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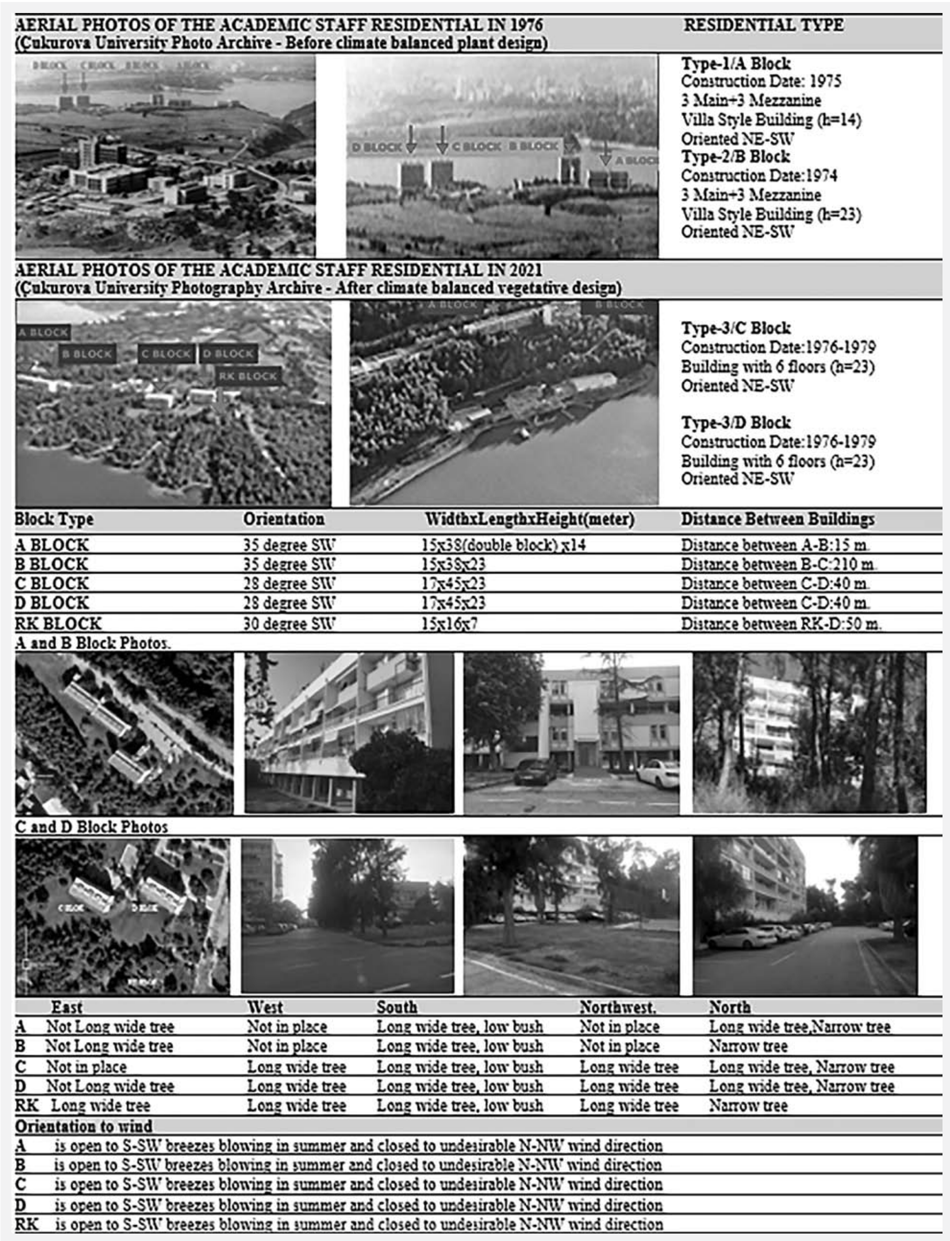

AERIAL PHOTOS OF THE ACADEMIC STAFF RESIDENTIAL IN 1976 (Çukurova University Photo Archive - Before climate balanced plant design)	RESIDENTIAL TYPE
	Type-1/A Block Construction Date: 1975 3 Main+3 Mezzanine Villa Style Building (h=14) Oriented NE-SW **Type-2/B Block** Construction Date:1974 3 Main+3 Mezzanine Villa Style Building (h=23) Oriented NE-SW
AERIAL PHOTOS OF THE ACADEMIC STAFF RESIDENTIAL IN 2021 (Çukurova University Photography Archive - After climate balanced vegetative design)	
	Type-3/C Block Construction Date:1976-1979 Building with 6 floors (h=23) Oriented NE-SW **Type-3/D Block** Construction Date:1976-1979 Building with 6 floors (h=23) Oriented NE-SW

Block Type	Orientation	WidthxLengthxHeight(meter)	Distance Between Buildings
A BLOCK	35 degree SW	15x38(double block) x14	Distance between A-B:15 m.
B BLOCK	35 degree SW	15x38x23	Distance between B-C:210 m.
C BLOCK	28 degree SW	17x45x23	Distance between C-D:40 m.
D BLOCK	28 degree SW	17x45x23	Distance between C-D:40 m.
RK BLOCK	30 degree SW	15x16x7	Distance between RK-D:50 m.

A and B Block Photos.

C and D Block Photos

	East	West	South	Northwest.	North
A	Not Long wide tree	Not in place	Long wide tree, low bush	Not in place	Long wide tree,Narrow tree
B	Not Long wide tree	Not in place	Long wide tree, low bush	Not in place	Narrow tree
C	Not in place	Long wide tree	Long wide tree, low bush	Long wide tree	Long wide tree, Narrow tree
D	Not Long wide tree	Long wide tree	Long wide tree, low bush	Long wide tree	Long wide tree, Narrow tree
RK	Long wide tree	Long wide tree	Long wide tree, low bush	Long wide tree	Narrow tree

Orientation to wind	
A	is open to S-SW breezes blowing in summer and closed to undesirable N-NW wind direction
B	is open to S-SW breezes blowing in summer and closed to undesirable N-NW wind direction
C	is open to S-SW breezes blowing in summer and closed to undesirable N-NW wind direction
D	is open to S-SW breezes blowing in summer and closed to undesirable N-NW wind direction
RK	is open to S-SW breezes blowing in summer and closed to undesirable N-NW wind direction

Fig. 1 Building and outdoor features

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Holistic Approach to Ecological Design Parameters of Building and Landscape Design on Outdoor Thermal Comfort in Hot, Humid Climate

Energy performance
Hot, humid climate
Outdoor thermal comfort
Plant design
University residential building

In this study, academic staff residential buildings were studied as part of a university campus located in a hot and humid climate zone in Türkiye. Within the scope of the study, the energy efficient architectural and landscape design decisions of the buildings built in 1976 were examined. The aim was to determine the energy performance of buildings built about 50 years ago and to quantify the effect of changing landscape conditions on thermal comfort. In this aim, the outdoor thermal comfort level was determined by creating microclimate simulations for the hottest day and time of the year. Microclimatic analyses were performed with ENVI-met software and thermal comfort was evaluated with two metrics, average PMV and ASHRAE scale. The energy performance of the buildings was determined using ecological design parameters. An approach to global environmental problems is the use of ecological design principles, including architectural and landscape design principles. It is important to consider both architectural design criteria and landscape design criteria when discussing an ecological design in the built environment. Architectural and landscape design decisions for hot and humid climate regions together increased energy efficiency by 51.1% to 75.5%. It was found that although the plant design improves energy performance in buildings by that range value, it improved outdoor thermal comfort by 15% to 22%. As a result, the study evaluated climate-balanced plant design with building energy performance in order to improve outdoor thermal comfort.

Introduction

According to the United Nations report, the built environment, including residences, consumes approximately 40% of the produced energy and natural resources, while construction materials consume approximately 4% (Li, 2006; UNEP, 2017). According to the Energy Information Administration survey, it has been reported that 41.7% is consumed by the built environment and 5.9% is consumed from the use of construction materials (U.S., 2020). The construction sector, which causes environmental pollution, uses energy in the stages of construction, use and demolition, starting from the extraction of raw materials. Ryn (2007) describes that environmental crisis is as a design crisis. Buildings, landscapes, and how things are constructed contribute to environmental crises and pollution (Ryn, 2007).

NATO Foreign Ministers approved the agenda on climate change and security on 23-24 March 2021. On 1-12 November 2021, the 26th United Nations Climate Change Conference (COP26) decided to gradually reduce the use of coal and other fossil fuels. NATO's attention was drawn to the issue of global warming, albeit late, due to the negative rate of increase in global warming in the next ten years and the obstacles it will create in terms of military operations. If carbon dioxide emissions cannot be reduced by 2050, it will be inevitable for our planet to face global climate disasters. As a result, various design parameters need to be reconsidered in order to reduce energy consumption and improve thermal comfort in new buildings. The reconsidered built environment is based on an ecological design approach. In order to reduce high energy losses, ecological design methods have been developed at the international, national, regional, and local levels. To achieve this objective, standards, regulations, and codes have also been developed and implemented around the world based on the performance of buildings. Over the last ten years, Türkiye has implemented important legal regulations in accordance with the European Union Building Energy Performance Directive. With the general requirements of building energy performance regulations, the Energy Performance Regulation in Buildings entered into force in our country in 2009. On October 11, 2021, the Ministry of Environment, Urbanization and Climate Change was formed, extending the responsibility of the Ministry responsible for the environment and urbanization of the country. Accordingly, all buildings designed and constructed after 2009 are evaluated by an interdisciplinary team, constructed as energy-efficient buildings, and controlled by the ministry that has expanded its responsibilities. However, in order to increase the energy efficiency of the building stock built before 2009, a thorough analysis of the buildings' current energy performance is necessary (Karagöz, 2016).

By calculating the microclimatic effect caused by changing landscape conditions, the study aims to reveal the energy performance of buildings built about 50 years ago and the importance of improving thermal comfort. The study chose a building group built in 1976 for residential academic staff at the university campus. The relationship between the energy efficient criteria of this building group and architectural design has been examined. Thus, the energy performance and architectural design of the buildings, as well as outdoor comfort, were evaluated together. This study compared the outdoor thermal comfort inside the campus between 1976 and 2021, and also presented the active role of climate balanced vegetative design on improving outdoor thermal comfort. This study shows how changes in planting design and tree species affect thermal comfort in a built environment using microclimate simulation (with ENVI-met software).

A value was reached for the influence of architectural design parameters on outdoor thermal comfort conditions at the end of the study. This context suggests that the design principles of university residential buildings and their immediate surroundings will support the production of housing in the future to cope with changing climatic conditions.

LITERATURE REVIEW

Some research has been done on outdoor thermal comfort in the built environment. It has been seen that these studies can be classified into two groups, namely comparative studies of urban heat islands in metropolitan centers and historical cities and thermal comfort studies of the relationships between buildings, building environments, and public spaces (Allegrini et al., 2012; Boeri & Gaspari, 2015; Gaspari & Fabbri, 2017).

It is evident that previous studies have investigated the correlation between the morphology of residential blocks and microclimates from different perspectives as second group. Some explored the influence of morphology on the wind environment (Kubota et al., 2008), while others simulated ventilation between buildings (Mei et al., 2017; Rosheidat et al., 2008). Some emphasized the energy budget balance and influence of urban morphology (Unger, 2004), while others examined the outdoor thermal comfort in extreme temperature conditions depending on the climate zone. Some of them focused on relation with building type and outdoor thermal comfort (Berkovic et al., 2012; Zhang et al., 2022), while other focused on relation with landscape design and outdoor thermal comfort (Tan et al., 2021.; Shashua-Bar et al., 2011.; Yılmaz et al., 2018; Rui et al., 2019; Mutlu and Yılmaz, 2021; Yang et al., 2018).

Although different perspectives have been used to examine thermal comfort's impact on pedestrian microclimates, there are still some limitations as a holistic assessment. So, it is important that the relationship between the energy performance of the buildings and, the architectural and landscape design be evaluated together with outdoor comfort conditions. It differs from other studies in evaluating building typology and landscape design together to determine outdoor thermal comfort, including plant design types. A major difference of the research is how buildings and building environments interact for outdoor thermal comfort in humid and hot climates, including location, orientation, distances between buildings, types of buildings (building shapes, dimensions, etc.) and landscape design.

MATERIAL AND METHOD

- **Identification of the study area** – The study area was chosen as the academic residential structure group in Adana province, Çukurova University campus in Türkiye. On the east and north sides of the Seyhan dam lake, this area is a natural park located north of Adana. It is at an altitude of about 50 meters above the lake level. Residential blocks are designed in three different types. In Fig. 2, the location of the study area in Türkiye and the location of the study area within the university campus are given.

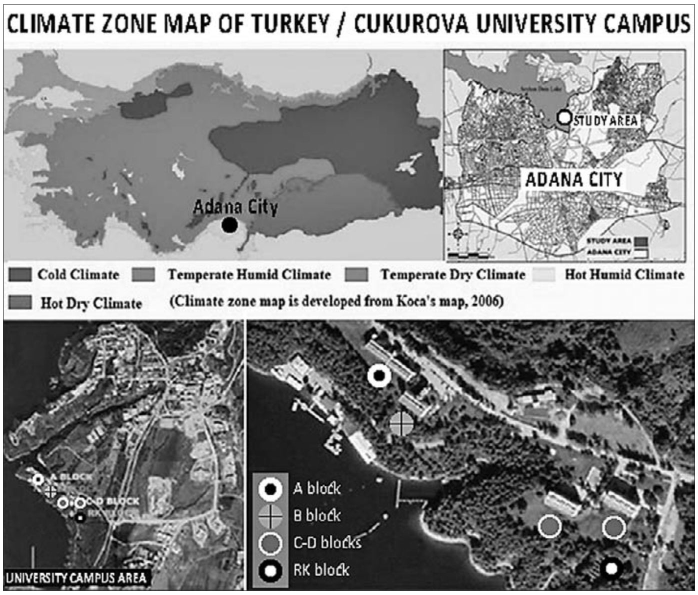


FIG. 2 LOCATION OF THE STUDY AREA AT THE ÇUKUROVA UNIVERSITY, TÜRKIYE

- **Information about features of building and outdoor green area** – When the old photographs of the blocks as A, B, C, D and RK, which are included in the residential group, and it's the current photographs obtained through on-site inspections are examined, the improvement created by the landscape design is seen in Fig. 1 building type and building orientations are included. The figure 1 includes the characteristics and design parameter of the buildings, including the year of construction, the number of floors, floor height, the type of building and building orientations.

The tree species detected in the field study are as follows: *Acacia cyanophylla* (Cyprus Acacia), *Acer negundo* (Maple tree), *Casuarina equisetifolia* (Iron tree), *Cercis siliquastrum* (Judas), *Cupressus sempervirens var. horizontalis* (Splayed Cypress), *Eucalyptus camaldulensis* (Eucalyptus), *Fraxinus excelsior* (Ash tree), *Jacaranda mimosifolia* (Jacaranda), *Melia azedarach* (Margosa tree), *Olea europaea ssp. oleaster* (Wild olive tree), *Pinus brutia* (Red pine tree), *Pinus pinea* (Pine tree), *Platanus orientalis* (Sycamore tree), *Schinus molle* (Wild black pepper tree), *Thuja orientalis* (Thuja tree), *Washingtonia filifera* (Palm tree), Cynodon dactylon (Bermuda Grass) is used in grass areas.

- **Information about location and texture** – This section evaluates the climate, geography, and building texture data of the residential building group. Residential area has hot and humid climates. In accordance with the hot and humid climate, the study area's buildings are located close to water and on top level of hilly terrain in forest land. This area is located in a dense plant/green texture with its current situation. It is located in a low-density residential area. On a monthly basis, Adana province sees the highest monthly temperature of 35.1 °C (August). The 16th of August is the hottest day of the year, and 14:00 pm is the hottest hour of the year on the defined date (Meteorology General Directorate, 2020). Settlement texture and buildings are arranged in a dispersed and discrete manner to benefit from air flow. As the location selection, the high region, which can benefit more from the effect of the wind, was preferred. It is to be planted away from the structure at a distance of ¼ of the mature height of the tree to reduce solar gain (Williams, 2021). In order to be protected from extreme heat effect of summer in Adana, protection from the sun was provided outdoor with the shade area formed by the trees on the south and west facades of the buildings. It was preferred to be planted at a distance from the building, as it would cut off the desired southwesterly wind at a rate of 1/4.

Method

The methodology of this study includes three main stages:

– The first stage includes the evaluation of architectural and landscape design parameters that determine effective energy use. At the end of the chapter, the evaluation of architectural and landscape design parameters that effective efficiency performance values of the built environment are determined.

– The second stage includes microclimate simulation. Within this scope, two different thermal comfort models were produced. The first includes the analysis of microclimate simulation for the period when the settlement area was first formed. This stage covers the first period of the studies to improve the thermal comfort situation. The second covers the analysis of microclimate simulation for the year 2021, which is the current conditions of the built environment. This stage covers the period when the work to improve the thermal comfort situation is completed. At the end of the stage, a comparison of the thermal comfort model for the two periods is performed. According to the comparison results, suggestions are presented to improve thermal comfort.

– At the end of the study, architectural design parameters that determine effective energy use and outdoor comfort were evaluated together. Thus, the energy efficiency performance values that occur together with the improved outdoor thermal comfort conditions of the sample buildings located in the hot and humid climate region have been revealed.

First of all, the tree species in the study area were determined. For this purpose, the shape, size and texture characteristics of tree species planted 40-45 years ago in the university campus were determined. Climate-balanced outdoor design criteria have been obtained, which will be the basis of the studies to improve the thermal comfort of the study area. These criteria are location and texture (Lechner, 2001; Zeren, 1978), building orientation (Guzowski, 2010; Yıldız et al., 2012; Kısa Ovalı, 2009; Özdemir, 2005; Göksal & Özbalta, 2002; Altunkasa, 1990; Watson, 1983; Olgyay, 1963), building and outdoor green area features (Loibl et al., 2010). The situation of outdoor design criteria and tree species in the study area was evaluated.

The data to be used in the microclimate simulation model are handled separately for two different periods. Climatic data and spatial data are calculated separately for the initial construction period and current use. Thermal comfort analysis is conducted using ENVI-met SCIENCE simulation software. Adana province has the highest monthly average temperature of 35.1 °C. It is the hottest day of the year on the 16th of August, and it is the hottest hour of the year at 14:00 pm (the average temperature data of the province of Adana by the General Directorate of Meteorology).

ENVI-met SCIENCE, which is used in the study for climatic modeling and thermal comfort analysis, is a three-dimensional local climate model designed to produce simulations of surface, plant and air interactions in the environment in spatial grids of different sizes from 0.5×0.5 m to 10×10 m. The purpose of simulation is to reveal the thermal comfort status according to the climatic characteristics, spatial characteristics (building mass, open spaces and green areas) and user characteristics of the area examined.

In the study, it was found appropriate to determine the plan-square scale of 2×2 m, considering the goal of obtaining detailed data and compliance with the building dimensions. In this case, the area where thermal comfort analyzes are carried out consists of 14,960 grid-squares (230×260 m^2), together with the external environment, which is thought to affect the thermal comfort of the campus. Adana is located in a hot and humid climate zone. Therefore, it is of great importance to be protected from the heat in outdoor in summer. For this reason, two 24-hour climatic simulation data were used for the hottest day of the year (16 August). Thanks to the BioMet software, which is an extension of the ENVI-met SCIENCE software, 2 thermal

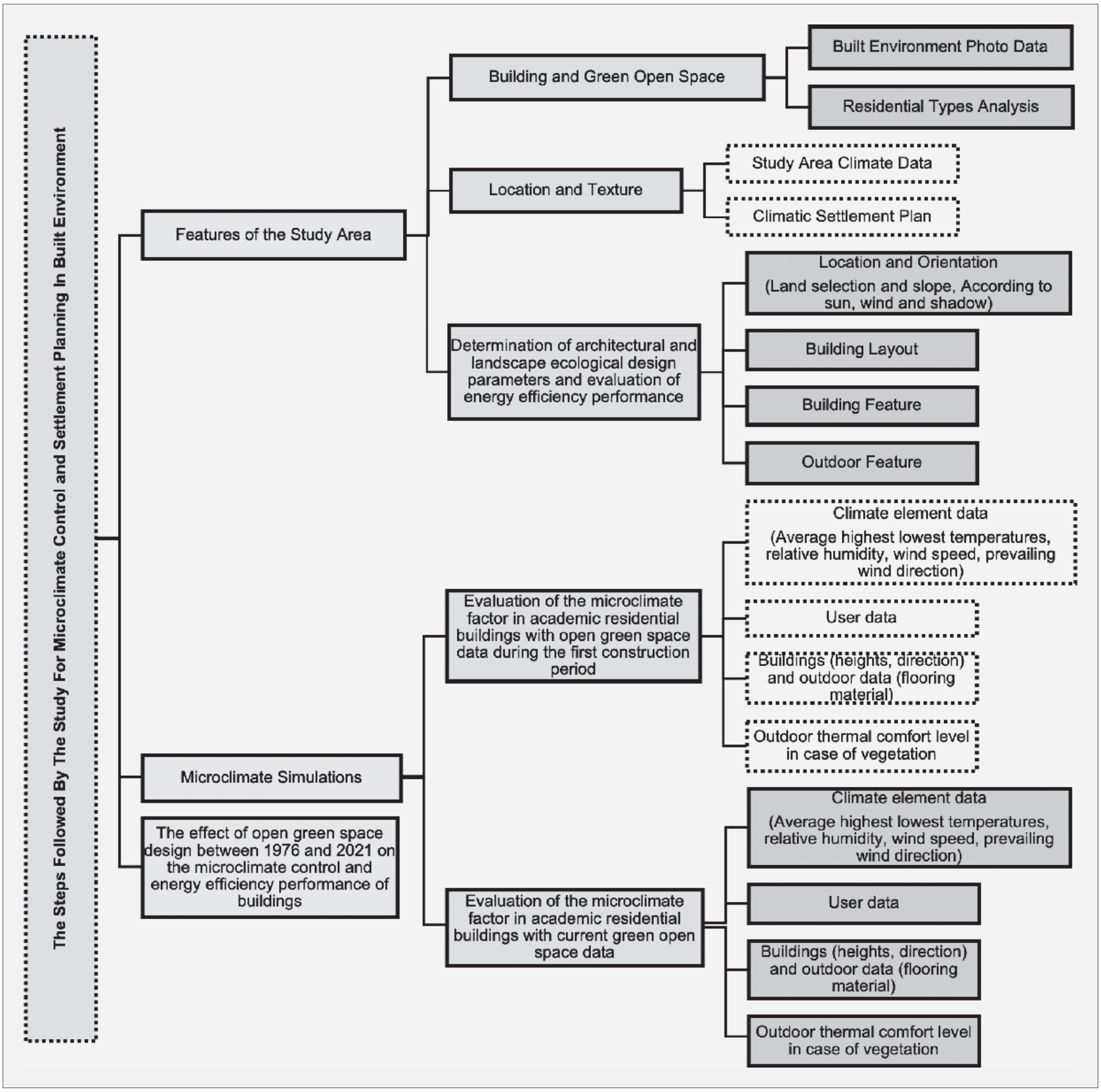


Fig. 3 Flow chart of the study

comfort models were produced, in the hottest (14:00 pm) hours.

After evaluating the thermal comfort data formed by the changing microclimate factor between the current state of the residential blocks (2021) and their first construction period (1974-1979), a comparison was made (based on Adana's year-round bioclimatic comfort and thermal requirements, based on ISO 7730 pmv index and ASHRAE scale). Based on all the findings obtained, the suggestion is that plant design should be considered in order to improve the outdoor thermal comfort.

According to the ecological design criteria, the energy performance of the buildings and the thermal comfort of outdoor spaces were analyzed at the end of the study. In order to apply the method determined in the field study, on-site observation technique was used. In the application of the observation technique, a criterion observation scheme was created for the residential buildings. A three-step answer section and a notes section have been added to each criterion. In this answer part, "Yes", "Partly" and "No" options were included. For these options, the point value of "5, 3, 0" was accepted, respectively. In one criterion, 100% – 71% performance impressions were evaluated as 5 points, 70% – 31% performance impressions were evaluated as 3 points and 30 – 0% performance impressions were evaluated as 0 points. In addition, the weights of each category are taken equal. Thus, the evaluation of the energy efficiency performance of the building and its surroundings has been provided (Vardar & Karadayı, 2020).

As shown in Fig. 3, the flow chart of the study is used to determine if the layout and outdoor green space design of the building group contribute to the ecological design criteria and microclimate control, as well as to evaluate the energy efficiency of the building.

Results

In the study, the prevention of heat gains by architectural and landscape design in the hot and humid climate region in summer was compared with two different methods. In order to understand the built environment and provide data for analysis, first of all, buildings, outdoor green area features, residential area selection criteria and texture features were examined. Then, architectural and landscape design parameters that determine effective energy use were evaluated together. Finally, Adana's year-round bioclimatic comfort and thermal requirements are discussed in a microclimate simulation of the residential area. At this stage, it was evaluated how much the improvement in the microclimate and landscaping in the hot and humid climate region affected thermal comfort.

Evaluating the Energy Efficiency Performance of Ecological Architectural and Landscape Design Parameters

External environmental factors (topography, climate conditions, etc.) and structural factors such as the location, orientation, form of the building at the settlement scale, adjacent building spacing and heights, and the building envelope are among the parameters that determine energy efficiency in buildings (Akın & Kaplan, 2019). Lechner (2021) argues that the right decisions made during the design phase of the building can reduce the building's energy use by between 50% and 90%. Another important aspect of building energy efficiency is a climate-appropriate design of the building envelope, which includes the roof, walls, and foundation (Manioğlu & Koçlar Oral, 2010). This study evaluates the measures taken in and around the building to reduce the negative effects of high temperatures during the hottest period of the year on comfort conditions. As a result of the wind direction factor having a much greater impact on orientation decisions in hot humid climates than solar radiation, there is important data that the prevailing wind direction in the study area is 225 degrees southwest (August 16) and 45 degrees northeast (February 5). The long facades of the building are oriented in the direction of the prevailing wind to reduce the discomfort caused by humidity with passive cooling techniques (Karagöz, 2016). In site selection, the cool windy hill regions of the south-facing slopes (0-6 degrees land slope) are preferred (Özdemir, 2005). When the studies on Energy Efficient Settlement and Building Design Principles in Hot-Humid Climate Regions are examined, it is seen what various design parameters given in the Table I are focused on (Koca, 2006; Ovalı, 2009; Manioğlu & Oral, 2010; Dikmen, 2011; Beyaztaş, 2012; Oscan, 2013; Özaydoğdu, 2015; Harputlugil, 2016).

The energy efficiency performance range values of these criteria were used while determining the status of architectural design parameters determined for effective energy use in the study area. Site selection was evaluated as 5 points for the slope between 0-6% on top of the slope, 3 points on the slope between 6% and 10%, and 0 points if the slope is higher.

The type selection of the green tissue around the building was used in accordance with the directions. However, the distance between the building and the tree on the south façade is greater in the C and D blocks, which does not provide a shaded area outside for the hottest period. Depending on the climate zone (hot and humid climate zone), the open space between buildings should be between 5H and 7H away from the prevailing wind direction (Özdemir, 2005). This interval is given 5 points, between H-5H 3 points. At this distance, the interval below and above the optimum value (-H, +7H) according to the appropriate building spacing parameter was evaluated as 0 points.

The Form of the Building, provided that the facade is orientated in the most appropriate direction, the ratio of the building length to the depth is among the factors affecting energy efficiency (Göksal & Özbalta, 2002). Building dimensions located on the hills on the east-west axis (Zeren, 1987, Orhon et al., 1988), optimum 1:1.7 (0.58) or maximum 1:3 (0.33) buildings provide optimum conditions for comfort (Olgyay, 1963; Karagöz, 2016). The values of the blocks area were calculated in the study as A: 0.39, B. 0.39, C: 0.37, D: 0.37, RK: 0.93. The optimum and maximum range value was evaluated as 5 points, the maximum value between 0.33 and 0.39 was evaluated as 3 points, and above this value was evaluated as 0 points.

The most suitable covering material to be used on the floor between buildings in outdoor space has been determined as gravel, grass, light color asphalt (Özdemir, 2005).

Grass and dark color asphalt materials are used around Blocks A, B, C and D. Therefore, this criterion was evaluated as 3 points. In the RK block, 5 points were given because grass was used as a cover instead of asphalt.

Optimum, good and valid orientation ranges were evaluated together according to the hot and humid climate region determined by Zeren (1987), Orhon et al. (1988), Altunkasa (1990), Gültekin et al. (2001), Özdemir (2005) in their studies. The most inclusive values are given in Table II.

According to the samples examined, priority is given to protecting the internal energy of the building in the least hot period (winter) and increasing the ventilation and cooling possibilities in the hottest period (summer) depending on the hot and humid climate zone feature. In the study, structures with a building orientation between 3° southeast and 30° southwest were given 5 points and a performance range of 100% – 71% was used for this criterion. For the 0° south-35° southwest range, 3 points and 70-31% performance representation were applied, while 0 points and 30 – 0 performance representation were applied to the orientation outside these values. Orientation in accordance with the prevailing wind was evaluated as 0° south – 45° southwest orientation 5 points, 45°-50° southwest orientation was evaluated as 3 points, and above 50° southwest orientation was evaluated as 0 points.

The building roof systems need to cover with light colored materials that reflect sunlight. The double skinned roof system is another method that can be preferred to provide indoor comfort. When the continuous circulation of the air between the two roof layers is ensured through ventilation, the heat stored in the indoor roof is lower than the external roof (Koca, 2006). In the study area, a double skin roof system was applied in blocks A, B, C and D. However, dark colored material is used in A and B blocks, and light-colored reflective material is used in C and D blocks. For this reason, it was evaluated as 5 points for a light-colored roof material and double skin roof system, 3 points for a dark colored roof material and double skin roof system, and 0 points for the absence of a double skin roof application. A hipped roof system was applied in the RK block, and a dark colored roof material was used (Fig. 4).

Architectural and landscape design parameters determining energy efficiency performance values were evaluated. The status of these criteria in the study area is showed graphically. When the percentages of meeting the architectural design parameters that determine the energy efficiency performance values are evaluated, D block ranks first with 75.5%, C block ranks second with 70%, A

Table I Ecological design parameters

Site selection/orientation	Building layout	Buildings features	Outdoor layout
Location of the structure	Width/length rate of plan	Building material	Ratio of hard material and grass surface
Slope	Width/length rate of facade	Building shell	Tree design
Orientation	Distance between building	Building facade	Tree type selection
Shadow effect	Distance between building rows	Solar energy use	Type/location relationship
Wind effect	Building array		Wind effect
			Shadow effect

Table II Building orientation for hot and humid climate region

Optimum solar orientation	Good orientation ranges	Valid orientation ranges	Proper settlement according to the wind
Wide facade, 3° south to southeast	10° southwest to 19° southeast	19° southwest to 30° southeast	Structure raised above ground open to the wind. 0-43° northeast is the wind direction that should be avoided in the least hot period. In the hottest period, 180° south and 225° southwest are the wind direction that should be protected.

Fig. 4 Architectural and landscape ecological design parameters and energy efficiency performance values

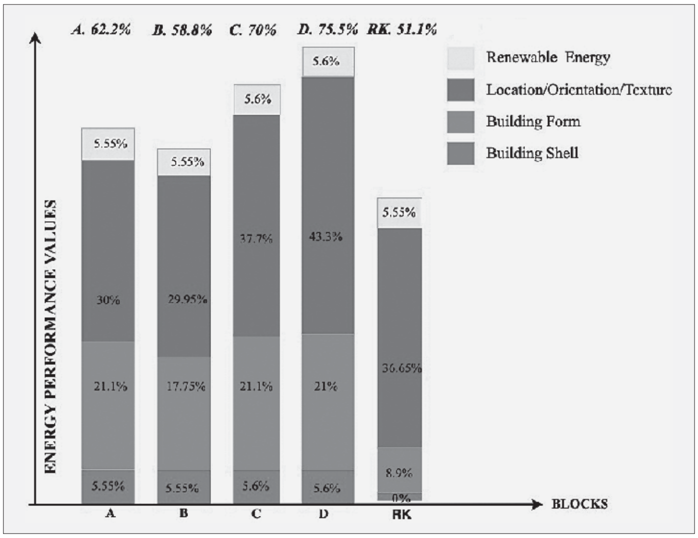


Fig. 5 Energy performance values of building

block ranks 3rd with 62.2%, B block ranks 4th with 58.8% and RK block ranks 5th with 51.1%. The percentage of meeting the 1st criterion (Location/Orientation/Texture) for blocks A, B, C, D and RK was calculated as 71.1%. The percentage of meeting the 2nd criterion (Building Form) was calculated as 64.8, the percentage of meeting the 3rd criterion (Building Shell) was 80%, and the percentage of meeting the 4th criterion (Renewable Energy) was calculated as 100%. Figure 5 includes the energy efficiency performance values of the buildings.

Microclimate Simulation Model of the Study Area

Space thermal comfort is one of the most important factors that increase its performance in terms of technical, functional, and behavioral aspects. A comfortable thermal environment is one in which the majority of people, both indoors and outdoors, can maintain their physical and mental activities regardless of the climate conditions. Depending on the level of ambient conditions, distress, palpitation, and other disturbances may occur if the places where individuals are located do not meet thermal comfort conditions (Boeri & Gaspari, 2015; Gaspari & Fabbri, 2017; Toksoy, 1993; Orhon, 1998; Santamouris, 2011; Yeang, 2012; Altunkasa, 2019; Altunkasa & Uslu, 2020). To monitor the changes in outdoor thermal comfort, two different situations in the area were compared in this context. These conditions are as follows:

– Evaluation of the situation where the buildings are placed and the surfaces outside the forestation areas made by DSI (General Directorate of State Water Works) on the shores of the dam lake are left as bare soil, asphalt, and concrete,

– Evaluation of soil floor surfaces other than asphalt and concrete surfaces covered with grass and trees detected in the study area.

It was determined that simulations should be sampled with the C and D blocks and the rectorate's residence, due to physical similarity between the two buildings and the complexity that can result from the approximately double number of grid-squares being analyzed and the excessive simulation time being required. Thermal comfort analysis was carried out using ENVI-met SCIENCE simulation software. This software analyzes outdoor thermal comfort at the grid-square or pixel level, with grid-square dimensions ranging from 0.5-1.00 m^2 indoors to 2×2, 4×4, 5×5, and 10×10 m^2 outdoors. In order to obtain clearer results, 2×2 m^2 grid squares were used in this study. Thermal comfort analyses were performed on 14,960 grid squares since the study area measures 230×260 m. As the time period for the simulation, the climate data of the day with the highest temperature on who Ali-Toudert & Mayer (2006, 2007), Allegrini et al. (2012), Doya, Bozonnet & Allard (2012), Srivanit & Hokao (2013), Almhafdy et al. (2015), Ramyar, Zarghami & Bryan (2019) were used in their studies. So, the average highest temperature of 35.1 °C in the study area during the period of 1985-2020 occurred on August 16 at 14.00, the data of this time period were also used. In addition, Table III provides information about the space and users.

Based on Fanger (1972) Predicted Mean Vote (PMV) index, thermal comfort analysis was conducted according to ISO 7730 standard. PMV is a measure of thermal comfort perceived by individuals based on various combinations of climate elements, space, and user characteristics, reflecting thermal comfort in any situation of the examined space and users. PMV also analyzes the numerical values of climate elements to determine thermal comfort, which provides a qualitative result. These results are described using the seven, nine, or eleven-point ASHRAE scale (ASHRAE Handbook, 1981). The ASHRAE scale, which was originally organized as a seven-point scale, can be modified to include two or four levels to measure thermal comfort in areas with extreme climate conditions (Gaspari & Fabbri, 2017; Toksoy, 1993; Bruse, 2004; Huttner, Bruse & Dostal, 2008; Huttner & Bruse, 2009; ASHRAE, 2018). Thus, the eleven-point scale in Table IV was used because there are extreme climate conditions according to the ASHRAE scale in the study area. Adana's year-round bioclimate comfort and thermal requirements table, as well as PMV and ASHRAE scales, were used to evaluate the simulation model results.

As part of the simulation model, 24-hour data on August 16 and data on the place and user

Table III Data on climate, space and user used in thermal comfort analysis

Climate elements		16 August 02:00 pm	User data	
Average highest temperatures (ºC)		35,1	Average age	40
Average relative humidity (%)		45,6	Average height	1.68
Average wind speed(m/s)		2,9	Weight average	65
Prevailing wind direction		225° (GB)	Body mass index	18.5-24.9 kg/m¸ (normal weight)
DATA on BUILDINGS and OUTDOORS			Metabolic ratio	0.80 (for outdoor events)
Building heights	C and D blocks	23 m	Clothes feature	For summer 0.60 clo (trousers, skirts and shirts made of thin fabric) For winter 1.10 clo (trousers, skirts and shirts, sweaters and jackets made of thick fabric)
	RK block	10 m		
Building directions	Wide facades of all buildings with NW-SE Axis and NE-SW View			
Surface finishing materials	Asphalt, concrete, soil and grass surface		Elevation above ground level	1,50 m

Table IV The Eleven-point ASHRAE scale used in the study

More than 4.50		Unacceptable extremely hot	Added according to climate values
3.50	4.50		
2.50	3.50	Very hot	Seven-point ASHRAE scale
1.50	2.50	Hot	
0.50	1.50	Slightly warm	
0.50	-0.50	Comfortable (neutral)	
-0.50	-1.50	Slightly cold	
-1.50	-2.50	Cold	
-2.50	-3.50	Very cold	
-3.50	-4.50	Extremely cold	Added according to climate values
Less than -4.50		Unacceptable	

shown in Table III were used to calculate PMV values using ENVI-met BioMet. The two cases of the study area were calculated separately. Using Leonardo's thermal comfort visualization module, data were classified and converted into PMV maps (Fig. 6).

Using the microclimate simulation maps in Fig. 6, two basic conclusions can be drawn regarding plant design:

– In the absence of vegetation and in the current situation, there were significant differences in thermal comfort with the PMV unit. Those areas above 4.50, which is the lowest level of thermal comfort acceptable; while 80.90% of the total area is covered when vegetation is absent, this rate decreases to 69.14% when vegetation is present (thermal comfort gain 14.54%). In the absence of vegetation, the areas between 3.50 and 4.50, which constitute the extreme hot level, were 19.10%, but with vegetation, this rate increased to 23.29% (thermal comfort gain 21.94%). There were no very hot levels (2.50-3.50) in the absence of vegetation, but 7.57% (thermal comfort gain 100%) when there was vegetation.

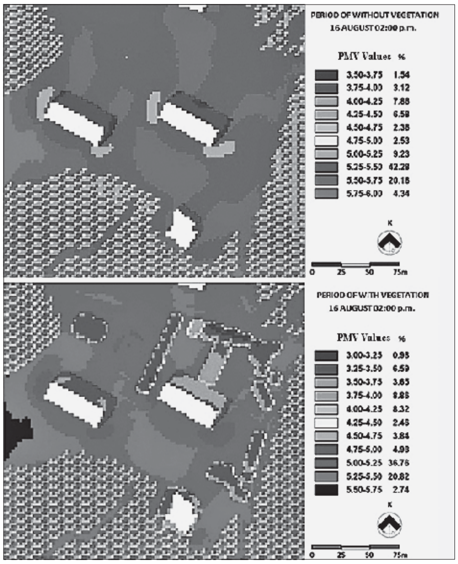
– The studies describe the thermal comfort situation at 1.50 m above the surface, that is, the microclimate perceptions of outdoor users on green areas or hard surfaces. For various outdoor activities throughout the year, the open spaces in the south of the buildings provide the best thermal comfort. Due to the complete exposure of west and southwest building areas to solar radiation, PMV values were unacceptable. For this reason, it is important to plant trees that are deciduous in winter, branch high and have a sparse/medium density texture in areas west-southwest of buildings to prevent this problem. Furthermore, this composition must be positioned within the building's height.

Discussions

Through microclimate simulations, the study investigates how planting design and tree species affect thermal comfort in a built environment. In order to improve outdoor thermal comfort, climate-balanced plant design and building energy performance are evaluated together. El-Bardisy et al. (2016) conducted microclimate simulations with ENVI-met to demonstrate how trees regulate microclimates in the outer space of a Cairo public school (Egypt). Simulations were run based on Ficus nitida (evergreen) and Delonix regia species on days with the highest temperatures during the school period (4 May 2014, 11:00 am). As a result of these findings, the average PMV value is 3.60 when there are no trees in the area, 2.90 when there is a crown of evergreen trees, and 3.00 when there is a crown of deciduous trees. It covers 80.90% of the total area with a PMV value of 4.50, which is the lower limit of the unacceptable thermal comfort level in the working area. Areas with PMV values between 3.50 and 4.50 constituting extremely hot level constitute 19.10% in the absence of vegetation. Areas that define the very hot level range of 2.50-3.50 PMV values are not available in the study area.

According to El-Bardisy et al. (2016) and Shashua-Bar et al. (2000), the downward radiation transmissivity on Evergreen Ficus nitida is less than 10% throughout the year, causing the PMV to be slightly lower in summer. Nevertheless, evergreen trees may reduce thermal comfort during winter due to their ability to block out sunlight. Evergreen trees were used in the south of the buildings in the study area. Since the distances of these trees to the buildings are greater than the height of the buildings, they do not block

Fig. 6 The PMV values/ratio of the study area on early condition and current condition



the sunlight during winter months. Therefore, there was no decrease in thermal comfort levels during winter months.

According to Tzu-Ping et al. (2012), who discovered that when microclimate conditions are above Taiwan's thermal comfort range, park attendance decreases by 80% to 50% when the sky view factor increases (shade decreases). As the sky view factor decreases (shade increases) during the period when microclimate conditions are under Taiwan people's thermal comfort range, park attendance is less than 20%. It can be understood from the findings of this study and those obtained around the residential buildings that evergreen trees on the northern façade of the buildings provide an advantage in terms of improving thermal comfort during hot weather. For this reason, recreation areas were placed in these areas with both the shadow formed on the northern façade of the building and the shade created by the trees in summer, which is considered to be very hot. Thanks to the thermal comfort improved by plant design, basketball and football fields were added to this area later.

Altunkasa (2019), Altunkasa and Uslu (2020), who conducted a similar study in the same campus on plans that recommend vegetation-free and climate-balanced vegetative design for the Çukurova University, Faculty of Architecture, which is in the construction planning stage, found areas with a PMV value of 2.50-3.00 at a rate of 4.64%. It was determined that the lowest PMV levels (3.00-3.25) were only 0.98% in this study. It is possible that this situation has arisen due to the main reason explained below in the context of plant design: the vegetative design study of Altunkasa (2019) was organized in accordance with the climate-balanced species selection and composition principles developed by Olgyay (1973) and implemented by Altunkasa (1987, 1990) according to the conditions of the Çukurova region.

Tan et al. (2021) presented that the relationship between increasing tree coverage and the resulting cooling effect is not linear. This result showed that the improvement in thermal comfort is related to more vegetation types and their combined use rather than increased vegetation. Three different plant combinations were used to cooling the outdoor space in the study. It was seen that the combination of trees, shrubs and plants improved thermal comfort by showing more cooling effect than the others. So, as a reference to our study comparing the thermal comfort of 1976 and currently, thermal comfort was improved with the combination of trees, shrubs and grass rather than the increasing tree cover.

A building designed according to ecological criteria reduces harmful effects on the environment, maintains ecological balance, and provides the necessary comfort and health conditions. Türkiye's existing dense building stock should be improved to reduce negative environmental effects of building energy consumption. This study found that the location, texture, and orientation characteristics of new buildings should be designed in accordance with the climate and environment in it. Moreover, in existing buildings, landscaping design and microclimate control can improve outdoor thermal comfort levels.

Conclusion

The goal of this study was to investigate, through a structured literature review that compares the outdoor thermal comfort of academic staff buildings on campus in 1976 and today. As a result of the study, the situations that cause improvement in the thermal comfort of the existing building stock are summarized. The lower limit of the thermal comfort level is 4.50; while 80.90% of the total area is covered by this level during the first stage of vegetation, this rate decreases to 69.14% during the second stage (thermal comfort gain 14.54%). In the first stage of vegetation, the area between 3.50 and 4.50, which represents the extreme hot level, was 19.10%, but in the presence of vegetation, this rate increased to 23.29% (thermal comfort gain 21.94 %). Areas defining the very hot level (2.50-3.50) were not found in the first stage of vegetation but gave a value of 7.57% (thermal comfort gain 100%). The open spaces in the south of the buildings are most comfortable for different activities throughout the year due to their thermal comfort. PMV values were found to be unacceptable in both cases in the outdoor areas to the west and southwest of the buildings. It is therefore important to select trees that are deciduous in the winter, branching as high as possible, and having a sparse or medium density texture in the areas west and southwest of the buildings in order to avoid this problem. In this composition, the height of the building must be at least equal to the composition's height. Thanks to the existing vegetation, a 15-22% increase in thermal comfort is achieved on the hottest days and hours of the year.

In the study in which the prevention of heat gain in summer for the hot and humid climate region was compared with two different methods; landscape design and prevention of heat gain in summer for the surroundings of blocks A, B, C, D and RK showed a positive performance of 84%. The effect of this positive energy performance level on human comfort was calculated with ENVI-met software for the hottest day and time of the year. Architectural and landscape design decisions for hot and humid climate regions together increased energy performance by 51.1% to 75.5%. It was found that although the plant design improves energy performance in buildings by that range value, it improved outdoor thermal comfort by 15% to 22%. According to the study, building design alone is not enough to increase outdoor thermal comfort in hot and humid climates, and that building and plant design should be coordinated at the design stage.

The natural environment plays a significant role in the efficient use of energy in the built environment, and by improving the thermal comfort of people in hot and humid climates, outdoor space can be more effectively used. Under the heading of effective energy use, the main criteria of ground-orientation-texture, building form, building envelope and renewable energy use were examined. Renewable energy criterion showed the highest performance with 100%. While the building envelope criteria showed 80% performance and the ground-orientation-texture criteria 71.1%, the building form showed a positive performance of 68.8%. Therefore, both in the case of new architectural designs as well as in the case of the improvement of existing buildings, it is essential to analyze the factors of the natural environment correctly. The findings on the topography, climate, and natural vegetation of the study will provide valuable insights regarding energy efficiency in hot and humid climate.

As a final word, we need to rethink energy performance of the current building stock in order to improve outdoor thermal comfort levels in especially hot and humid climate, due to the direct relationship between the built environment and energy use, in today's world when effects of the global climate crisis are under way.

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Sources of illustration and tables

Figs. 1-6	Authors
Tables I, III	Authors
Table II	Authors according to literature
Table IV	Authors according to ASHRAE scale

Authors' biographies and contributions

Yelda Durgun Şahin, Ph.D., graduated from the Department of Architecture in 2001. In 2006, she earned a master's degree in the field of architecture. She completed her doctoral studies in 2019 and was promoted to assistant professor in 2020 and associate professor in 2023. Currently, she serves as an associate professor of architecture at Adana Alparslan Türkeş Science and Technology University.

Ceren Altunkasa received a Bachelor of Science degree in 2015, in Landscape Architecture from Çukurova University in Türkiye. In 2019, she completed her master's degree at the same university. Currently, she is employed by a private company.

Conceptualization: Y.D.Ş.; methodology: Y.D.Ş. and C.A.; software: C.A.; validation: C.A. and Y.D.Ş.; resources: Y.D.Ş. and C.A.; writing – original draft preparation: Y.D.Ş. and C.A.; writing – review and editing: Y.D.Ş.; visualization: Y.D.Ş.