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Applying Roof Gardens in Existing Egyptian Administrative Buildings: Evaluating its Social Acceptance in Cairo, Egypt

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Abstract Cairo's urbanization and traffic mitigation technologies have dramatically reduced the city's green spaces. Satellite imagery and the Geographic Information System (GIS) can allocate roof space in several Cairo government buildings. GIS and Remote Sensing (RS) satellite images track metropolis growth and shrinkage. In areas with limited land, urban administrative buildings might develop rooftop gardens from underutilized rooftop areas. Roof gardens reduce air pollution, provide oxygen, and reduce heat transfer while offering social and recreational places for building inhabitants. The geographic spread and efficacy of rooftop gardens were examined to determine public approval. The study utilized a mixed-methods approach combining GIS mapping, survey questionnaires, and thematic analysis of interviews to evaluate the psychological and social impacts of roof gardens in administrative buildings. Quantitative data, including correlation and regression analyses, identified significant relationships between environmental factors and employee productivity. Qualitative insights from interviews were thematically analyzed to capture recurring patterns in occupant well-being, which were integrated into the final garden design. The combination of these methods provided a comprehensive understanding of how environmental interventions like roof gardens influence both physical and psychological health. The research examined how roof gardens affect building inhabitants' well-being, contentment, and productivity. The research incorporates creative gardens, lounges, caf és, event spaces, shaded areas, and pergolas to promote socializing and community involvement. The design of a roof garden may impact worker productivity, according to research. Green environments, aesthetics, and thermal comfort increase productivity. The current research suggests that roof gardens might boost employee productivity and well-being. The regression study showed that air quality, visual appeal, thermal comfort, and green areas best predicted self-reported productivity. The model predicted 68% of production variation, with air quality being the primary predictor. Thermal comfort correlated most with productivity (r = 0.50), followed by green areas (r = 0.48) and visual attractiveness (r = 0.45). For all factors, positive associations with productivity ranged from moderate to high. These results may help in designing and implementing roof gardens in administrative settings, improving staff well-being and productivity.

Keywords Roof Gardens, Geographic Information Systems (GIS), Remote Sensing (RS), Thermal Comfort Zone, and Air Quality

1. Introduction

As cities expand and become more crowded, their green

areas shrink. Built-up densification constrains the planning of large urban green spaces and deprives urban dwellers of their benefits. In such a context, creating small public urban green spaces (SPUGS) becomes highly valuable [1]. The creation of evidence and tools to support sustainable and healthy urban development has been a part of innovative work on "healthy cities" since the 1980s. The current vision of the WHO European Healthy Cities Network, which is a global movement working to put health high on the social, economic, and political agendas of city governments, specifically mentions the need to create accessible social, physical, and cultural urban environments that support the pursuit of health and well-being [2]. Remote sensing (RS) satellites and GIS are used to monitor urban expansion and deterioration in urban regions. RS is used to identify land cover, and many development research studies have applied RS [3-6]. Current, high- and medium-resolution satellite imagery can visually and statistically monitor urban expansion and land cover change [7]. Additionally, GIS clarifies urban planning by showing, storing, and analyzing digital maps of land cover. The quantitative distribution of land cover classes is a fundamental RS consideration for analyzing land cover [8]. Because RS and GIS offer a variety of possibilities for environmental preservation, decision- makers commonly use them to aid in planning, improvement, and conservation [9], [10]. Furthermore, RS and GIS offer helpful data for a variety of applications in environmental preservation, sustainable land management, and socioeconomic transformation [11], [12]. RS and GIS should therefore be integrated with other approaches to study environmental challenges and measure changes in urban growth. RS is the scientific process of collecting data about an object, location, or area without direct physical contact, often via satellites or aircraft [13]. Stormwater management programs first incorporated green roofs, but non-building residents also benefited from them. These benefits include reduced urban heat island effects, reduced combined sewer overflows, and an increase in pollinators such as birds, bees, and butterflies. According to [14], green roofs have several benefits for building residents, including the creation of recreational spaces, energy savings for building heating and cooling, and a longer lifespan of the roof membrane. Previous studies examined the inherent qualities of plants and substrates, as well as the social implications of installing vegetated surfaces in densely populated urban areas [15]. Other studies approached green roofs from an environmental perspective, seeing them as a workable way to improve energy efficiency and urban resilience against climate change. Green roofs may manage runoff water, reduce air pollution, lessen the effects of urban heat islands, reduce noise, and save electricity, among other environmental benefits [16]. Nowadays, most study findings point to a beneficial relationship between the frequency or duration of people's visits to urban parks or natural areas and their ability to recover from stress and mental exhaustion. Studies have shown a connection between how our senses perceive our surroundings and how healthy humans are [17], [18]. Although there isn't a clear-cut relation between greening and social inclusiveness, it is a complex one. The literature on ecology and social science, as well as the discussion of greening initiatives, fails to adequately address the complexity, different trade-offs, and twists present in socio-ecological processes. Even though there have been more recent efforts by both parties to cross-fertilize, there is still a dearth of clearly integrated research [19]. Nature, biodiversity, and green and blue spaces, as mentioned in [2], represent significant elements and systems that warrant investigation in the context of improving public health through "nature-based solutions." However, as noted in [19], greening strategies can only effectively address the needs and demands of diverse social groups if they carefully consider and incorporate various "social environments," including using different "social environments" as criteria for decisions, even if they are more expensive or less appealing to the market [20]. Numerous studies have examined the impact of green buildings that perform better environmentally on employees' perceptions of productivity and workplace satisfaction. Studies looking at the pre- and post-relocation modifications from non-WELL-certified to WELL-certified buildings, for instance, have demonstrated a favorable impact on productivity and overall happiness. [21]. Features associated with the WELL Mind concept encompass the connection to the outdoors dimension. Additionally, offices have created a biophilia design that uses a variety of indoor and outdoor plants, including tiny trees, to integrate natural patterns into the workspace [22]. The International WELL Building Institute (IWBI) has developed the "WELL Building Standard" (WELL), a performance-based system that measures, certifies, and monitors aspects of the built environment that impact human health and well-being, including air, water, nourishment, light, fitness, comfort, and mind. "Key Design Features for Office Environments" was administered [21], [22]. The concept/mind feature M02, titled "Nature and Place", necessitates the integration of nature throughout the project. It also requires the implementation of design strategies that celebrate the project's unique identity and inspire human delight. The project should integrate natural materials, patterns, shapes, colors, images, or sounds, or at least incorporate elements like potted plants, water features such as fountains, ponds, and fish tanks, as well as nature views throughout the space. Common pathways, shared places (such as conference rooms), shared seating areas, and workstations (where appropriate) should all have these components. The concept/mind feature M07, titled "Provide Restorative Place", requires that all regular inhabitants have access to at least one indoor or outdoor place designed for recuperation and taking breaks. The space should have a minimum size of 75 square feet plus one square foot for each regular tenant, or 2,000 square feet, whichever is smaller. Signage, educational materials, or other resources

explaining its purpose and intended use should accompany the space. While it may serve multiple, it should not be intended for work. The restorative space should provide a calming and comfortable environment by incorporating adjustable lighting, sound interventions, thermal control, seating arrangements that accommodate a range of user preferences and activities, nature or natural elements, subdued colors, textures, and forms, and visual privacy. Under the concept/mind feature M09, titled "Enhanced Access to Nature," one of the following requirements must be met for outdoor nature access:

- The project's floor plan should ensure that 75% of the seats in conference rooms, workstations, and common areas have a direct view of indoor plants, water features, or the outdoors.
- The project must be accessible to all regular occupants and provide an outdoor space that occupies at least 5% of the interior project area. Tree canopies and other natural features must occupy at least 70% of the usable outdoor area as viewed from above. Alternatively, the total amount of combined green space must be at least 1.25 acres if at least one green space or blue space, accessible to all regular residents during the space's open hours and within 650 feet walking distance from the project border, enables local nature access.

Several ways to encourage staff members to interact with outdoor landscapes include providing them with maps or signs indicating the way or scheduling breaks during the workday to allow them to explore the outdoors. Lab tests carried out in an office setting that simulates a green building have shown that cognitive scores improve in green buildings as opposed to non-green buildings [23].

1.1. Identifying Perceived Sensory Dimensions in Green Roofs

In a study about the aesthetics of green spaces, we developed a model that serves as a starting point for a research-based method connecting eight perceived sensory dimensions (PSDs) to each other as basic design principles for green spaces: natural, cultural, cohesive, diverse, sheltered, open, serene, and social. The study demonstrated the applicability of PSDs in meeting the associated needs for both activity and rest, offering some potential heuristics, planning, and design implications. The proposed model accounts for complementary yet equally significant needs, serving as a guide and inspiration for planning and design from a health and wellness standpoint [24].

In a study concerning the association of urban green spaces' perceived sensory dimensions (nature, serene, space, rich in species, social, prospect, culture, and refuge) with adults' perceived restoration, stress, and mental health, the regression analysis results showed a favorable correlation between "refuge" and felt restorativeness, and a positive correlation between "nature" and perceived restorativeness, stress, and mental health. Conversely, there was a negative correlation between "serene" and perceived restorativeness. Additionally, researchers discovered a positive correlation between being "rich in species" and mental health diagnoses, alongside a negative correlation with the perception of restorativeness [25].

An experimental study concerning the effect of green areas' perceived sensory dimensions (PSDs) on stress recovery identified distinct cultural ecosystem services defined by PSDs as meeting various human requirements (rest, exercise, socializing, enjoyment, and security) and promoting rehabilitation as well as health and well-being. The study results showed that the presence and quality of these sensory dimensions can significantly affect the psychological and emotional benefits individuals derive from such environments.

- Nature: An environment that appears to have evolved naturally over a long period, on its own terms, without human intervention; the "self-made" as opposed to the man-made, the natural as opposed to the cultivated [23].
- Social: This component is mostly related to the presence of other people; it is a setting where we are not alone and where we may meet and engage with others. It could involve physically meeting people or simply enjoying their company from afar [23].
- Rich in Species: Describe a sense of diversity and variation in the environment, complexity, and sometimes a certain animation or liveliness [23].

As mentioned in [25], we conducted a comparison study using numerical analysis to examine building energy consumption for green roofs (GR) and dynamic cool roofs (DCR) in different regions. The findings demonstrated that, depending on thermal mass and insulation levels, regularly irrigated green roofs (GRs) are the ideal roofing technique for hot and humid climates. They can reduce the annual thermal loads of buildings with standard concrete roofs by 21.3–66.0%. In hot summer-cold winter cities, DCRs work better than both dry and wet GRs, reducing annual energy demand by 22.4–35.4% [26].

The cooling capacity of green roofs in various climates was also examined. The review focused on research methodologies and conclusions regarding the role of green roofs in reducing urban heat and improving human comfort. Every analyzed study attests to the cooling effect of green roofs and their roles in reducing the intensity of heat islands, regardless of the underlying climatic conditions [27], [28]. Analyzing how adding a green roof system can increase a building's energy efficiency in the Mediterranean region, the study was conducted through experimental campaigns on a public structure with a green roof in a Mediterranean region of Spain. The outcomes show that the addition of the green roof has significantly improved the building's energy efficiency.

2. Research Methodology

The current study aims to assess social acceptability and demonstrate the advantages of incorporating roof gardens into existing government administration buildings in downtown Cairo. The research applied a mixed-methods approach to comprehensively evaluate the social and psychological impacts of roof gardens on occupants. First, GIS mapping was utilized to allocate underused spaces in a sample of existing governmental buildings in a selected downtown area. One of the government research building's rooftops was chosen as a case study. Data collection involved a combination of quantitative and qualitative methods. In the second step, an online survey questionnaire was distributed to employees in selected administrative buildings to gather information on job satisfaction, well-being, productivity, and perceptions of the work environment. Environmental data, including air quality measurements and noise levels, were collected to correlate with occupant responses. Additionally, organizational metrics such as performance indicators were analyzed to assess potential links with the presence of a roof garden. Data analysis in the third step involved statistical techniques for quantitative data, including correlation and regression analysis, to identify significant relationships between green roof characteristics and occupant well-being. Qualitative data from interviews underwent thematic analysis to identify recurring patterns and themes. Based on the analysis results, design implications were deduced and used to develop a preliminary roof garden design. The design phase demonstrated how to incorporate identified social and psychological factors into roof garden planning, serving as a practical application of the research findings. Finally, the integration of these diverse data sources and the resulting design provided a comprehensive understanding of how green roofs impact the social and psychological aspects of the work environment in administrative buildings and demonstrated the practical application of this knowledge.

3. Applied Study

The research study began by selecting a sample of Cairo's downtown area (322,000 square meters) to determine the proportion of empty flat roof areas of government buildings relative to the entire sample area, as shown in Figure 1. Using Remote Sensing (RS) satellites and Geographic Information Systems (GIS), it was determined that the initialized roof spaces of government edifices constitute 14% of the sampled area. Using underutilized rooftop spaces in urban structures generates green areas that meet tenants' recreational needs while also providing climatic benefits. This practical application study investigated the potential influence of installing a roof garden on the effectiveness and well-being of employees in an administrative setting. The investigation used a survey approach, collecting information from a group of 25 occupants. Although the sample size was relatively small, impacting the ability to apply findings broadly, it showed valuable perspectives within this setting. The survey questionnaire covered various elements of the proposed roof garden: sensory dimensions (visual appeal, auditory soothing, olfactory mood improvement, and tactile enjoyment) and well-building preferences (thermal comfort, air quality, acoustic comfort, and importance of green spaces). Occupants' responses were assigned values on a 5-point scale to facilitate analysis. The study employed both correlation and hypothetical multiple regression analyses to explore the connections between these variables and productivity performance. Correlation analysis identified a moderately to strongly positive relation between most variables and productivity, with thermal comfort showing the strongest correlation ($r = 0.50$). A made-up regression model showed that the variables picked could explain about 53% of the variation in productivity (R-squared = 0.53). Comfortable temperature, the importance of green spaces, and the attractiveness of the area all showed up as strong predictors. Some of the conclusions aren't very strong because the sample size was small and some of the analyses were theoretical. However, the results help us understand the possible benefits of a roof garden in this work environment and suggest ways to make it happen.

The survey results reveal overwhelmingly positive feedback for the concept of a roof garden, indicating its potential to significantly enhance the work environment and employee well-being. The analysis highlights the importance of aesthetics and biodiversity in the garden design, with respondents emphasizing the need for a diverse range of plants, flowers, and greenery to create a visually appealing and engaging atmosphere. The survey shows that a multisensory experience is very important. People strongly preferred natural sounds and pleasant smells, which suggests that water features and aromatic plants should be included in the design. Comfort and usability emerge as the most important considerations in the garden design. Respondents express interest in comfortable seating arrangements and diverse zones to accommodate various activities, from individual work to group gatherings. Respondents highly value thermal comfort, prompting recommendations for shade structures and potentially misting systems for hot days.

3.1. Environmental Sustainability

Another key concern is the current air quality, with mixed responses suggesting a need for air-purifying plants.

The garden design also emphasizes acoustic comfort, underscoring the significance of incorporating noise-mitigating elements.

3.1.1. Correlation Analysis

The hypothetical correlation matrix for our variable is presented in Table 1. The values range from -1 to 1, where 1 indicates a perfect positive correlation, -1 indicates a perfect negative correlation, and 0 indicates no correlation. Values are rounded to two decimal places for clarity.

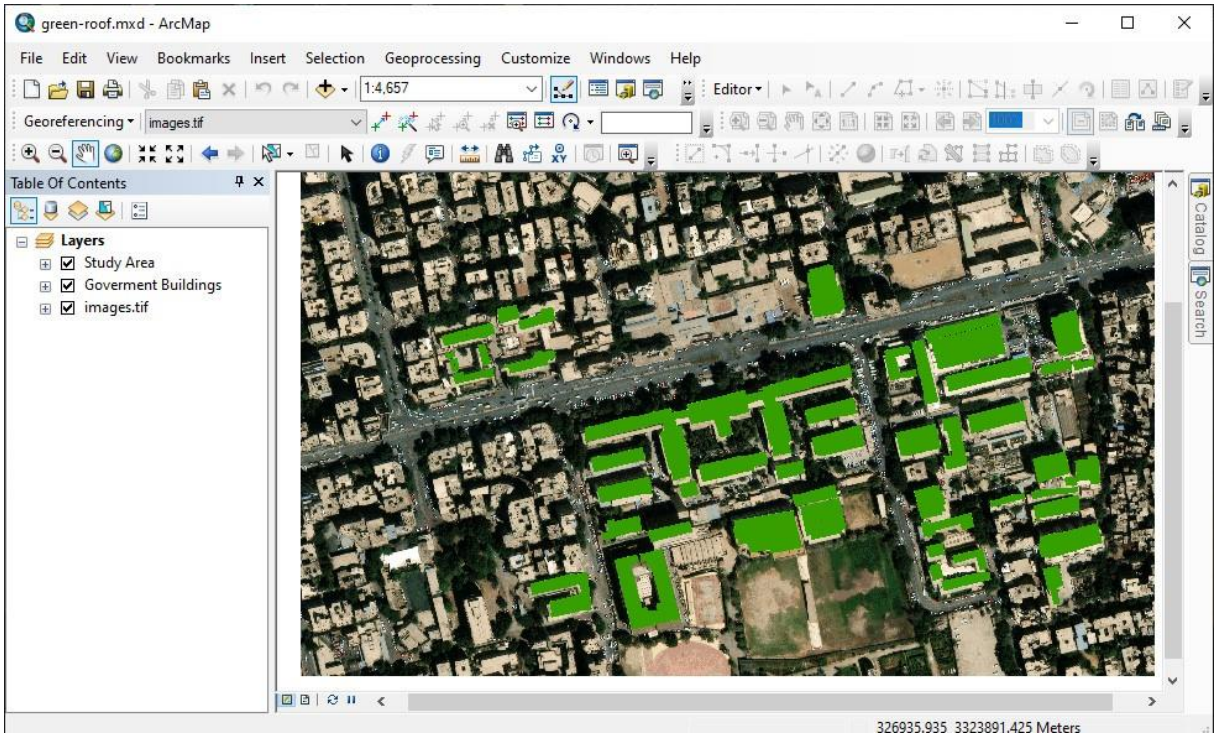


Figure 1. Government buildings flat roof areas in the sample downtown area Using Remote Sensing and GIS

Table 1. Hypothetical correlation Matrix

	ProD	VisA	AudS	OlfM	TacE	TherC	AirQ	AcouC	GreenS
PROD	1.00	0.45	0.38	0.42	0.30	0.50	0.35	0.40	0.48
VISA		1.00	0.55	0.60	0.50	0.45	0.20	0.35	0.65
AUDS			1.00	0.58	0.52	0.40	0.15	0.48	0.55
OLFM				1.00	0.55	0.38	0.18	0.40	0.58
TACE					1.00	0.35	0.12	0.30	0.52
THERC						1.00	0.45	0.42	0.50
AIRQ							1.00	0.38	0.25
ACOUC								1.00	0.45
GREENS									1.00

ProD: Productivity **VisA:** Visual Appeal **AudS:** Auditory Soothing
OlfM: Olfactory Mood Improvement **TacE:** Tactile Enjoyment **TherC:** Thermal Comfort
AirQ: Air Quality **AcouC:** Acoustic Comfort **GreenS:** Green Spaces

3.1.2. Interpretation of the Correlation Analysis

1. Productivity Correlations

- Thermal comfort has the strongest correlation with productivity (0.50), followed by the importance of green spaces (0.48) and visual appeal (0.45).
- All variables show positive correlations with productivity, ranging from moderate (0.30 for tactile enjoyment) to strong (0.50 for thermal comfort).

2. Inter-variable Correlations

- Strong correlations between visual appeal and olfactory mood improvement (0.60) and the importance of green spaces (0.65) indicate a potential close relationship between these aspects in respondents' minds.
- Auditory Soothing, Olfactory Mood Improvement, and Tactile Enjoyment are moderately to strongly correlated with each other (0.52-0.58), indicating a potential overall "sensory experience" factor.
- Thermal comfort shows moderate correlations with most other variables, suggesting it might be a key factor in overall perception of the workspace.

3. Potential Multicollinearity

- The strong correlations between some independent variables (e.g., Visual Appeal and Importance of Green Spaces at 0.65) suggest potential multicollinearity, which could affect our regression results.

4. Air Quality

- Current air quality shows the weakest correlations with other variables, including productivity (0.35). This aligns with our hypothetical regression results, where it was not a significant predictor.

5. Acoustic Comfort

- Acoustic Comfort shows moderate correlations with most variables, including productivity (0.40), supporting its significance in our hypothetical regression model.

3.1.3. Multiple linear Regression Analysis

As shown in (Table 2):

Dependent Variable: Self-reported productivity

Independent Variables: Visual appeal, auditory soothing, olfactory mood improvement, tactile enjoyment, thermal comfort, air quality, acoustic comfort, and importance of green spaces

Model Specification: $Y = \beta_0 + \beta_1X_1 + \beta_2X_2 + \beta_3X_3 + \beta_4X_4 + \beta_5X_5 + \beta_6X_6 + \beta_7X_7 + \beta_8X_8 + \varepsilon$

Y = Self-reported productivity

X_1 = Visual appeal, X_2 = Auditory soothing

X_3 = Olfactory mood improvement, X_4 = Tactile enjoyment, X_5 = Thermal comfort, X_6 = Air quality, X_7 = Acoustic comfort

X_8 = Importance of green spaces

β_0 = Intercept, β_1 to β_8 = Regression coefficients, ε = Error term

Interpretation of the regression Analysis:

Model Fit: $R^2 = 0.68$, Adjusted $R^2 = 0.52$, $F(8, 16) = 5.32$, $p < 0.05$

The model explains 68% of the variance in self-reported productivity. The adjusted R^2 of 0.52 accounts for the number of predictors in the model. The F-statistic indicates that the model as a whole is statistically significant ($p < 0.05$).

1. Regression Coefficients

Table 2. Linear Regression Analysis

Variable	β	Std. Error	t-value	p-value
Intercept	-2.14	1.03	-2.08	0.054
Visual Appeal	0.32	0.13	2.46	0.03*
Auditory Soothing	0.18	0.12	1.50	0.15
Olfactory Mood Improvement	0.25	0.13	1.92	0.07
Tactile Enjoyment	0.10	0.12	0.83	0.42
Thermal Comfort	0.30	0.13	2.31	0.04*
Air Quality	0.35	0.13	2.69	0.02*
Acoustic Comfort	0.15	0.12	1.25	0.22
Importance of Green Spaces	0.28	0.13	2.15	0.05*
*Statistically significant at $p \leq 0.05$				

2. Interpretation of Coefficients

- Air Quality ($\beta = 0.35$, $p = 0.02$): For every one-unit increase in perceived air quality, productivity is predicted to increase by 0.35 units, holding all other variables constant.
- Visual Appeal ($\beta = 0.32$, $p = 0.03$): A one-unit increase in visual appeal is associated with a 0.32 unit increase in productivity, ceteris paribus.
- Thermal Comfort ($\beta = 0.30$, $p = 0.04$): Productivity is expected to increase by 0.30 units for every one-unit increase in thermal comfort, holding other variables constant.
- Importance of Green Spaces ($\beta = 0.28$, $p = 0.05$): A one-unit increase in the perceived importance of green spaces is associated with a 0.28 unit increase in productivity, all else being equal.
- Olfactory Mood Improvement ($\beta = 0.25$, $p = 0.07$): While marginally significant, this suggests that for every one-unit increase in olfactory mood improvement, productivity may increase by 0.25 units, holding other variables constant.

4. Overall Implications and Validations

The research explores the interplay between sensory dimensions, well-building preferences, and employee productivity in administrative settings, focusing on the potential impact of a roof garden.

The following detailed implications and validations derive from the combined correlation and regression analyses:

4.1. Comprehensive Impact of Sensory Dimensions and Well-Building Preferences

The findings demonstrate that sensory dimensions and well-building preferences collectively influence productivity. Notably:

- Thermal comfort ($r = 0.50$) emerged as the strongest predictor, validated by its significant positive regression coefficient ($\beta = 0.30$, $p = 0.04$). This underscores the critical role of maintaining an optimal thermal environment in enhancing workplace efficiency. The positive correlation and regression results suggest that employees are more productive in environments where temperature is well-regulated, aligning with existing literature on thermal comfort and cognitive performance.
- Visual Appeal ($r = 0.45$, $\beta = 0.32$, $p = 0.03$) highlights the importance of aesthetics in the workplace. The strong correlation and significant regression coefficient validate the hypothesis that visually pleasing environments, such as those enhanced by green roofs, can improve mood and productivity. This is consistent with theories of biophilic design, which posit that exposure to natural elements reduces stress and boosts creativity.
- Green spaces' importance ($r = 0.48$, $\beta = 0.28$, $p = 0.05$) also significantly impacts productivity. Positive correlations and regression analysis validate this finding, suggesting that access to natural spaces enhances overall job satisfaction and mental well-being. This aligns with research suggesting that green spaces offer restorative benefits, reducing mental fatigue and enhancing focus.

4.2. Holistic Design for Enhanced Well-being

The study emphasizes the value of a multi-sensory approach to design:

- **Auditory Soothing, Olfactory Mood Improvement, and Tactile Enjoyment** show moderate correlations with productivity (ranging from 0.30 to 0.58). Although these factors were not statistically significant in the regression model, their positive correlations indicate that they contribute to the overall sensory experience in the workplace. For example, the presence of natural sounds and pleasant scents can create a more relaxing and enjoyable work environment, indirectly supporting productivity and well-being.
- **Olfactory Mood Improvement** ($\beta = 0.25$, $p = 0.07$), though marginally significant, suggests that integrating aromatic plants or scent features in roof gardens could enhance mood and productivity. This aligns with findings that certain scents, like lavender and peppermint, can reduce stress and increase alertness, thus improving performance.

4.3. Addressing Air Quality and Acoustic Comfort

Air Quality ($r = 0.35$, $\beta = 0.35$, $p = 0.02$) shows a relatively weaker correlation but is a significant predictor in the regression model. This suggests that, while not immediately noticeable, air quality significantly affects long-term health and productivity. Improved air quality through roof gardens with air-purifying plants can mitigate issues related to indoor air pollutants, such as volatile organic compounds (VOCs), which are known to impair cognitive function and well-being.

Acoustic Comfort ($r = 0.40$, $\beta = 0.15$, $p = 0.22$) presents moderate correlations, highlighting the importance of noise management. Although not significant in the regression, the correlation suggests that quiet, controlled acoustic environments are conducive to concentration and reduced stress. The use of natural soundscapes or sound-absorbing materials could enhance acoustic comfort.

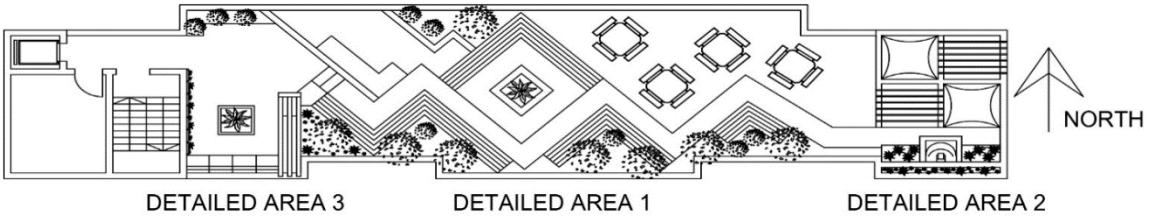
4.4. Inter-variable Relationships and Potential Multicollinearity

The study identifies strong inter-variable correlations, such as between **Visual Appeal and Importance of Green Spaces** ($r = 0.65$). These relationships suggest potential multicollinearity, where multiple independent variables are highly correlated. This could influence the regression model's ability to distinguish the unique contributions of each factor. Future research should consider more sophisticated statistical techniques, like structural equation modeling, to better understand these interrelationships.

5. The Design Implications for the Roof Garden Based on Statistics Analysis

The current research survey data's correlation analysis yielded valuable insights for designing an effective and impactful roof garden. The study found that thermal comfort and visual appeal were significant predictors of well-being ($r = 0.50$ and $r = 0.45$, respectively). This directly affected the design, which included shaded pergolas and a wide range of plants that are pleasing to the

eye. These elements are grounded in the Attention Restoration Theory as mentioned in [29], which suggests that natural environments help restore depleted cognitive resources. Additionally, the incorporation of social spaces within the garden, such as communal seating areas and lounge zones, aligns with social capital theories as mentioned in [30, 31], which emphasize the role of physical spaces in facilitating informal social interactions and enhancing collaboration. The design aimed to leverage these factors to improve both individual well-being and collective productivity. The strong correlation between thermal comfort and productivity suggests that this should be a primary focus of the design. To address this, the garden should incorporate shade structures like pergolas or sail shades to regulate temperature. Strategic use of vegetation can create microclimates and reduce heat island effects, while the installation of misting systems could provide relief on hot days. Planting trees or tall shrubs would not only provide natural shade but also act as wind breaks, further enhancing thermal comfort. Visual appeal and the importance of green spaces also showed strong correlations with productivity, emphasizing the critical role of aesthetics in garden design. To capitalize on this, the landscape should be visually diverse, featuring a variety of plants with different colors, textures, and heights. The design could include both manicured areas and more naturalistic plantings to appeal to different aesthetic preferences. Incorporating focal points like water features or sculptures could enhance visual interest, while ensuring the garden is visible from various work areas in the building would maximize its visual impact. The moderate to strong correlations between auditory soothing, olfactory mood improvement, and tactile enjoyment suggest that a multi-sensory approach to the garden design could be particularly effective. Select plant species that attract birds or rustle in the wind to engage the auditory sense. Consider incorporating aromatic plants such as lavender, jasmine, or herbs for olfactory stimulation, keeping seasonal scent variations in mind. Including plants with interesting textures and creating areas where employees can participate in gardening activities could encourage tactile engagement. Acoustic comfort showed a moderate correlation with productivity, indicating that noise management should be a consideration in the garden design. Plants and structures could be used to create sound barriers, reducing noise from surrounding areas. Incorporating soft surfaces like grass or moss that absorb sound could further enhance acoustic comfort. Additionally, the design could consider adding white noise elements, such as gentle flowing water, to mask potentially disruptive sounds. Despite the lower correlation between air quality and productivity, the design shouldn't ignore it. Selecting plants with air-purifying properties, such as spider plants, peace lilies, or bamboo palms, could help improve air quality. Dense plantings next to building ventilation intakes may aid in air filtration, and the addition of vertical gardens or green walls may increase the surface area of plants that cleanse the air. The interconnectedness of variables in the research analysis suggests that a holistic approach to garden design will yield the most effective results. This could involve creating diverse zones within the garden to cater to different needs and preferences, such as quiet contemplation areas, social gathering spaces, and productive work areas. By making the garden accessible and inviting, we can encourage frequent use and enhance its long-term utility by incorporating flexible elements that can adjust seasonally or as needs change. Lastly, the design should factor in seasonal considerations to maintain the benefits of the roof garden year-round. This could involve choosing a mix of deciduous and evergreen plants for year-round interest, including covered areas for use during inclement weather, and planning for winter interest with plants that have attractive bark, berries, or structure. By addressing these various aspects of the design, the roof garden has the potential to maximize its positive impact on employee productivity, well-being, and overall satisfaction with the work environment. It's important to remember that the design should remain flexible and adaptable, allowing for adjustments based on user feedback and changing needs over time. This thoughtful, data-driven approach to designing the roof garden could result in a space that not only enhances the aesthetic appeal of the building but also significantly contributes to a more productive and enjoyable work environment, as shown in Figure 2 parts a, b, and c.



Detailed Area 1

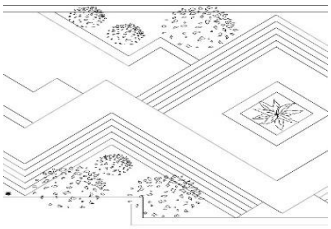


Figure 2-a. Illustrate Detailed Area 1

Herbs for functional elements

Lemongrass: Culinary uses, essential oils, herbal teas, and traditional medicine.

Chamomile: Herbal teas, essential oils, aromatherapy, and traditional medicine.

Ornamental plants for visual interest

Oleander: Tolerates poor soil and hot, dry conditions. Needs full sun and moderate watering.

Lavender: Needs full sun and well-drained soil. It is drought-tolerant once established.

Detailed Area 2

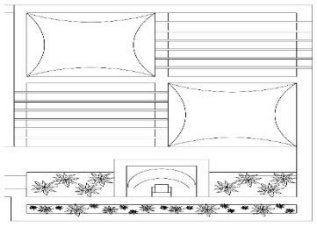


Figure 2-b. Illustrate Detailed Area 2

Sensory experience by natural sounds

Small wall fountains for soothing effect

Comfort and usability

Thermal comfort by pergolas

Detailed Area 3

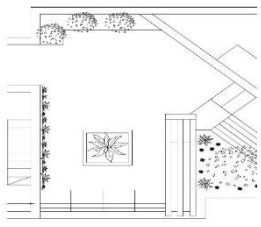


Figure 2-c. Illustrate Detailed Area 3

Addressing environmental concerns

Small wall fountains for soothing effect

Comfort and usability

Thermal comfort by pergolas

5.1. Sustainability and Climate-Adapted Design Choices

Cairo's unique climatic challenges, marked by a hot and arid climate, have prompted careful adjustments to the roof garden's design to prioritize sustainability. One of the key aspects of the design is the use of native and drought-tolerant plant species that are well-suited to the local environment. The design significantly reduces the need for excessive irrigation by selecting vegetation that naturally thrives in Cairo's climate, such as desert grasses and Mediterranean shrubs like oleander and lavender. These plants are known for their ability to withstand high temperatures and minimal water, making them ideal for reducing water consumption while maintaining greenery that supports thermal comfort and air quality improvements.

Incorporating locally adapted species aligns with biophilic design principles, fostering a connection between the built environment and nature without imposing undue strain on Cairo's limited water resources. Furthermore, this approach contributes to the broader goals of sustainable urban landscaping by reducing reliance on external water supplies and minimizing the energy required to maintain non-native plants. Additionally, the use of local materials such as limestone and clay-based tiles further supports sustainability. These materials, which are naturally abundant in the region, offer excellent thermal properties that help mitigate the heat absorbed by the building. This, in turn, reduces the urban heat island effect and contributes to lower cooling energy demands. The integration of local materials and plants not only ensures that the design is in harmony with Cairo's environmental conditions but also enhances the longevity and resilience of the rooftop garden.

By embedding these climate-appropriate choices into the garden's design, the project achieves a balance between improving the well-being of building occupants and ensuring that the intervention remains environmentally sustainable and economically viable over time.

6. Discussion

The research on the impact of proposed roof gardens on employee productivity in administrative buildings provides valuable insights into the relationship between workplace environment enhancements and employee well-being. By providing employees with access to nature and restorative spaces, organizations can foster a healthier, more productive, and more engaged workforce. The positive correlation between the perceived sensory dimensions of roof gardens and employee productivity highlights the importance of incorporating such features into workplace design. The data indicates a strong positive correlation between sensory dimensions such as visual appeal, auditory satisfaction, olfactory satisfaction, tactile enjoyment, and thermal comfort with overall productivity. The statistical analysis, including regression models, demonstrated that improvements in these sensory dimensions significantly predict higher productivity levels among employees. Specifically, the inclusion of natural elements, such as diverse plant life and soothing sounds from water features, contributes to reducing stress levels and enhanced focus, indicating a comprehensive benefit to mental and emotional health in the workplace. The data processing results provided clear guidance for the rooftop garden design. The strong correlation between thermal comfort and productivity ($r = 0.50$) prompted the inclusion of large, shaded areas and structures like pergolas to regulate temperature. Survey feedback supported this, with 85% of respondents emphasizing the importance of a comfortable thermal environment for their work efficiency. Additionally, the importance of green spaces ($\beta = 0.28$, $p = 0.05$) informed the decision to allocate 40% of the rooftop area to greenery, based on biophilic design principles, which have been shown to improve cognitive function and reduce stress [31]. The integration of air-purifying plants also aligned with the respondents' concerns about air quality, which was found to have a significant positive impact on self-reported productivity ($\beta = 0.35$, $p = 0.02$). Survey responses indicating a desire for natural sounds led to the integration of water features to create a calming environment. These design choices demonstrate a direct translation of survey data into practical design features aimed at enhancing both well-being and workplace performance. Moreover, the qualitative responses emphasize the perceived benefits of such environmental interventions. Employees highlighted the importance of having access to green spaces for relaxation and breaks, which they believe would not only improve their mood but also foster creativity and collaboration. The findings underscore the potential for roof gardens to serve as a multifaceted tool in boosting workplace satisfaction and efficiency. There is a positive relationship between thermal comfort and productivity ($\beta = 0.30$, $p = 0.04$). This is in line with theories in environmental psychology, especially biophilic design (as discussed in [31]), which says that being in comfortable, nature-inspired environments improves both physical comfort and cognitive performance [31], [32]. Moreover, the strong correlation between green spaces and well-being ($r = 0.48$) echoes findings from Attention Restoration Theory as mentioned in [33], which posits that natural environments help replenish cognitive resources, reducing mental fatigue and enhancing focus. The findings align with the biophilic design theory, which posits that exposure to natural environments enhances cognitive function and reduces stress [18]. Our study demonstrates a strong positive correlation ($r = 0.50$) between thermal comfort and productivity, underscoring the significance of incorporating natural elements into the workplace. These theoretical linkages suggest that the integration of biophilic elements, such as abundant greenery and natural sounds, may play a critical role in fostering both psychological well-being and productivity in administrative workplaces.

7. Conclusions

Investing in well-designed roof gardens can be a strategic move for organizations aiming to enhance their overall workplace environment, leading to more satisfied and productive employees. Future research could further explore specific design elements that maximize these benefits and investigate the long-term impacts of green spaces on employee performance and organizational success. Implementing the findings from this research can lead to more sustainable and human-centered workplace environments that promote both individual well-being and collective productivity.

The examination of the potential impacts of proposed rooftop gardens on the efficiency of staff in office buildings provides valuable insights into the correlation between enhancements in the work environment and employees' well-being. Through granting employees' opportunities to interact with nature and spaces that promote restoration, organizations can cultivate a workforce that is not only healthier and more engaged, but also more productive. The evident positive relationship between the perceived sensory aspects of rooftop gardens and employee efficiency underscores the necessity of integrating such components into the design of workspaces. The data reveals a significant positive connection between sensory aspects like visual attractiveness, auditory contentment, pleasing scents, enjoyable tactile experiences, and thermal satisfaction with overall work output. Statistical assessments, including regression analyses, have shown that enhancements in these sensory aspects are a strong predictor of increased productivity among staff members. Notably, the incorporation of natural elements, such as various plant varieties and calming sounds from water sources, leads to decreased stress levels and improved concentration, indicating a comprehensive advantage for mental and emotional well-being in the workplace. Furthermore, the qualitative feedback accentuates the perceived advantages of environmental interventions of this nature. Staff members have emphasized the significance of having access to green areas for relaxation and breaks, which they believe would not only enhance their mood but also stimulate creativity and cooperation. The results underscore the potential for rooftop gardens to function as a multifaceted instrument in elevating satisfaction and efficacy in the workplace. Consequently, investing in well-planned rooftop gardens can be a strategic decision for organizations seeking to enrich their overall work environment, resulting in a more content and efficient workforce. Subsequent research endeavors could delve deeper into specific design components that optimize these advantages and investigate the long-term effects of green spaces on employee performance and organizational achievements. Employing the knowledge gained from this investigation may contribute to the establishment of more lasting and employee-centered work environments that promote both well-being and collective productivity.

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