air pollution has become a global problem that affects the health of millions of people every year. Among the air pollutants, heavy metals are particularly infamous as they tend to bioaccumulate, can be toxic to human health even at low concentrations, and that even those that are necessary for living things as nutrients can be harmful at high concentrations. Boron (B), a microelement, is both extremely dangerous and important for human health, as it can cause toxic effects when used more or less. As with other heavy metals, the ingestion of B through the respiratory tract is extremely harmful to health. It is very important to monitor the change of B concentration in the air and reduce the pollution level. In order to contribute to the studies in this field, the change of B concentrations in some indoor plants grown in controlled, smoking and traffic environments was determined within the scope of this study. The results of the study showed that camel sole, diphenbahya, drasena, chiefera and yukka species are quite suitable for monitoring the change of B concentrations in the air. It has been determined that the most suitable species that can be used to reduce B pollution in the air are rubber and spatiphyllium.

Keywords: Bor; B; heavy metal; cigarette; traffic

1. Introduction

Today, environmental pollution has reached extents that threaten human health (Çetin et al. 2023; Savaş et al., 2021; Yücedağ et al., 2019). The gradual increase in populations living in urban centers, especially in developing countries, has brought along many problems in urban areas (Çetin et al., 2018a; Çetin et al., 2018b; Zeren Çetin and Şevik, 2020; Yücedağ et al., 2021). Studies conducted in urban areas include air (Çetin et al., 2019; Türkyılmaz et al., 2019; Türkyilmaz et al., 2020; Varol et al. 2022a; Varol et al. 2022b), water (Ucun Özel et al., 2019) and soil (Çetin et al., 2022a) show that the pollution is at higher levels.

The modern age has also significantly changed people's lifestyles, about 90% of people's lives are spent indoors (Çetin and Çobanoğlu, 2019; Çetin et al., 2017a; Çetin et al., 2017b; Çetin, 2019; Varol et al., 2021a, Varol et al., 2021b). According to the United States Environmental Protection Agency (EPA), indoor air is up to 100 times more polluted than outdoor air and, unlike atmospheric pollution, indoor pollutants are approximately 1000 times more likely to infect the lungs (Jo et al., 2020). Therefore, studies on indoor pollution sources and pollutants are of great importance.

Heavy metals are at the forefront of air pollution factors that pose the greatest threat to human health, both indoors and outdoors (Zeren Çetin 2022; Akarsu et al. 2019; Zeren et al 2017; Elsunousi et al., 2021). Boron, an infamous heavy metal, enters the human body through the respiratory and digestive tracts or mucous membranes and accumulates mostly in the bones. Nausea, severe vomiting, abdominal pain and diarrhea manifest the effect of boric acid and borax in humans. It can also cause osteoporosis, heart disease, stroke, diabetes and aging (Nielsen and Stoecher, 2009). B is fatal in the range of 5-6 g for children and 10-25 g for adults (Baykut et al., 1987). Therefore, since Boron, like other heavy metals, is very harmful to health, it is very important to monitor the change of B concentration in the air and reduce the pollution level. For this purpose, it is aimed to determine the change of B concentration in some indoor plants grown in different environments, based on the habitat and plant species.

2. Methodology

The types that are the subject of the study are selected from the regions designed in the interior. It is used to give direction to the design. The interior design proposal drawings of the types used are as shown in the Figure 1.

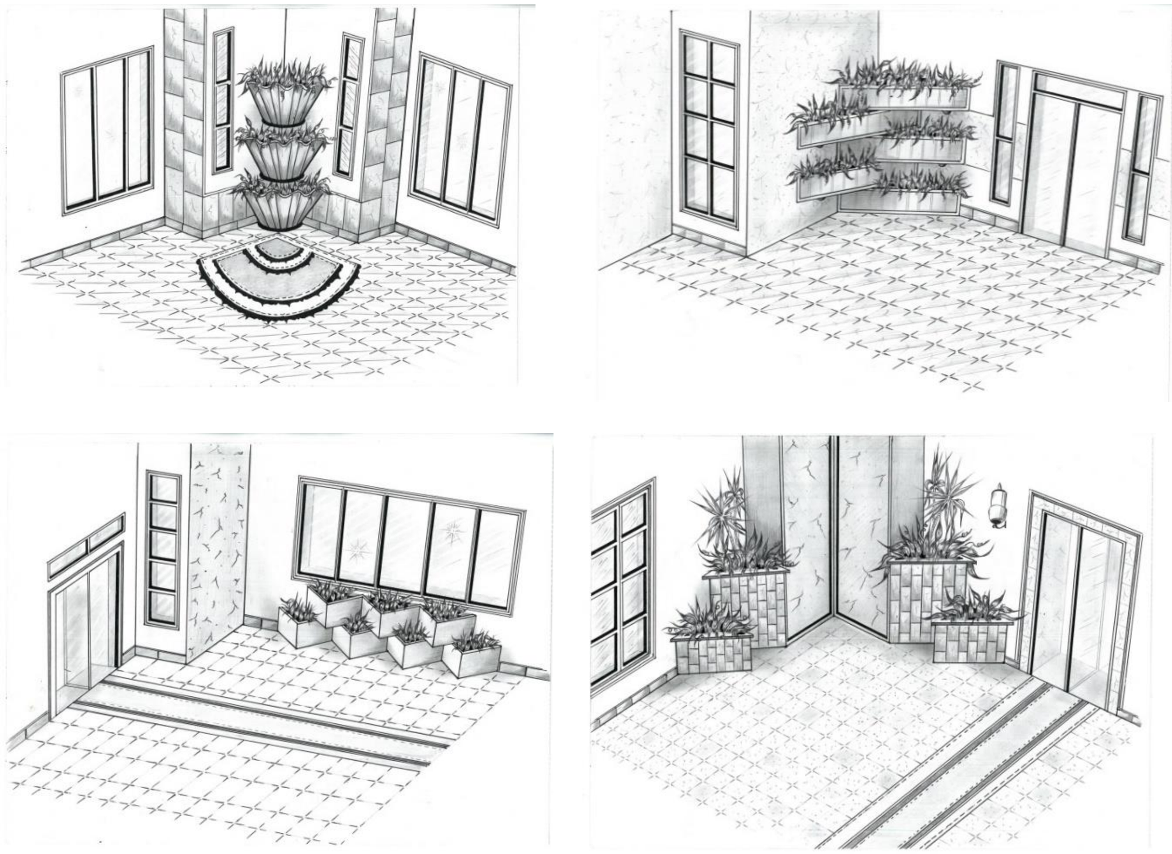

Figure 1. Showing of indoor plants used in architectural designs as materials

The collected samples were labeled, brought to the laboratory and separated into organs in the laboratory. Afterwards, the samples were labeled, laid out on cardboard plates and left to dry.

Branch and fruit samples were crushed and left to dry in glass petri dishes so that they could dry more easily. The samples, which were aerated by mixing at least once a week for about two months in the laboratory, were air-dried, then taken into cardboard cups and dried in an oven at 50 °C for one month. The dried samples were bagged and labeled in an airtight manner so that they would not be affected by air humidity and sent to the laboratory for analysis.

In the next step, the plant samples were ground into powder and 0.5 g was weighed and put into tubes designed for microwave. 10 mL of 65% HNO_3 was added to the samples. During these processes, it was worked in the fume hood.

The obtained data were evaluated with the help of the SPSS package program, variance analysis was applied to the data, and homogeneous groups were obtained by applying the Duncan test to the values with statistically differences at least 95% confidence level. The data obtained were simplified and interpreted by tabulating.

3. Results

The average concentration values, the F value obtained as a result of the analysis of variance, the error rate and the groups formed as a result of the Duncan test by determining the variation of the B concentration evaluated within the scope of the study on the basis of species in plants grown in different environments are given in Table 1.

Table 1. Variation of B concentration (ppm) by species

Species	Environment			Average
	Control	Cigarette	Traffic	
DT	13.93 b	23.79 b	29.66 b	22.46 a
DB	24.12 c	41.82 d	52.13 d	39.36 a
DC	10.38 a	35.90 c	44.75 c	30.34 a
KC	177.43 f	94.44 f	117.73 f	129.86 c
SF	10.14 a	35.53 c	44.30 c	29.99 a
SP	58.08 e	80.98 e	100.95 e	80.00 b
YK	55.87 d	15.37 a	19.16 a	30.13 a
F Value	444437.7***	20053.7***	11161.5***	35.3***

When the variation of B concentration on the basis of species is examined according to the results of analysis of variance, it is seen that the variation of B concentration on the basis of species in all environments is statistically significant at the 99.9% confidence level. When the groups formed as a result of the Duncan test are examined, it is noteworthy that each species is included in only one group in all environments.

In the controlled environment, the species formed six groups as a result of the Duncan test, DC (10.38 ppm) and SF (10.14 ppm) with the lowest values formed the first group, while each of the other species was in a separate group. After DC and SF, DT (13.93 ppm) with the lowest values formed the second group, DB (24.12 ppm) third group and YK (55.87 ppm) fourth group. KC (177.43 ppm) and SP (58.08 ppm), where the highest values were obtained, formed the last two groups.

When the mean values in smoking environments and the groups with Duncan's test are examined, it is seen that the lowest value was obtained in QC with 15.37 ppm, and the highest value was obtained in the liver with 94.44 ppm. WC (15.37 ppm) and DT (23.79 ppm) with the lowest values formed the first two groups, while DC (35.90 ppm) and SF (35.53 ppm) formed the third group. KC (94.44 ppm), SP (80.98 ppm) and DB (41.82 ppm), where the highest values were obtained, formed a separate group.

In the traffic environment, as in the controlled and smoking environments, six groups were formed as a result of the Duncan test. WC (19.16 ppm) and DT (29.66 ppm) with the lowest values formed the first two groups, while DC (44.75 ppm) and SF (44.30 ppm) formed the third group. KC (117.73 ppm), SP (100.95 ppm) and DB (52.13 ppm), where the three highest values were obtained, formed the last three groups.

As a result of Duncan test, only three groups were formed in terms of mean values. While KC (129.86 ppm) with the highest values formed the last group, SP (80.00 ppm) formed the second group, while all other species were in the first group. While the average B concentrations of the species in the first group varied between 22.46 ppm (DT) and 39.36 ppm (DB), the value obtained in the second group was twice the value obtained in the first group, and the value obtained in the third group was three times the values obtained in the first group. It is noteworthy that more than the changes in the concentrations of element B in Table 2.

Table 2. Change of B concentration (ppm) by medium

Species	Environment			F Value
	Control	Cigarette	Traffic	
DT	13.93 a	23.79 b	29.66 c	2104.2***
DB	24.12 a	41.82 b	52.13 c	3704.0***
DC	10.38 a	35.90 b	44.75 c	9901.3***
KC	177.4 c	94.44 a	117.73 b	10924.1***
SF	10.14 a	35.53 b	44.30 c	9185.2***
SP	58.08 a	80.98 b	100.95 c	6384.7***
YK	55.87 c	15.37 a	19.16 b	39890.9***
Average	49.99 a	46.83 a	58.38 a	0.43 ns

When the results of the table showing the change in the concentration of element B on the basis of the environment are examined, it is seen that the change of the B concentration on the basis of the environment is statistically significant ($p<0.001$) at the 99.9% confidence level. In terms of average values, the change of B concentration on the basis of environment is not statistically significant ($p>0.05$).

When the mean values and the groups formed as a result of Duncan's test are examined, it is seen that there are three groups in all species. The lowest B concentrations were obtained in the control medium in species other than KC and YK, and in cigarette medium in KC and YK. In KC and YK species, the highest B concentrations were obtained in the control environment, while the highest B concentrations in all other species were obtained in the traffic environment. It was determined that B concentration changed as control<cigarette<traffic in species other than KC and YK species. According to the mean values, there is no statistically significant difference between the environments.

4. Discussions

As a result of the study, it was determined that the variation of B concentration on the basis of species, both in different habitats and according to the average values, in all species subject to the study changed statistically significantly. In studies carried out to date, it has been frequently emphasized that the most important factor affecting the change in heavy metal concentration is the plant species

It was determined that the change of B concentration on the basis of environment in all species was statistically significant. Heavy metal accumulation in plants varies considerably depending on environmental conditions. Because heavy metals can accumulate in the plant body by being absorbed by the root, through the air through the leaves and by entering the stem parts directly (Chen et al., 2021). Therefore, heavy metals in the air can enter the plant body both through the leaves and directly into the stem parts (Çetin et al., 2022a; Çetin et al., 2022b; Özel et al., 2021a; Özel et al., 2021b; Özel et al., 2021c; Özel et al., 2021d). As a result of the study, it was determined that the B concentration changed as control<cigarette<traffic in species other than KC and YK species. This shows that traffic is a very important source of B, and cigarettes can be a source of B. In studies conducted to date, both traffic (Çetin and Jawed, 2021) have been shown to be among the important sources of heavy metal pollution.

Biomonitors are important tools that can be used to monitor heavy metal pollution in the air, as well as to reduce heavy metal pollution in the air (Çetin et al., 2020; Şevik and Çetin, 2016; Cesur et al., 2021; Cesur et al., 2022; Çetin and Jawed, 2022; Türkyılmaz et al., 2020; Şevik et al., 2019a; Şevik et al., 2019b; Şevik et al., 2020a, Şevik et al., 2020b). Within the scope of this study, it was determined that the highest B accumulation was in KC and SP species in all species. Therefore, these two types can be used effectively to reduce B pollution in the air.

5. Conclusions

It was determined that camel sole, diphenbahya, drasena, chiefera and yukka species are quite suitable for monitoring the change of B concentration in the air. It has been determined that the most suitable species that can be used to reduce B pollution in the air are rubber and spatiphyllium. The variation of B concentration on the basis of species, both in different habitats and according to the average values, in all species subject to the study changed statistically significantly. In studies carried out to date, it has been frequently emphasized that the most important factor affecting the change in heavy metal concentration is the plant species. Biomonitors are important tools that can be used to reduce heavy metal pollution in the air. It was determined that the highest B accumulation was in KC and SP species in all species. Therefore, these two types can be used effectively to reduce B pollution in the air. The use of nutrient contents of the in areas, where different tree species are grown, at different levels might cause specific nutrients to be remarkably depleted in the course of time. Thus, alternation is recommended for architecture activities, as in the indoor architecture activities. The results of Boron show that the design of indoor for plant species selected is important.

It is seen that the plant species used as indoor plants in architectural designs should be paid attention to. In the designs made, the use of different species in the change of Boron concentration in some indoor plants that can be used in architectural designs depending on the growing environment, healthy design of the indoor environment has been made both in the design and in the environmental aspect. The types to be used in the designs should be especially close to the windows and hung on the walls, and should be designed at least 30 cm above the ground.

Architecture design make choose rubber (KC), and spatiphyllium (SP) species of indoor plant as design material and environment as well as prevent the pollution indoor areas. The suggestions of drawing in material section for design that give how to make design indoor plant in architecture design.

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Author Statement

The authors confirm contribution to the paper as follows: study conception and design: Adel, Mehmet; data collection: Mehmet; analysis and interpretation of results: Adel and Mehmet; draft manuscript preparation: Adel. All authors reviewed the results and approved the final version of the manuscript.

Conflict of Interest

The authors declare no conflict of interest.

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Research Article

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Vibration Control of Flexible Manipulators by Active Cable Tension

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Abstract

The end point vibrations of the serial manipulator should be controlled during motion or working process. In this study the residual vibrations of the flexible manipulator were controlled with cable tensions. The finite element model was established in ANSYS Mechanical APDL. The open loop and closed loop control simulations were performed under the trapezoidal velocity motion profiles. Zero and three different initial strain values were assigned to the cables. As a result, the end point vibration amplitudes, axial forces of the cables and the bending strain values of the one element near the fixed end were observed in order to define the limitations of the sensors and actuators which will be selected for experimental setup.

Keywords: Vibration Control, Flexible Manipulator, Finite Element Analysis

1. Introduction

The serial manipulators are commonly used in industry for many applications as path following motions, pick and place operations etc. The end effector vibrations must be controlled during the operations. There are two ways to suppress the end point vibrations as passive and active control. The passive vibration control can be achieved by using appropriate velocity motion profiles to actuate the manipulator.

Trapezoidal velocity motion profile is the basic velocity motion profile in order to actuate a serial manipulator. Trapezoidal velocity profiles consist of three-time parameters as acceleration time, deceleration time and constant velocity time. Selection of these time parameters are crucial for elimination of end point vibrations of a flexible manipulator or to keep them at a certain level. Some studies (Malgaca et al., 2016; Yavuz et al., 2016) proved that selection of the trapezoidal motion profile time parameters which are related with the natural period of the one degree of freedom flexible manipulator, reduces the residual vibrations. The same approach was also applied on two degrees of freedom flexible manipulator and the reduced residual vibrations were obtained in the study (Karagülle et al., 2017). In these studies, (Karagülle et al., 2017; Malgaca et al., 2016; Yavuz et al., 2016) when the deceleration time of trapezoidal motion profile was selected as integer multiples of first natural period of the manipulator, the residual vibrations were suppressed.

In the literature, different velocity profiles that have smoother acceleration changes than trapezoidal velocity motion profiles were suggested and used to drive a motor or dynamic system. The firstly proposed the 3rd order S-curve motion profile which has seven-time segment by Castain and Paul (Castain and Paul, 1984) was used also in practice (Liu and Chen, 2018; Liu, 2002; Lu and Chen, 2016).

The effect of the time parameters of 3rd order polynomial S-curve and trapezoidal motion profiles on transient and residual vibrations of a flexible manipulator were investigated (Akdağ and Şen, 2021). Finite element model of manipulator was established, and numerical calculations were done by using Newmark method.

Active vibration control of the flexible manipulators can be performed by using another actuator such as piezoelectric actuators or input shaping methods (Malgaca et al., 2017; Tzes and Yurkovich, 1993).

Vibration control was achieved by using active cable tension for many different cases such as vibration control of large trusses (Preumont and Achkire, 1997; Preumont et al., 2000), cable stayed bridges (Warnitchai et al., 1993) or even membrane antenna structure vibrations (Liu et al., 2018).

In this study, the finite element model of the flexible beam with cables was established Ansys Mechanical APDL instead of Ansys Workbench in order to perform the closed loop control simulations. The open loop and closed loop control simulations were performed under the trapezoidal motion profiles. Zero initial strain and three different initial strain values were assigned to the cables for performed simulations. As a result, the end point vibration amplitudes, axial forces of the cables and the bending strain values of the one element near the fixed end were observed in order to define the limitations of the sensors and actuators which will be selected.

2. Methodology

The finite element model of the flexible beam with cables was established in ANSYS APDL in order to perform the closed loop control simulations by writing scripts. Flexible beam was modeled by using BEAM188 element and the cables were modeled by using LINK180 element. LINK180 elements were modeled as members that carry only axial tension forces to model the cables. Detailed schematic view of the model is shown in Figure 1. The model parameters were given in Table 1 and established model in Ansys APDL was shown in Figure 2.

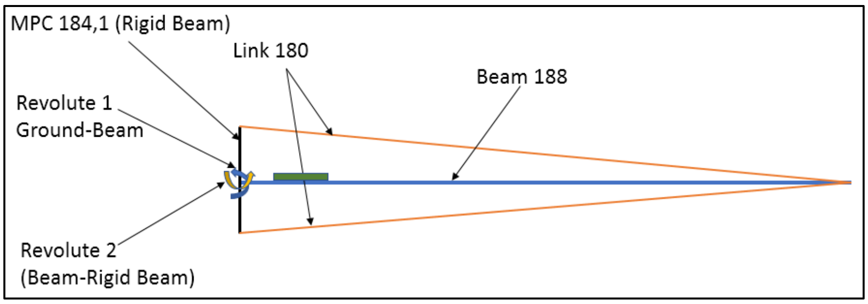
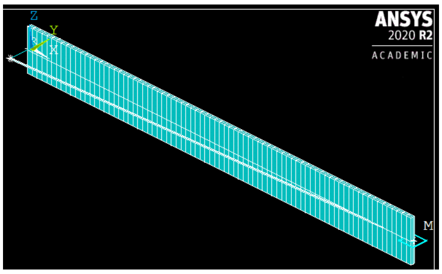


Figure 1. Schematic FE model of the tendon controlled flexible beam



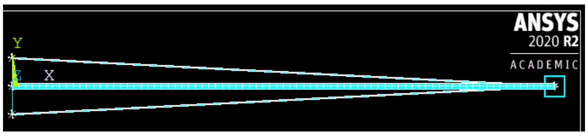


Figure 2. Established M-model in ANSYS APDL

Table 1. Model parameters

Elastic modulus	$2x10^{11}$ Pa
Poisson ratio	0.3
Density	7850 kg/m^3
Payload mass	1.25 kg
Inertia of payload	$633.445x10^{-6}$ kgm^2
Cable Diameter	Ø1 mm
Cross section	3.8x40 mm^2
Beam length (L2)	400 mm
Rayleigh damping coefficients	η=0 and β=$3.75x10^{-5}$
Motor rotational spring constant	Km2=16000 Nm/rad
Number of finite elements	ne2=80
Time step	Δt=0.005 s

Symmetric trapezoidal velocity motion profiles were used to actuate the manipulator. The manipulator was rotated 90˚ in 1 sec. The motion vector of trapezoidal motion profiles was defined as qm=[Tacc-Tdec-Tm]. Used symmetric trapezoidal motion profile parameters were defined acceleration and deceleration times as percentage of the motion time. Tacc and Tdec values were defined in Tables and Figures as %Tm. The used velocity motion profile is shown Figure 3.

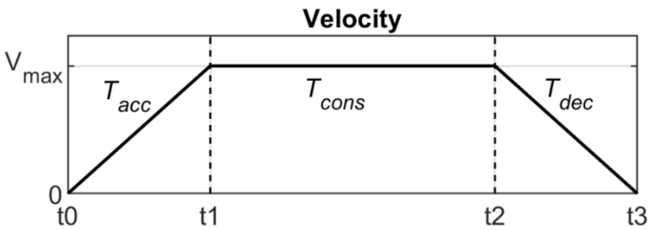


Figure 3. Trapezoidal Velocity Motion Profile

The effect of the pretension amount of the cables on the natural frequency of flexible manipulator was also observed. The closed loop control algorithm which includes proportional control (Kp) was established in ANSYS APDL. Bending strain values on an element which is away 15 mm from fix end was used as a feedback for closed loop control.

3. Results and Discussions

Obtained natural frequencies from both modal analyses and fast Fourier transform by using free vibration responses of residual vibrations were shown in Table 2. The reason the differences between the modal analyses and fast Fourier transform frequency result, both cables are not effective at the same time on the stiffness matrix. The axial load on one of the cables becomes zero during motion and that cable cannot make any contribution to the stiffness. The duration of this noncontributing region changes according to the actuation velocity profile. This situation was understood from the observation of the axial forces on the cables during the motion as shown in Figure 4.

Table 2. Obtained first natural frequencies

		Trapezoidal Motion Cases				
Pretension	**Modal Analyses**	**[0.1-0.1-1]**	**[0.2-0.2-1]**	**[0.3-0.3-1]**	**[0.4-0.4-1]**	**[0.5-0.5-1]**
No cable	5.5786 Hz	5.5786 Hz	5.5786 Hz	5.5786 Hz	5.5786 Hz	5.5786 Hz
0	7.9992 Hz	6.9316 Hz	6.8777 Hz	6.9794 Hz	6.9628 Hz	6.9134 Hz
5N	8.0279 Hz	6.9128 Hz	6.9466 Hz	7.7108 Hz	7.1592 Hz	6.9994 Hz
10N	8.0564 Hz	6.9319 Hz	7.0433 Hz	7.4993 Hz	7.3843 Hz	7.0978 Hz
15N	8.0848Hz	6.9504 Hz	7.1987 Hz	7.4894 Hz	7.9754 Hz	7.2699 Hz

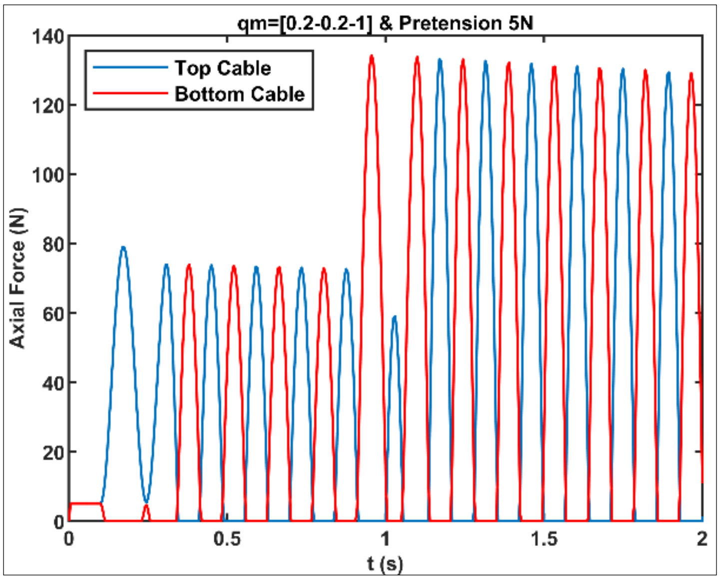


Figure 4. Axial forces on the cables during the qm=[0.2-0.2-1] with 5N pretension

The observation of the pretension amount effect on the vibration results for both qm=[0.3-0.3-1] and qm=[0.4-0.4-1] for all pretension values and without cable model were shown in Figure 5 (a) and (b). It was obtained that the vibration amplitudes are not directly affected by the pretension amount on cables. It is related with the natural period and given motion profile parameters. It was known that the coinciding or close values of the first natural period of the manipulator and the acceleration time of the motion profile reduce the vibration amplitudes. These effects were explained in detail in (Akdağ and Şen, 2021; Akdağ and Şen, 2023).

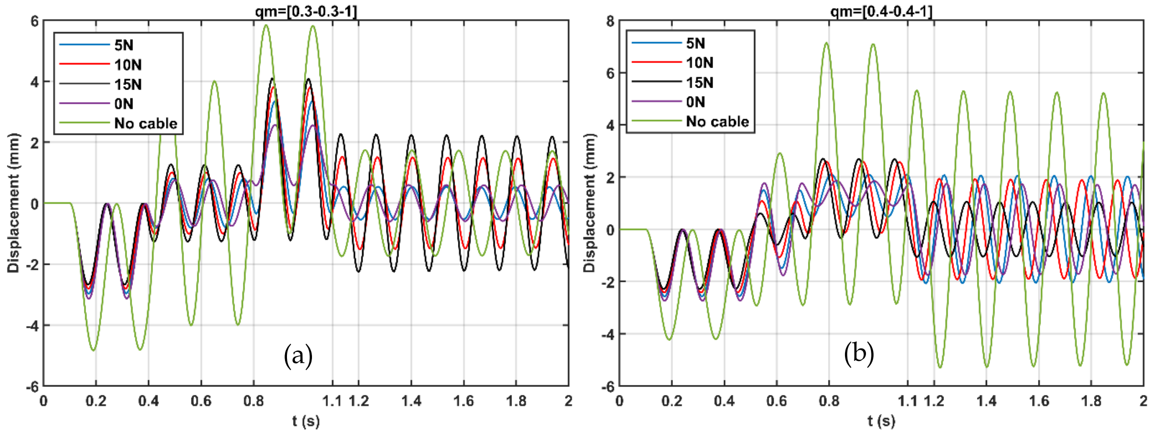


Figure 5. The effect of the pretension values on the vibration amplitudes

There should be a limitation for initial pretension amount. Two parameters should be taken into consideration. During the motion axial force on the cables should not reach up to yield force. And the axial force of the cable should not cause the buckling failure of the beam. For this reason, axial yield force (Fax_{yield}) and maximum axial load (P_{crt}) that the beam can carry can be calculated from Eq. (1) and Eq. (2), respectively. During the motion, these values should be observed. The obtained max Fax_{yield} on cables will also be used for calculation of the needed torque amount of control motor. According to the obtained result from Table 2 and Table 3 reached max Fax load 208.9676 N for 15N pretension and for qm=[0.1-0.1-1]. However, this value is higher than Fax_{yield}. Therefore, if the 15N pretension are going to be used motion case qm=[0.1-0.1-1] should not be chosen. If the diameter of cable increased, then it can be safe for use. The reached maximum holding torque value was obtained as 4.179352Nm. This can be taken as a reference for selection of the control motor. However, the real torque value of the motor should be selected after performing the closed loop control simulations.

$$Fax_{yield} = \sigma_{yield} A_{cable} \rightarrow \sigma_{yield} = 250MPa, A_{cable} = \pi(0.5x10^{-3})^2 \quad (1)$$
$$Fax_{yield} = 196.35\ N$$

$$P_{crt} = \frac{\pi^2 EI}{L_e^2} \rightarrow L_e = 2L \rightarrow P_{crt} = 564N \quad (2)$$

Table 3. Axial forces on cable 1 for open loop control

	Trapezoidal Motion Cases/CableTension1 (N)				
Pretension	**[0.1-0.1-1]**	**[0.2-0.2-1]**	**[0.3-0.3-1]**	**[0.4-0.4-1]**	**[0.5-0.5-1]**
5N	161.5214	133.1011	60.7261	53.3922	97.4236
10N	186.3857	119.3072	62.7435	55.4848	94.5357
15N	205.5897	98.3538	65.0928	57.945	83.83
	Needed Holding Torque (Nm)				
5N	3.230428	2.662022	1.214522	1.067844	1.948472
10N	3.727714	2.386144	1.25487	1.109696	1.890714
15N	4.111794	1.967076	1.301856	1.1589	1.6766

Table 4. Axial forces on cable 1 for open loop control

	Trapezoidal Motion Cases/CableTension2 (N)				
Pretension	**[0.1-0.1-1]**	**[0.2-0.2-1]**	**[0.3-0.3-1]**	**[0.4-0.4-1]**	**[0.5-0.5-1]**
5N	162.0161	134.2044	67.7446	44.6053	98.7319
10N	187.1463	122.4846	81.1568	58.7313	98.3083
15N	208.9676	109.608	91.2579	65.5933	94.4689
	Needed Holding Torque (Nm)				
5N	3.240322	2.684088	1.354892	0.892106	1.974638
10N	3.742926	2.449692	1.623136	1.174626	1.966166
15N	4.179352	2.19216	1.825158	1.311866	1.889378

In Ansys APDL closed loop control algorithm includes proportional control (Kp) was established by written a script. Bending strain value on the element which is away 15 mm from the fix-end was read from the simulation and used as a feedback for closed loop control. Obtained closed loop results for different Kp values and different motion profiles were shown in Figure 6 (a), (b) and (c).

The closed loop simulations were also studied for different motion profiles. The end point vibrations were suppressed significantly only using proportional controller and vibration control has been successfully performed.

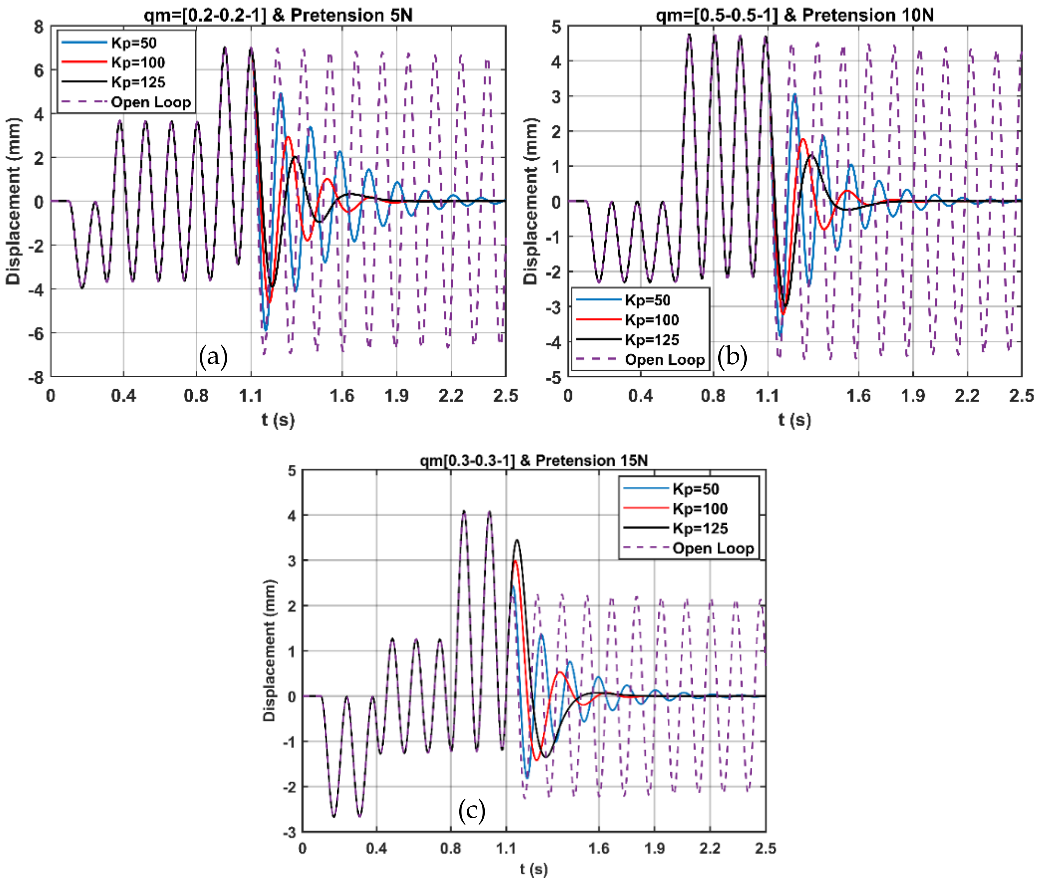


Figure 6. Closed loop control for different Kp values for same pretension axial load

4. Conclusions

The finite element model of the flexible beam with cables was established using Ansys Mechanical APDL instead of Ansys Workbench in order to perform the closed loop control simulations. The open loop and closed loop control simulations were performed under the trapezoidal motion profiles. Zero initial strain and three different initial strain values were assigned to the cables for performed simulations. As a result, the end point vibration amplitudes, axial forces of the cables and the bending strain values of the one element near the fixed end were observed in order to define the limitations of the sensors and actuators which will be selected. According to the obtained results the outcome will be as follows.

- For this system for control motor torque should be at least 4.2 Nm and strain gauge max limit value at least 3x10-4 m/m. These values should multiply minimum 1.5 as a safety factor.
- And for the setting of the initial pretension values a force measuring sensor is needed. That can carry up to 200N because the max Fax on the cables reaches approximately this value.
- According to obtained results the closed loop vibration control of flexible manipulator can be achieved by active cable tension.

Author Statement

All authors reviewed the results and approved the final version of the manuscript.

Conflict of Interest

The authors declare no conflict of interest.

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Review Article

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An Overview of Impact of Agrochemicals on Human Health and Natural Environment

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Abstract

Agrochemicals exposure periods and levels, types of agrochemicals used and various environmental condition of the areas are factors for acute and chronic poisoning on human health and environment. Although agrochemicals are the result of modern technology that depends on inorganic fertilizers and pesticides, their continuous use against agricultural pest and disease vectors poses serious threats upon both human health and environment. Overuse of these chemicals have severe effects on human and environment that may lead to immediate and long-term effects. In developing countries, it is very difficult to find out the impact on the environment due to lack of awareness, training, and adequate knowledge for using agrochemicals. Investigating farmer's awareness of agrochemicals residues and their behaviors regarding application is important in order to reduce human factors that negatively affect environmental safety. This review focuses on a summary of both national and international studies regarding the impact of pesticide and chemical fertilizer residues on nature, both human and environment. The review has revealed the hazardous effects like cancer, neural disorders, and other health related problems and environmental risks associated with agrochemicals exposure.

Keywords: Agrochemicals, human health, environmental impact

1. Introduction

Despite being an expensive input, agrochemicals (pesticides and fertilizers) are viewed as a means of advancing crop production technology. Increased crop production is ensured by balanced use, optimum doses, proper technique, and appropriate timing of pesticide applications. The requirement for fertilizers and pesticides for crops differ according to soil and meteorology (Bhandari, 2014). The developing world makes extensive use of agrochemicals, and the need for pesticides is rising as a result of the current crop production system, which places a premium on high agricultural yields. Pesticides, which are composed of chemicals that can control pests or influence plant growth, have given poor nations one method to raise yields. Many farmers in underdeveloped nations believe that using pesticides is the best way to safeguard their crops against pests, which tend to pose their biggest threat and this year have spread to portions of Africa. As such, pesticides can provide the only form of crop insurance available (Sarkar et al., 2021). Pesticides are substances, tools, or organisms that have been chemically synthesized and are frequently used in agriculture to control, eliminate, combat, or repel pests, diseases, and parasites. Based on their chemical makeup, pesticides—which contain both organic and inorganic moieties—can be divided into many classes. These pesticides include organochlorines, organophosphates, carbamates, formamidines, thiocyanates, organotin, dinitrophenols, synthetic pyrethroids and antibiotics (Bohmont, 1990). Due to the fact that farmers frequently lack proper personal protective equipment (PPE) and frequently lack the ability to read labels, which are typically the primary source of safety instructions, health risks related to the handling and use of pesticides are more prevalent in developing nations. On these subjects, farmers rarely have access to in-person training. When residential areas are close by, pesticide use issues may go beyond the farming region. Children are especially vulnerable to the dangers of pesticides due to their use and storage in homes. Statistics reveal that a sizable number of suicides occur each year as a result of pesticides. According to the Network of African Science Academies, 2019 the market for neonicotinoid insecticides is expanding at the quickest rate. These pesticides have a lower human toxicity than earlier classes of pesticide, but still pose problems for pollinators and aquatic organisms and are partially banned in the EU. Over the longer term, neonicotinoid use could have serious implications for biodiversity and the environment (Sarkar et al., 2021).

No segment of the population of developing countries like Bangladesh is completely protected against exposure to agrochemicals (pesticides) and the potentially serious health effects. Despite their popularity and extensive use, there is serious concern about health risks arising from the exposure of farmers when mixing and applying pesticides or working in treated fields (Biswas et al., 2014). Although the effects of pesticide use are frequently not noticed, there is evidence that farmers, their families, and those who live close to farmed areas may face long-term health problems (Larsen et al., 2017). In developing countries, incidents involving handlers of pesticides occur more often and the health impacts may be more immediate, given a frequent lack of PPE and minimal education about the correct way to spray chemicals. Approximately 20% of the 800,000 persons who commit suicide each year die from pesticide ingestion. The negative health effects associated with pesticide use include respiratory, integumentary, cardiovascular, gastrointestinal, and neurological problems. In Morocco, there were over 2000 different causes of acute pesticide poisoning between 2008 and 2014; 50 % of the pesticides involved were classes I (extremely or highly hazardous) and II (moderately hazardous) according to WHO classifications (World Health Organization, 2021). Cancer is one of the longer-term impacts that is hardest to precisely link to pesticide use. Consuming food that has residues beyond legal limits can have negative effects on one's health (Joko et al., 2020). However, in West Africa, episodic studies by local scholars, students, donor projects and public health agencies allow three cautious generalizations. First, dichlorodiphenyltrichloroethane (DDT, a type of pesticide) residues from spraying programs can linger for decades in the food chain, with milk, meat, fish, and even human breast milk affected. It is difficult to emphasize the harm that pesticides cause to children. Pesticides stored inside homes are also common causes of childhood poisoning (Sarkar et al., 2021). The extension initiatives, particularly the plant protection department, have vanished in Somalia. This situation led lack of awareness of the proper use of pesticide, lack of plant quarantine and pesticide regulations and this encouraged import of international banned synthetic chemicals to Somalia, for example DDT, Aldrin, Aldicarb, and Nicotine sulphate which have high risk of poisoning. Organophosphorus, carbamates, and organochlorines can act as endocrine disruptors and alter hormone function in addition to their primary function as pesticides by blocking, mimicking, replacing, or acting to subvert the roles that hormones naturally play in living species. In this survey (Sarkar et al., 2021), it is observed that the majority of farm workers apply pesticides without protective gear, use empty containers of pesticides as utensils, agro-dealers sell pesticide products together with food items in same places, also ignore of considering the right dose, time and direction of the wind. If this situation continues for some decades, it may cause chronic diseases to humans, environment, animals, and agroecosystem areas degradation at large (Dayib, 2019).

The aim of this study is to discuss the multifaceted relationship between the use of agrochemicals (pesticides and fertilizers) in agriculture and its effects on crop production, human health, the environment, and ecosystems. The text highlights the potential benefits and risks associated with agrochemicals, addressing various dimensions such as agricultural productivity, pesticide usage, health implications, environmental impact, regulatory frameworks, and potential alternative solutions. It emphasizes the need for responsible and informed practices in agrochemical use, considering factors like proper application techniques, risk assessment, regulatory compliance, and the exploration of more sustainable approaches to ensure a balance between agricultural advancement and the protection of human health and the environment.

2. Human Health Hazard

The links between agrochemicals and human health were suspected as early as the 1960s and 1970s. In locations with significant pesticide use, US epidemiologists noticed an extraordinary increase in Non-Hodgkin's Lymphoma cases (Gupta, 2012). Agrochemicals have an impact on more than just the environment and nonhuman biota. Humans can be exposed to agrochemicals directly by unintentional, deliberate, or occupational reasons as well as indirectly through residues in food and the environment. Infant and kid exposure to harmful pesticides is a serious problem, especially in crowded urban tenements and slums. Several more recent studies and reviews bring to light some critical health implications of agrochemical exposure. These can be classified as acute and chronic illnesses.

2.1. Acute Illness

The typical symptoms of acute pesticide poisoning in humans are fatigue, headaches and body aches, skin discomfort, skin rashes, poor concentration, feelings of weakness, circulatory problems, dizziness, nausea, vomiting, excessive sweating, impaired vision, tremors, panic attacks, cramps, etc., and in severe cases coma and death (Bödeker & Dümmler, 1993). Diagnosis of acute pesticide poisoning generally occurs when one or more of these symptoms, which appear in a short time after contact with pesticides, are detected. 16% of respondents cited eye discomfort, 21% headaches, 6% dizziness, 5% skin irritation, and 7% vomiting after handling pesticides as the survey's most noticeable health issues. The interviews further revealed that 30% of the respondents experienced multiple health effects, with the duration of ailment also being quite significant. Traders indicated an average duration of 7 hours in terms of eye irritation, 13 hours for headaches and 21 hours for dizziness (Dasgupta et al., 2005).

2.2. Chronic Illness

Besides causing acute poisoning, pesticides can also cause chronic illnesses if they are incorporated over a longer period, even though the amounts taken up are relatively small. The workers in agrochemical production centers, as well as across other stages of the supply chain, retailers, and pesticide applicators are directly exposed. People who live near agricultural fields or are present there are also affected. There are cases of inadvertent consumption (homicides), as well as the planned consumption of chemicals as a method of suicide. Several studies show multiple health problems due to exposure, such as birth defects, cancer, and neurological disorders. However, a person's health situation and mitigating behaviors will decide how much of an impact this has on them. Bioconcentration is the process in which the accumulation of the chemical in an organism occurs from the surrounding air or water. For instance, DDT, for example, is fat-soluble and accumulates in fish or human fatty tissue (lipids). Other chemicals, such as glyphosate, are digested and eliminated from the body.

A recent report by the UN Environment Program observes a significant association between occupational and residential exposure to pesticides and adverse health outcomes, including cancers and neurological, immunological, and reproductive effects. Based on clinical research conducted in laboratories, an extensive account of the physiochemical, toxicokinetic, and toxicodynamic features, stages of intoxication, symptoms of poisoning, and treatments relating to commonly used pesticides has been gathered (United Nations Health Program, 2022). Health damage due to pesticide poisoning has been a public health issue ever since the beginning of the widespread use of chemical pesticides in agriculture. Mortality or morbidity (acute or chronic) are consequences.

The Task Force of WHO published the first global assessment on human pesticide poisoning in 1990, which estimated one million cases and a fatality rate of 20,000 per year (Boedeker et al., 2020). Due to its widespread availability, intentional pesticide poisoning as a method of suicide is fairly popular, especially in developing nations. Globally, 110,000–168,000 suicides were reported by this method annually over the 2010–2014 period, which accounts for 14–20% of total suicides.

Under real-world circumstances, exposure from many sources, such as air, water, food, and beverages, is highly frequent. The consumption of agricultural foods and animal products exposes people to a variety of chemical residues. In human systems, this chemical cocktail may have additive effects and be more dangerous than a single molecule. Renal damage is consistent with chronic kidney disease incidence in Sri Lanka and was reported to be linked to the synergistic effects of exposure to glyphosate with other pollutants like paraquat, under stressful physical labor conditions, such as high temperatures in lowland tropical regions (Devi et al., 2022).

3. Impact of Agrochemicals on Environments

3.1. Adverse Effects on Non-Target Animals, Microbial Community, and Non-Target Plants

The bird and other small wild animals are in threat because of the use of pesticides (Biswas et al., 2014). According to the farmers, the most significant environmental effects of pesticides usage were, decline in abundance of pollinating bees (40%) and butterflies (18%), the disappearance of the red-billed oxpecker (20%), and other non-target insects dying (12%) when or after spraying and wildlife mortalities (10%). The birds disappeared when the government subsidized a common facility for livestock in the 1980s. Since then, the birds have only been observed in forest areas. Only 3% of the farmers had seen signs of poisoned birds so the alternative that the birds moved to another habitat for other reasons, such as the lack of ticks and insect parasites on the animals cannot be excluded. The populations of helpful soil microorganisms can decrease when soil is heavily treated with pesticides and other agrochemicals. Overuse of chemical fertilizers and pesticides has effects on the soil organisms that are similar to overuse of antibiotics in humans. Indiscriminate use of chemicals might work for a few years, but after a while, there are not enough beneficial soil organisms to hold on to the nutrients (Biswas et al., 2014).

Weeds are intended to be killed by herbicides. So, it is not surprising that they can injure or kill desirable species if they are applied directly to them. In addition to killing non-target plants outright, Pesticide exposure can kill non-target plants directly in addition to having sublethal effects on them. Phenoxy herbicides, including 2,4-D, can injure nearby trees and shrubs if they drift onto leaves (Dreistadt, 2016).

Contrary to causing damage, many insects are highly beneficial and serve useful purposes. Bees produce honey and are also important for the pollination of various crops, contributing to a good yield. It may also happen that an insect which at first caused no trouble in the crop becomes a pest after spraying because its natural enemy was removed, even though this was not the intention. This is one more reason for not spraying more frequently than necessary. One could also enquire into alternative control methods, such as those mentioned in the introduction, or consider using pesticides which are selective in their action. If the active ingredient of a pesticide only slowly departs from the environment, it is considered persistent. Persistent compounds can accumulate in the environment, in the soil or the food chain. Eventually, however, they also accumulate in meat, fish, or milk. In this way humans also become exposed to the pesticide. A prime example of a persistent pesticide is DDT. Another effect of excessive spraying is that the harmful organism becomes tolerant (less sensitive) to the pesticide used. More and more pesticide must then be used to obtain the same degree of control, with all the harmful consequences involved for humans and the environment. Moreover, the resistance of the harmful organism simply increases so that it becomes necessary to use a different pesticide to which the pest is not yet resistant (Boland et al., 2004).

Threatened plant species are particularly at risk from this. When soil microbes and beneficial insects are destroyed as a result of pesticide treatment, plants might also experience indirect effects. Herbicide contamination of water could also have devastating effects on aquatic plants. Oxadiazon was reported to significantly lower algal growth in one research (EPA, 1996).

3.2. Water Contamination

Agriculture development is closely related to the use of pesticides. The use of pesticides has helped in preventing the losses caused by pest attacks and has improved the production potential of crops, but these excess quantities are leaching down to groundwater and causing pollution (Khanna & Gupta, 2018). Although the agricultural soil is the primary recipient of agrochemicals, water bodies that are adjacent to agricultural areas are usually the ultimate recipient of agrochemicals residues. There is a suspicion that agrochemical residues are common in surface water systems, especially in irrigation drains, which ultimately pollute the pond and river water, and can harm the aquatic environment (Biswas et al., 2014). On farms, agrochemicals are used to either increase soil fertility, eradicate weeds, or combat pests and diseases—actions designed to boost agricultural output and meet human demand for food. Gravity causes water that falls on the earth's surface to continue to seep in until a saturation zone is achieved. Thus, the relative rate of percolation and degradation within the soil profile, which processes are regulated by climate, soil characteristics, chemical characteristics, application rate, aquifer depth, and farming practices, determines the risk of contamination. Due to the higher capacity of sand for infiltration than clay, agrochemical use on sandy soil has a higher potential to leach to groundwater. If the parent compound's degradation rate is greater than its rate of percolation through the soil profile, groundwater contamination is also less likely to happen. Adsorption describes how firmly a particular agrochemical sticks to the soil while traveling down with water. The length of time a chemical remains in its original form in the soil is known as persistence. Groundwater vulnerability or susceptibility, which is independent of the kind of pollution, is the result of the contributions of these variables. In regions with high rainfall, agrochemicals like nitrogen-based fertilizers and herbicides left unused by plants may leak to contaminate groundwater. After the chemicals have been utilized, this contamination may not occur for several days or even months. Some common compounds that are mobile and difficult to attenuate in the subsoil make up the most prevalent pollutant. The use of agrochemicals such as fertilizers and pesticides constitute an important aspect of modern agriculture as they are needed to control various pests and improve soil fertility. The benefits are increased supplies of food, but problems arise when significant amounts of agrochemicals accumulate as residue in soils and percolate into groundwater. (Adeoye et al., 2013)

4. Conclusions

Global production, consumption, and export of chemical pesticides often follow unscientific practices, augmented by aggressive marketing. As a result, even substances that are prohibited in one nation may be exported to another. Additionally, the importing nations, which are mainly developing nations, have either lax rules or little enforcement of existing regulations. This is made worse by technical developments that call for greater use of these chemicals, such as the ability to tolerate herbicides through genetic engineering. Agrochemicals on the other hand are considered a quick, easy, and inexpensive solution for controlling weeds and insect pests and increasing yield in agricultural landscapes. However, the use of pesticides comes at a significant cost. Almost every aspect of our environment has been poisoned by pesticides. The long-term effect of low-level exposure to one agrochemical is highly influenced by concomitant exposure to other agrochemicals. Most of the farmers are not capable of taking decisions on pest management and pesticide application. Often, they apply pesticides when there is no real need, or they use the wrong chemicals at the wrong doses, methods, and times. As a result, they kill the beneficial organisms easily and create pest resistance causing greater problems and crop losses.

Pesticides should be strictly handled according to the regulations which contribute to reduction of the adverse effects of pesticides on human health and environment. However, existing regulatory and management protocols are based on assessment frameworks that suffer from methodological drawbacks. As a result, the usage of agrochemicals judged safe by these frameworks has steadily increased worldwide. The impact of pesticide mixtures and synergistic long-term ecological repercussions are not taken into account by the present assessment frameworks. The assessment frequently fails to take into account the interconnectedness of the sinks and the complex nature of the agrochemicals' environmental impact. This leads to the legal usage of various agrochemicals that have the potential to have long-term negative effects on the environment and human health. For green environment and reducing chronic effect biological solution can play effective role. Biofertilizer is a super alternative to chemical fertilizers. Biopesticide also becomes an alternative solution for pest control. IPM and using several natural products and biological agents also give us hope to minimize the adverse effect of agrochemicals.

With the aim of offering explicit and definitive guidance, designed to provide clear and actionable recommendations:

- Global production, consumption, and export of chemical pesticides often involve unscientific practices and aggressive marketing, leading to cross-border export of prohibited substances and lax enforcement of regulations in importing developing nations.
- Technical advancements, like genetic engineering for herbicide tolerance, exacerbate the reliance on agrochemicals, which are seen as quick and inexpensive solutions for boosting agricultural yield.

- However, pesticide use has significant environmental costs, polluting various aspects of the environment and causing long-term impacts due to interactions between different agrochemicals.
- Farmers often lack the expertise to make informed decisions on pest management and pesticide application, leading to misuse and resistance development in pests.
- Strict adherence to regulations is vital to mitigate the adverse effects of pesticides on human health and the environment, but existing assessment frameworks have methodological limitations, resulting in the continued use of supposedly safe agrochemicals.
- The complexity of agrochemical interactions and environmental impact is often not adequately considered in assessments, leading to the legal use of potentially harmful chemicals.
- Biological solutions, such as biofertilizers, biopesticides, integrated pest management (IPM), and natural products, offer promising ways to reduce the negative effects of agrochemicals and promote a greener environment.

Author Statement

The author confirms sole responsibility for the whole paper.

Conflict of Interest

The author declares no conflict of interest.

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A Case Study on PV-Aided Net Zero-Energy Building: the Daycare in IKCU

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Abstract

At the core of our growing societies, energy supply stands as one of the major concerns today, and it will be an inevitable challenge for our near future. As the nations are looking to find solutions for the transition from fossil fuels – depleting at a high rate – to alternative energy sources, solar energy through PV cells is getting attention as an affordable and easily implemented option especially for power supply in commercial and residential buildings. This work consists in analyzing the possibility to cover the entire energy needs of a building via PV solar cells for the case of a constructed daycare. In this case study, HVAC energy requirement has been calculated by the TS825 standard. The standard specifies a method for calculating the net heating/ventilation energy need and provides the rules for calculating the maximum allowable temperature in buildings. First, dimensions of the investigated building are taken and characteristics affecting the thermal insulation are assessed. Then, other energy needs, mainly lighting and electrical devices, are computed in the analysis as internal electricity needs. The scope of this work extends to the assessment of indoor air quality for occupants of building, which is an important aspect in our case study where the occupants are children. ASHRAE standards 62.1 is utilized for this purpose. The standard specifies minimum ventilation rates and other measures intended to provide acceptable indoor air quality to human occupants and that minimizes adverse health effects. The results are obtained for monthly varying solar exposition in the specified area where the building is located to provide supply for the determined energy demand via solar energy. Finally, monocrystalline PV panel system has been proposed with proper orientation and adequate power potential. Based on the obtained results, as well as the economical aspect, inferences and suggestions are made for improvements.

Keywords: Photovoltaic panels; power generation; zero-energy building

1. Introduction

As the world population continues growing, energy demand due to industrial and human-based activities increases in parallel (Kaviraj and Robi, 2018). Usage of renewable energy sources has become an attractive alternative to conventional energy sources to meet the growing energy demand while reducing greenhouse gas emissions (Ardehali et al., 2017). One of the most promising renewable energy sources is solar or radiant energy which can be harvested via photovoltaic (PV) panels (Fumo et al., 2021). Recent progress in efficiency of PV panels has allowed the rise of concepts like zero and net-zero energy buildings.

A zero-energy building is a construction that generates adequate energy for annual energy consumption. Such buildings are designed to reduce energy consumption to a minimum and produce the remaining energy using renewable sources (Zhang et al., 2018). The concept of zero energy buildings has gained increasing popularity due to the growing concerns on sustainable environment and energy-efficient buildings. PV panel systems are commonly used in zero energy buildings to generate renewable energy-based electricity. PV panels convert sunlight into electricity without any harmful emissions. The size and capacity of the PV systems depend on the building's energy demand and the available solar irradiation. PV-aided zero energy buildings have been researched extensively in recent years (Tonui, 2016).

In western countries, the main factor affecting the total energy demand in buildings is the heating, ventilation, air conditioning and refrigeration (HVAC-R) units. A review of energy consumption in buildings across developed countries by Firth et al. in 2016 documented that space heating accounted for the largest proportion of energy consumption in both residential and commercial buildings (Firth et al., 2016). The authors note that this is due to a combination of factors, including the climate conditions and building design. This fact is better illustrated in Fig. 1 by a pie chart for the US (National Academies of Sciences, Engineering and Medicine, 2010).

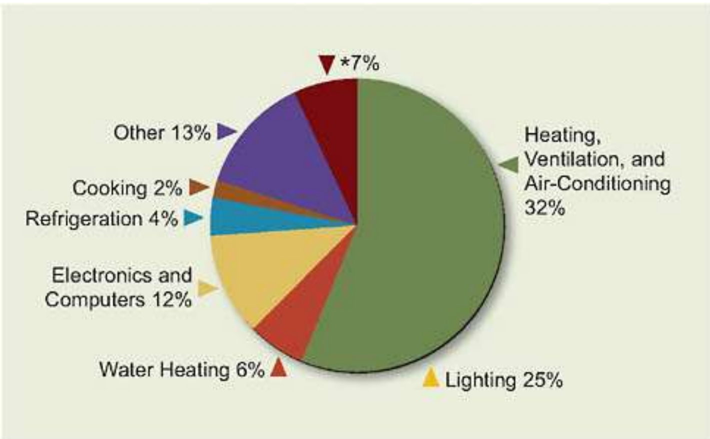

Figure 1. Energy use in U.S. commercial buildings (National Academies of Sciences, Engineering and Medicine, 2010)

At this point Turkish Standard TS825, that is a technical norm developed by the Turkish Standards Institution (TSE), provides a guideline for the calculation of energy requirement in the residential/commercial buildings. The title of the standard is "Energy Performance of Buildings - Calculation of Energy Use for Heating and Cooling" (Turkish Standards Institution, 2018). In Turkiye, it is estimated that buildings that obey the TS825 regulations for insulation can save up to 60% of the energy used for heating purpose. As energy represents a major issue today in the world and especially in the country, TS825 has become a mandatory norm for all new buildings as of June, 2000. The purpose of TS825 is to provide a standardized method for assessing the energy performance of buildings, particularly with respect to heating, heat gains and heat losses. The standard allows engineers and designers to determine the energy performance of buildings using a range of parameters, including the building placement, wall specifications, ceiling layers, floor type and layers, window types and area, door type, indoor and outdoor temperature level for each month, heating and cooling systems, ventilation system and type, and solar heat gains. We mainly utilized from this standard and the methodology within it to determine the monthly and annual heating energy requirement for the building considered in our case study, i.e., the daycare (nursery) at Izmir Katip Celebi University. In that calculation method, TS825 mainly takes into consideration: building properties such as construction materials, insulation, heat losses through conduction convection and ventilation; as well as heat gains from internal sources and solar radiation, to determine the heating energy need for the building. Other factors considered when calculating the energy need in our work are the energy needs for cooking, lighting, refrigeration, electronic devices, and water heating. Their values are relatively constant, and they are taken as monthly and yearly average. The calculation provides an accurate estimation of the total energy demand of the building. The procedure is detailed in section 2. Our assumption is that under TS825 specified conditions, PV-panels will provide 100% of the energy needs for the daycare in our case study, making it a net zero-energy building.

Next, indoor air quality and personal comfort conditions have been considered while calculating the total energy consumption of the investigated domain. ASHRAE 62.1 standard (ASHRAE, 2022) is used for ventilation rates and indoor air quality requirements. This standard provides guidelines for the assessment of indoor air quality of occupants in various spaces. In a daycare, where the occupants are kids/children, this standard is crucial in achieving a viable zero energy building and ensuring the health and safety of kids. Furthermore, ASHRAE 55 is utilized for the determination of personal comfort conditions especially for the ventilation speed point of view (ASHRAE, 2017).

In this case study, we investigate usage of PV panels for the daycare building at Izmir Katip Çelebi University to cover all the energy requirement in an annual period. First, the monthly and annual heating energy loads of the selected nursery are calculated via TS825 standard. Next, energy consumption due to the electronic appliances, lighting and specific devices are determined to obtain total energy requirement of the investigated building. PV panel type and total number of PV panels have been determined according to the maximum energy requirement case experienced in January. Furthermore, a detailed cost analysis has been performed to compare the investment cost of possible PV solutions.

2. Methodology

The first step in our work is to measure the building properties needed at all calculation stages of the TS825. They include mainly: measurements of dimensions, heat losing surfaces, area of each component considered in calculations, and total window and door areas in each direction. The data are presented in Table 1.

The heating energy need for the building, as stated in the previous sections, is the main factor affecting the total energy demand. That value was calculated according to the systematic calculation method using the TS825 with the data listed in Table 1. The calculation steps contain: calculation of heat loss of the building (through conduction, convection), calculation of heat gain of the building (internal and solar gains), and lastly, calculation of the heating energy need using the obtained data. In order to determine the specific heat loss of the building, we initially focused on the heat loss through conduction and convection. Then we calculate the heat loss through ventilation, and we add the two values to get the total heat loss value as shown in Eq. (1).

$$H = H_T + H_V \tag{1}$$

Table 1. Main dimensions and specifications of the investigated building

Building dimensions (m)		Layer/wall areas (m^2)		Gross volume (m^3)	Window area (m^2)		Door area (m^2)		Internal Temp. (°C)
Length	18.9	Reinforced Concrete	53.4	1791	North	20.6	North	0	20
Width	25.5	External Wall	202.5		East	16.3	East	5.9	
Height	3.7	Ceiling	484.1		West	13.0	West	0	
Floor Height	3	Floor	484.2		South	15.6	South	1.9	
		Total Area	1297.6		Total	65.5	Total	7.9	
		Net Usage	573.3						

where, H is the total specific heat loss, HT is the heat loss through conduction and convection heat transfer mechanisms, and HV denotes the heat loss through ventilation. First, we calculate the thermal permeability resistance (R) values of each building components via Eq. (2) to determine the HT.

$$R = \frac{d}{\lambda} \tag{2}$$

where, R corresponds to the thermal permeability resistance (m2K/W), d is the thickness of the building component, and λ is the thermal conductivity of the components (W/mK). Note that the thermal conductivity values are provided in Annex E of the TS825 (Turkish Standards Institution, 2018). R-value calculation for multi-layered building components is made by simply adding the R-values of each structural element (layer) of the component. Utilizing the R-values previously calculated, we derive the total thermal performance coefficient (U), from the inverse function of total thermal permeability resistance (1/U) formula, for each component, as shown Eqs. (3) and (4).

$$\frac{1}{U} = R_i + R + R_e \tag{3}$$

$$U = \frac{1}{R_i + R + R_e} \tag{4}$$

In equations (3) and (4), R_i and R_e are the surface thermal transmission resistance of the inner and outer surfaces, respectively. R_i and R_e values are provided in TS825 standard for various building scenarios. The heat loss by conduction and convection (HT) value is then calculated by summing up the products of each component's total thermal performance coefficient (U) by its specific area (A), and adding to it the heat loss transmitted through the thermal bridges, as shown in equation (5):

$$H_T = \sum AU + \sum Ul \tag{5}$$

In the case of our building that doesn't contain thermal bridges, the term (∑Ul) is ignored from equation (5) which can then be developed for each component, giving us Equation (6):

$$\sum \mathrm{AU} = U_D A_D + U_p A_p + U_k A_k + 0.8\, U_T A_T + 0.5\, U_t A_t + U_d A_d + 0.5 U_{ds} A_{ds} \quad (6)$$

where:

U_D = Thermal permeability coefficient of the outer wall (W/m²K),

U_P = The thermal transmittance coefficient of the window (W/m²K),

U_k = Thermal permeability coefficient of the outer door (W/m²K),

U_T = Thermal permeability coefficient of the ceiling (W/m²K),

U_t = Thermal permeability coefficient of the base/floor on the ground (W/m²K),

U_d = Thermal permeability coefficient of the sole in contact with the outside air (W/m²K),

U_{ds} = The coefficient of thermal permeability of the building elements in contact with the indoor environments at low temperatures (W/m²K),

A_D = Area of the outer wall (m²),

A_P = Area of the window (m²),

A_k = The area of the outer door (m²),

A_T = Ceiling area (m²),

A_t = Floor-to-floor/floor area (m²),

A_d = Area of floor/floor in contact with outside air (m²),

A_{ds} = Area of building elements in contact with indoor environments at low temperatures (m²).

The calculation of heat loss by ventilation, Hv includes both natural and mechanical ventilations affecting to the building. In the case of the daycare building of our study, since there is no mechanical ventilation, only natural ventilation is considered and calculated as follows:

$$H_V = \rho.c.V^1 = \rho.c.n_h\, V_h = 0.33\, n_h.V_h \quad (7)$$

where, ρ is the unit volume mass of air, c is the specific heat capacity, V^1 corresponds to air exchange rate by volume, n_h is the air exchange rate, and V_h denotes the ventilated volume. As density and specific heat capacity of the air slightly change (depending on temperature and pressure), their variations are neglected in the equation, and values are taken at 20 °C and 100 kPa. The enthalpy increase between the incoming and outgoing air is also neglected.

Heat gains need to be calculated to determine the monthly and annual energy demand of the building. Heat gain term refers to the amount of heat that enters the building through various sources such as solar radiation, appliances, lighting, and occupants. In this study, we calculate total heat gains as the sum of internal and solar gains. Average monthly internal heat gains (ϕ_i, month) include metabolic heat gains from humans, heat gains from the hot water system, heat gains from cooking, heat gains caused by the lighting system, heat gains from various electrical devices used in buildings. These values are taken as the average and considered constant throughout the year. For our building category (school), internal heat gain can be calculated via:

$$\phi_{i,\,month} \leq 5 \times A_n \text{ (W)} \tag{8}$$

Here, A_n is the usage area of the building that can be obtained as follows:

$$A_n = 0{,}32 \times V_{gross} \tag{9}$$

V_{gross} is the heated gross volume of the building. On the other hand, the monthly solar gain ($\phi_{S,\,month}$) refers to the amount of energy gained by solar radiation from sunlight through the windows. The gains from passive solar energy systems are neglected in this work. The average solar gain is calculated using equation (10).

$$\phi_{S,\,month} = \Sigma\, r_{i,\,month} \times g_{i,\,month} \times I_{i,\,month} \times A_i \tag{10}$$

where, $r_{i,\,month}$ is the monthly average shading factor of transparent surfaces in "i" direction, $g_{i,\,month}$ denotes the solar energy transmission factor of transparent elements in "i" direction, $I_{i,\,month}$ is the monthly average solar radiation intensity on vertical surfaces in the "i" direction, and A_i is the total window area in the "i" direction. While $r_{i,\,month}$ and $I_{i,\,month}$ values are provided by the TS825, $g_{i,\,month}$ is calculated with the help of Eq. (11).

$$g_{i,month} = F_w \cdot g_{\perp} \tag{11}$$

Here, F_w is the correction factor for glasses and $g_{\perp}$ denotes the solar energy transmission factor for the beam perpendicular to the surface measured under laboratory conditions. It is not always appropriate to consider the sum of the internal gains and solar energy gains as useful energy in terms of reducing the heating energy need. Because in times of high heat gains, the gains may be more than the instantaneous losses, or the gains may come when heating is not needed. The indoor temperature control system is not perfect, and some heat is stored in the building elements. Therefore, internal gains and solar gains are reduced by a utilization factor (η) that is the magnitude of this factor depends on the relative size of the gains and losses and the thermal mass of the building. The calculation of (η) is made using equations (9) and (10):

$$\eta_{month} = 1 - e^{(-1/KKO_{month})} \tag{12}$$

where KKO_{month} is the gain/loss ratio, and it is calculated as follows:

$$KKO_{month} = (\phi_{i,month} + \phi_{s,month}) / H(\theta_{i,month} - \theta_{e,month}) \tag{13}$$

Here, ϕ and θ are the abbreviation of heat gains and temperature levels. Note that, when the KKO_{month} value is 2.5 or above, it is considered that there is no heat loss for that month. The monthly average internal and external temperatures, $\square_{i,ay}$ and $\square_{e,ay}$ are provided by TS825 in Annex B, section 1 and 2 respectively. With the help of the parameters calculated in the previous steps, we finally obtain the annual heating energy need for our building adding up the monthly heating energy need values for our building according to equations (14) and (15).

$$Q_{year} = \sum Q_{month} \tag{14}$$

$$Q_{month} = \left[H(\theta_{i,month} - \theta_{e,month}) - \eta(\phi_{i,month} + \phi_{s,month})\right].t \tag{15}$$

where, Q_{year} and Q_{month} are the annual and monthly heating energy need of the investigated building, t is the time in the unit of seconds. The energy demand other than heating energy has been considered for the electrical devices used in the daycare. Main equipment list contain computer, washing Machine (A++), camera system, fridge (A++), deep-freeze (A+, 102L), microwave (A++), oven, fume hood and kettle. The annual energy requirement for these devices was calculated according to the number of devices, the power they consume and their respective daily working hours.

It is important to mention that the building investigated in our study lacks insulation in its components. Insulation represents a major parameter in the calculation method of TS825. The use of insulation material in the building components is recommended because it has a significant impact on the heat loss of the building by conduction, resulting in lower energy need (Turkish Standards Institution, 2018). Since the investigated daycare does not have any insulation material in its walls and other building components, we have conducted separate calculations for the heat loss through conduction and convection, assuming cases in which insulation materials are used for the walls and ceiling. The insulation material used for this purpose were selected according to the recommendations from TS825. This step is conducted for comparison purpose to analyse the impact of using insulation material.

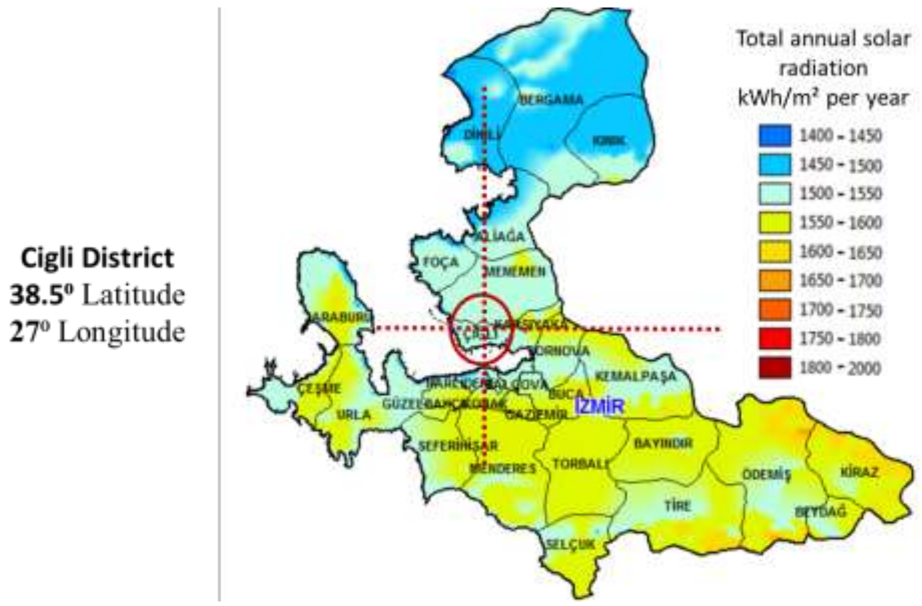

Figure 2. Solar irradiation map and latitude of Çiğli District (GEPA, 2023)

Once the energy demand of the selected building has been calculated for monthly and annual periods, PV panel type and required number of PV panels were investigated. Figure 2 presents the solar irradiation map of Çiğli district. Furthermore, latitude of the selected building is a crucial parameter for PV system design as tilt angle of the PV panels is directly depended on the latitude. We utilize from a simplified equation set to calculate the optimal tilt angle (β) of each season:

$$\begin{array}{r} \text{During summer:} \\ \text{For spring and autumn months:} \end{array} \quad \begin{cases} \beta = (0.9 \times \text{Latitude}) - 23.5^0 \\ \beta = \text{Latitude} \pm 2.5^0 \\ \beta = (0.9 \times \text{Latitude}) + 29^0 \end{cases} \tag{16}$$

Figure 3. Effects of latitude and longitude on PV panel tilt angle

PV panel orientation should be altered according to the PV panel tilt angle calculations. In most of the PV panel applications in our country, tilt angle is kept constant. In this case, an optimal angle value should be determined for annual radiant harvesting. Note that tilt angle only varies with latitude (Fig. 3). We may sum winter, summer, spring, autumn tilt angles and divide by four to find an approximate annual tilt angle. Another simplified equation can also be utilized for annually constant tilt angles:

$$\beta = (0.87 \times \text{Latitude}) + 3.1^0 \tag{17}$$

3. Results and Discussions

The results of our work using the methods described in Section 2, are reported in this section. Parameters and properties used at each calculation step are described in tables and values found are reported. As mentioned in the first section, the energy need for heating purpose in the building (H), is the dominant factor when determining the total energy need. It is defined in section 2 as the sum of heat loss through conduction and convection (H_T), and heat loss through ventilation. (H_v). Table 2 describes the calculation of (H_T).

Table 2. Building heat loss through conduction and convection: calculation steps

Surface type	Layer element	Element thickness d (m)	Thermal cond. λ (W/mK)	Conduction resistance R, (m^2K/W)	Overall coefficient U (W/m^2K)	Surface area A (m^2)	Heat loss A x U (W/K)
Wall surfaces	Ri			0.13			
	Plaster	0.02	1	0.02			
	lime sandstone	0.172	0.35	0.491			
	Plaster	0.008	0.35	0.023			
	Re			0.04			
			Total	0.704	1.419	202.5	287.5
Wall surfaces (reinforced concrete)	Ri			0.13			
	Plaster	0.02	1	0.02			
	Reinforced Concrete	0.172	2.5	0.069			
	Plaster	0.008	0.35	0.023			
	Re			0.04			
			Total	0.282	3.551	53.4	189.6
Ceiling	Ri			0.13			
	Plaster	0.02	1	0.02			

	Reinforced Concrete	0.18	2.5	0.072			
	Re			0.08			
			Total	0.302	2.65	484.2	1478.3
Floor	Ri			0.17			
	PVC flooring	0.005	0.23	0.022			
	Screed	0.03	1.4	0.021			
	Leveling Screed	0.02	1.4	0.014			
	lightweight concrete	0.1	1.1	0.091			
	Re			0			
			Total	0.317	1.573	484.2	761.9
External Door					4	7.92	31.68
Window					2.4	65.48	157.15
Sum of the heat loss from the building elements by conduction and convection $\mathbf{H_T}$.							2710.4

The value for the total heat loss through conduction and convection of the daycare was found as H_T = 2710.428 W/K. Next, the heat loss through ventilation, (only natural ventilation in our building) was calculated using Eq. (7) and the following value was found as H_V = 378.3 W/K. Finally, the total heat loss of the building was obtained by summing up H_T and H_V according to equation (1). The total heat loss coefficient of the building is **H = 3088.78 W/K.**

Once the heat losses due to the building structure and ventilation system were determined, we calculated the heat gains of the building as the sum of internal gains and solar gains. The internal heat gain was calculated as an average value using Eq (9), which is about 2866.3 W. On the other hand, the average solar gain was calculated monthly, in each cardinal direction, as described in Eq. (10). The calculation steps and results are reported in Table 3. Note that $r_{i,month}$ and $g_{i,month}$ values are taken from the TS 825 standard as 0.8 and 0.68, respectively.

Table 3. Average monthly solar gains: calculation steps

	$\mathbf{I_{i,month}}$ **(kg.m²/h)**			$\mathbf{A_i}$ **(m²)**				$\boldsymbol{\phi_s}$ **(W)**
	I_{South}	I_{North}	$I_{East/West}$	A_{South}	A_{North}	A_{East}	A_{West}	
Jan.	72	26	43					1587.5
Feb.	84	37	57					2035.6
Mar.	87	52	77	15.6	20.58	16.3	13	2547.8
Apr.	90	66	90					2937.2
May	92	79	114					3482.3

Jun.	95	83	122		3680
Jul.	93	81	118		3576.9
Aug.	93	73	106		3296.1
Sept.	89	57	81		2684.5
Oct.	82	40	59		2084.1
Nov.	67	27	41		1524.4
Dec.	64	22	37		1379.2

Gain utilization factor was calculated for each month via Eq. 12, and the values are reported in Table 4. At last, the annual heating energy requirement of the building (Q_{year}), was determined as the sum of the monthly heating energy requirement values (Q_{month}) by using Eqs. (14) and (15), respectively.

Table 4. Main calculation steps and results on the annual heating energy requirement of the building

	Heat losses			Heat gains				
	Specific Heat loss	Temp. diff.	Heat loss	Internal heat gain	Solar energy gain	KKO	Gain utilization factor	Heating energy require-ment
Months	$H=H_T+H_V$ (W/K)	$\theta_i-\theta_e$ (K,°C)	$H(\theta_i-\theta_e)$ (W)	ϕ_i (W)	ϕ_s (W)	γ (-)	η_{month} (-)	Q_{month} (kJ)
Jan		11.6	35829.8		1587.5	0.12	0.99	8.13×10^7
Feb		11	33976.6		2035.6	0.14	0.99	7.53×10^7
Mar		8.4	25945.8		2547.8	0.20	0.99	5.33×10^7
Apr		4.2	12972.9		2937.2	0.42	0.90	2.02×10^7
May		θ_e high	0		3482.3	0	0	0
Jun	3088.78	θ_e high	0	2866.3	3680	0	0	0
July		θ_e high	0		3576.9	0	0	0
Aug		θ_e high	0		3296.1	0	0	0
Sep		θ_e high	0		2684.5	0	0	0
Oct		1.5	4633.2		2084.1	1.004	0.63	4.21×10^6
Nov		7	21621.5		1524.4	0.190	0.99	4.47×10^7
Dec		10.7	33049.9		1379.2	0.12	0.99	7.47×10^7

The total heating energy requirement of the building was calculated as the sum of the monthly heating energy needs and found as: $Q_{year} = 3.54 \times 10^8$ kJ. This value corresponds to 9.83×10^4 kWh. This theoretical value obtained using the TS 825 standard assumes a permanent daily and monthly use of electricity in the building. In reality, the building is functional 12 hours a day, 23 days a week, or 276 hours monthly. It represents only 38% of 720 hours calculated. This means that in reality, only 38% of the energy calculated is needed. The real heating energy requirement becomes 3.74×10^4 kWh.

Table 5. Annual energy consumption of devices in the daycare

Device	Pcs.	Power (W)	Daily working hour (h)	Daily Energy consumption (kWh)	Monthly energy consumption (kWh)	Annual energy Consumption (kWh)
Computer	1	15.2	8	0.12	3.6	108
Washing Machine (A++)	1	800	1	0.8	24	720
Camera System	1	10	24	0.24	7.2	216
Fridge (a++)	1	60	24	1.44	43.2	1296
Deep Freeze (A+, 102 litres)	1	50	24	1.2	36	1080
Microwave (A++)	1	300	1	0.3	9	270
Oven	1	2500	1	2.5	75	2250
Fume Hood	1	12	1	0.012	0.36	10.8
Kettle	1	1200	0,5	0.6	18	540
	1	28	8	0.224	6,72	201.6
Total				7.436	223.1	6692.4

We have calculated that the annual energy consumption of electrical devices used in the daycare is about 6692.4 kWh; therefore, the total energy requirement of the building per year rises to 4.40×10^4 kWh.

The remaining energy requirement for the daycare was assessed by identifying all devices consuming electricity in the building and calculating their monthly and annual consumption, reported in Table 5.

Five different types of PV-panels were investigated to provide the amount of energy needed for the investigated daycare, t. The criteria considered for this selection are the amount of solar irradiation at the building location, the total area to be covered with PV-panels considering individual panel size, and the calculated energy requirement of the building. The average daily irradiation time for each month at the building location are presented in Table 6.

Table 6. Çiğli district annual sunbathing time (GEPA, 2023)

Month	Duration (h)
January	4.98
February	5.99
March	7.17
April	8.19
May	9.88
June	12.07
July	12.38
August	11.6
September	9.8
October	7.78
November	5.69
December	4.39

The types of PV-panels investigated in our work and their properties are reported in Table 7.

Table 7. Monocrystalline PV-panels and main properties (solaravm.com/solar-gunes-paneli, 2023)

Panel	Power (W)	Dimensions (mm)	Weight (kg)	Efficiency (%)	Price (TRY)
Jinko Solar JKM370M-72-J	370	1956×992×50	27	19.1	3689
Jinko Solar JKM535M-72H	535	2278×1134×35	28	20.8	5632
Lexron LXR-410M	410	1987×1001×35	22	19.1	5044
AlfaSolar 3S72M400	400	1994×1008×42	24	20.0	4016
ELINPlus ELNSM6612M	395	1979×1002×40	22.5	19.9	3965

For each PV-panel type investigated, the corresponding number of panels and the total area needed to provide the amount of energy requirement of the daycare, were calculated according to the amount of solar irradiation. The calculation was made for the month of January as it is the month during which the energy need reaches its peak value: 9142.58 kWh. Table 8 presents the values obtained.

Table 8. Number of PV-panels required

PV-Panel	Sunbathing time (h)	Panel Power (kW)	Energy generation (Jan) (kWh)	Energy requirement (Jan.) (kWh)	Number of PV	Total surface needed (m^2)
Jinko Solar JKM370M-72-J	149.4	0.37	55.278	9142.58	166	320.93
Jinko Solar JKM535M-72H		0.535	79.929		115	295.5
Lexron LXR-410M		0.41	61.254		150	296.87
AlfaSolar 3S72M400		0.4	59.76		153	307.5
ELINPlus ELNSM6612M		0.395	59.013		155	307.21

We observed that with the PV-panels investigated, the number of panels needed to cover the daycare energy needs, is in the range of 115 to 166, meaning an average of 140 panels depending on the panel power. It corresponds to an area between 307 and 321 m^2, or an average of 315 m^2. Among our PV-panels, the best performer is the Jinko Solar JKM535M-72H: with its efficiency of 20.8% it can generate enough energy for the daycare with 115 panels, which represents a surface of just 296 m^2.

The optimal tilt angle (β) for the panels was calculated for the investigated building located in the Cilgi district in Izmir, at a latitude of 38.5°. The results are reported in Table 9.

Table 9. Optimal tilt angle for Çiğli district

Season	β
Summer	11.15
Spring	41
Autumn	36
Winter	63.65

Alternatively, a constant value for (β) can also be calculated using Eq. (17) in case the solar panel will stay in the same direction all through the year. In our case, the annually constant tilt angle was found as β = 36.6°.

As mentioned in the previous sections, our building does not have insulation although it is recommended in the TS825 standard. In this view, we have conducted theoretical calculations assuming cases in which a layer of insulation material is applied to the walls and the ceiling components of the daycare. Three cases have been considered. For each case, a different insulation material was selected for the walls, while one single material was maintained for the ceiling in all three cases. The materials used for the wall insulation are Extruded Polystyrene (XPS) Styrofoam, Glass foam, and Wood fiber, while the ceiling insulation was evaluated using Expanded Polystyrene (EPS) Styrofoam. These materials were selected based on their thermal conductivity values in accordance with the suggestions from TS828, and their availability on the market. The thickness of the materials is an important factor when considering insulation. Thicker layers allow better insulation, but they should remain in compliance with local building codes and regulations. In our work, we have calculated the thickness of the investigated materials in order to obtain a reduction of 50% in heat loss through conduction and convection (H_T) value, for each case considered.

The insulation materials investigated with their properties and the calculated thickness values required for the desired insulation performance are shown in Table 10.

Table 10. Properties of insulation materials used in experimental cases

Material	Wall insulation			Ceiling insulation
	Case 1	Case 2	Case 3	
	XPS Styrofoam	Glass foam	Wood fibered	EPS Styrofoam
Thermal conductivity (W/mK)	0.035	0.055	0.065	0.04
Thickness required (m)	0.01536	0.0158	0.016	0.02

The impact of these insulation materials on the heat loss and the total energy demand of the building were calculated and compared with the real case where there is no insulation. The results are presented in Table 11.

Table 11. Impact of insulation on heat loss and total energy demand

	Insulation Material	Thermal conductivity (W/mK)	Thickness required (m)	Heat loss (W/K)	Energy need (kWh)
Case 1	XPS Styrofoam	0.035	0.01536	2180	63730.39
Case 2	Glass foam	0.055	0.0158	2206	64748.32
Case 3	Wood fibered	0.065	0.016	2215	65087.57
Real Case	No insulation			3088.79	98292.18

As we can see from these results, the use of insulation material to reduce (H_T) value by 50%, results in 29.4%, 28.5% and 28.2% drops in heat loss for insulation cases 1, 2 and 3 respectively.

Consequently, the annual total energy need of the building in each of the three insulation cases drops by 35.2%, 34.1%, and 33.8% respectively. With these new values, the corresponding number of PV panels required was determined for the three insulated cases, with each of the five PV-panels selected previously, and comparison was made with the real situation where there is no insulation. These results are detailed in Table 12.

Table 12. Number of PV-panels needed for insulation cases

	Case 1	Case 2	Case 3	Real Case
Jinko Solar JKM370M-72-J	113	115	115	165
Jinko Solar JKM535M-72H	78	79	80	114
Lexron LXR-410M	102	104	104	149
AlfaSolar 3S72M400	105	106	107	153
ELINPlus ELNSM6612M	106	108	108	155

As shown from these results, when insulation is applied, the number of PV-panels needed to cover the entire energy need of the daycare decreases by approximately 30% depending on the PV-panel used. From these panels, the Jinko Solar JKM535M-72H has the best performance and would allow to cover the energy demand with just 78, 79, or 80 panels in each of the three insulated cases respectively, while the initial case without insulation requires 114 panels. We observe here the use of insulation plays a very important role in limiting the heat loss of the building, allowing the energy need to decrease significantly. While our theoretical study assumed insulation layers only on the wall surface and ceiling components of the building, it is important to remember that insulation layers can also be applied to other components like the reinforced concrete part of the walls or the floor. Furthermore, the thickness of the insulation layers used in our study was minimized in order to provide the most realistic case possible, but the average thickness of insulation layers is well above our values, as it can be seen in the examples from the TS825 standard, where the thickness of the layers is about 3 times our value. All these remarks imply that the use of insulation have potential to reduce exponentially the energy need.

In order to evaluate the real cost of utilizing the investigated PV-panels to meet the total energy demand of the daycare building, a cost analysis was conducted. This analysis takes into account the price of the PV-panels, estimation of Turkish market prices for installation and maintenance costs.

The prices of the investigated PV-panels are provided in Table 13.

Table 13. Total price of the investigated PV panels

Panel	Price for single panel (TRY)	Number of panels	Total Price (TRY)
Jinko Solar JKM370M-72-J	3689	166	612374
Jinko Solar JKM535M-72H	5632	115	647680
Lexron LXR-410M	5044	150	756600
AlfaSolar 3S72M400	4016	153	614448
ELINPlus ELNSM6612M	3965	155	614575

The price varies from approximately 613000TRY to 757000TRY, depending on the type of PV-panel used, with an average of 700000TRY.

The most recent information we have gathered concerning the installation price for PV-panels from suppliers and reviewers indicates that installation of solar panels costs between 21TRY and 25TRY per Watt installed (globalenerjimarketim.com and keremcilli.com/gunes-enerjisi-santrali-kurulum-maliyeti-2022 websites both accessed in 2023). This value is fairly in the range of prices given by Forbes (forbes.com/home-improvement/solar/cost-of-solar-panels) for PV-panels installation in the US. This represents on average of 1.4 million TRY to be paid for labor.

The total cost of the project is found to be in the range of 2.023 to 2.18 million TRY. The maintenance of PV-panels is estimated to be between 1% and 2% of the installation cost. In our case, this represents approximately 21000TRY per year. On the other hand, when we consider the insulated cases, the cost of PV-panels changes according to the new number of PV-panels needed to cover the energy demand. For each case, the total prices of the PV-panels are given in detail in Table 14.

Table 14. Total price of the PV-Panels for insulated cases

Panel	Price for single panel (TRY)	Number of panels			Total Price		
		Case 1	Case 2	Case 3	Case 1	Case 2	Case 3
Jinko Solar JKM370M-72-J	3689	113	115	115	417671	423398	425306
Jinko Solar JKM535M-72H	5632	78	79	80	440998	447045	449059
Lexron LXR-410M	5044	102	104	104	515370	522436	524790
AlfaSolar 3S72M400	4016	105	106	107	420592	426359	428280
ELINPlus ELNSM6612M	3965	106	108	108	420508	426273	428194

The results show that the total prices of the PV panels decrease by around 30% for the insulation cases. The price of the insulation materials was calculated according to their unit price and the surface to be covered: 202.5m of wall surface, and 484.1m for the ceiling. Table 15 shows an estimation of these prices for each case.

Table 15. Price of insulation materials

	Material	Price (TRY)
Case 1	XPS Styrofoam	21796,93
Case 2	Glass foam	65390,78
Case 3	Wood fibered	54492,32
Ceiling	EPS Styrofoam	3647,57

In order to get the total cost of the project, the labor cost was also calculated with the same method used previously for the real case and found to be in the range of 966000TRY and 985000TRY. According to these data, the total cost of the project for insulation cases ranges between 1.38 and 1.56 million TRY.

4. Conclusions

In this work, we have explored the feasibility of meeting the energy needs of a daycare building through the use of photovoltaic (PV) solar cells. The global increase in energy demand and the need for sustainable and environmentally friendly solutions, has led to a growing interest in renewable energy sources such as solar power and emphasized the importance of solutions like PV-aided net zero-energy buildings. Our study focused on the heating, ventilation, and air conditioning (HVAC) energy requirements, as they represent the biggest share in both residential and commercial buildings. By utilizing the TS825 standard, which provides guidelines for calculating the energy performance of buildings, the heating energy requirement of the daycare building was determined. The analysis took into account factors such as building dimensions, thermal insulation properties, heat losses, and heat gains. The monthly and annual energy demand of the building was accurately estimated based on these calculations. We then considered other energy needs, including lighting and electrical devices, to determine the overall energy requirement of the building.

Based on our analysis, we proposed the use of monocrystalline PV panels to meet the energy demand of the daycare building. After scaling the selected PV-panels to our project, the orientation and power potential of the PV panels were determined based on the maximum energy requirement experienced in January. The required number of PV-panels needed to cover the energy demand of the building was found to be in the range of 115 to 166 panels. Since our building lacks insulation which is an important parameter when dealing with heat loss and energy demand in buildings, as shown in the TS825 standard, theoretical calculations were conducted, assuming the presence of insulation layers in the walls and the ceiling components of our building. Three cases have been considered. For each case, a different material with different thermal conductivity was selected for the wall insulation, while one standard material was kept constant for the ceiling insulation. Comparison between the results of real case without insulation and theoretical cases with insulation, showed that the total energy demand of the building can be reduced by 33.8%, 34.1%, and 35.2%, which are very significant. Likewise, the number of PV-panels required to cover the energy demand of the daycare dropped by approximately 30%, with an optimal value of just 78 PV-panels, using the Jinko Solar JKM535M-72H under the insulation conditions described in case 1.

We conducted a cost analysis to evaluate the economic aspects of implementing the solutions suggested. The total cost of the project includes the price of the panels and the labour for installation and was found in the range of 2.023 to 2.18 million TRY depending on the PV - panel selected. The initial investment associated with implementing a PV panel system capable of meeting the entire energy demand of the building may represent a challenge, especially for buildings with limited budgets. On the other hand, the use of insulation material allows this initial investment to be reduced by a very significant amount as shown by our theoretical calculations with insulation, where the total cost of the project dropped to values between 1.38 and 1.56 million TRY. Furthermore, insulation has potential to reduce the initial cost even more, as layers could be applied to other components of the building. A good number of insulation materials can be chosen from, according to the cost and the thermal conductivity, among other factors. The optimal thickness can be determined according to the building regulation and the desired insulation performance. For these reasons, the use of insulation is our main recommendation in view of the implementation of the project. Besides insulation, some other options remain available to make the project more realistic and deserve further evaluations. A more specific PV-panel system could be considered, with usage exclusively limited to the ideal irradiation conditions, allowing a reduced dependence on the grid electricity. Also, the use of energy storage could have a great positive impact since solar energy is intermittent. Additional energy generated in peak irradiation period would serve during days with less daylight.

Overall, our findings suggest that it is indeed possible to cover the entire energy needs of the daycare building through PV-panels, making it a net zero-energy building. The use of renewable energy sources like solar power not only reduces greenhouse gas emissions but also contributes to a sustainable and environmentally friendly future. The results of this study provide valuable insights and recommendations for improving energy efficiency in commercial and residential buildings.

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Author Statement

All authors reviewed the results and approved the final version of the manuscript.

Conflict of Interest

The authors declare no conflict of interest.

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