Journal of Engineering Research

Volume 8
Issue 3 *issue 3*

Article 30

2024

Unlocking the Potential of Rooftop Sustainable Systems: Understanding Barriers and Facilitators

Mahmoud Desouki
Department of Architecture, Nile Higher Institute for Engineering and Technology, Mansoura, Egypt., mahmouddesouki@nilehi.edu.eg

Taghreed A. El-Haddad
Faculty of Science, Tanta University, Egypt, taghreedabdelazizelhaddad@gmail.com

Journal of Engineering Research (JER)
Vol. X – No. Y, 2023

https://digitalcommons.aaru.edu.jo/cgi
ISSN: 2356-9441 e ISSN: 2735-4873

Unlocking the Potential of Rooftop Sustainable Systems: Understanding Barriers and Facilitators

Mahmoud Desouki [1], Taghreed A. El-Haddad [2],

[1] Department of Architecture, Nile Higher Institute for Engineering and Technology, Mansoura, Egypt – email: mahmouddesouki@nilehi.edu.eg
[2] Faculty of Science, Tanta University, Egypt – email: taghreedabdelazizelhaddad@gmail.com

***Abstract*- Urbanization is reducing green spaces in old cities globally, including Egypt, adversely impacting air quality, climate, and psychological well-being. The rooftop has the potential to offer viable alternatives that provide multiple benefits. They can host sustainable systems, and foster social activities. Despite these advantages, their adoption in cities like Tanta the Egyptian city, one of the world's most densely populated cities with a shrinking per capita green space, remains limited. Most rooftops are often serving as dumping grounds for trash and unused items. This study aims to explore the reasons behind this underutilization to find ways to encourage the use for sustainable purposes. Employing a mixed-methods approach, it combines a comprehensive survey of homeowners with semi-structured interviews with experts, including a real-estate developer, an architectural consultant engineer, a solar systems consultant engineer, and a landscape consultant designer. This research aims to uncover the various factors influencing the adoption of sustainable rooftop systems. The findings offer insights into homeowners' attitudes towards rooftop agriculture, technical and economic aspects of sustainable rooftop systems, guiding government policies to promote sustainable urban development. The research highlights that significant barriers such as economic constraints, cultural resistance, and complex ownership structures limit the use of rooftops. Findings suggest that clearer regulations and financial incentives, there is a readiness to adopt sustainable rooftop practices, indicating a key area for policy improvement. Ultimately, this research contributes to creating sustainable, resilient cities capable of addressing the challenges posed by rapid urbanization and environmental degradation.**

***Keywords*- Urbanization Impact, Sustainable rooftops, environmental resilience.**

I. INTRODUCTION

Urbanization in Egypt has had a significant impact on the green areas in old cities, with consequences that span environmental, social, and infrastructural dimensions. The rapid urban growth rate of 2% in Egypt has led to the need to accommodate almost one million new citizens in urban areas each year [1]. In many Egyptian cities, the rapidly growing population is leading to the loss of green spaces. Specifically, Cairo lost 910,894 square meters of green areas from 2017 to 2020, resulting in a decrease in the green space available per person from 0.87 to 0.74 square meters [2]. The World Health Organization suggests a minimum of 9 square meters of green space per person, with an ideal target of 50 square meters per individual [3]. Green areas are replaced by buildings and infrastructure. it results in decreasing green spaces, which are essential for providing oxygen, reducing air pollution, and providing habitats for wildlife [4]. According to a study in the International Journal of Low-Carbon Technologies, urbanization and energy have become the two primary issues in developing countries, with urban areas responsible for more than 70% of global energy-related CO2 emissions [5]. Additionally, it leads to an increase in temperatures due to the urban heat island effect [6]. The urban heat island effect is a phenomenon in which cities experience higher air temperatures compared to the surrounding countryside [7]. On average, cities can be 1-7°F warmer during the daytime and can still be up to 5°F warmer during the night compared to surrounding rural areas [8]. This can harm the health of citizens as well as the environment [9]. Therefore, measures must be taken to protect existing green areas and create new ones to mitigate the effects of urbanization on old cities in Egypt [10].

In urban areas, the decline in green spaces can be countered by implementing green roofs, which offer a practical solution. Green roofs have multiple ecological advantages: they help combat the urban heat island effect by providing shade to building surfaces, deflecting solar radiation, and releasing moisture into the atmosphere [11], [12]. It enhances the resilience of cities by reducing greenhouse gas emissions [13]. It also can aid in sustainable water management practices by efficiently controlling urban stormwater runoff and lowering its volume [14]. Research indicates that roof gardens have a positive impact on socializing and recreational activities [15]. The potential of roof gardens provides restorative and positive experiences, even for small and simple green roofs [16].

A range of studies have explored the potential benefits of utilizing rooftops in Egypt. They highlighted the potential of green roofs in addressing environmental issues and reducing energy consumption [17], [18]. Another study emphasized the role of rooftop solar panels in achieving nearly zero energy buildings, particularly in remote off-grid areas [19]. A research study underscores the potential of roof planting to improve the quality of life and contribute to sustainable development [20]. The prior research collectively indicates that rooftops in Egypt are not being fully utilized, potentially due to limited awareness of their benefits, along with the necessity for more research and practical implementations [19], [21], [22].

Tanta is one of the densest Egyptian cities [23]. According to Statista which is a German company working in the market and consumer data, Tanta city is the second most crowded city in the world [24]. The rapid urbanization in Tanta has led to a significant decrease in green areas, resulting in the intensification of urban heat islands [25]. Tree Massacre, is how the city citizens described the decision to cut down the streets. Residents of Tanta were surprised by the local government's decision to auction off more than 1,500 trees. These trees cut down from various

doi: XXXXXXXXXX

Journal of Engineering Research (JER)
Vol. X – No. Y, 2023

https://digitalcommons.aaru.edu.jo/cgi
ISSN: 2356-9441
e ISSN: 2735-4873

locations such as main roads and recreational spaces, were offered in a public auction [26]. This expansion not only decreased the recreational areas but also caused a loss of productive agricultural lands [27]. To address this issue, the development of sustainable urban green areas has been proposed, with a focus on maintaining ecological balance and organization [28]. Additionally, the optimization of urban green infrastructure, such as the introduction of urban trees, has been suggested as a means to reduce solar irradiance and mitigate the urban heat island effect [29].

A comprehensive review of existing literature reveals a gap in the application and understanding of these systems in the Egyptian context. Studies highlight the environmental and social benefits of rooftop systems but lack a focused analysis of their underutilization, especially in densely populated urban areas like Tanta.

To address this gap, the study employs a mixed-methods approach. A semi-structured interviews with key stakeholders – a real-estate developer, a consultant engineer, a CEO of a solar systems company, and a landscape designer – will offer a multi-dimensional perspective on the technical, economic, and regulatory factors influencing rooftop system adoption. Complementing this, a survey targeting homeowners in Tanta will provide insights into public perception and acceptance of rooftop systems.

By bridging the research gap, the study aims to contribute valuable insights to urban planning and policy-making. It seeks to inform strategies that could transform urban landscapes into more sustainable and environmentally resilient spaces, using Tanta as a case study with potential applicability to other similar urban settings.

II. METHODOLOGY

This study adopts a mixed-methods approach to investigate the underutilization of rooftop sustainable systems in Tanta, Egypt, and to identify potential barriers and facilitators to their adoption.

1. Qualitative Component

The qualitative component of the study involves analyzing open-ended survey responses to gain deeper insights into homeowners' attitudes toward rooftop sustainable systems. Thematic analysis will be used to identify key themes and patterns in responses, offering an understanding of personal experiences.

Interview Design: Semi-structured interviews will be conducted to gain in-depth insights into the technical, economic, and regulatory aspects influencing the adoption of sustainable rooftop systems. Key stakeholders have been interviewed, including a real-estate developer, an architectural design consultant engineer, a solar systems consultant, and a landscape consultant. These participants were selected based on their expertise and involvement in urban development.

Interviews have been conducted in-person or via video conferencing, or by phone depending on the preference of the participants. Each interview lasted approximately 30-60 minutes and was recorded with consent for accuracy in data collection. The recorded interviews were transcribed verbatim. Thematic analysis has been employed to identify common patterns and insights. The interviews helped to formulate the survey questions to the next phase.

All research activities were conducted in accordance with ethical standards. Participants were informed about the purpose of the research, and their consent was obtained before participation.

2. Quantitative Component

The quantitative component of the study involves a homeowners' survey. A structured questionnaire has been developed, aimed at assessing homeowners' perceptions, and attitudes toward rooftop usage. The questionnaire included demographic questions, as well as items measuring knowledge of, interest in, and perceived barriers to sustainable system implementation. The questions format has been varied between open-ended, and closed-ended questions to verify the qualitative component.

The survey in the study targeted a broad spectrum of homeowners in Tanta, categorized by age, gender, socioeconomic status, and urban location. According to the latest official census for the Central Agency for Public Mobilization and Statistics in 2023, the total population of Tanta-first district and second district- is 593600 [30]. The sample size was 273 respondents, representing a certain percentage of the total population. The sample size was calculated using SurveyMonkey, an online survey tool [31], ensuring a 90% confidence level, and 5% marginal error to achieve statistical significance and representativeness. The surveys were distributed in both online and in-person formats aiming to increase the response rate. In-person surveys were conducted in various neighborhoods to ensure a broad range of perspectives.

Closed-ended questions' responses have been analyzed by SPSS the statistical software. Descriptive statistics will provide an overview of the data, while inferential statistics, such as regression analysis, Chi-square, and Pearson's and Spearman tests [32] were used to identify significant predictors of attitudes and intentions.

III. RESULTS AND DISCUSSION

THE STAKEHOLDERS' SEMI-STRUCTURED MEETINGS

The stakeholders' semi-structured meetings were performed between January, and June 2024. The conversations of the meetings were recorded, transcribed, analyzed, and summarized as follow. the rationale behind selecting specific stakeholder categories for interviews, including an Architectural Design Consultant and a Real-estate Developer. The Architectural Design Consultant offers expertise in the practical and aesthetic aspects of rooftop development, while the Real-estate Developer provides insights into market dynamics and regulatory challenges.

doi: XXXXXXXXXX

Journal of Engineering Research (JER)
Vol. X – No. Y, 2023
©Tanta University, Faculty of Engineering
ISSN: 2356-9441 https://digitalcommons.aaru.edu.jo/cgi e ISSN: 2735-4873

This diversified approach allows for a holistic analysis of both the technical and economic dimensions.

A registered consultant engineer specialized in architectural design, with more than 40 years of experience. He had his Ph.D. degree 10 years ago. He is running his own consultancy studio, beside his academic profession as a head of department of architecture in an engineering higher institute. He has implemented many roof gardens in Tanta, and Cairo. He invites his clients to benefit from their rooftop specially if they own the roof whether if they live in the last floor. He describes the responding clients as luxurious ones in order to bear the initial high cost. He sometimes incorporates solar water heaters. He doesn't cultivate a built-in planting on the roof because he fears of poor implementation and water insulation. Also, he doesn't use modern soil-less planting because it is not a common culture. He believes that the rooftop can afford an opportunity to give a green social place for family's recreation especially in light of the limited entertainment venues in the city of Tanta. He thinks that the common ownership of the rooftop is a main reason that prevents the positive usage. He recommends to modify the laws regulations to make the rooftop a private ownership in order to be used a private garden or a private cafe.

The CEO of a construction and real estate company, bringing nearly thirty years of experience to the role. He inherited the company from his father, continuing a family legacy in the industry. He sells the rooftops of residential towers to the top floor owner if they are between 170-230 m^2. These owners often attempt to construct additional flats on these rooftops, typically in violation of building regulations. Occasionally, wealthy individuals may develop these spaces into roof gardens. For rooftops larger than 500 m^2, ownership is shared among the apartment owners. However, these larger rooftops are commonly underutilized, serving mainly for satellite dishes and trash disposal. He notes that in Tanta, it is uncommon for rooftops to be used sustainably. He believes that with proper ownership structure, possibly under large entities, rooftops could be effectively used for electricity generation, cultivation, or recreational activities. However, this would require changes to governmental regulations and a shift in cultural perceptions towards rooftop usage. Until such changes are implemented, He does not plan to invest in sustainable rooftop systems.

The author interviewed an accomplished consultant in architectural engineering specializing in landscape. With over 25 years of experience, he led the landscape department at Orascom Construction before founding Space Right, a landscape design and execution studio. Space Right operates in Cairo and Tanta, Egypt, and recently expanded with a new branch in Dubai, UAE. He has implemented multiple roof gardens in Tanta. He has never merged sustainable systems like solar cells. He also uses soil-based cultivation and doesn't use soil-less cultivation systems. He has consistently advocated for his clients to transform their rooftops into gardens. However, only a minority, primarily those with sufficient financial resources to afford the necessary roof modifications for cultivation, have responded. Even among the wealthier minority, only a few are convinced about the investment value of such a project. He attributes the limited interest in rooftop garden investments to a lack of cultural awareness regarding the significance of landscaping. Additionally, many overstated unfounded fears, such as concerns about roof insulation leaks, structural load, plant regularly watering, and cost, leading them to be apprehensive about the concept. He highlights the benefits of rooftop gardens, noting their role in enhancing social sustainability, particularly in densely populated areas. He points out that they provide a welcoming space for family gatherings, offer educational opportunities for children about responsibility through planting, simplify pet care, save money usually spent on outdoor activities, and serve an aesthetic purpose. Smart irrigation systems can address water management issues in rooftop gardening, especially for beginners. They aid in ensuring proper plant drainage and moisture insulation. Additionally, the act of gardening itself offers mental benefits; it clears the mind and relaxes the nerves. Engaging with the natural cycles of plants, such as observing the changing seasons of flowers and the ripening stages of fruits, can positively stimulate a person's mood.

The author reached out to a mechanical engineer boasting over 13 years of expertise in solar systems. He has served as a project manager at Taqa Arabia, an Egyptian joint-stock company, also possesses a Master's degree in solar energy. This is in addition to that he works as an instructor at the Renewable Energy Authority. He characterizes the majority of his clientele as large-scale entities, including factories, corporations, and hotels. He notes that residential usage of solar systems is predominantly confined to villa owners, particularly in the installation of solar heaters. He ascribes the minimal residential adoption of solar cells in Egypt to various factors. Key among these is the substantial cost of the system, with the smallest unit capable of generating 5 kilowatts priced between 250,000 and 300,000 Egyptian pounds. Additionally, this unit necessitates a space of approximately 50 square meters. The second reason, is that government subsidies for residential solar energy usage extend only up to 2000 kilowatts. Consequently, it is not economically feasible for a homeowner to invest in a solar energy unit unless their consumption exceeds 2000 kilowatts. Typically, household energy usage in Egypt does not surpass 1000 kilowatts, further limiting the appeal of such installations. Additionally, the installation of a solar unit requires it to be connected to a single electricity meter, meaning the beneficiary needs to be the sole owner of the area where the unit is installed, posing yet another barrier as the ownership of the roof is usually shared among the residents of one building. He holds the view that for economically implementation of solar cells on rooftops in Egypt currently, the customer should be a business entity where electricity is a critical and high-

doi: XXXXXXXXXX

Journal of Engineering Research (JER)
Vol. X – No. Y, 2023

https://digitalcommons.aaru.edu.jo/cgi
ISSN: 2356-9441
e ISSN: 2735-4873

consumption element in its production process. He believes that any attempt to promote the installation of solar cells for home use on rooftops at the current time and laws would be a waste of time and money.

THE SURVEY RESULTS

The conducted survey included 273 respondents, presenting a diverse demographic profile in terms of age, gender, employment, education, housing type, area affluence, and rooftop area. As illustrated in the charts in Figure 1, 2, 3, 4, 5, 6, 7. The survey sample consisted mainly of males (71%) in the 40-50 age range, with fair representation from those over 50 and in their thirties. Youth representation was lower. Most participants were employees or ran private businesses, and were highly educated, with many holding higher degrees. They lived primarily in owned homes in middle-class areas, with smaller rooftops under 300 square meters. The gender disparity and the concentration of respondents in certain age and social classes may influence the study outcomes and should be considered when interpreting the survey results. So, the researcher has performed statistical analysis for the survey results.

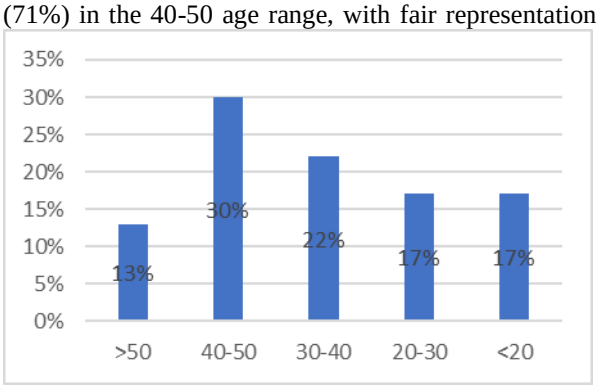

Figure 1: Age groups

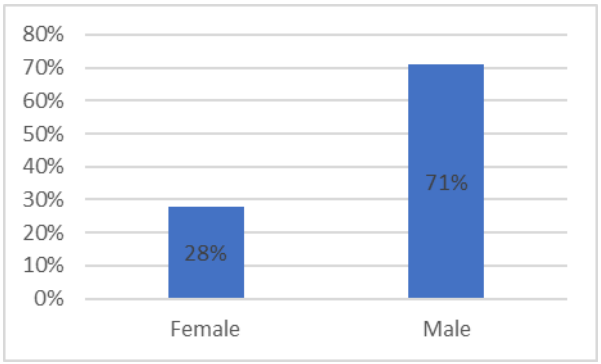

Figure 2: Sample sex

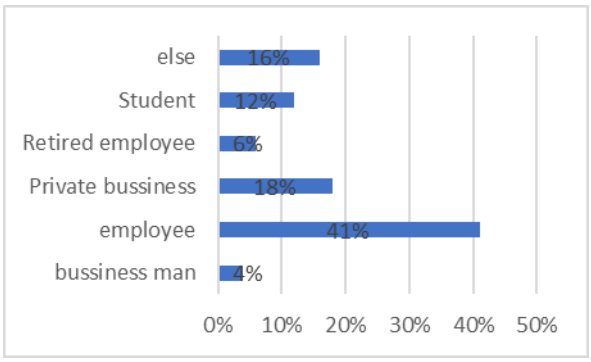

Figure 3: Sample jobs

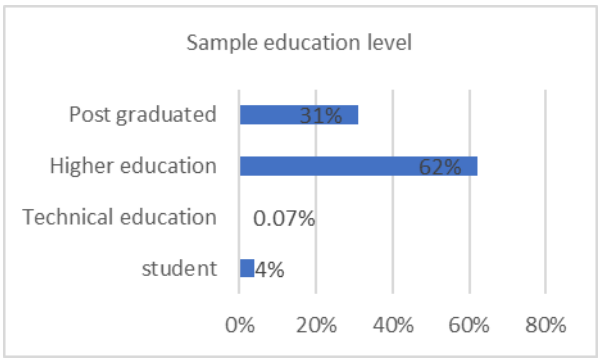

Figure 4: Sample education level

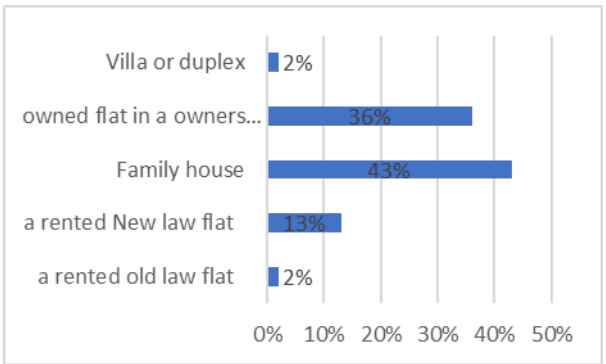

Figure 5: Sample housing style

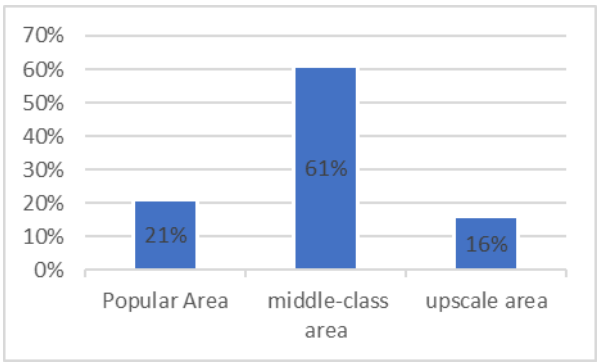

Figure 6: Sample location affluence

doi: XXXXXXXXXX

Journal of Engineering Research (JER)
Vol. X – No. Y, 2023
©Tanta University, Faculty of Engineering
ISSN: 2356-9441 https://digitalcommons.aaru.edu.jo/cgi e ISSN: 2735-4873

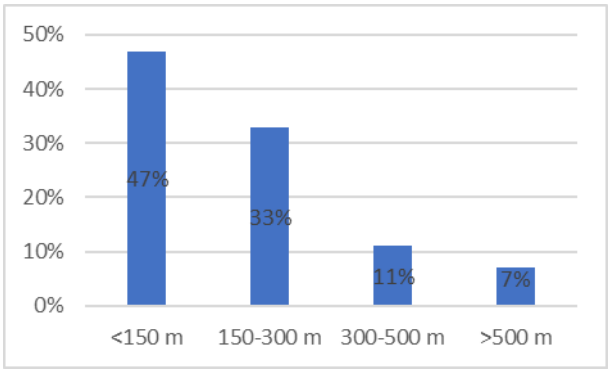

Figure 7: Sample rooftop area

Figure 8 indicates a slight majority of respondents (53%) reported not utilizing their rooftop. This implies a significant potential for unused space that could be leveraged for sustainable practices. As shown in figure 9, among those who do use their rooftops (46%), the primary use is for placing satellite dishes and similar equipment, indicated by a substantial 54%. We can describe this as almost unused. Family social gatherings are the next most common use at 23%, suggesting rooftops play a role in social life. Only a small fraction utilizes rooftops for sustainable systems (12%) and roof cultivation (1%), indicating low engagement with green practices. Poultry farming is utilized by 10%, showing some inclination towards domestic food production.

Figure 10 shows that indifference seems to be a significant reason for non-use, with 27% of respondents indicating they "don't care" about rooftop use, which could point to a lack of awareness or interest in the potential benefits. Restrictions imposed by the building owner are also a notable barrier, with 14% not using the roof because the owner banned them, and only 19% permits specific purposes like satellite placement. Economic factors, such as the perceived high cost of rooftop preparation (15%), and practical considerations, like time and effort (20%), also deter usage. The "another reason to tell" category is negligible at 1%, suggesting the survey captured the primary reasons for non-use.

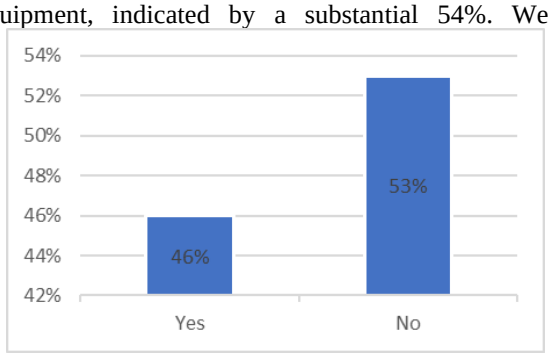

Figure 8: Do you utilize the rooftop of your residence?

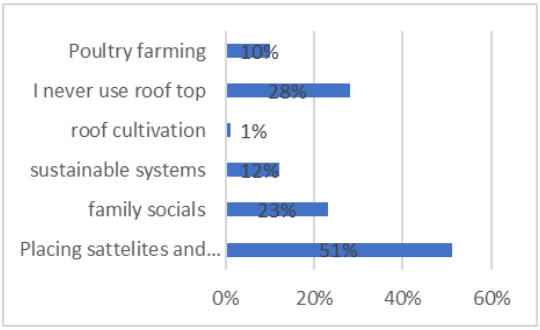

Figure 9: If you go on the roof, what you use it for (can choose more than one choice).

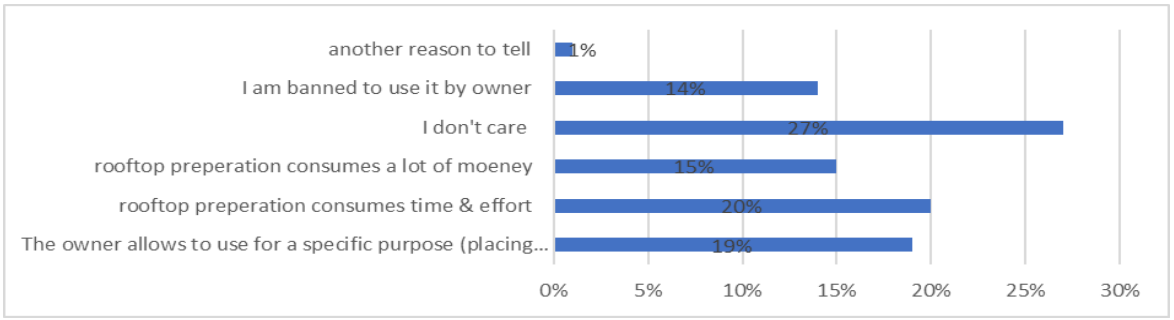

Figure 10: in case of not using the roof top tell the reason.

The findings reveal that most rooftops in Tanta are not used for sustainable purposes, largely due to economic, practical, and cultural barriers.

As shown in Figure 11, 13, 15. A notable proportion of residents have considered sustainable rooftop solutions (43%) and rooftop farming (42%), while a significant majority (65%) have thought about creating

doi: XXXXXXXXXX

Journal of Engineering Research (JER)
Vol. X – No. Y, 2023

https://digitalcommons.aaru.edu.jo/cgi
ISSN: 2356-9441
e ISSN: 2735-4873

rooftop gardens for family gatherings. Despite these considerations, there is a large gap between thought and action. Only 4% have acted upon their thoughts regarding sustainable systems, 8% have implemented rooftop farming, and 12% have created rooftop gardens for family nights. Those percentages surge to 95%, 91%, 87% not performing their ideas as shown in figures 12, 14, 16.

For the open-ended question why didn't you performed your thoughts: Many respondents cited high cost and low return as barriers. They noted that the initial expenses were substantial and not justified by the benefits in the short term. Additionally, the productivity of solar cells was not seen as sufficient to offset their costs, contributing to the perception of rooftop systems as economically unfeasible. Respondents also highlighted space limitations and legal uncertainties as obstacles to system implementation. Many noted that their rooftops lacked space to serve all residential units. Others were unsure about the legal procedures for installing or faced challenges with shared or structurally unsuitable rooftops. Several individuals expressed a general disinterest for utilizing rooftops. Some also pointed out a lack of awareness about the benefits. A few mentioned the absence of companies that supply or install such systems in Tanta, or the lack of technical expertise.

The majority (84%) are not aware of the state's rooftop regulations, which could contribute to the low implementation rate as shown in figure 17. Figure 18 shows a positive response to potential incentives is evident, with 56% indicating that state subsidies would encourage them to use their rooftops positively. An additional 35% are unsure, indicating that proper awareness and understanding of subsidies could influence their decisions.

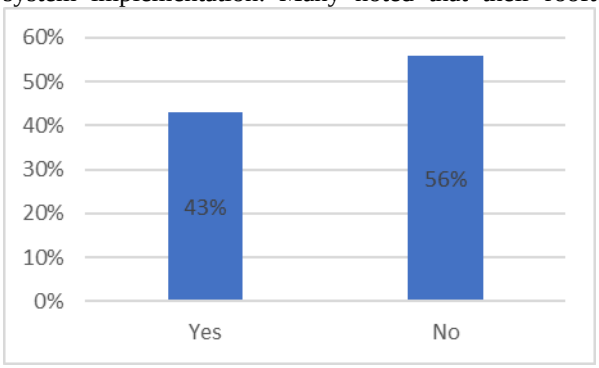

Figure 11: Have you thought about installing a sustainable system?

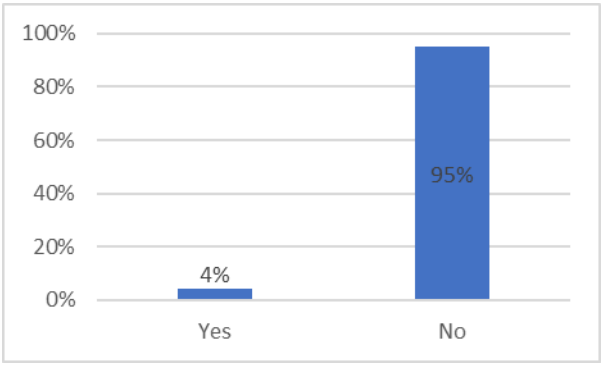

Figure 12: have you performed your thoughts?

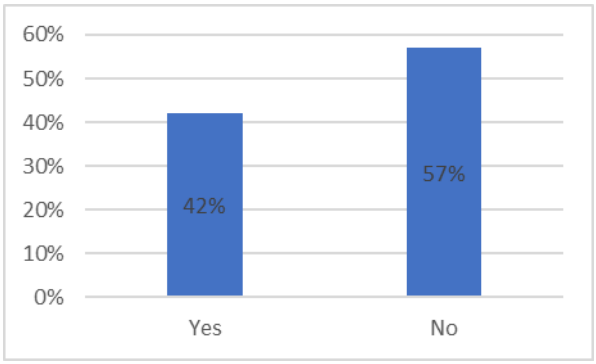

Figure 13: Have you thought about rooftop farming?

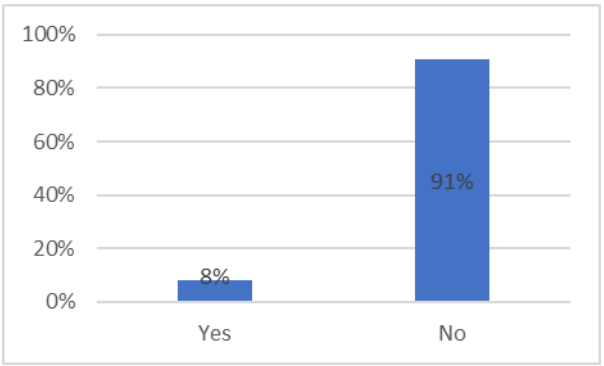

Figure 14: have you implemented your thoughts?

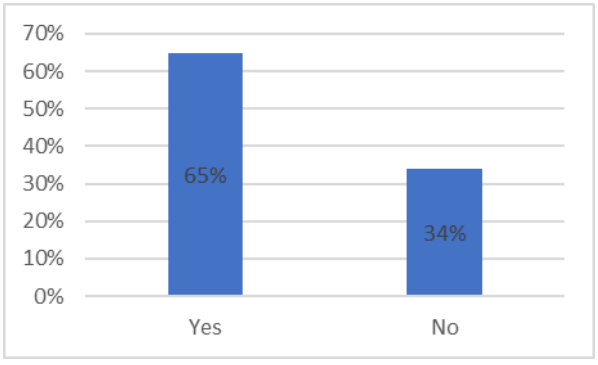

Figure 15: Have you thought about creating a roof garden?

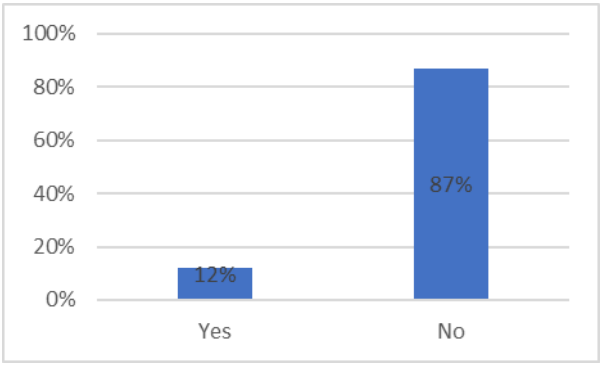

Figure 16: Did you implement your idea?

doi: XXXXXXXXXX

Journal of Engineering Research (JER)
Vol. X – No. Y, 2023

https://digitalcommons.aaru.edu.jo/cgi
ISSN: 2356-9441
e ISSN: 2735-4873

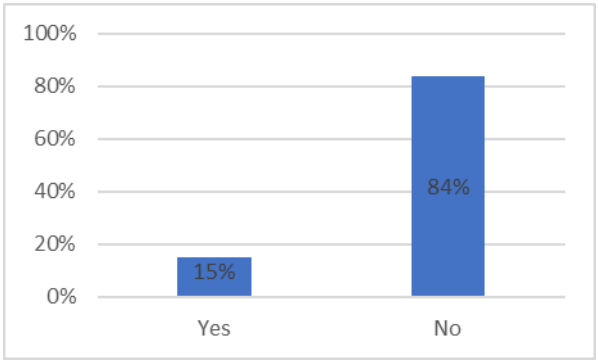

Figure 17: Do you know the state's rooftop regulations?

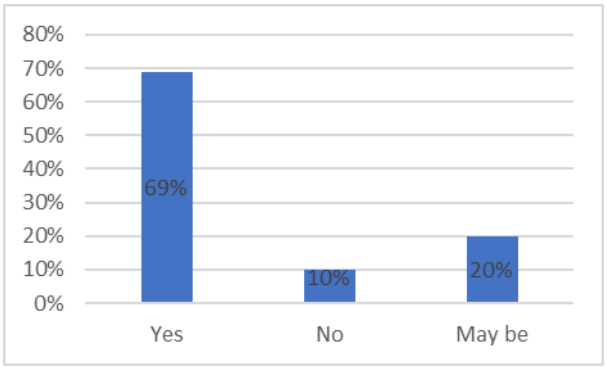

Figure 19: is there a feasibility on using roofs?

Figure 19 demonstrates a significant majority (69%) of the respondents believe that it is feasible to use rooftops, suggesting a positive perception towards the potential utility of rooftops. Only 10% explicitly think it is not feasible, while 20% are unsure, indicating some reservations or lack of information about rooftop usage. This result shows that there is a potential willingness among the population to engage with rooftop spaces, possibly for leisure or other purposes.

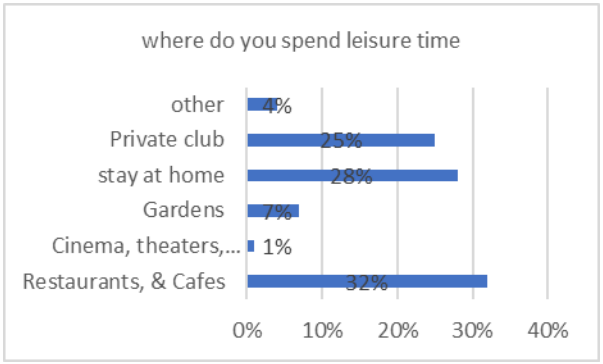

Figure 20: places for leisure time.

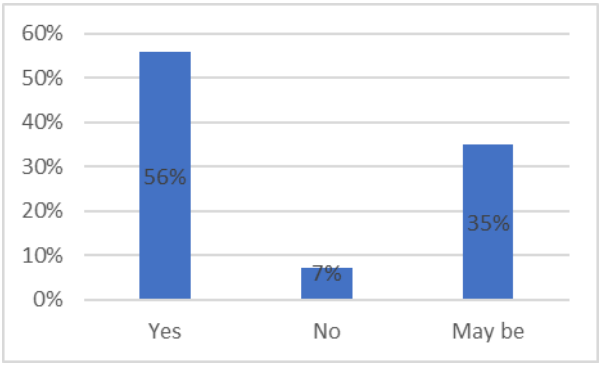

Figure 18: will a subsidization encourages using the roof?

Figure 20 shows that restaurants and cafes are the most popular venues for spending leisure time, preferred by 32% of respondents. Staying at home is the next chosen option at 28%, followed by private clubs at 25%. Gardens are favored by only 7%, and cinemas or theaters by a mere 1%. An additional 4% spend their leisure time in other unspecified ways.

A chi-square test has been implemented for each of sample features (age, gender, employment, education level, residence style, location, and area of rooftop) questions and the rest of the questions. The p value found to be less than 0.05 between the sample features and many of the questions responses. Commenting will be limited to related items. Results demonstrated a significant correlation between the age of respondents and their interactions with rooftop usage. Younger individuals tend to be more engaged in considering and implementing sustainable rooftop systems and gardens, likely due to higher environmental awareness or affinity for innovation. Age also influences attitudes toward the feasibility of rooftop use and the effectiveness of state subsidies in promoting such activities. These insights suggest that promotional strategies for rooftop utilization might need to be customized to cater to the diverse preferences and perceptions across different age groups.

The chi-square test results reveal significant gender differences in various aspects of rooftop usage, including restrictions from owners, perceptions of cost, and the creation and implementation of rooftop gardens. Additionally, gender influences beliefs about the feasibility of rooftop utilization and the effectiveness of state subsidies to promote such usage. These findings suggest that males and females may engage differently with rooftop spaces, highlighting the need for gender-sensitive approaches in policies and initiatives to ensure equitable encouragement and support for rooftop modifications across genders.

The chi-square test results indicate that employment status significantly influences various aspects of rooftop usage, including access restrictions, financial

doi: XXXXXXXXXX

Journal of Engineering Research (JER)
Vol. X – No. Y, 2023

ISSN: 2356-9441 https://digitalcommons.aaru.edu.jo/cgi e ISSN: 2735-4873

concerns, engagement with modern rooftop cultivation, and social uses of rooftops. Individuals' jobs affect their economic capabilities, flexibility, and lifestyle choices, which in turn influence how they perceive and utilize rooftops. Additionally, employment status impacts how individuals view the feasibility of rooftop usage and the effectiveness of state subsidies. These findings suggest the need for urban planning and policy measures to consider the unique circumstances of different professional groups to promote sustainable rooftop utilization effectively.

The chi-square test results indicate a significant link between education level and various aspects of rooftop usage. Higher educational attainment correlates with fewer restrictions and greater interest in utilizing rooftops, as well as with the consideration and implementation of sustainable rooftop systems. More educated individuals are also more likely to perceive the feasibility of using rooftops for innovative purposes. These findings suggest that educational background plays a crucial role in shaping how individuals engage with and perceive the potential of rooftop spaces, highlighting the importance of educational initiatives in promoting sustainable urban development.

The chi-square test results demonstrate that residence style significantly influences residents' interactions with and attitudes towards rooftop usage. The type of housing affects not only practical considerations like cost and effort associated with setting up rooftops but also residents' interest in and ability to implement sustainable systems and rooftop gardens. Furthermore, housing style impacts where individuals spend leisure time and their perception of the feasibility and benefits of using rooftops. The effectiveness of incentives like state subsidies also varies with residence style, suggesting the need for urban policies tailored to the unique characteristics of different housing types to promote effective and sustainable rooftop utilization.

The chi-square test results reveal that the luxury level of a district significantly influences rooftop usage behaviors. Residents of more affluent areas are less likely to face restrictions from owners, and are more engaged in contemplating and implementing sustainable rooftop systems, including modern cultivation techniques and rooftop gardens for socializing. These individuals also perceive a higher feasibility in using rooftops and choose different leisure activities, likely due to greater access to resources and fewer constraints. This underscores the need for policies that address economic disparities, ensuring equitable access to rooftop innovations across various socio-economic groups.

The chi-square test results indicate that the size of a rooftop significantly affects homeowners' perspectives on its use. Larger rooftop areas are associated with increased concerns about high costs and complexity, leading to disinterest and a lack of awareness about state regulations. These homeowners are also less likely to view their rooftops as attractive leisure spaces, potentially due to the perceived effort and financial burden involved in optimizing these areas. Additionally, those with larger rooftops may be more responsive to financial incentives, suggesting that targeted policies and subsidies could help overcome barriers to utilizing these spaces effectively.

Pearson's and spearman tests have been implemented between each of the sample features questions and the rest of questions. Many questions showed weak direct or inverse correlation. Commenting shall Comments will be limited to moderate or strong links.

Pearson's and spearman tests revealed that there is a moderate inverse correlation between housing type and rooftop preparation refusal due to effort and time. That could be explained that the richer he is, the easier it is for him to pay material and other costs.

A moderate inverse correlation between housing type and thinking of rooftop usage. That could be explained that the richer he is, the more alternatives he has for outings, such as clubs. that was confirmed by the inverse correlation between housing style and both of cultivating the roof, and make a friend's roof garden.

Respondents who prefer staying at home were queried about their reasons for not partaking in outdoor leisure activities. The predominant reasons include a shortage of suitable entertainment venues, particularly in Tanta, and significant urban congestion. Many respondents also prefer the comfort of their homes due to physical limitations, demanding household chores, and a general aversion to crowded or public settings. Additionally, dissatisfaction with the quality and safety of available leisure spaces was noted, compounded by time constraints and the financial costs of engaging in outdoor activities.

The respondents were asked to make suggestions for making sustainable roof systems more accessible and attractive. Respondents suggest several measures to improve the accessibility and attractiveness of sustainable roofing systems. Key recommendations include reducing costs, providing financial incentives and discounts, and improving public awareness through educational campaigns. Respondents also emphasize the need for government support, either through direct subsidies or by facilitating easier installation processes. The availability of expert companies that can offer reasonable costs and installment plans is also seen as crucial. Additionally, legal facilitation, such as simplifying licenses and providing tax exemptions, could help overcome significant barriers. The recurring theme across suggestions is the

doi: XXXXXXXXXX

Journal of Engineering Research (JER)
Vol. X – No. Y, 2023
©Tanta University, Faculty of Engineering
ISSN: 2356-9441 https://digitalcommons.aaru.edu.jo/cgi e ISSN: 2735-4873

need for a comprehensive approach that includes financial, technical, and legal support to make sustainable roofing more attractive and feasible for homeowners.

IV. CONCLUSION

This research has investigated the underutilization of rooftop spaces in Tanta, Egypt, highlighting the multifaceted barriers and potential for transforming these areas into sustainable systems. The study highlights a significant underutilization, mainly due to economic barriers, cultural resistance, and regulatory complexities. This reluctance is attributed to the high initial costs and complicated ownership structures in densely populated areas. The study encountered several limitations that might impact the breadth of its conclusions. It was geographically confined to Tanta, a densely populated city in Egypt, which may not reflect the diverse urban conditions found elsewhere. The sample mainly included homeowners who have access to rooftops, likely omitting varied viewpoints from tenants and those without rooftop access. Additionally, the use of self-reported data could lead to bias, with participants possibly overstating their interest in or capabilities for implementing sustainable rooftop systems.

Key stakeholders, have underscored the need for regulatory reforms to simplify the installation processes and ownership models. They also pointed out the necessity of cultural change through education and awareness campaigns that could demystify the benefits of rooftop utilization and encourage to engage with these spaces actively.

The quantitative data illustrates a readiness to consider rooftop systems if incentivized properly and supported by clearer guidelines and governmental support. Most respondents recognize the feasibility of transforming rooftops but are hindered by the lack of incentives and tangible examples.

The study suggests several strategies to encourage the adoption of rooftop systems, including reforming policy to modify building codes and ownership laws to support rooftop installations. It recommends the introduction of financial incentives such as subsidies, tax rebates, and financing options to alleviate the economic challenges. Additionally, it advocates for educational campaigns at both local and national levels to raise awareness about the benefits of rooftop systems. Lastly, the establishment of demonstration projects is proposed to provide tangible, examples.

Implementing the recommended strategies can transform underused areas into lively, green, and socially engaging spaces. Such changes can mitigate urban heat island effects, lower energy consumption, and improve urban life quality. This will make cities like Tanta more sustainable and resilient, better equipped to handle rapid urbanization and environmental issues.

Future research should widen the geographic and demographic scope of the study to enhance its relevance and inclusivity. This includes assessing the long-term effectiveness of rooftop systems and experimenting with different incentive and regulatory approaches to better understand and address barriers to their adoption.

REFERENCES

[1] M. Carucci, R. Malec, and S. Guido, “Urbanisation and Urban Development in Egypt I Infographics.” 2019.
[2] D. Aly and B. Dimitrijevic, “Public green space quantity and distribution in Cairo, Egypt,” Journal of Engineering and Applied Science, vol. 69, no. 1, Dec. 2022, doi: 10.1186/s44147-021-00067-z.
[3] World Health Organization, “Health Indicators of sustainable cities,” The Rio+20 UN Conference on Sustainable Development, no. May, pp. 17–18, 2012.
[4] Blessing Aibhamen Edeigba, Ugochukwu Kanayo Ashinze, Aniekan Akpan Umoh, Preye Winston Biu, and Andrew Ifesinachi Daraojimba, “Urban green spaces and their impact on environmental health: A Global Review,” World Journal of Advanced Research and Reviews, vol. 21, no. 2, pp. 917–927, Feb. 2024, doi: 10.30574/wjarr.2024.21.2.0518.
[5] I. Hegazy, W. Seddik, and H. Ibrahim, “Towards green cities in developing countries: Egyptian new cities as a case study,” International Journal of Low-Carbon Technologies, vol. 12, no. 4, pp. 358–368, 2017, doi: 10.1093/ijlct/ctx009.
[6] A. M. M. Irfeey, H. W. Chau, M. M. F. Sumaiya, C. Y. Wai, N. Muttil, and E. Jamei, “Sustainable Mitigation Strategies for Urban Heat Island Effects in Urban Areas,” Sustainability (Switzerland), vol. 15, no. 14, Jul. 2023, doi: 10.3390/su151410767.
[7] E. Berg and C. Kucharik, “The Dynamic Relationship between Air and Land Surface Temperature within the Madison,Wisconsin Urban Heat Island,” Remote Sens (Basel), vol. 14, no. 1, pp. 1–19, 2022, doi: 10.3390/rs14010165.
[8] C. He et al., “The effects of night-time warming on mortality burden under future climate change scenarios: a modelling study,” Lancet Planet Health, vol. 6, no. 8, pp. e648–e657, 2022, doi: 10.1016/S2542-5196(22)00139-5.
[9] EPA, “Heat Island Impacts | US EPA,” Environmental Protection Agency US. pp. 1–7, 2021.
[10] E. H. Ayad and S. E. A. Rasheed, “Sponge cities technology: Guidelines for Applying in Egypt,” IOP Conf Ser Earth Environ Sci, vol. 1113, no. 1, 2022, doi: 10.1088/1755-1315/1113/1/012005.
[11] EPA, “Using Green Roofs to Reduce Heat Islands | US EPA,” United States Environmental Protect Agency. 2022.
[12] K. Dhir, “EVALUATION OF URBAN HEAT ISLAND EFFECT IN In Partial Fulfillment of the Requirements In the Graduate College,” 2021.
[13] F. Barriuso and B. Urbano, “Green roofs and walls design intended to mitigate climate change in urban areas across all continents,” Sustainability (Switzerland), vol. 13, no. 4, pp. 1–14, 2021, doi: 10.3390/su13042245.
[14] G. Mihalakakou et al., “Green roofs as a nature-based solution for improving urban sustainability: Progress and perspectives,” Renewable and Sustainable Energy Reviews, vol. 180, no. November 2022, p. 113306, 2023, doi: 10.1016/j.rser.2023.113306.
[15] S. Pouya, “EVALUATION OF ROOF GARDENS AS A RECREATION AREAS REKREASYON ALANLARI OLARAK ÇATI BAHÇELERİNİN DEĞERLENDİRMESİ Özet,” 2019.
[16] M. Mesimäki, K. Hauru, and S. Lehvävirta, “Do small green roofs have the possibility to offer recreational and experiential benefits in a dense urban area? A case study in Helsinki, Finland,” Urban For Urban Green, vol. 40, pp. 114–124, Apr. 2019, doi: 10.1016/j.ufug.2018.10.005.
[17] M. Desouki, M. Madkour, A. Abdeen, and B. Elboshy, “Multicriteria decision-making tool for investigating the feasibility of the green roof systems in Egypt,” Sustainable Environment Research, vol. 34, no. 1, Dec. 2024, doi: 10.1186/s42834-024-00207-z.

doi: XXXXXXXXXX

Journal of Engineering Research (ERJ)
Vol. X – No. Y, 2023
©Tanta University, Faculty of Engineering
ISSN: 2356-9441 https://digitalcommons.aaru.edu.jo/cgi e ISSN: 2735-4873

[18] A. M. S. Hassan, A. R. Tantawy, B. Elboshy, and M. Desouki, "Exploring the potential of value engineering to reduce the economical pressure on the construction industry in the case of luxury housing," Mansoura Engineering Journal, vol. 49, no. 4, Jan. 2024, doi: 10.58491/2735-4202.3213.

[19] M. Dabaieh, N. N. Makhlouf, and O. M. Hosny, "Roof top PV retrofitting: A rehabilitation assessment towards nearly zero energy buildings in remote off-grid vernacular settlements in Egypt," Solar Energy, vol. 123, pp. 160–173, Jan. 2016, doi: 10.1016/j.solener.2015.11.005.

[20] V. A. R. Ibrahim, "Roof Planting as a Tool for Sustainable Development in Residential Buildings in Egypt," The Academic Research Community publication, vol. 2, no. 4, pp. 496–511, Dec. 2018, doi: 10.21625/archive.v2i4.425.

[21] Z. Faisal and A. S. Elsaadany, "Green roof awareness, opportunities, and challenges in Egypt," in IOP Conference Series: Earth and Environmental Science, Institute of Physics, 2022. doi: 10.1088/1755-1315/1113/1/012006.

[22] M. Abd El-Hafeez, A. Elmokadem, N. Megahed, and D. El-Gheznawy, "Methodology for the Design and Evaluation of Green Roofs in Egypt," 2016.

[23] N. Elshaboury and W. M. AlMetwaly, "Modeling construction and demolition waste quantities in Tanta City, Egypt: a synergistic approach of remote sensing, geographic information system, and hybrid fuzzy neural networks," Environmental Science and Pollution Research, vol. 30, no. 48, pp. 106533–106548, Oct. 2023, doi: 10.1007/s11356-023-29735-8.

[24] M. Szmigiera, "Cities with the highest population density globally 2021," Statista. 2021.

[25] H. Effat, L. Taha, and K. Mansour, "Change Detection of Land cover and Urban Heat Islands using Multi-Temporal Landsat Images, application in Tanta City, Egypt," Open Journal of Remote Sensing and Positioning, vol. 1, no. 2, pp. 1–15, Dec. 2014, doi: 10.15764/RSP.2014.02001.

[26] E. Emarah, "محافظة الغربية تبيع أشجار الكافور بعد قطعها. والأهالي_ «مذبحة للأشجار» _ بوابة أخبار اليوم الإلكترونية، Akhbar Elyom, Jul. 28, 2021. Accessed: Dec. 31, 2023. [Online]. Available: https://akhbarelyom.com/news/newdetails/3441894/1/%D9%85%D8%AD%D8%A7%D9%81%D8%B8%D8%A9-%D8%A7%D9%84%D8%BA%D8%B1%D8%A8%D9%8A%D8%A9-%D8%AA%D8%A8%D9%8A%D8%B9-%D8%A3%D8%B4%D8%AC%D8%A7%D8%B1-%D8%A7%D9%84%D9%83%D8%A7%D9%81%D9%88%D8%B1-%D8%A8%D8%B9%D8%AF-%D9%82%D8%B7

[27] A. A. Belal and F. S. Moghanm, "Detecting urban growth using remote sensing and GIS techniques in Al Gharbiya governorate, Egypt," Egyptian Journal of Remote Sensing and Space Science, vol. 14, no. 2, pp. 73–79, 2011, doi: 10.1016/j.ejrs.2011.09.001.

[28] A. H. A. Mahmoud and M. A. El-Sayed, "Development of sustainable urban green areas in Egyptian new cities: The case of El-Sadat City," Landsc Urban Plan, vol. 101, no. 2, pp. 157–170, 2011, doi: 10.1016/j.landurbplan.2011.02.008.

[29] W. M. Elbardisy, M. A. Salheen, and M. Fahmy, "Solar irradiance reduction using optimized green infrastructure in arid hot regions: A case study in el-nozha district, cairo, egypt," Sustainability (Switzerland), vol. 13, no. 17, Sep. 2021, doi: 10.3390/su13179617.

[30] CAPMAS, "Estimated population of the departments on 1-1-2023," Jan. 2023. Accessed: Jan. 05, 2024. [Online]. Available: chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/https://www.capmas.gov.eg/Admin/Pages%20Files/202331512347%D8%B9%D8%AF%D8%AF%20%D8%A7%D9%84%D8%B3%D9%83%D8%A7%D9%86%20%D8%B9%D9%84%D9%89%20%D9%85%D8%B3%D8%AA%D9%88%D9%89%20%D8%A7%D9%84%D9%85%D8%B1%D8%A7%D9%83%D8%B2%20%D9%88%D8%A7%D9%84%D8%A7%D9%82%D8%B3%D8%A7%D9%85%20%D9%81%D9%89%201%D9%80%201%D9%80%202023.pdf

[31] SurveyMonkey, "Sample Size Calculator and Tips for Determining Sample Size _ SurveyMonkey." Accessed: Jan. 04, 2024. [Online]. Available: https://www.surveymonkey.com/mp/sample-size-calculator/

[32] M. Desouki, T. A. El-Haddad, and B. El-Boshey, "Revolutionary Artificial Intelligence Architectural design solutions; is it an opportunity or a threat?" Mansoura Engineering Journal, vol. 48, no. 6, Oct. 2023, doi: 10.58491/2735-4202.3091.