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Analyzing the Impacts of Innovative Nature Based Solutions (I-NbS): A Case of Terra the Sustainability Pavilion, Dubai

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Abstract

In today's world, increasing needs have brought about various consumption problems. This problem has evolved from being a local issue to a global one. Nowadays, it is addressed in various ways under the climate crisis. To address this issue, many strategies and policies are being developed through sustainable design approaches. Nature-Based Solutions (NbS) are the most common among sustainable practices. NbS practices, which are nature-inspired and aim to solve problems by drawing inspiration from nature, contribute significantly to sustainable ecosystems both ecologically and economically. Within the scope of this study, the benefits of integrating NbS practices with innovative, sustainable design strategies, known as Innovative Nature-Based Solutions (I-NbS), have been examined. The chosen study area, "Terra the Sustainability Pavilio " was specially designed for Dubai Expo 2020. The study area is globally renowned for its design, and it holds significant importance both in terms of design and sustainability. It was selected as the study area due to its innovative and sustainable features. As a result of these investigations, an I-NbS index has been created, and a numerical formula has emerged as a result. This numerical formula has been calculated for Terra - The Sustainability Pavilion, which is a highly successful application in hot climate conditions. As a result of the study, the necessity of criteria in NbS applications, the landscape value in I-NbS applications, and the need to be attentive in future studies have been highlighted with expert group data. Differences between applications were investigated with the expert group for the relationship between I-NbS applications and future recommendations. Parameters that express landscape value were extracted from the literature and queried to reveal the relationship between I-NbS and landscape value. These goals were revealed through statistical studies conducted with AHP (Analytical Hierarchy Process) and SPSS (Statistical Package for the Social Sciences) software. The results of the study have revealed a strong connection between the findings and the data of "Terra the Sustainability Pavilion" among Nature-Based Solutions (I-NbS). The relationship between "Terra the Sustainability Pavilion," which is significant both aesthetically and functionally, and Nature-Based Solutions (I-NbS) studies has been demonstrated through statistical data.

Keywords: Nature based solution, Innovative-NbS, innovative landscape

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Nature Based Solutions (NbS) and Climate Change (CC)

Climate change (CC) is defined as the difference in climate observations that should be under normal conditions‘ and ‚differentiation in the climate as a result of human activities that directly or indirectly cause changes in the structure of the global atmosphere‘ (United Nations, 2021). Today, climate change has begun to be felt as a much more serious threat to all living things globally. Climate change (CC), is defined as statistically significant changes in weather events such as precipitation, temperature, humidity, wind and temperature level in a particular region, unlike those seen over a long period of time. For example, rise in sea level, changes in precipitation patterns, heavy precipitation, increases in temperature, frequency of droughts, rising sea levels with storms and increasing floods are some of these hazards. These hazards cause serious problems for the socio-economic, ecological and infrastructure systems of cities (Vousdoukas et al., 2018). Climate changes observed on a global scale for the 21st century, global warming are the important global changes encountered in the last 65 years. Climate change (CC) is a global and complex problem with its impact on various components of ecological, environmental, socio-political and socio-economic disciplines (Feliciano et al., 2022; Abbass et al., 2022). It is stated by many scientific studies that global CC will affect almost all living things and this effect will be negative and destructive for many living species, and that some species may face the danger of extinction in this process. It is stated that some living things will be in danger of extinction (Ning et al., 2021).

Today, many developed countries aim to reduce the effects of climate change by taking precautions with many strategies and solutions in order to ensure the resilience of cities and the safety of city residents. Nature based solution (NbS) has adopted the idea of having livable cities and contributing to people's quality of life, which was put forward in 2013 (Sowińska-Świerkosz, García 2021). Nature-based solutions aim to protect and redesign natural and degraded ecosystems in a sustainable way by dealing with the challenges posed by the social environment in an effective and applicable way. In this process, it plans many actions by providing services to the well-being of people, increasing biodiversity and the ecosystem (Cohen-Shacham et al., 2016). With a different definition, nature-based solutions are solutions inspired by nature, supported by nature, using natural processes or similar to it (UN-Water 2019).

Nature-based solutions cover the implementation of adaptation to climate change and mitigation of its effects in urban areas. Planning target natural systems by considering the benefits for both nature and society creates innovative solutions (Warren, 2020). In different interpretations, while helping to make the living spaces livable and greener, nature-based solutions produce strategies that can be a useful infrastructure for the needs of the city. Nature-based solutions are defined as a valuable tool used to strengthen the resilience of ecosystems, protect biodiversity and, in parallel, provide solutions to a wide range of societal challenges such as climate change adaptation and disaster risk reduction (IUCN, 2020). In the last 10 years, NbS has been helping to achieve global targets for reducing greenhouse gas (GHG) emissions to mitigate climate change, which is very important as greenhouse gas sources and carbon sinks of natural ecosystems. Today, however, there is increasing interest in the potential of NbS (Seddon et al., 2020). It has eight criteria/targets for framing green/blue interventions as NBS actions according to the IUCN Global Standards. These goals aim to contribute both to the welfare of the society and to the universe in ecological terms. In order to achieve its goals, it carries out “restoraion, issue specific, infrastructure, and management and protection studies”. The common purpose of these studies is to be "ecosystem based approaches". These goals also have human-oriented gains and ecological contributions to society. These are “human well-being” and “biodiversity benefits” (Fig. 1) (IUCN, 2019).

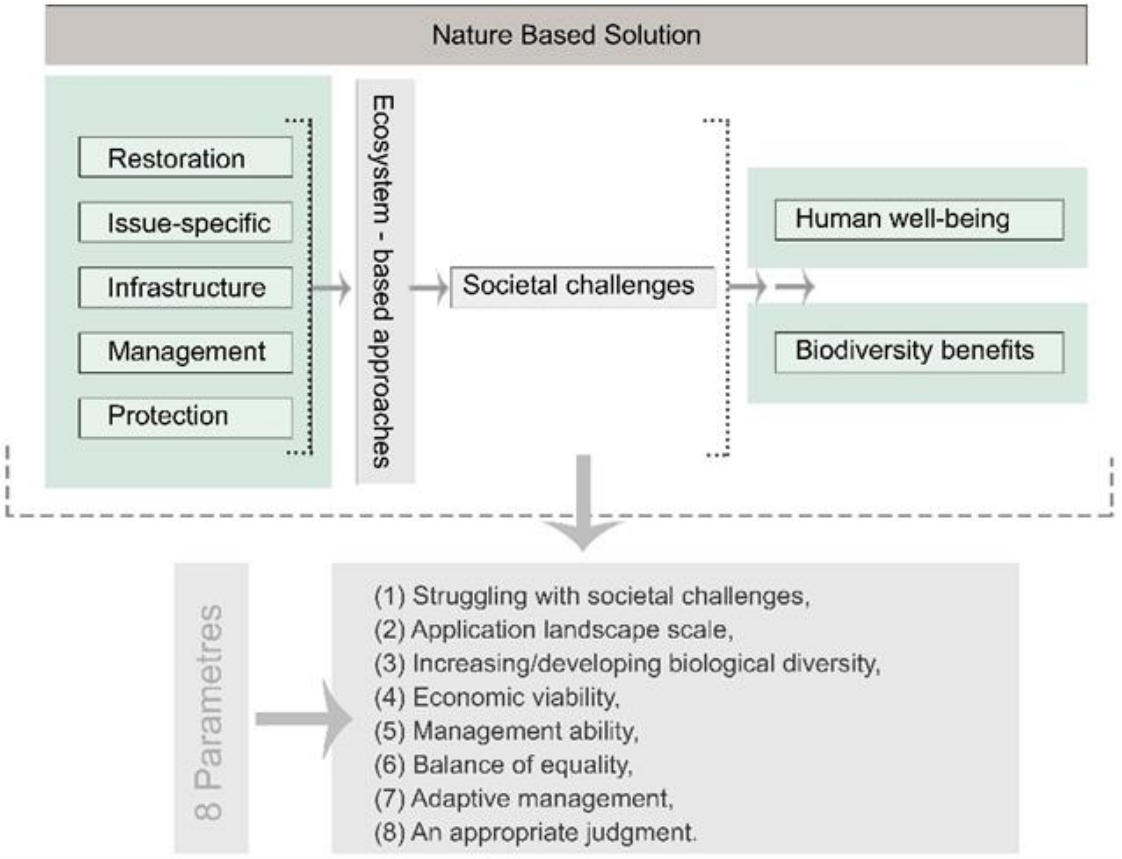


Fig. 1: International Union for Conservation of Nature (IUCN)'s NbS action plan (IUCN, 2019)

Hot Climate Zone (HcZ) and Climate Change (CC)

One of the important factors that cause climate change and threaten cities is fossil fuel consumption. On the other hand, fossil fuel consumption increases more proportionally to the heating or cooling demands of the buildings. This consumption shows its effect more than the cities in normal conditions due to the increase in cooling demand in hot climate zones. Because the change in outdoor conditions changes the heating and cooling demands and this change increases the energy consumption (Christenson et al., 2006; Alola et al., 2019). This consumption, which is a global problem, has made climate change an irreversible environmental problem around the world.

Therefore, it is envisaged to take the necessary result-oriented measures against the negative effects of this problem and to work in harmony. In order to reduce the effects of climate change in the world, many plans should be developed and their continuity should be ensured. Within the scope of the study, NbS solutions were examined in the fight against global CC. In the fight against this problem, it is very important to examine it in hot climate conditions. In line with the definition of the problem, the objectives of the study are as follows;

- How do nature based solutions combine with innovative solutions?
- Which applications are innovative Nature based solutions.
- What is being done in innovative solutions in hot climate conditions?
- Formulating the calculation of the "I-NbS Index" and applying it on the example.

Material and Method
Study Area

Dubai, which is located in the United Arab Emirates, which consists of 7 states in total, is the state where the study area is located. Dubai (URL-1), which has a total area of 4,115 km², has a total population of 2,964,382 million in 2022. Dubai is one of the fastest growing cities in the world, growing at a rate of 10.7% per year. Dubai was first established in 1833 when about 800 settlers from the Bani Yas tribe came to Dubai creek. This port gave rise to a thriving economy on fishing, maritime trade and eventually led to the status of a port city. Dubai's population in the 1930s was about 20,000 and this number continued to rise (URL-2).

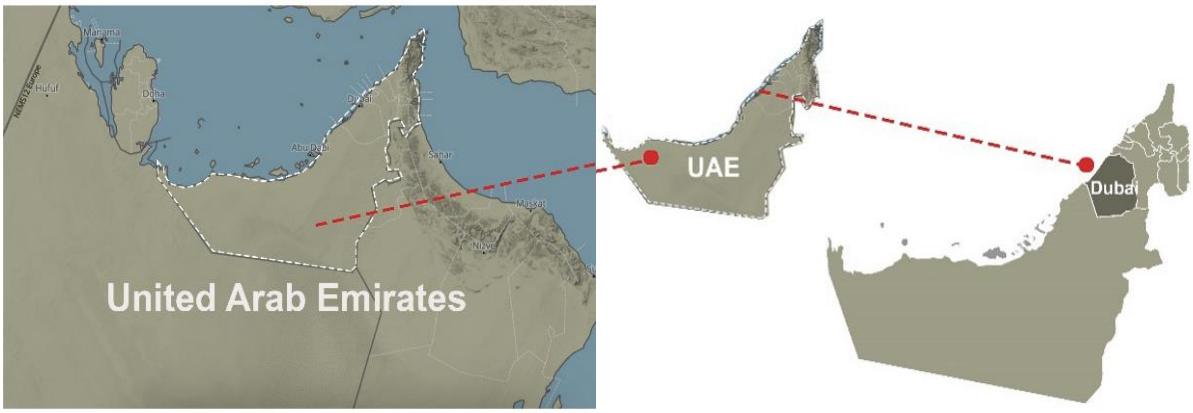


Fig. 2: Dubai location (Meteoblue, 2023)

In the United Arab Emirates (UAE), the energy consumed for cooling is quite high due to climatic data. In the UAE, many energy strategies are implemented and targets are set in order to solve this problem (Abdul-Zahra, Ayad 2021). Due to the climatic effects and desert heat in the UAE, much more energy is spent to cool the buildings. In the city, there are tremendous applications that can be a solution to this problem. While these applications contribute to the ecosystem, they also attract thousands of tourists every period as they offer a visual feast. The study area was chosen as Terra - The Sustainability Pavilion located in Dubai Expo 2020 area. Terra offers to show and explore how daily choices can change in order to increase human beings' relationship with nature, reduce their carbon footprint and reduce our environmental impact. This and the motto actually coincide with the application purpose of nature-based solutions. Terra's gray water recycling system, innovative irrigation techniques aim to reduce water use in the landscape by 75 percent. Aiming to strive for a sustainable future for everyone, Terra is an exemplary project with innovative solutions (Expo, 2020). Terra is a world-class example designed by Grimshaw Architects. (Landezine, 2020) (Fig. 3).

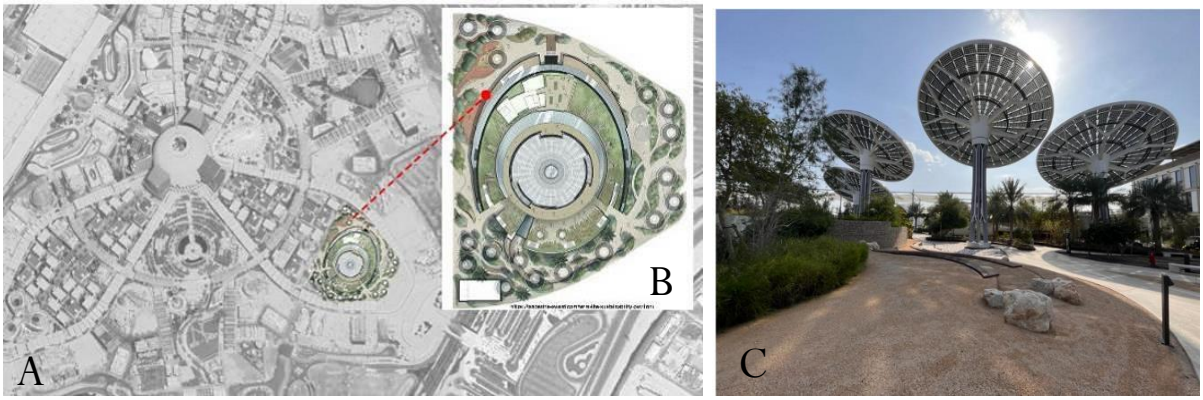


Fig. 3: Terra-The Sustainability Pavilion (A: GoogleMappro, B: Landezine,2020, C:Author's own photo)

Method and Data

The method consists of 3 stages. In the two-stage method, both stages were carried out with an expert group. The second stage is based on user evaluations.

(i) Which of the 20 NbS applications identified in the literature with 30 experts in the first stage of the method are related to i-NbS and which of these criteria are related to innovation? The answer to the question has been sought (Fig. 4).

(ii) In the second stage of the method, first of all, a formula was created to calculate the “I-NbS Index Value”. Then, these criteria, which were grouped with the same 30 expert groups, were evaluated on Terra - The Sustainability Pavilion and the "I-NbS Index Value" was calculated. This evaluation was made through the Terra - The Sustainability Pavilion application. The applications determined in the first stage of the method were questioned by showing Terra's pictures. In line with these inquiries, the “I-NbS Index Value” was calculated. The main reason why the application was chosen as Terra - The Sustainability Pavilion is that it is a very successful NbS example. While Terra is very important from an ecological point of view, it is also a very important work in terms of aesthetics.

(iii) In the third stage of the study, the opinions of the experts on the contributions of I-NbS applications to the ecosystem were questioned. At the same time, at this stage, the landscape value of I-NbS applications was questioned. As a result of the inquiries, statistical data were obtained.

First Stage; Determination of I-NbS Applications by AHP Method

First-stage decision modeling and criteria hierarchy have been created for AHP (Analytical Hierarchy Process). In the decision modeling in Figure 5, the "purpose" is at the top of the hierarchical structure. Then there are the “criteria” created by literature studies. Accordingly, “alternatives” were constructed (Saat, Sodenkamp 2010; Liu et al., 2020). The alternatives in this matrix were formed in 2 groups as a result of the literature studies and the finding to be obtained; “Which criteria are associated with which application in nature-based solution applications during the design and implementation stages, and which of these criteria should be at the forefront of the application?” has been the answer to the question. In order to answer all these questions, thanks to AHP (Analytical Hierarchy Process) analysis; 20 scale criteria created by literature studies; With the help of the calculated criteria weights, it was decided which ones should be grouped under the same group (Figure 5-6). In order to obtain findings with expert work, a criterion matrix was created. As a result, the matrix prepared for expert opinion was as in Figure 4-5 (Liu et al., 2020; Khan, Ali 2020).

After the criteria matrix, alternatives and objectives were determined, the next stage of the analysis was started. Pairwise comparison matrices were created (Figure 4). These matrices were created to question expert opinions. Comparison of each criterion is made both among themselves and among all alternatives for which each criterion is determined. In the analysis, a pairwise comparison is made between the criteria (Yu, 2002; Liu et al., 2020). An acceptable scale was used by Saaty (1980), whose results were evaluated. The recommended maximum consistency ratio value for this scale is 0.10. If the calculated ratio is <0.10, the comparison matrix created is consistent, if >0.10 the matrix needs to be rearranged (Saaty, Bennett 1977; Leal 2020; Onur, 2023). A value of 1 (equal importance) given by the experts in the matrix, "The two elements contribute equally to the goal", the value of 3 (Moderately important) "This criterion may be slightly preferable over the other", the value of 5 (quite important) "This criterion is more important than the other". Strongly preferred”, value of 7 (very important) This criterion may be strongly preferred over the other, value of 9 (Extremely important) This criterion may be favored extremely strongly over the other and 2,4,6,8 (Intermediate values) means “expressing intermediate values”.

After these stages, it was passed to the decision-making stage of the experts among the criteria. This stage is the comparison and scoring stage. 30 experts (architect, landscape architect) were interviewed for comparison and scoring between the criteria. Pairwise comparison matrices were created to determine under which alternative the criteria (c1……..- c20) should be grouped by the experts (Figure 5-6). The last step in the AHP process is to establish their relative priorities (weights) for the criteria. The relative weights of the criteria with respect to each other were obtained. The importance or weight of each criterion relative to the other criterion was questioned. Comparisons of the weighting process were made with a numerical scale developed by Saaty et al., (2012). This scale made it possible to establish the relative priority of each criterion over the others through pairwise comparisons. This consistency/reliability ratio was calculated to determine the reliability of pairwise comparisons. Since this rate was below 0.10, it was accepted that it showed sufficient consistency (Kuruüzüm and Atsan, 2001) (Figure 6). At the end of the AHP, it was decided which criterion was more important and had more weight than which criterion. In short, grouping and decision-making were done with the patterning and comparison matrix.

Fig. 4: Some photos from the workspace shown to the experts (Author's own photo)

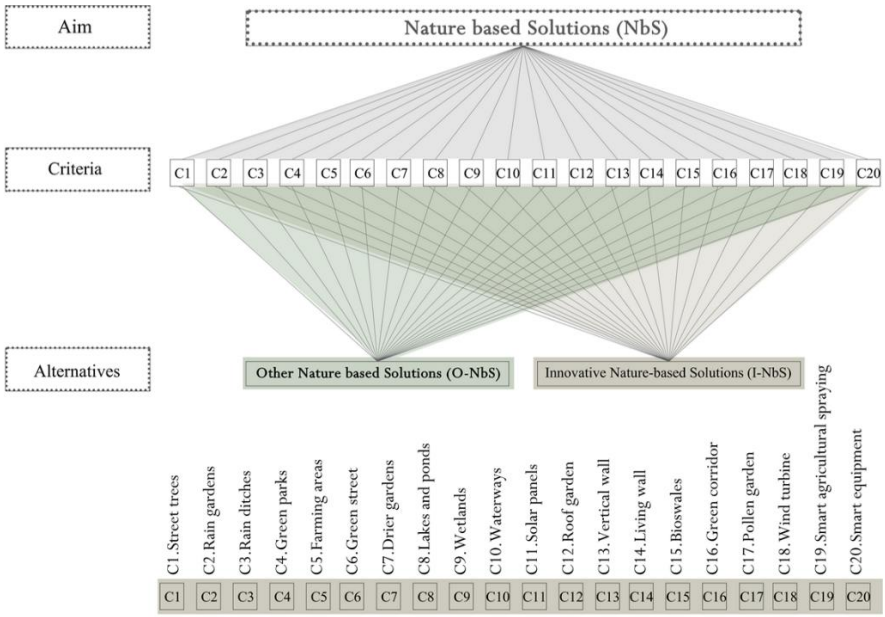


Fig. 5: Criteria matrix

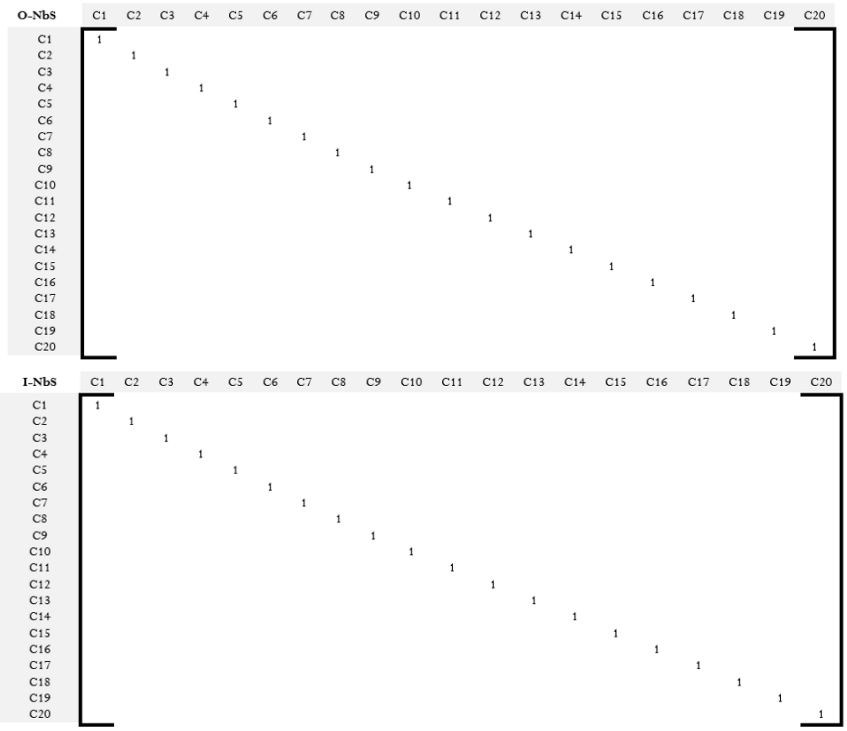


Fig. 6: Comparison matrix tables of experts

Second Stage: Calculation of I-NbS Index Value

At this stage of the method, 20 criteria determined by literature studies were questioned by 30 experts. At this stage, I-nbs applications, which were questioned and grouped by 30 experts, were questioned on Terra - The Sustainability Pavilion. Terra is an important application example that offers innovative solutions. This application, which was decided by the experts, was questioned on Terra. Terra is an important practice in Dubai. Although NbS applications are very important on a global scale, Terra differs by adding innovation to these applications. The fact that it has added smart applications to both solar energy and other applications is among the important features of Terra. Which of these methods together make more accurate design decisions? These evaluations were made through the Terra - The Sustainability Pavilion application. The applications determined in the first stage of the method were questioned by showing Terra's pictures. In line with these inquiries, the evaluation of the user was measured. 18 application forms were translated into 18 questions and the participants were questioned. The criteria in the survey questions were translated into question sentences. The answers to the questions were questioned in the questionnaire with a 5-point Likert attitude scale as I strongly agree, agree, have no idea, disagree, strongly disagree.

Third Stage; Expert Opinion of the Landscape Value of I-NbS Applications

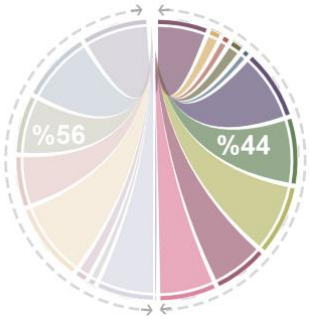
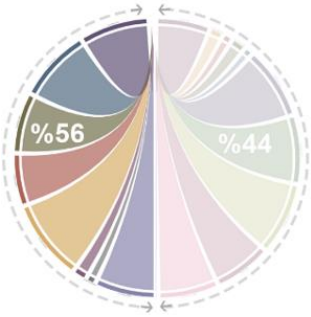
At this stage of the study, the opinions of the expert group about the contributions of I-NbS applications to the ecosystem were received. In the last stage of the study, the landscape value of I-NbS applications was questioned. SPSS software was used to analyze the queries. In order to make evaluations, 10 parameters representing "NbS and landscape value" were determined. These parameters were translated into 10 questions. Inquiries were made with a 5-point Likert attitude scale. Correlation analysis was performed to evaluate the results after the interrogations. In the correlation analysis, it was determined which landscape value parameters had a positive correlation between each other.

Findings

Findings on the first stage; Grouping of I-NbS Applications by Expert Group

According to the findings obtained from the experts, when we look at the percentage weights in the criteria weights, other "O-NbS" applications with 44% and I-NbS applications with 46% received high weight. This result indicates that 10 criteria (C1.Street trees, C2.Rain gardens, C3.Rain ditches, C4.Green parks, C5.Farming areas, C6.Green corridors, C7.Drier gardens, C8.Lakes and ponds, C9. .Wetlands, C16.Green corridor) reveals that it is more important in NbS applications. The sub-applications that make up the I-NbS applications are C17.Pollen garden, C18.Wind turbine, C10.Waterways, C11.Solar panels, C12.Roof garden, C13.Vertical Wall, C14.Living Wall, C15.Bioswales, C19. Smart agricultural spraying was determined as C20.Smart equipment (Table 1, Figure 6). According to the results obtained from the experts, I-NbS applications have received very high results compared to other applications. The fact that these results are related to "innovation" is thought to be an important factor. In today's changing and developing process, innovation is very important. This term has also taken its place in NbS applications. The use of smart NbS applications, especially in the use of pesticides, has achieved very high results.

Table 1: Distribution of criteria

	Applications	Weighting score	Alt kriterler	Weighting score
NbS	Other NbS Applications	 **0,441 - %44**	C1.Street trees	0,127
			C2.Rain gardens	0,024
			C3.Rain ditches	0,014
			C4.Green parks	0,026
			C5.Farming areas	0,011
			C6.Green street	0,176
			C7.Drier gardens	0,167
			C8.Lakes and ponds	0,176
			C9.Wetlands	0,136
			C16.Green corridor	0,143
	I- NbS	 **0,559 - %56**	C10.Waterways	0,025
			C11.Solar panels	0,198
			C12.Roof garden	0,126
			C13.Vertical wall	0,146
			C14.Living wall	0,178
			C15.Bioswales	0,167
			C17.Pollen garden	0,146
			C18.Wind turbine	0,014
			C19.Smart agricultural spraying	0,215
			C20.Smart equipment	0,154

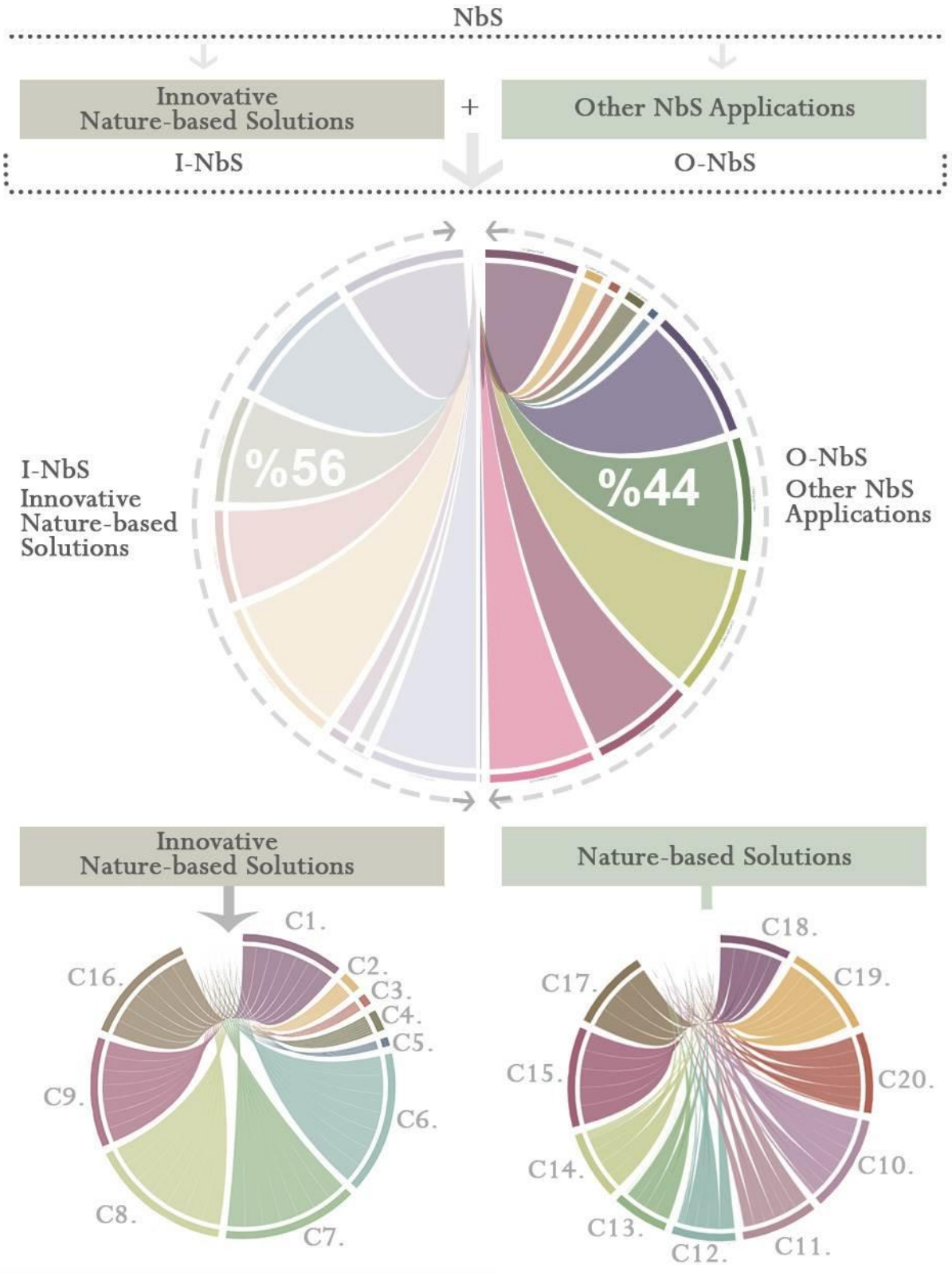


Fig. 7: Distribution of criteria and relationship between them

When we examine the grouping results of the applications from the findings obtained from the expert group, we can see that C1.Street trees (0,127), C2.Rain gardens (0,024), C3.Rain ditches (0,014), C4.Green parks (0,026), C5.Farming areas (0,011), C6.Green street (0.176), C7.Drier gardens (0.167), C8.Lakes and ponds(0.176), C9.Wetlands (0.136), C16.Green corridor (0.143) have gained weight under NbS applications. When we look at these results, C16.Green corridor (0,143) applications for Nbs gained more weight than other applications. This result shows that this application is more important than the others are. The purpose of AHP analysis for this study was to group I-NbS applications. Looking at the results of I-NbS applications, C17.Pollen garden (0,146), C18.Wind turbine (0,014), C10.Waterways (0,025), C11.Solar panels (0,198), C12.Roof garden (0,126), C13.Vertical Wall (0.146), C14.Living Wall (0.178), C15.Bioswales (0.167), C19.Smart agricultural spraying (0.215), C20.Smart equipment (0.154) applications achieved the highest results under innovative applications. Among these applications, C19.Smart agricultural spraying and C11.Solar panels applications have achieved quite high results compared to the others (Table 2, Figure 7).

Table 2: Grouping results according to AHP weights

Ecological Applications	Total weights	Sub-criteria	Score weights of alternatives		
			Score weights	**Other NbS Applications**	**I-NbS**
NbS	**Other NbS Applications** **0,441 %44**	C1.Street trees	0,016	**0,127**	0,120
		C2.Rain gardens	0,016	**0,024**	0,010
		C3.Rain ditches	0,013	**0,014**	0,018
		C4.Green parks	0,018	**0,026**	0,085
		C5.Farming areas	0,011	**0,011**	0,048
		C6.Green corridors	0,349	**0,176**	0,017
		C7.Drier gardens	0,219	**0,167**	0,046
		C8.Lakes and ponds	0,225	**0,176**	0,018
		C9.Wetlands	0,015	**0,136**	0,125
		C16.Green corridor	0,118	**0,143**	0,017
	I-NbS **0,559 %56**	C17.Pollen garden	0,027	0,011	**0,146**
		C18.Wind turbine	0,011	0,018	**0,014**
		C10.Waterways	0,025	0,011	**0,025**
		C11.Solar panels	0,322	0,025	**0,198**
		C12.Roof garden	0,014	0,024	**0,126**
		C13.Vertical wall	0,04	0,049	**0,146**
		C14.Living wall	0,145	0,076	**0,178**
		C15.Bioswales	0,158	0,086	**0,167**
		C19.Smart agricultural spraying	0,104	0,125	**0,215**
		C20.Smart equipment	0,154	0,147	**0,154**

Note: Inconsistency rate is calculated as 0.00075

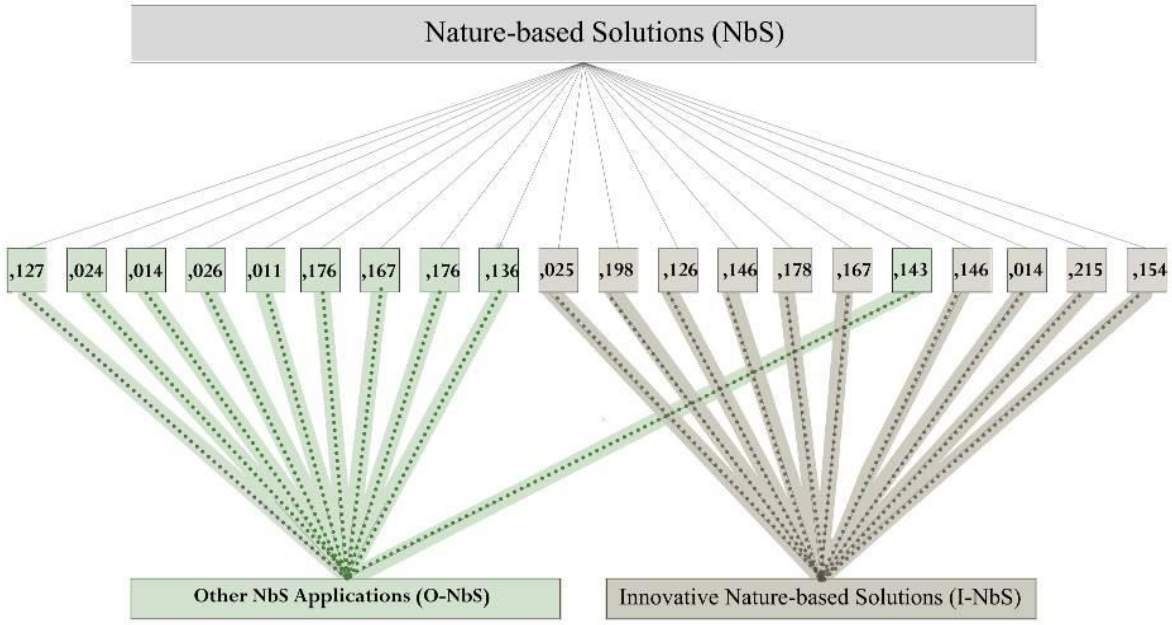


Fig. 7: Criteria matrix result

In order to evaluate the results of I-Nbs applications in themselves, radat matrices were made for each application in Figure 8. When the radar matrices are examined, the application with the highest relations among the criteria is C20.Smart equipment, C18.Wind turbine, C11. Solar panel and C19.Smart agricultural spraying (Figure 8). The lowest relationship is c10. Waterways has also been seen (Figure 8). These relationships are closely related to the results obtained from the experts. In particular, it is thought that the reason for the high weight of the smart agricultural spraying application is the increase in the world population, the decrease in agricultural production and food supply, and the concern that a global food crisis may occur. This country needs to take measures to meet its domestic consumption and increase production permanently. Because smart agricultural spraying application is an important I-NbS application for the future of humanity and all living things, food production and food security. This application is one of the most up-to-date and modern applications that increase efficiency by making use of technology. Therefore, the results are considered to be high. The fact that the country where Terra - The Sustainability Pavilion is implemented is Dubai, one of the 7 campuses of UAE, allows it to benefit from solar energy at the maximum level. Especially, the "tree" applications working with solar power, inspired by the tree habitus in Terra, are quite remarkable. Its remarkableness is also supported by data obtained from statistical studies. The dependence of urban systems on nature and natural resources coincides with the results of the expert group. For example, the hot climate conditions of Dubai have enabled applications to be ahead in terms of solar panels. However, adding "innovative" solutions to these potentials has brought the design to the "perfect" level. This perfection is supported by the fact that the preferences of the users are quite high and the results obtained from the expert group.

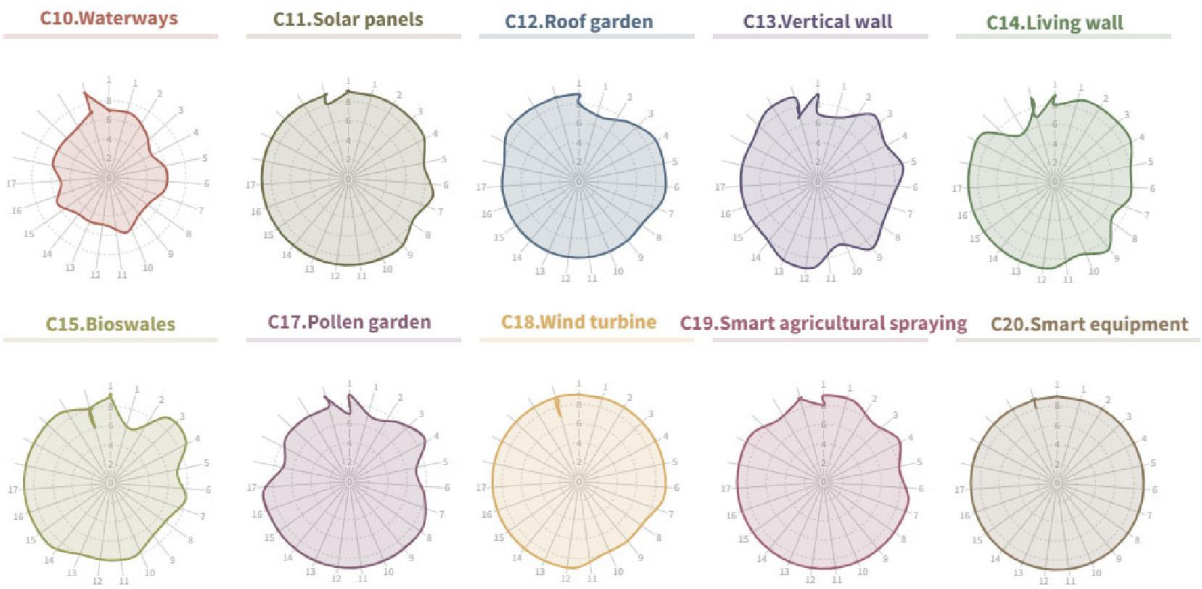


Fig. 8: Radar matrix graphs for all applications

Findings on the Second Stage; Formulating the I-NbS Index Value and Creating the Calculation Method

While calculating the I-NbS value, experts were asked to give points for Terra - The Sustainability Pavilion, with 1 being the lowest and 9 the highest for each criterion. The highest I-Nbs value is "Nvalue x 90"; 2700, the lowest value is "Nvalue x 9"'; It is 270. A scale order of the given score was created. Very low I-NbS value between Nvalue x 9-20 points, low level I-NbS value between Nvalue x 21-32 points in scale order, moderate I-NbS value between Nvalue x 33-44 points, Nvalue x I-NbS at normal level between 45-56 points, Nvalue x I-NbS value at high level between 57-68 points, Nvalue x very high between 69-80 points The Nvalue x represents a very high level of I-NbS between 81-90 points. Each of the 10 application forms was given points by the experts. The I-NbS Value calculation formula (i) was prepared within the scope of the study. N represents people in the formula. Therefore, it starts from N1 and goes to N30. "CPG + CVT + CW + CSP + CRG + CVW+ CLW+ CB+ CSAS+ CSE" represents 10 application forms. Applications in the formula are coded with abbreviations. Codes, "PG; Pollen garden, WT; Wind turbine, W; Waterways, SP; Solar panels, RG; Roof garden, VW; Vertical wall, LW; Livingwall, B; Bioswales, SAS; Smart agricultural spraying, SE; It is in the form of "Smart equipment". The formula and evaluation values (i) are given.

(i) Calculation of I-NbS Index Value

(i) $N_1 \times [\sum \{ C_{PG} + C_{VT} + C_W + C_{SP} + C_{RG} + C_{VW} + C_{LW} + C_B + C_{SAS} + C_{SE} \}] + N_2 \times [\sum \{ C_{PG} + C_{VT} + C_W + C_{SP} + C_{RG} + C_{VW} + C_{LW} + C_B + C_{SAS} + C_{SE} \}] + \ldots\ldots \ldots N_X \times [\sum \{ C_{PG} + C_{VT} + C_W + C_{SP} + C_{RG} + C_{VW} + C_{LW} + C_B + C_{SAS} + C_{SE} \}]$

(i_1) $N_1 \times [\sum \{C_{PG} + C_{VT} + C_W + C_{SP} + C_{RG} + C_{VW} + C_{LW} + C_B + C_{SAS} + C_{SE} \}] = [\sum \{\ldots\}]$

(i_2) $N_2 \times [\sum \{C_{PG} + C_{VT} + C_W + C_{SP} + C_{RG} + C_{VW} + C_{LW} + C_B + C_{SAS} + C_{SE} \}] = [\sum \{\ldots\}]$

(i_3) $N_3 \times [\sum \{C_{PG} + C_{VT} + C_W + C_{SP} + C_{RG} + C_{VW} + C_{LW} + C_B + C_{SAS} + C_{SE} \}] = [\sum \{\ldots\}]$

(i_4) $N_4 \times [\sum \{C_{PG} + C_{VT} + C_W + C_{SP} + C_{RG} + C_{VW} + C_{LW} + C_B + C_{SAS} + C_{SE} \}] = [\sum \{\ldots\}]$

(i_5) $N_5 \times [\sum \{C_{PG} + C_{VT} + C_W + C_{SP} + C_{RG} + C_{VW} + C_{LW} + C_B + C_{SAS} + C_{SE} \}] = [\sum \{\ldots\}]$

(i_6) $N_6 \times [\sum \{C_{PG} + C_{VT} + C_W + C_{SP} + C_{RG} + C_{VW} + C_{LW} + C_B + C_{SAS} + C_{SE} \}] = [\sum \{\ldots\}]$

(i_7) $N_7 \times [\sum \{C_{PG} + C_{VT} + C_W + C_{SP} + C_{RG} + C_{VW} + C_{LW} + C_B + C_{SAS} + C_{SE}\}] = [\sum \{\ldots\}]$

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(i_X) $N_X \times [\sum \{C_{PG} + C_{VT} + C_W + C_{SP} + C_{RG} + C_{VW} + C_{LW} + C_B + C_{SAS} + C_{SE}\}] = [\sum \{\ldots\}]$

Calculation of "I-NbS Value" in Terra - The Sustainability Pavilion

After the I-NbS Index formula of the study was created, this formula was applied for the study area, Terra - The Sustainability Pavilion. The index value of Terra - The Sustainability Pavilion was calculated with the expert group grouping I-NbS applications in the formula. Each user gave Terra between 1 and 9 points for each application, and these scores were formulated. According to the results obtained, experts *"$N_1$85, $N_2$84, $N_3$90, $N_4$84, $N_5$85, $N_6$80, $N_7$83, $N_8$78, $N_9$82, N_{10}81, N_{11}84, N_{12}84, N_{13}84, N_{14}85, N_{15}84, N_{16}85, N_{17}84, N_{18}90, N_{19}84, N_{20}85, N_{21}80, N_{22}83, N_{23}78, N_{24}82, N_{25}81, N_{26}84, N_{27}84, N_{28}84,+ N_{29}85, N_{30}90*" it was scored as experts. (i, Table 3).

(i) $N_1 \times [\sum \{ C_{PG} + C_{VT} + C_W + C_{SP} + C_{RG} + C_{VW} + C_{LW} + C_B + C_{SAS} + C_{SE} \}] + N_2 \times [\sum \{ C_{PG} + C_{VT} + C_W + C_{SP} + C_{RG} + C_{VW} + C_{LW} + C_B + C_{SAS} + C_{SE} \}] + \ldots\ldots \ldots N_{30} \times [\sum \{ C_{PG} + C_{VT} + C_W + C_{SP} + C_{RG} + C_{VW} + C_{LW} + C_B + C_{SAS} + C_{SE} \}]$

(i_1) $N_1 \times [\sum \{C_{PG} + C_{VT} + C_W + C_{SP} + C_{RG} + C_{VW} + C_{LW} + C_B + C_{SAS} + C_{SE}\}] = [\sum \{85\}]$
(i_2) $N_2 \times [\sum \{C_{PG} + C_{VT} + C_W + C_{SP} + C_{RG} + C_{VW} + C_{LW} + C_B + C_{SAS} + C_{SE}\}] = [\sum \{84\}]$
(i_3) $N_3 \times [\sum \{C_{PG} + C_{VT} + C_W + C_{SP} + C_{RG} + C_{VW} + C_{LW} + C_B + C_{SAS} + C_{SE}\}] = [\sum \{90\}]$
(i_4) $N_4 \times [\sum \{C_{PG} + C_{VT} + C_W + C_{SP} + C_{RG} + C_{VW} + C_{LW} + C_B + C_{SAS} + C_{SE}\}] = [\sum \{84\}]$
(i_5) $N_5 \times [\sum \{C_{PG} + C_{VT} + C_W + C_{SP} + C_{RG} + C_{VW} + C_{LW} + C_B + C_{SAS} + C_{SE}\}] = [\sum \{85\}]$
(i_6) $N_6 \times [\sum \{C_{PG} + C_{VT} + C_W + C_{SP} + C_{RG} + C_{VW} + C_{LW} + C_B + C_{SAS} + C_{SE}\}] = [\sum \{80\}]$
(i_7) $N_7 \times [\sum \{C_{PG} + C_{VT} + C_W + C_{SP} + C_{RG} + C_{VW} + C_{LW} + C_B + C_{SAS} + C_{SE}\}] = [\sum \{83\}]$

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(i_{30}) $N_{30} \times [\sum \{C_{PG} + C_{VT} + C_W + C_{SP} + C_{RG} + C_{VW} + C_{LW} + C_B + C_{SAS} + C_{SE}\}] = [\sum \{90\}]$

$= \sum\{ N_1 + N_2 \ldots\ldots\ldots N_{30}\} = \{85+ 84+ 90 + 84 + 85 + 80+83+78+82+ 81 + 84 + 84+ 84 + 85 + 84+ 85 + 84+90 +84 + 85 +80+83+78+82+81+84+84+84+85+90\} = \{2540\}$

Table 3: Total weights all applications of I-NbS

Total Weights		
$\sum\{ N_1\} = 85$	$\sum\{ N_{11}\} = 84$	$\sum\{ N_{21}\} = 80$
$\sum\{ N_2\} = 84$	$\sum\{ N_{12}\} = 84$	$\sum\{ N_{22}\} = 83$
$\sum\{ N_3\} = 90$	$\sum\{ N_{13}\} = 84$	$\sum\{ N_{23}\} = 78$
$\sum\{ N_4\} = 84$	$\sum\{ N_{14}\} = 85$	$\sum\{ N_{24}\} = 82$
$\sum\{ N_5\} = 85$	$\sum\{ N_{15}\} = 84$	$\sum\{ N_{25}\} = 81$
$\sum\{ N_6\} = 80$	$\sum\{ N_{16}\} = 85$	$\sum\{ N_{26}\} = 84$
$\sum\{ N_7\} = 83$	$\sum\{ N_{17}\} = 84$	$\sum\{ N_{27}\} = 84$
$\sum\{ N_8\} = 78$	$\sum\{ N_{18}\} = 90$	$\sum\{ N_{28}\} = 84$
$\sum\{ N_9\} = 82$	$\sum\{ N_{19}\} = 84$	$\sum\{ N_{29}\} = 85$
$\sum\{ N_{10}\} = 81$	$\sum\{ N_{20}\} = 85$	$\sum\{ N_{30}\} = 90$

Table 4: I-NbS apllications, codes and total weights of I-NbS apllications

I-NbS Apllications	I-NbS Applications Code	$N_1 + N_2 \ldots\ldots N_{30}$ Total Weights of I-NbS Apllications
C17.Pollen garden	PG	254
C18.Wind turbine	WT	260
C10.Waterways	W	207
C11.Solar panels	SP	**314**
C12.Roof garden	RG	257
C13.Vertical wall	VW	**264**
C14.Living wall	LW	253
C15.Bioswales	B	241
C19.Smart agricultural spraying	SAS	**270**
C20.Smart equipment	SE	**267**

Findings of Thirds Stage; Questioning the Relationship Between I-NbS and Landscape Value

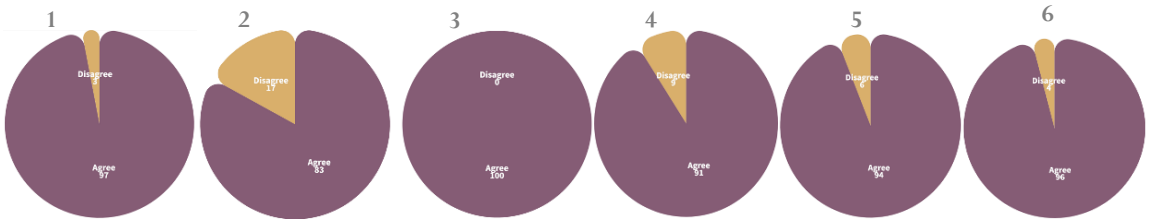
This stage of the study is the final statistical stage. At this stage, six questions were asked to the experts. These questions are; “Do you think its innovative solutions are important for NbS applications?”, “Do you think I-NbS applications are important for the ecosystem?”, “Would you like to visit/experience Terra-The Sustainability Pavilion?”, “Innovative in your future applications, “I -Can you include NbS solutions?”, “Do you think that I-NbS applications are important in terms of biodiversity in the ecosystem?”, “Do you think that the aesthetic value of I-NbS applications are effective as well as their ecological effects?”, When the answers to these questions were examined, the findings obtained are given in Table 3. When the results are examined, it is seen that all the questions questioning the relationship between I-NbS and ecology have received very high results. 97% of the participants found Innovative solutions important for NbS applications. 83% of users said that these solutions are very important for the ecosystem. In the third question, which is among the highest results, all users gave the answer "I agree". All users wanted to visit/experience Terra-The Sustainability Pavilion. It is thought that this result is influenced by the fact that the users like the applications very much and find them successful. In the fourth question, 91% of the participants answered yes. This result shows that the participants will include I-NbS solutions in their future studies. This result is a very high result. In another question, it was questioned what the experts think about whether I-NbS applications are beneficial to the ecosystem in terms of biodiversity. In the answers received, 94% replied that I-NbS is a very important application in terms of biodiversity. In the last question, the issue of whether I-NbS applications have aesthetic value as well as ecological contributions to the ecosystem was questioned. In the responses received, the answer was yes, it contributed to the rate of 96%. This result shows that I-NbS has a very high aesthetic contribution as well as ecological contributions (Table 5).

Table 5: Opinions of experts on the contributions of I-NbS to the ecosystem

Variables	Agree	Disagree
1*	%97	%3
2*	%83	%17
3*	%100	-
4*	%91	%9
5*	%94	%6
6*	%96	%4

1* Do you think innovative solutions are important for NbS applications?
2* Do you think I-NbS applications are important for the ecosystem?
3* Would you like to visit/experience Terra-The Sustainability Pavilion?
4* Can you include innovative I-NbS solutions in your future applications?
5* Do you think I-NbS applications are important in terms of biodiversity in the ecosystem?"
6* Do you think that the aesthetic value of I-NbS applications is effective as well as their ecological effects?

Graphs of the Results Obtained



The landscape value parameters obtained as a result of the literature studies were questioned by the experts at this stage. The determined 10 parameters were translated into 10 questions and questioned by the experts with a 5-point Likert attitude scale. Experts were asked to answer the questions with parameters 1,2,3,4,5. On the score scale, it is expressed as 1 (strongly disagree), 2 (disagree), 3 (no idea), 4 (agree), 5 (strongly agree). With the literature studies, the parameters were established as follows; 1. Beautiful, 2. Original, 3. Impressive, 4. Natural, 5. Harmonious, 6. Relaxing, 7. Safe, 8. Recreational, 9. Unique, 10. Well-kept (Clay, Smidt, 2004, Guneroglu, 2017, Inoue et al., 2022, Solecka et al., 2022). Among the results obtained, a very high positive correlation (0.741**) was found between the 3. Impressive and 4. Natural parameters. Another high positive correlation (0.719**) was found between the 4th Natural and 5th Harmonious parameters. The third positive high correlation (0.657**) was determined between the 4. Natural and 6. Relaxing parameters (Table 6). In these results, these parameters have features that increase the landscape value in I-NbS applications. These parameters should be included in the designs and design decisions should be made that support the landscape value at the same time while making I-NbS applications.

Table 6: Correlation table

Parameters	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10
*C1	1									
*C2	0,258	1								
*C3	0,210	0,485	1							
*C4	0,516	**0,633****	**0,741****	1						
*C5	0,141	**0,601****	0,345	**0,719****	1					
*C6	0,158	**0,548****	0,415	**0,657****	0,145	1				
*C7	0,354	0,315	0,318	0,413	0,124	0,428	1			
*C8	**0,618****	0,253	0,485*	0,214	0,148	0,485	0,124	1		
*C9	**0,587***	**0,621****	**0,625****	0,142	0,345	0,145	0,254	0,354	1	
*C10	**0,589***	**0,514***	**0,481***	0,103	0,297	0,145	0,219	0,435	0,657	1

**C1. Beautiful, *C2. Original, *C3. Impressive, *C4. Natural, *C5. Compatible, *C6. Relaxing, *C7. Safe,* C8. Recreational, *C9. Unique, *C10. Well-Groomed*

Correlation Values and Symbols

Symbol	Symbol description	Value range
	Very strong correlation	0,600 and above
	Strong correlation	0,450 - 0,600
	Mid-level correlation	0,300 - 0,450
	Low correlation	0,150 - 0,300
	Very low correlation	0- 0,150

***Correlation is significant at the 0.01 level (2-tailed).*
**. Correlation is significant at the 0.05 level (2-tailed)*

In the last stage of the findings, factor analysis was performed on the data collection containing 10 criteria in order to obtain findings with principal component analysis. As a result of the analysis, 3 components were identified, which accounted for approximately 74% of their variance. The factor analysis results are given in Table 8. As a result of the analysis, it was determined that the factor loads varied between 0.768 and -0.217 (Table 8). As a result of the analysis, it was determined that the 1st factor loading, which constituted 48.215% of the total variance, was “Original (0.748), Impressive (0.621), Natural (0.728)” parameters. It was determined that the second factor loading, which constituted 21,157% of the total variances, was the parameters "Natural (0.348), Safe (0.357), Relaxing (0.341)". It was determined that the third factor load, which constituted 10.154% of the total variances, was the "original (0.248), natural (0.267) and safe (0.234)" parameters (Table 7).

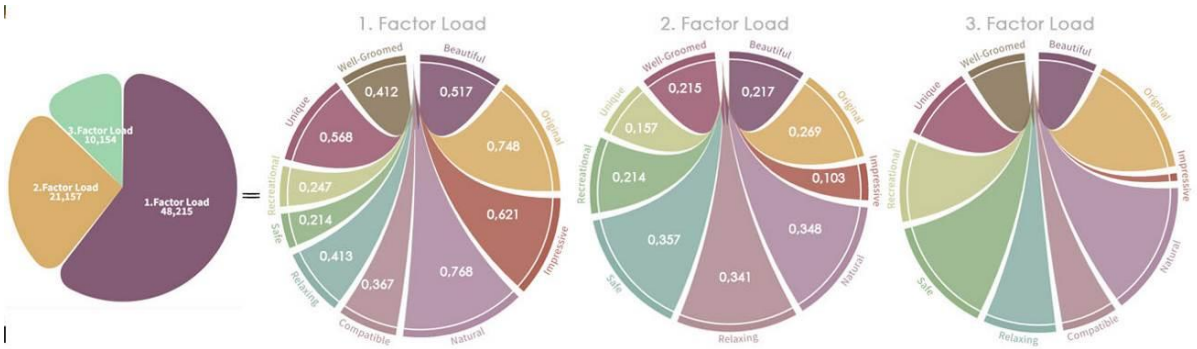
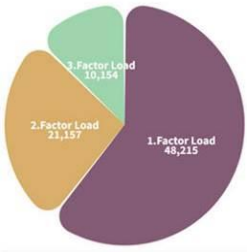


Fig. 9: Distribution of factor loads

Table 7: Factor analysis results of the criteria

	Criteria codes	Criteria	Factor loads		
			1	2	3
	C1	Beautiful	0,517	0,217	0,118
	C2	Original	**0,748**	0,269	**0,248**
	C3	Impressive	**0,621**	0,103	0,015
	C4	Natural	**0,768**	**0,348**	**0,267**
	C5	Compatible	0,367	-0,217	0,112
	C6	Relaxing	0,413	**0,341**	0,147
	C7	Safe	0,214	**0,357**	**0,234**
	C8	Recreational	0,247	0,214	0,167
I-Nbs and Landscape Value Parameters	C9	Unique	**0,568**	0,157	0,148
	C10	Well-Groomed	**0,412**	0,215	0,119
		% of variance	**48,215**	21,157	10,154

Conclusion and Recommendations

The fact that the destructive effects of population growth and urban dynamics on the natural environment can be felt in daily life are among the main causes of the climate crisis. It is seen that ecological solutions are needed for transferring awareness about the protection of nature to practices, rational use of resources, better quality of life and healthy living of people. The basic principle in this regard is human-oriented design inspired by nature. The main goal is to improve the carrying capacity of local ecosystems in a sustainable way by changing consumption habits and decision mechanisms. Within the scope of this study, NbS applications, which is the most comprehensive study applied as a solution to these problems, were examined. The contribution of combining NbS applications with innovative solutions has been determined.

The results obtained in line with these determinations are as follows;

- Combining NbS applications with innovative solutions was preferred more (56%) by the expert group and it was concluded that it would be more beneficial to the ecosystem.
- It was concluded that 10 applications, which are among the NbS applications, have more innovative features than the others. Applications with innovative features by experts are as follows; C1.Street trees, C2.Rain gardens, C3.Rain ditches, C4.Green parks, C5.Farming areas, C6.Green corridors, C7.Drier gardens, C8.Lakes and ponds, C9.Wetlands, C16.Green corridor
- “Smart agricultural spraying” applications (0.215) were selected as the highest result for I-NbS applications in the expert group results.
- “Solar panel” applications (0.198) were chosen as the second important application for I-NbS applications in the expert group results.
- Vertical gardens, which are among the oldest and classical applications of NbS applications, are the applications with the third highest results by experts. Although there are many NbS and Innovative NbS applications, C14.Living wall (0.178) has the third highest result.
- A numerical index formula has been created for the Innovative-NbS application.
- Calculation was made for Terra, which is the working area, with the created formula. Terra has achieved very high scores from each of those apps.

- In the index calculation, C11.Solar panels (314) got the highest result from the applications. Solar panel application was among the highest results in both index calculation and AHP analysis. According to these results, it is said that solar panel application is very important for NbS and Innovative-NbS applications.
- Another high result in the index calculation was C19.Smart agricultural spraying (270). Just like in the solar panel application, the Smart agricultural spraying application also obtained very high results from the AHP analysis during the expert opinion. According to these results, it is said that Smart agricultural spraying application is very important for NbS and Innovative-NbS applications.
- Another high result was obtained from the application of C20.Smart equipment (267).
- As a result of another analysis made with the experts, it was concluded that they will definitely include NbS applications in their future studies, that NbS is very important for the ecosystem, that it contributes to the city in terms of aesthetics as well as ecological terms, and that it is very important in terms of biodiversity (Table). 5). The answers to these questions vary between 83% and 100%. This distribution is a very high frequency.
- Correlation analysis and factor analysis were performed to reveal the relationship between innovative-NbS applications and landscape value.
- As a result of the correlation analysis, a very high correlation (**0.741) was obtained between the 3. Impressive and 4. Natural parameters. This positive correlation is a very high result. Taking advantage of this result of the analysis, it can be said that these two parameters feed each other positively and it is an Innovative-NbS application that increases the landscape value (Tablo 6).
- Another highly positive correlation as a result of the correlation analysis is C4. Natural, *C5. It was obtained between Compatible (**0.741) parameters. This positive correlation is a very high result. Taking advantage of this result of the analysis, it can be said that these two parameters feed each other positively and it is an Innovative-NbS application that increases the landscape value (Tablo 6).
- As a result of the factor analysis, 3 different factor components were obtained (Table 7).
- As a result of factor analysis, the highest parameter was C4.Natural (0.768) (Table 7). This result shows that naturalness is a very important factor in Innovative-NbS applications. Among the studies to be done, the naturalness parameter should be given importance (Table 7, Figure 9).
- Another high result of factor analysis is C2. The original parameter has been. Looking at this result, it is quite surprising that the original parameter is after the naturalness parameter. We can say that the most important conclusion that can be drawn from these results is as follows; In addition to the fact that the naturalness parameter is very important in the designs to be made, it is also very important that the design is original (Table 7, Figure 9). This result obtained from the factor analysis coincides with the result stated by the experts in Table 5. The success of a design is also very important in terms of its contribution to the ecosystem, as well as the visual aesthetic concerns it presents. This result also coincides with the success of the Terra application. Because Terra is a highly successful application for sustainability and NbS applications. However, behind the application's popularity and success, it is seen that its ecological and sustainable features, as well as its aesthetic features, are important.

It is thought that the data obtained as a result of this study will set an example for future studies. It should not be forgotten that the solution to every problem exists in nature. When natural solutions are produced to problems, the result will be both ecological and aesthetic. Also, when innovative features are added to all these features, the result can be quite successful. Terra, which is the subject of the study, is an example of this. Every design to be made should be built on concepts such as naturalness, originality and sustainability.

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