Research 3

Enhancing Environmental Sustainability in University Buildings: The Role of Green Walls and Smart Agriculture in Mitigating Carbon Dioxide Emissions Across Varied Egyptian Climates

Journal of
Survey in Fisheries Sciences

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Enhancing Natural Ventilation in Low-Rise Residential Buildings in Egypt through Solar Chimney Application

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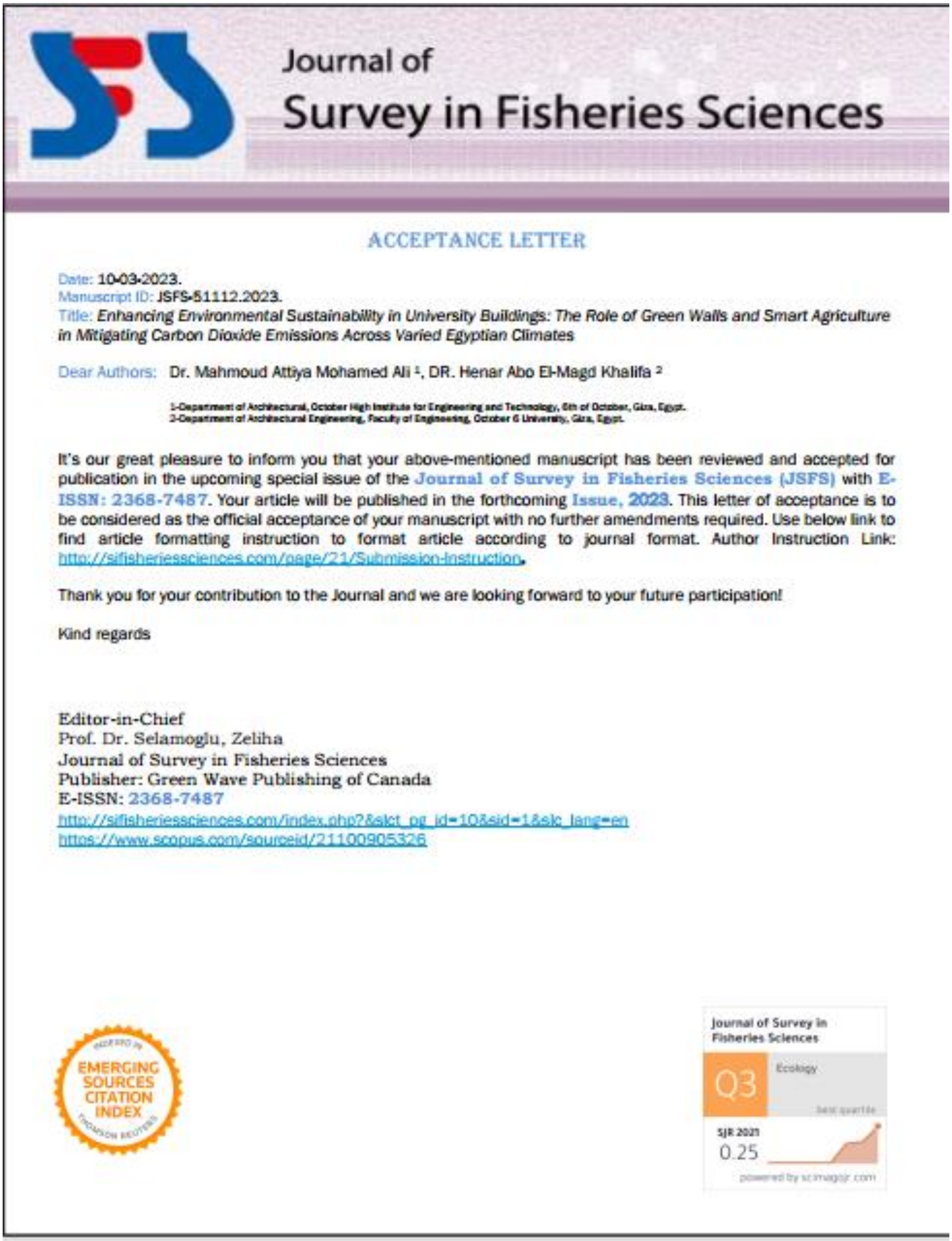
Dual Research



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ACCEPTANCE LETTER

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Title: *Enhancing Environmental Sustainability in University Buildings: The Role of Green Walls and Smart Agriculture in Mitigating Carbon Dioxide Emissions Across Varied Egyptian Climates*

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It's our great pleasure to inform you that your above-mentioned manuscript has been reviewed and accepted for publication in the upcoming special issue of the **Journal of Survey in Fisheries Sciences (JSFS)** with **E-ISSN: 2368-7487**. Your article will be published in the forthcoming **Issue, 2023**. This letter of acceptance is to be considered as the official acceptance of your manuscript with no further amendments required. Use below link to find article formatting instruction to format article according to journal format. Author Instruction Link: http://sifisheriessciences.com/page/21/Submission-Instruction.

Thank you for your contribution to the Journal and we are looking forward to your future participation!

Kind regards

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Journal of Survey in Fisheries Sciences (SFS) ISSN: 2368-7487, is published three times annually in February, June, and October. This is a scientific journal reporting on research in aquatic disciplines related to fisheries.

Research papers on fisheries /aquaculture and fishery-related subjects will be considered for publication. All material submitted must be original and unpublished. Three categories of papers are considered for publication: “Original research,”, “Short communications,” and “Reviews.”

Topics of interest to the journal include new information on various animal and plant species related to fisheries and aquaculture. Specific areas of interest include aquatic ecosystems, methods of propagation and culture of high value aquatic resources, pollution and its effect on the environment and aquatic species, nutrition, health and diseases of aquatic species, research on fish processing and production of new products, protection [illegible]covering stocks and sustainable exploitation of [illegible] resources, and finally the economic and social aspects of fisheries.

Journal of Survey in Fisheries Sciences

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Abstract

Green walls represent a vital intervention for addressing sustainability in university buildings located in hot climates. They serve as a shield against intense sunlight, facilitate oxygen production through photosynthesis, and ultimately curtail CO_2 emissions. These emissions reduction efforts play a pivotal role in combating the adverse effects of the greenhouse effect and the resultant climate change. This research confronts the challenge of escalating CO_2 emissions within university classroom spaces, primarily stemming from the inefficiency of building envelopes. Its core objective is the reduction of CO_2 emissions through the integration of green walls within university classroom spaces. This goal is realized through an applied study employing simulation software, Design Builder v7.0, within the classrooms of the October High Institute for Engineering and Technology. The outcomes underscore the potential of green walls to achieve a 12.1% reduction in CO_2 emissions compared to baseline scenarios.

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Section

Articles

Author Biographies

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Keywords: Environmental Sustainability, Green Walls, Smart Agriculture, Carbon Dioxide Emissions, University Buildings.

ملخص البحث

تعد الحوائط الخضراء من أهم المعالجات التي يجب أن يتم اختيارها لمعالجة المباني الجامعية في المناخ الحار لأنها تعمل على حماية المبني من أشعة الشمس وتساعد في إنتاج الأكسجين الناتج من عملية البناء الضوئي التي تتم للنباتات وبالتالي تخفض من معدل انبعاثات ثاني أكسيد الكربون والتي بدورها تساهم في تقليل الاثار السلبية لظاهرة الاحتباس الحرارى والتي هي المسبب الرئيسي في التغيرات المناخية ، ويتناول البحث مشكلة زيادة معدل انبعاثات غاز co_2 للقاعات الدراسية في المباني الجامعية نظرا لعدم كفاءة الغلاف الخارجي، وكان الهدف الرئيسي من البحث تخفيض معدل انبعاثات غاز ثاني أكسيد الكربون باستخدام الحوائط الخضراء للقاعات الدراسية في المباني الجامعية محل الدراسة ، وذلك عن طريق دراسة تطبيقية باستخدام برنامج المحاكاة Design Builder v 7.0 للقاعات الدراسية وهى دراسة حالة معهد أكتوبر العالي للهندسة والتكنولوجيا، وتشير النتائج الى أن استخدام الحوائط الخضراء للقاعات الدراسية في المباني الجامعية يعمل على خفض معدل انبعاثات غاز co_2 بنسبة تزيد عن 20 % عن حالة الأساس.

الكلمات الدالة:
الحوائط الخضراء- الزراعة الذكية - انبعاثات co_2 -المباني الجامعية.

Enhancing Environmental Sustainability in University Buildings: The Role of Green Walls and Smart Agriculture in Mitigating Carbon Dioxide Emissions Across Varied Egyptian Climates

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Abstract:

Green walls represent a vital intervention for addressing sustainability in university buildings located in hot climates. They serve as a shield against intense sunlight, facilitate oxygen production through photosynthesis, and ultimately curtail CO_2 emissions. These emissions reduction efforts play a pivotal role in combating the adverse effects of the greenhouse effect and the resultant climate change. This research confronts the challenge of escalating CO_2 emissions within university classroom spaces, primarily stemming from the inefficiency of building envelopes. Its core objective is the reduction of CO_2 emissions through the integration of green walls within university classroom spaces. This goal is realized through an applied study employing simulation software, Design Builder v7.0, within the classrooms of the October High Institute for Engineering and Technology. The outcomes underscore the potential of green walls to achieve a 12.1% reduction in CO_2 emissions compared to baseline scenarios.

Keywords: Environmental Sustainability, Green Walls, Smart Agriculture, Carbon Dioxide Emissions, University Buildings.

Research Problem:

The crux of this study revolves around the surge in CO_2 emissions within university classroom spaces, an issue predominantly stemming from the absence of green walls on the classroom facades.

Research Objectives and Practical Study:

This research embarks on a comprehensive exploration with the primary goal of assessing the efficacy of green walls and smart agriculture as viable interventions to curtail CO2 emissions within university classroom environments. To facilitate this investigation, the simulation software Design Builder v7.0 serves as a pivotal tool.

Research Questions:

What strategies can effectively mitigate CO2 emissions within university classroom spaces situated in hot climates through the integration of green walls and smart agriculture?

Research Hypothesis:

It is hypothesized that the incorporation of green walls and smart agriculture will yield a significant reduction in CO2 emissions within university classroom settings.

Methodology:

To achieve the research objectives, a theoretical approach is followed, which includes reviewing previous studies and their impact on the current study, studying the adopted concepts, and an analytical approach to deduce the optimal model for classrooms in university buildings. An applied methodology is also used, employing simulation through the Design Builder v7.0 software to study the environmental aspects and prevailing patterns. This involves using green walls and smart agriculture in the external envelope, simulating each case separately, presenting and comparing the results, and ultimately achieving the research objectives, as well as the objectives and findings of previous studies.

1 Introduction:

In light of the global challenges resulting from the failure to adequately address the negative impacts of climate change, the consequences of which are now evident to everyone, (1) major industrialized countries have neglected to address the causes of climate change or take action to rectify them over the past century or the present. The calls from environmental organizations around the world, which have warned of the destructive effects and issued pleas for action to mitigate the impacts of climate change in all aspects of life, have gone unanswered. (2) One of the areas in which decisions must be made is the field of building design, with architects leading the way in rehabilitating these buildings. The building sector must contribute to solving the problem of global warming by reducing carbon dioxide emissions through the use of smart agriculture in green walls. (3) With the increasing awareness of climate data and the emergence of sustainable construction ideas(36), which have led to the development of green design standards(4), meeting the requirements for quality indoor environments in architectural spaces, free from environmental pollutants, is crucial. Therefore, this article will discuss how to reduce the carbon dioxide emissions rate in university classroom buildings by using green walls(37).

2 Green Cover:

Carefully chosen and designed green elements play a vital role in creating a pleasant climate as a fundamental component of urban space design.(5),(6) The realistic visualization of plants and trees through computer technology has attracted significant interest from users and researchers. Green construction has become a critical element in addressing the climate crisis, in addition to its importance in protecting human health, natural resources, (7),(8) and its economic benefits (Figure 1). Reducing carbon emissions from the construction sector is crucial to achieving the goal of the Paris Agreement, which aims to limit global warming to less than two degrees Celsius. In 2020, the construction and operation of buildings accounted for 37% of global energy-related carbon dioxide emissions, (9) according to a recent report by the United Nations Environment Program. Green construction represents a golden opportunity to reduce carbon emissions. (10)

Figure (1) The vertical garden at the Sheikh Ibrahim bin Mohammed Al Khalifa Center

3 Smart Agriculture:

Smart agriculture, also known as digital agriculture, is a manifestation of the Fourth Industrial Revolution and has become possible thanks to digital technologies (11). Entering the field of smart and precision agriculture, which relies on the use of modern technologies such as remote sensing, geographic information systems, the Internet of Things, and artificial intelligence systems (12), has become a characteristic of the era. Smart agriculture, also known as Farming 4.0 or digital agriculture, is the application of information and data technologies to improve complex agricultural systems. It encompasses individual machines and all farm operations. Smart agriculture integrates information and communication technologies into machines, (13) equipment, and sensors used in agricultural production systems. Technologies such as the Internet of Things(14) and cloud computing further enhance this development by introducing more robots and artificial intelligence into agriculture, allowing farmers to use smartphones and tablets to access real-time data about the status of almost anything involved in their daily operations,(15) including soil, plants, terrain, weather, asset location, asset condition, and resource utilization. Smart agricultural practices generate a large amount of data and information, which farmers can use to make data-driven decisions and take actions to improve productivity and profitability (16).

3.1 Internet of Things (IoT):

It allows remote control of machines through the network infrastructure. **(17)** It creates opportunities for direct integration between the physical world and digital systems. Smart agriculture operates using smart farming tools and devices connected to the internet. A sensor device is an electronic device that measures physical quantities from the environment and converts these measurements into a signal that can be read and interpreted by a tool. The measurements that have been read include, for example, temperature, humidity, light, pressure, noise, speed, direction, volume, and weight. (18) We need smart agriculture because "the smartest" agriculture is no longer an "advanced" tactic for smart farmers only, but it has become an increasingly necessary way to improve and sustain human and natural resources.(19) Agricultural labor is becoming increasingly scarce due to urban migration and aging populations. Intensifying climate change leads to less predictability in growth conditions. Consequently, land resources and biodiversity are diminishing. Smart farming tools can help reduce these impacts, (20) mitigate environmental constraints, and decrease production costs in agricultural activities. Smart farming tools offer a new level of technology in agriculture, including mapping, Robotics, Geomatics, Automation, decision-making, and statistical processes.

3.1.1 The Transformative Impact of IoT in Agriculture:

The integration of the Internet of Things (IoT) into agriculture represents a significant paradigm shift, yielding an array of benefits and advancements across various facets of farming practices. In this exploration, we delve into the multifaceted applications and advantages of IoT in agriculture, illuminating its pivotal role in elevating productivity, sustainability, and resource management within the agricultural sector (21),(22).

3.1.1.1 Automated Irrigation:

IoT sensors have ushered in automated irrigation systems that meticulously optimize water usage. These systems achieve this by continuously monitoring soil moisture levels, assessing prevailing weather conditions, and calibrating irrigation cycles according to the specific needs of crops. The result is highly efficient water management, translating into increased crop yields and resource conservation. (23)

3.1.1.2 Precise Weather Forecasting:

IoT-based weather stations offer real-time weather data, providing farmers with accurate forecasts. (24) Armed with this invaluable information, farmers can make well-informed decisions about planting, harvesting, and protecting their crops from potentially adverse weather conditions.

3.1.1.3 Sensor-Driven Precision Agriculture:

Precision agriculture has embraced IoT sensors to gather data on soil quality, nutrient levels, and crop health. This data, meticulously collected and analyzed, empowers farmers to precisely apply fertilizers and pesticides. The outcome is a dramatic reduction in resource wastage and a diminished environmental impact. (25)

3.1.1.4 Remote Crop Yield Enhancement:

IoT technologies have introduced remote monitoring of crop health and growth. This technological feat enables farmers to detect potential issues at an early stage and enact corrective measures promptly. The result is a marked improvement in crop yields and a reduction in losses.

3.1.1.5 Continuous Soil Health Monitoring:

IoT sensors maintain an ongoing vigil over soil conditions, monitoring factors such as pH levels and nutrient content. This vigilant monitoring ensures meticulous soil health management, ultimately culminating in optimal crop growth.

3.1.1.6 Optimized Storage, Logistics, and Distribution:

The IoT's pervasive influence extends to the tracking and management of stored crops. This translates into preservation of crop quality and substantial reductions in post-harvest losses. Additionally, IoT enhances the efficiency of logistics and distribution processes.

3.1.1.7 Remote Asset Oversight:

IoT devices facilitate remote monitoring of farm equipment and machinery. This oversight minimizes equipment downtime, consequently enhancing operational efficiency.

3.1.1.8 Elevation of Product Quality:

IoT-driven automation establishes consistent standards for product quality. This aligns agricultural output with market demands and customer expectations.

3.1.1.9 Real-Time Monitoring of Greenhouse Gas Emissions:

IoT sensors are harnessed to measure greenhouse gas emissions, enabling farmers to adopt eco-friendly practices and reduce their carbon footprint.

3.1.1.10 Precision Weed Control:

IoT technologies play a pivotal role in identifying and managing weeds. Through precision spraying and targeted control methods, IoT assists in maintaining crop health and yields.

3.1.1.11 Predictive Analytics for Sustainable Farming:

Combining IoT-generated data with advanced analytics empowers farmers with predictive insights into crop sustainability. This foresight aids in strategic planning for the long-term well-being of agricultural fields. (26)

Smart agriculture, driven by IoT technologies, offers a host of substantial advantages. Firstly, it significantly reduces the occurrence of human errors through the precise data collection and decision-making capabilities of IoT sensors. This not only ensures the accuracy of vital information but also enhances overall operational efficiency. (27)

Moreover, the comprehensive data collection and analysis facilitated by IoT-derived data extend far beyond mere precision. It encompasses the monitoring of business conditions, enhancing both employee safety and performance, optimizing equipment efficiency, and addressing a multitude of critical facets crucial to successful agricultural management. (28), (29)

One of the standout benefits is the consistent elevation of product quality and crop yields. Automation, an integral component of smart agriculture, allows for tighter control over the entire production process. This invariably results in consistently higher crop quality and substantially increased yields, positively impacting both productivity and profitability. (30)

Furthermore, cost management is markedly improved due to IoT's enhanced control over production processes. This fine-tuned oversight not only reduces operational costs but also ensures resource allocation optimization. (31),

The heightened efficiency inherent in smart agriculture stems from the streamlined automation of various agricultural processes. From irrigation to fertilization and pest control, IoT technologies bring forth a more efficient and sustainable approach to farming practices.

In addition to the economic advantages, smart agriculture diminishes dependency on human resources, mitigating labor shortages and optimizing workforce allocation. This is particularly crucial in the face of evolving labor dynamics in the agricultural sector.

Savings on insurance premiums are yet another noteworthy benefit. The implementation of IoT-based security measures curtails risks associated with theft, damage, and various other potential threats, resulting in reduced insurance costs.

Moreover, the early detection and prevention of diseases that may affect crops are made possible through the real-time data provided by IoT systems. This proactive approach to crop health safeguards agricultural yields and minimizes losses.

Lastly, IoT contributes to enhanced farm security, safeguarding valuable assets and ensuring the safety of farm workers. Through a network of interconnected devices, it actively monitors and responds to any irregular activities or security breaches, bolstering overall safety and peace of mind.

In summary, smart agriculture, underpinned by IoT innovations, presents a spectrum of advantages ranging from precision and productivity enhancements to cost-efficiency, labor optimization, and enhanced safety measures. These advantages collectively underscore the transformative potential of IoT in agriculture, revolutionizing the way farming is practiced and managed. The infusion of IoT into agriculture not only confronts the contemporary challenges of farming but also ushers in a new era of sustainable, efficient, and technologically advanced agricultural practices. These manifold advantages underscore the transformative potential of smart agriculture, promising to reshape the future of farming practices for the betterment of both farmers and the environment. (32)

4 Climatic regions in Egypt: (33)

The climatic regions include 8 different regions, under which many governorates fall, as shown

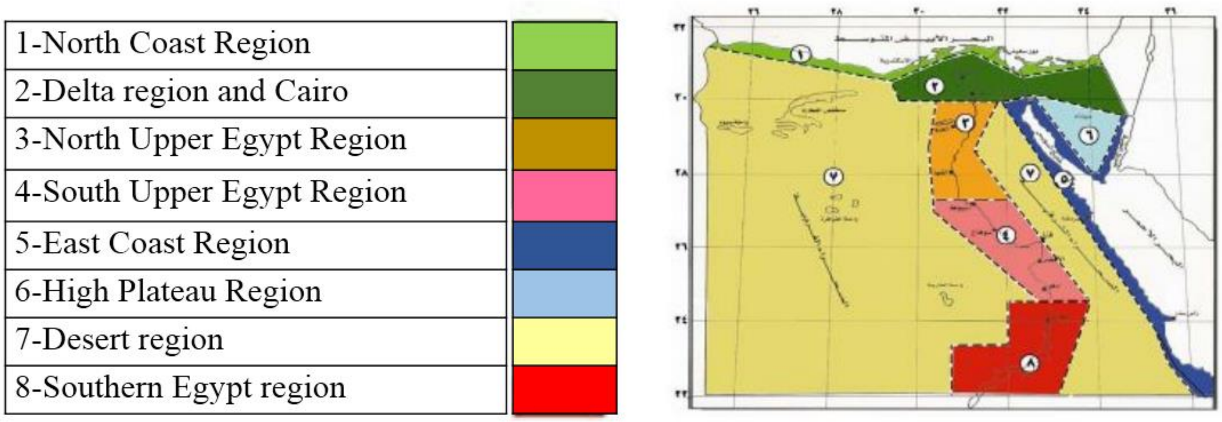


Figure (2) Climatic regions of the Arab Republic of Egypt

The following table shows the distribution of governorates according to the different regions, as shown in the energy code for buildings. Table (1) shows:

Table (1) the different climatic zones of the Arab Republic of Egypt Energy Code:

Region	Cities located in the region
1- North Coast Region	Al-Arish - Port Said - Damietta - Al-Beheira - Alexandria - Marsa Matrouh - Al-Salloum
2- Delta region and Cairo	Greater Cairo - Western - Eastern
3- North Upper Egypt Region	Beni Suef - Fayoum - Minya
4- South Upper Egypt Region	Assiut - Sohag - Qena
5- East Coast Region	Hurghada - Suez - Ras Sidr - Marsa Alam - Sharm El Sheikh - Taba - Dahab
6- High Plateau Region	St. Catherine - Al-Tur

7-	Desert region	Bahariya Oasis - Dakhla - Kharga - Siwa - Al-Owainat - Farafra
8-	Southern Egypt region	Aswan and Toshka - Abu Simbel

In this research endeavor, four provinces situated in distinct geographical regions were meticulously selected as study sites for the assessment and measurement of carbon dioxide emissions within university buildings. The investigation hinged on a practical approach, harnessing the capabilities of simulation programs. The primary objective was to elucidate the tangible effects of implementing smart agricultural practices within building walls to mitigate carbon dioxide emissions. The simulation process unfolded in several key phases:

a) Environmental Performance Evaluation:

The initial step involved a comprehensive evaluation of the proposed model's environmental performance. This entailed a detailed scrutiny of climate data relevant to each selected province and an in-depth analysis of solar radiation patterns.

b) Carbon Dioxide Emission Rate Identification:

The heart of the study was devoted to pinpointing the rate of carbon dioxide emissions, considering several pivotal factors. These encompassed the integration of green walls as an eco-conscious solution, the implementation of smart agriculture techniques, the assessment of various types of glass employed in building openings, an examination of the occupancy ratio within university buildings, and a meticulous analysis of the proportions of openings within the building's structure.

This multifaceted approach aimed to unravel the intricate interplay between smart agricultural interventions and carbon dioxide emissions within university buildings spanning diverse climatic regions. The study's goal was to offer valuable insights into sustainable building practices and environmental stewardship.

5 Case Study:

The study focused on the classrooms of higher education buildings in the October High Institute of Engineering and Technology. The characteristics of the classroom model in university buildings were determined, considering the different climatic regions in Egypt. The project name was October High Institute of Engineering and Technology, and the climate was hot and dry. The location was Giza. The renovation was completed in 2008.

The October Higher Institute of Engineering and Technology project consists of the ground floor, first floor, and second floor, as well as electrical and security rooms, site coordination, and services. The ground floor primarily includes student services units, accounts, the library, the academic counseling unit, the administrative section, classrooms, laboratories, and auditoriums. The first floor includes administrative offices, classrooms, drawing halls, upper management, and computer labs. The second floor includes the remaining classrooms, drawing halls, laboratories, and control rooms, as shown in figures (2) and (3).

Figure (2) shows the building of the October High Institute for Engineering and Technology, indicating the location of the classrooms in the university buildings under study.

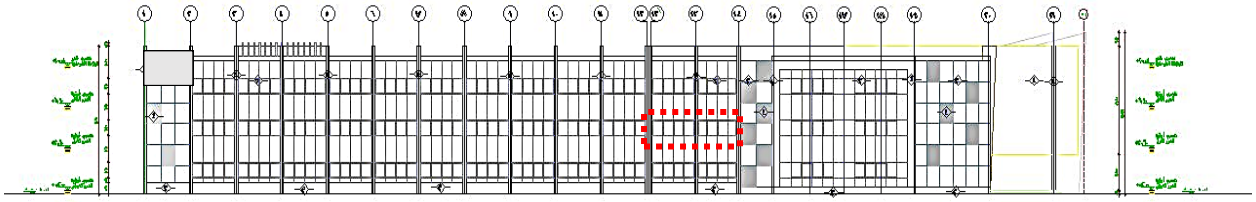


Figure (3) shows the northern facade of the October Higher Institute for Engineering and Technology building, showing the location of the classrooms in the university buildings under study. Source: researcher

5.1 Evaluation of Carbon Dioxide Emission Performance for the Case Study:

The evaluation of carbon dioxide emission rates for classrooms serves as an indicator of the extent to which the spaces achieve thermal comfort, which is influenced by material selection and the external envelope. After clarifying the principles of green building design and analyzing the green walls used, a comparison is made to assess the extent to which the green walls in the external envelope achieve thermal comfort within the classrooms in university buildings, considering the materials used for walls, glass, or opening ratios. The aim is to reduce the carbon dioxide emission rates for classrooms in university buildings**.**

5.2 Basis for Choosing the Case Study:

The study focuses on assessing classroom models within various climatic regions in Egypt, with particular emphasis on hot and dry areas. It addresses the current lack of environmental enhancements in university building classrooms and aims to transition them into eco-friendly, green building models. This transformation has led to an increase in carbon dioxide emissions rates within these classrooms, which has a detrimental impact on the occupants' well-being. To achieve the study's objectives, several crucial factors must be taken into account. Firstly, the chosen case study models should be representative of the specific climatic region under investigation. Secondly, the availability of necessary information for the simulation and evaluation phases is vital. Additionally, the selection of projects should prioritize those that require an in-depth examination of building materials to meet efficiency and environmental suitability standards. Lastly, these selected models must undergo thorough environmental design scrutiny, including an assessment of the materials used and their influence on carbon dioxide emissions rates.

5.3 Technical Method for Collecting and Documenting Data for the Selected Case Studies:

The collection and documentation of data for the chosen case studies were carried out through a combination of meticulous techniques, ensuring comprehensive and accurate information retrieval. The following methods were adopted for this purpose:

Field Visits, Photographic Documentation, and Researcher Observations: Researchers conducted field visits to the selected case study locations, during which they meticulously observed and documented relevant data. Photographic documentation played a pivotal role in capturing visual aspects and conditions, enabling a comprehensive understanding of the case studies.

Architectural and Site Maps: Detailed architectural and site maps of the case studies were utilized to extract crucial spatial and structural information. These maps provided an invaluable foundation for comprehending the physical layouts and configurations of the chosen sites.

Previous Research and Studies: Existing research and studies that pertained to the selected case studies were thoroughly reviewed and analyzed. This included a comprehensive examination of previous investigations that had delved into the same subjects, thereby enriching the pool of available data and insights.

By employing this multifaceted approach, the data collection and documentation process aimed to ensure the completeness and accuracy of information pertaining to the selected case studies. This, in turn, facilitated a robust foundation for subsequent analysis and research endeavors.

5.4 Methodology of the Applied Study:

The applied study was conducted employing a structured methodology that encompassed the following key elements:

a) Analysis of Climate Data for the Study Area:

The initial phase involved a meticulous analysis of climate data specific to the study area. This comprehensive examination aimed to gain insights into the prevailing climatic conditions, including temperature, humidity, precipitation patterns, and other relevant meteorological parameters. The climate data analysis provided a foundational understanding of the environmental context within which the study was situated.

b) B. Analytical Description of the Building Under Study:

In this critical phase, a comprehensive analysis of the building under investigation was conducted. It encompassed architectural attributes, the presence and impact of green walls, occupancy ratios, and the proportions of openings. These factors were visually presented in figures (4) and (5), providing a clear representation of the building's characteristics and their relevance to the study's objectives.

Through this comprehensive methodology, the applied study sought to provide a robust foundation for the evaluation and assessment of carbon dioxide emissions in the selected building. The integration of climate data analysis and a detailed building description facilitated a holistic understanding of the environmental dynamics influencing carbon dioxide emissions within the study area.

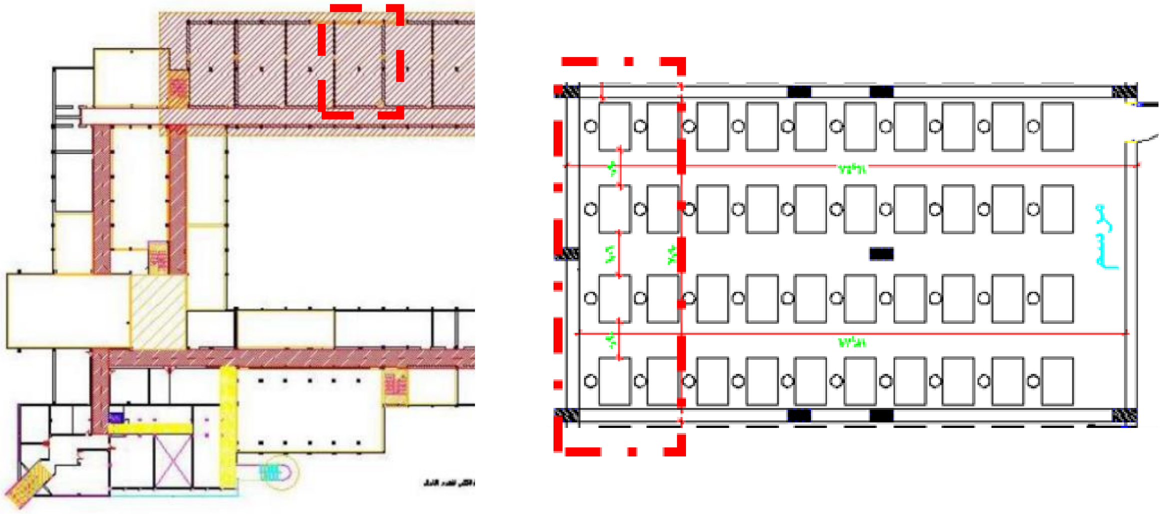


Figure (4) shows the plans of the model of classrooms in university buildings in the .study case. Source: Researcher

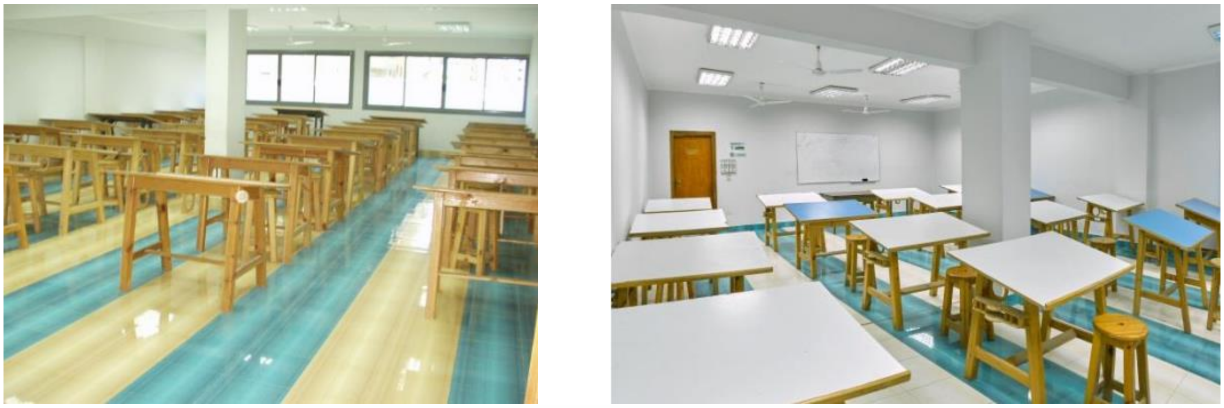


Figure (5) shows the building under study inside the October High Institute for Engineering and Technology.

C. Baseline Evaluation: The initial phase involved assessing classroom models in university buildings using Design Builder v7.0 software to establish a baseline for carbon dioxide emission rates.

D. Alternative Implementation and Testing: Alternatives, including green walls and smart agriculture, were implemented and rigorously tested using simulation software to analyze their impact on carbon dioxide emissions.

E. Result Comparison and Discussion: The study concluded with a thorough comparison and discussion of the results, focusing on the influence of green walls and smart agricultural practices on carbon dioxide emission rates.

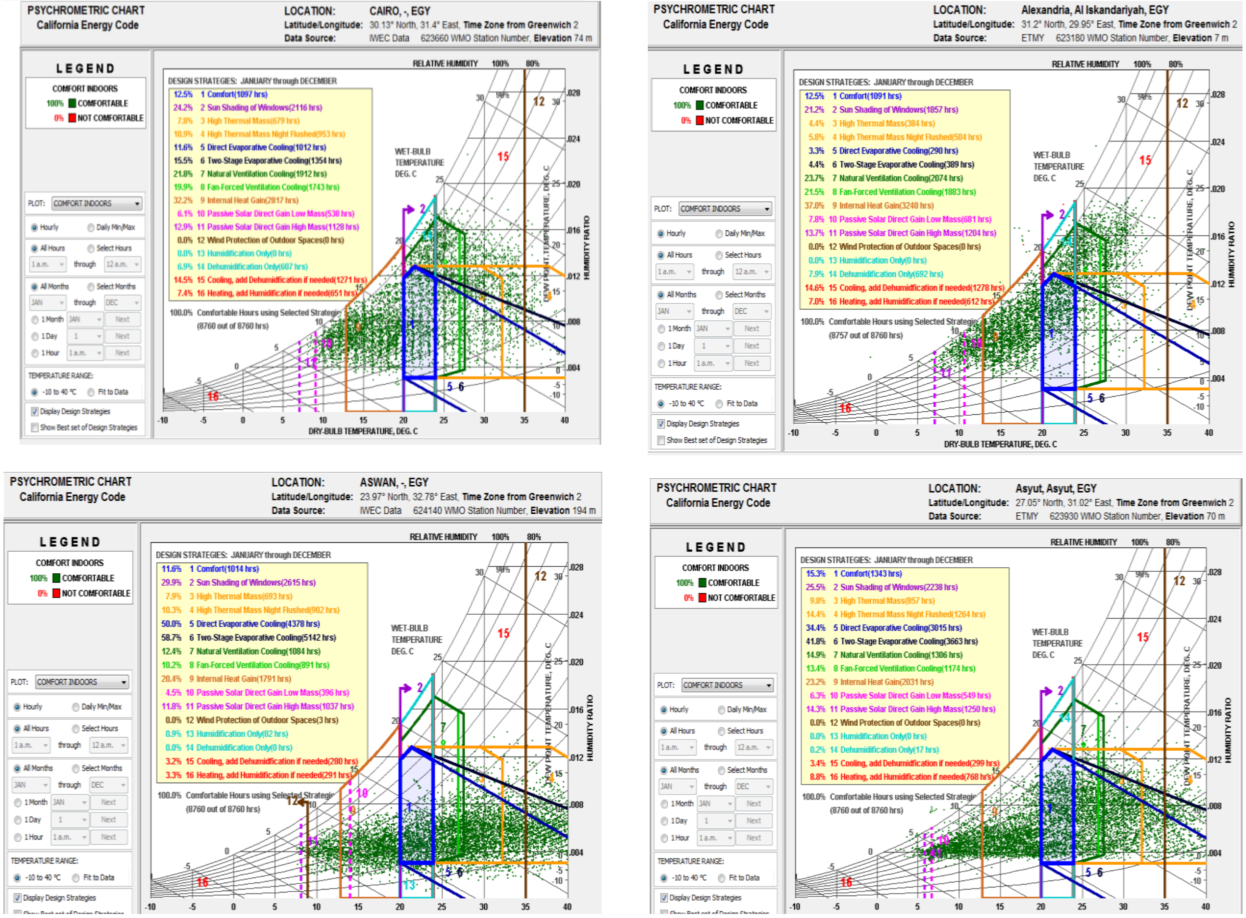
This approach provides a versatile platform for evaluating various alternatives and material options, enabling the selection of optimal solutions aimed at reducing carbon dioxide emission rates. The simulation's objectives encompass studying the impact of green walls on carbon dioxide emissions within university building classrooms, analyzing the effects of external green agriculture on the indoor environment of these classrooms, and conducting simulations to estimate savings percentages related to carbon dioxide emissions in these educational spaces. Collectively, these objectives contribute to a comprehensive exploration of eco-friendly building practices, focusing on emissions reduction and indoor air quality enhancement.

5.5 Analysis of the Classrooms in October High Institute of Engineering and Technology Building; The analysis was conducted through:

5.5.1 Analysis of the climatic data for the study region, Greater Cairo. (34)

Climatic data for the Greater Cairo region was used using Climate Consultant 6.0 software. The psychometric chart illustrates the relationship between temperature and relative humidity on the horizontal and vertical axes, respectively. It identifies the characteristics of the climate in Greater Cairo by determining the thermal comfort zone based on temperature and humidity, as well as occupancy rate, including clothing type and activity level, as shown in Figure (6).

Psychometrics of thermal comfort



PSYCHROMETRIC CHART
California Energy Code
LOCATION: CAIRO, -, EGY
Latitude/Longitude: 30.13° North, 31.4° East, Time Zone from Greenwich 2
Data Source: IWEC Data 623660 WMO Station Number, Elevation 74 m

LEGEND
COMFORT INDOORS
100% 🟩 COMFORTABLE
0% 🟥 NOT COMFORTABLE

PLOT: COMFORT INDOORS
● Hourly ○ Daily Min/Max
● All Hours ○ Select Hours 1 a.m. through 12 a.m.
● All Months ○ Select Months JAN through DEC
○ 1 Month JAN Next
○ 1 Day 1 Next
○ 1 Hour 1 a.m. Next
TEMPERATURE RANGE: ● -10 to 40 °C ○ Fit to Data
☑ Display Design Strategies
☐ Show Best set of Design Strategies

DESIGN STRATEGIES: JANUARY through DECEMBER

12.5%	1 Comfort(1097 hrs)
24.2%	2 Sun Shading of Windows(2116 hrs)
7.8%	3 High Thermal Mass(679 hrs)
10.9%	4 High Thermal Mass Night Flushed(953 hrs)
11.6%	5 Direct Evaporative Cooling(1012 hrs)
15.5%	6 Two-Stage Evaporative Cooling(1354 hrs)
21.8%	7 Natural Ventilation Cooling(1912 hrs)
19.9%	8 Fan-Forced Ventilation Cooling(1743 hrs)
32.2%	9 Internal Heat Gain(2817 hrs)
6.1%	10 Passive Solar Direct Gain Low Mass(538 hrs)
12.9%	11 Passive Solar Direct Gain High Mass(1128 hrs)
0.0%	12 Wind Protection of Outdoor Spaces(0 hrs)
0.0%	13 Humidification Only(0 hrs)
6.9%	14 Dehumidification Only(607 hrs)
14.5%	15 Cooling, add Dehumidification if needed(1271 hrs)
7.4%	16 Heating, add Humidification if needed(651 hrs)

100.0% Comfortable Hours using Selected Strategies (8760 out of 8760 hrs)

PSYCHROMETRIC CHART
California Energy Code
LOCATION: Alexandria, Al Iskandariyah, EGY
Latitude/Longitude: 31.2° North, 29.95° East, Time Zone from Greenwich 2
Data Source: ETMY 623180 WMO Station Number, Elevation 7 m

LEGEND
COMFORT INDOORS
100% 🟩 COMFORTABLE
0% 🟥 NOT COMFORTABLE

PLOT: COMFORT INDOORS
● Hourly ○ Daily Min/Max
● All Hours ○ Select Hours 1 a.m. through 12 a.m.
● All Months ○ Select Months JAN through DEC
○ 1 Month JAN Next
○ 1 Day 1 Next
○ 1 Hour 1 a.m. Next
TEMPERATURE RANGE: ● -10 to 40 °C ○ Fit to Data
☑ Display Design Strategies
☐ Show Best set of Design Strategies

DESIGN STRATEGIES: JANUARY through DECEMBER

12.5%	1 Comfort(1091 hrs)
21.2%	2 Sun Shading of Windows(1857 hrs)
4.4%	3 High Thermal Mass(384 hrs)
5.8%	4 High Thermal Mass Night Flushed(504 hrs)
3.3%	5 Direct Evaporative Cooling(290 hrs)
4.4%	6 Two-Stage Evaporative Cooling(389 hrs)
23.7%	7 Natural Ventilation Cooling(2074 hrs)
21.5%	8 Fan-Forced Ventilation Cooling(1883 hrs)
37.0%	9 Internal Heat Gain(3240 hrs)
7.8%	10 Passive Solar Direct Gain Low Mass(681 hrs)
13.7%	11 Passive Solar Direct Gain High Mass(1204 hrs)
0.0%	12 Wind Protection of Outdoor Spaces(0 hrs)
0.0%	13 Humidification Only(0 hrs)
7.9%	14 Dehumidification Only(692 hrs)
14.6%	15 Cooling, add Dehumidification if needed(1278 hrs)
7.0%	16 Heating, add Humidification if needed(612 hrs)

100.0% Comfortable Hours using Selected Strategies (8757 out of 8760 hrs)

PSYCHROMETRIC CHART
California Energy Code
LOCATION: ASWAN, -, EGY
Latitude/Longitude: 23.97° North, 32.78° East, Time Zone from Greenwich 2
Data Source: IWEC Data 624140 WMO Station Number, Elevation 194 m

LEGEND
COMFORT INDOORS
100% 🟩 COMFORTABLE
0% 🟥 NOT COMFORTABLE

PLOT: COMFORT INDOORS
● Hourly ○ Daily Min/Max
● All Hours ○ Select Hours 1 a.m. through 12 a.m.
● All Months ○ Select Months JAN through DEC
○ 1 Month JAN Next
○ 1 Day 1 Next
○ 1 Hour 1 a.m. Next
TEMPERATURE RANGE: ● -10 to 40 °C ○ Fit to Data
☑ Display Design Strategies

DESIGN STRATEGIES: JANUARY through DECEMBER

11.6%	1 Comfort(1014 hrs)
29.9%	2 Sun Shading of Windows(2615 hrs)
7.9%	3 High Thermal Mass(693 hrs)
10.3%	4 High Thermal Mass Night Flushed(902 hrs)
50.0%	5 Direct Evaporative Cooling(4378 hrs)
58.7%	6 Two-Stage Evaporative Cooling(5142 hrs)
12.4%	7 Natural Ventilation Cooling(1084 hrs)
10.2%	8 Fan-Forced Ventilation Cooling(891 hrs)
20.4%	9 Internal Heat Gain(1791 hrs)
4.5%	10 Passive Solar Direct Gain Low Mass(396 hrs)
11.8%	11 Passive Solar Direct Gain High Mass(1037 hrs)
0.0%	12 Wind Protection of Outdoor Spaces(3 hrs)
0.9%	13 Humidification Only(82 hrs)
0.0%	14 Dehumidification Only(0 hrs)
3.2%	15 Cooling, add Dehumidification if needed(280 hrs)
3.3%	16 Heating, add Humidification if needed(291 hrs)

100.0% Comfortable Hours using Selected Strategies (8760 out of 8760 hrs)

PSYCHROMETRIC CHART
California Energy Code
LOCATION: Asyut, Asyut, EGY
Latitude/Longitude: 27.05° North, 31.02° East, Time Zone from Greenwich 2
Data Source: ETMY 623930 WMO Station Number, Elevation 70 m

LEGEND
COMFORT INDOORS
100% 🟩 COMFORTABLE
0% 🟥 NOT COMFORTABLE

PLOT: COMFORT INDOORS
● Hourly ○ Daily Min/Max
● All Hours ○ Select Hours 1 a.m. through 12 a.m.
● All Months ○ Select Months JAN through DEC
○ 1 Month JAN Next
○ 1 Day 1 Next
○ 1 Hour 1 a.m. Next
TEMPERATURE RANGE: ● -10 to 40 °C ○ Fit to Data
☑ Display Design Strategies

DESIGN STRATEGIES: JANUARY through DECEMBER

15.3%	1 Comfort(1343 hrs)
25.5%	2 Sun Shading of Windows(2238 hrs)
9.8%	3 High Thermal Mass(857 hrs)
14.4%	4 High Thermal Mass Night Flushed(1264 hrs)
34.4%	5 Direct Evaporative Cooling(3015 hrs)
41.8%	6 Two-Stage Evaporative Cooling(3663 hrs)
14.9%	7 Natural Ventilation Cooling(1306 hrs)
13.4%	8 Fan-Forced Ventilation Cooling(1174 hrs)
23.2%	9 Internal Heat Gain(2031 hrs)
6.3%	10 Passive Solar Direct Gain Low Mass(549 hrs)
14.3%	11 Passive Solar Direct Gain High Mass(1250 hrs)
0.0%	12 Wind Protection of Outdoor Spaces(0 hrs)
0.0%	13 Humidification Only(0 hrs)
0.2%	14 Dehumidification Only(17 hrs)
3.4%	15 Cooling, add Dehumidification if needed(299 hrs)
8.8%	16 Heating, add Humidification if needed(768 hrs)

100.0% Comfortable Hours using Selected Strategies (8760 out of 8760 hrs)

Figure (6) shows the psychometric map of thermal comfort in different climate regions for the case study in the Climate Consultant 6.0 program. Source: http://www.energy-design-tools.aud.ucla.edu/climate-consultant/request-climate-

5.5.2 Data for the Classroom Models in University Buildings:

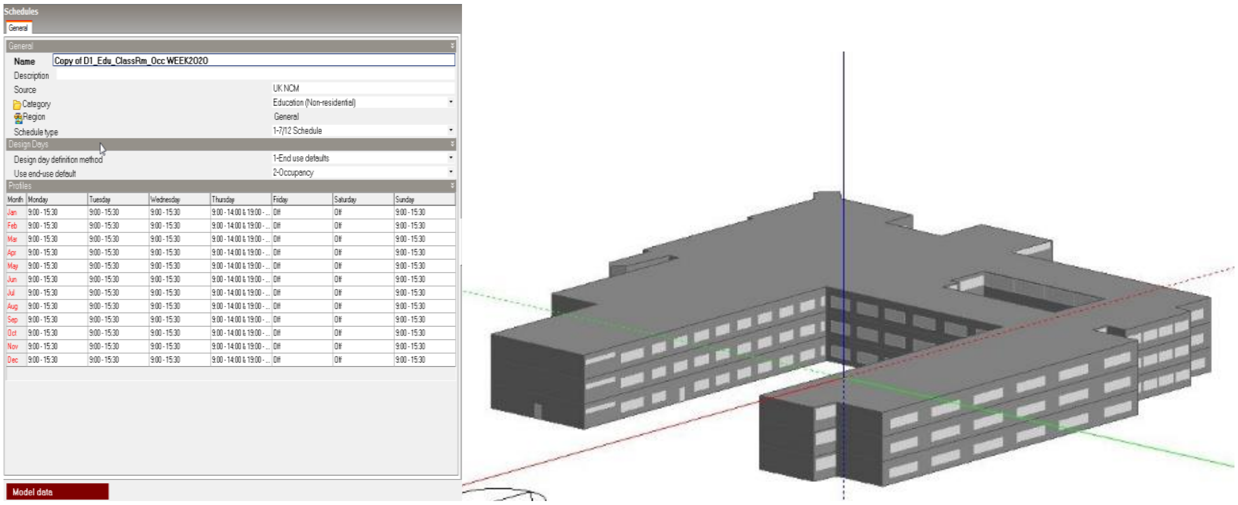
5.5.2.1 Architectural Design Data:

The purpose of studying the classroom models in university buildings before and after implementing the modifications is to determine the impact of green walls on carbon dioxide emission rates and the orientation and opening ratios based on different architectural dimensions of the classrooms in university buildings. A comparison will be made between the current state of the classrooms in university buildings and the modified state after implementing the alternatives. The comparison will address key design elements such as floor plans, opening ratios, walls, and orientation.

5.6 Evaluation of the Classroom Models in University Buildings Using Simulation; This is done through:

5.6.1 Simulation Methodology :(35)

The specifications and dimensions of the building are inputted into the software, and a simulation model is created to replicate the building's actual conditions. This model simulates all aspects related to carbon dioxide emission rates in the building, as shown in the following model taken from the DesignBuilder v7.0 software. This software analyzes the input data for the entire case study, as shown in Figure (7).



Name: Copy of D1_Edu_ClassRm_Occ WEEK2020
Description:
Source: UK NCM
Category: Education (Non-residential)
Region: General
Schedule type: 1-7/12 Schedule
Design day definition method: 1-End use defaults
Use end-use default: 2-Occupancy

Month	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
Jan	9:00 - 15:30	9:00 - 15:30	9:00 - 15:30	9:00 - 14:00 & 19:00 - ...	Off	Off	9:00 - 15:30
Feb	9:00 - 15:30	9:00 - 15:30	9:00 - 15:30	9:00 - 14:00 & 19:00 - ...	Off	Off	9:00 - 15:30
Mar	9:00 - 15:30	9:00 - 15:30	9:00 - 15:30	9:00 - 14:00 & 19:00 - ...	Off	Off	9:00 - 15:30
Apr	9:00 - 15:30	9:00 - 15:30	9:00 - 15:30	9:00 - 14:00 & 19:00 - ...	Off	Off	9:00 - 15:30
May	9:00 - 15:30	9:00 - 15:30	9:00 - 15:30	9:00 - 14:00 & 19:00 - ...	Off	Off	9:00 - 15:30
Jun	9:00 - 15:30	9:00 - 15:30	9:00 - 15:30	9:00 - 14:00 & 19:00 - ...	Off	Off	9:00 - 15:30
Jul	9:00 - 15:30	9:00 - 15:30	9:00 - 15:30	9:00 - 14:00 & 19:00 - ...	Off	Off	9:00 - 15:30
Aug	9:00 - 15:30	9:00 - 15:30	9:00 - 15:30	9:00 - 14:00 & 19:00 - ...	Off	Off	9:00 - 15:30
Sep	9:00 - 15:30	9:00 - 15:30	9:00 - 15:30	9:00 - 14:00 & 19:00 - ...	Off	Off	9:00 - 15:30
Oct	9:00 - 15:30	9:00 - 15:30	9:00 - 15:30	9:00 - 14:00 & 19:00 - ...	Off	Off	9:00 - 15:30
Nov	9:00 - 15:30	9:00 - 15:30	9:00 - 15:30	9:00 - 14:00 & 19:00 - ...	Off	Off	9:00 - 15:30
Dec	9:00 - 15:30	9:00 - 15:30	9:00 - 15:30	9:00 - 14:00 & 19:00 - ...	Off	Off	9:00 - 15:30

Figure (7) shows a model of the October High Institute for Engineering and Technology building, showing the classrooms' location in the university buildings /under study. In Design Builder 6.0 Source: https://designbuilder.co.uk

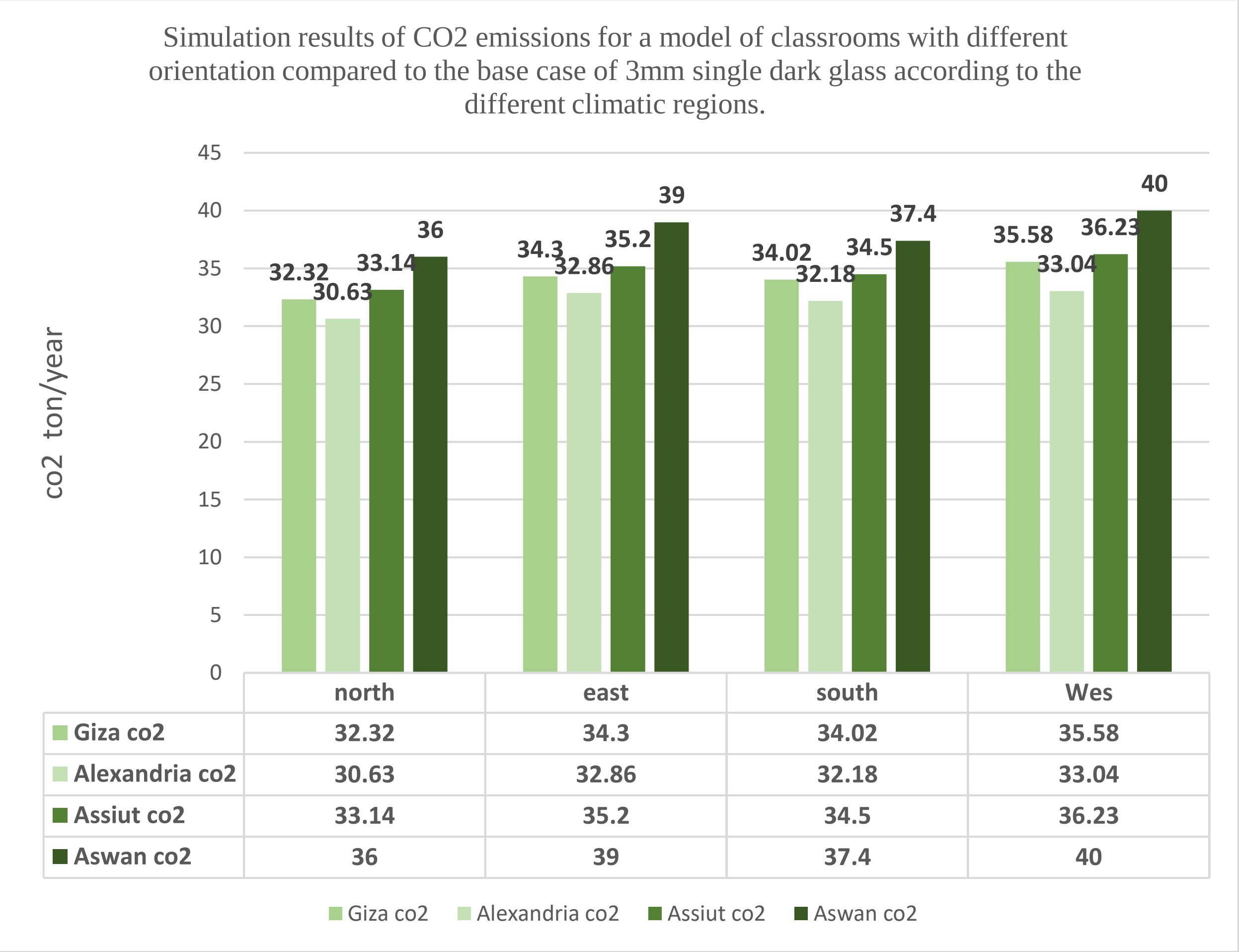
5.6.2 Building Operation Data:

The building adheres to a defined operational schedule, conducting its activities exclusively during daytime hours, from 8:00 AM to 4:00 PM, spanning most days of the week, except for Fridays and Saturdays

Furthermore, certain crucial parameters govern the building's operation. These include an occupant density of 0.55, indicating the presence of occupants within the space. Additionally, occupant clothing insulation varies seasonally, with a value of 0.9 clo in winter and 0.49 clo in summer. The metabolic rate for occupants is set at 1.0, encompassing activities like standing, walking, and computer usage. To accommodate specific operational needs, there is a schedule adjustment from 9:00 AM to 3:00 PM, with exclusions on Fridays and Saturdays. These parameters collectively define the operational framework for the building's simulation and analysis.

6 Discussion of Results:

- The first case: Comparing the simulation results of the CO2 emissions rate for the base case with different types of orientation for the model of classrooms in university buildings: in the case of a 25 cm thick red brick wall and 3 mm single glass (UV(5.894)). As Figure (8) shows:



	north	east	south	Wes
🟩 Giza co2	32.32	34.3	34.02	35.58
🟩 Alexandria co2	30.63	32.86	32.18	33.04
🟩 Assiut co2	33.14	35.2	34.5	36.23
🟩 Aswan co2	36	39	37.4	40

Figure 8 shows a comparison of the simulation results for the CO_2 emission rate of the classroom model in university buildings with different orientations compared to the baseline case with a 25 cm thick red brick wall and single 3 mm glass (UV (5.894)). The comparison is done across different climatic regions (Giza, Alexandria, Assiut, and Aswan).

From the analysis of Figure 8, it becomes evident that the CO_2 emission rate exhibits variations based on different orientations and distinct climatic regions. The simulation results reveal noteworthy disparities in CO_2 emissions for the classroom model within university buildings.

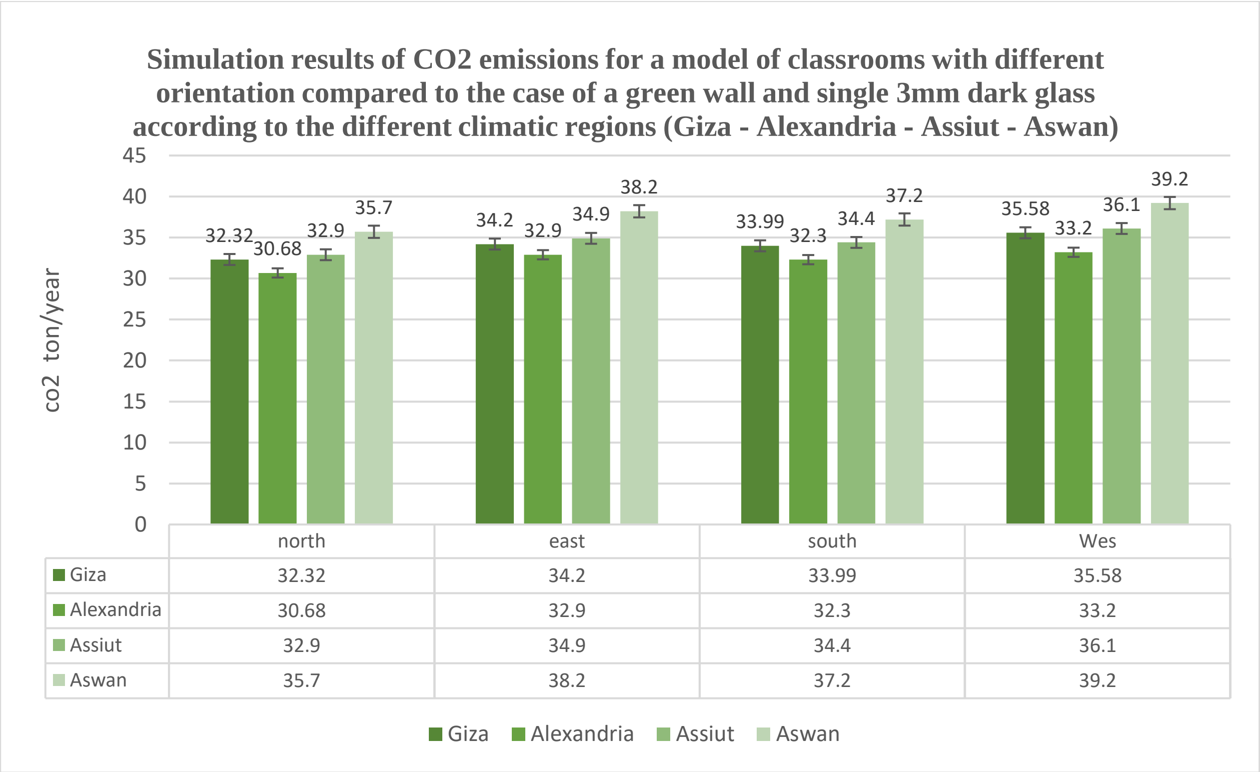
In the first scenario, with a west orientation and featuring a 25 cm thick red brick wall combined with a single 3 mm glass (UV(5.894)), the CO_2 emission rate reaches its peak at 40 tons per square meter per year in Aswan Governorate, signifying the highest rate within this model. Subsequently, the emission rate progressively decreases to 36.23 tons per square meter per year in Assiut Governorate, followed by 35.58 tons per square meter per year in Giza Governorate, and 33.04 tons per square meter per year in Alexandria Governorate.

In the case of an east orientation, along with the same 25 cm thick red brick wall and single 3 mm glass (UV(5.894)), Aswan Governorate once again records the highest CO_2 emission rate at 39 tons per square meter per year. This is trailed by 35.2 tons per square meter per year in Assiut Governorate, 34.3 tons per square meter per year in Giza Governorate, and 32.86 tons per square meter per year in Alexandria Governorate.

For a south orientation, coupled with the specified 25 cm thick red brick wall and single 3 mm glass (UV(5.894)), Aswan Governorate registers the highest CO2 emission rate at 37.4 tons per square meter per year, followed by 34.5 tons per square meter per year in Assiut Governorate, 34.02 tons per square meter per year in Giza Governorate, and 32.18 tons per square meter per year in Alexandria Governorate.

Lastly, in the instance of a north orientation, accompanied by the same 25 cm thick red brick wall and single 3 mm glass (UV(5.894)), Aswan Governorate once again leads with the highest CO2 emission rate at 36 tons per square meter per year. This is succeeded by 33.14 tons per square meter per year in Assiut Governorate, 32.32 tons per square meter per year in Giza Governorate, and 30.63 tons per square meter per year in Alexandria Governorate.

The analysis then proceeds to the second case, which involves a comparison of the simulation results for the CO2 emission rate. This comparison is conducted between the base case and various orientation scenarios for the classroom model within university buildings. Specifically, it explores the impact of a green wall in combination with 3 mm single glass (UV(5.894)), as illustrated in Figure (9).



Simulation results of CO2 emissions for a model of classrooms with different orientation compared to the case of a green wall and single 3mm dark glass according to the different climatic regions (Giza - Alexandria - Assiut - Aswan)

	north	east	south	Wes
🟩 Giza	32.32	34.2	33.99	35.58
🟩 Alexandria	30.68	32.9	32.3	33.2
🟩 Assiut	32.9	34.9	34.4	36.1
🟩 Aswan	35.7	38.2	37.2	39.2

Figure 9 shows a comparison of the simulation results for the CO2 emission rate of the classroom model in university buildings with different orientations compared to the baseline case with a 25 cm thick red brick wall and single 3 mm dark-tinted glass (UV(5.894)) across different climatic regions (Giza, Alexandria, Assiut, and Aswan)

In the second case, the analysis of Figure 9 highlights the variability of CO_2 emission rates across diverse orientations and different climatic regions. The results obtained from the simulations provide crucial insights into the emission patterns for the classroom model within university buildings.

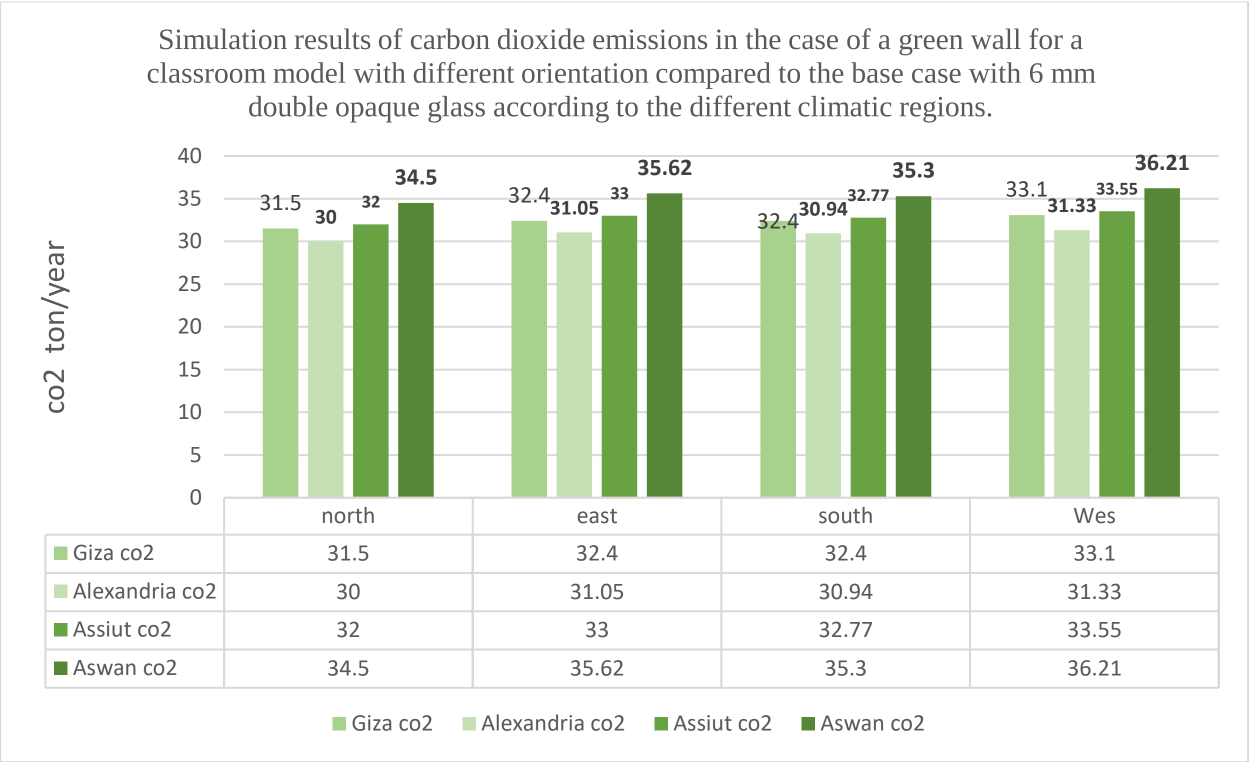
For the scenario involving a west orientation, along with a 25 cm thick red brick wall and single 3 mm dark-tinted glass (UV(5.894)), Aswan Governorate records the highest CO_2 emission rate at 39.2 tons per square meter per year, representing the pinnacle within this model. This is followed by a decrease to 36.1 tons per square meter per year in Assiut Governorate, 35.58 tons per square meter per year in Giza Governorate, and 33.2 tons per square meter per year in Alexandria Governorate.

For the east orientation, combined with the specified 25 cm thick red brick wall and single 3 mm dark-tinted glass (UV(5.894)), Aswan Governorate again exhibits the highest CO_2 emission rate, measuring at 38.2 tons per square meter per year. This is trailed by 34.9 tons per square meter per year in Assiut Governorate, 34.2 tons per square meter per year in Giza Governorate, and 32.9 tons per square meter per year in Alexandria Governorate.

In the case of a south orientation, paired with the same 25 cm thick red brick wall and single 3 mm dark-tinted glass (UV(5.894)), Aswan Governorate once more leads with the highest CO_2 emission rate, amounting to 37.2 tons per square meter per year. This is followed by 34.4 tons per square meter per year in Assiut Governorate, 33.99 tons per square meter per year in Giza Governorate, and 32.3 tons per square meter per year in Alexandria Governorate.

Lastly, for the north orientation, in conjunction with the specified 25 cm thick red brick wall and single 3 mm dark-tinted glass (UV(5.894)), Aswan Governorate maintains the highest CO_2 emission rate at 35.7 tons per square meter per year. This is succeeded by 32.9 tons per square meter per year in Assiut Governorate, 32.32 tons per square meter per year in Giza Governorate, and 30.68 tons per square meter per year in Alexandria Governorate.

The analysis subsequently proceeds to the third case, involving a comparative examination of the simulation results for CO_2 emission rates. This comparison encompasses various orientations for the classroom model within university buildings, focusing on the presence of a green wall and double dark glass (UV (1.048)), as depicted in Figure (10).



	north	east	south	Wes
Giza co2	31.5	32.4	32.4	33.1
Alexandria co2	30	31.05	30.94	31.33
Assiut co2	32	33	32.77	33.55
Aswan co2	34.5	35.62	35.3	36.21

Figure (10) illustrates the comparison of simulation results for the emissions of carbon dioxide (CO2) in the case of a green wall for the model of classrooms in university buildings, compared to the baseline case of a dark double-glazed 6mm glass, with different climatic regions (Giza - Alexandria - Assiut – Aswan)

Figure (10) presents a comprehensive analysis of CO2 emission rates within university classroom buildings, offering valuable insights into the interplay of building orientation and climatic regions on carbon emissions.

When examining the west orientation alongside green wall integration and dark double-glazed glass, Aswan Governorate emerges with the highest CO2 emission rate, peaking at 36.21 tons per square meter per year. This rate steadily diminishes as we transition to less arid regions:

Assiut Governorate at 33.55 tons per square meter per year,

Giza Governorate at 33.1 tons per square meter per year,

and Alexandria Governorate at 31.33 tons per square meter per year.

Similarly, in the case of an east orientation with green walls and dark double-glazed glass, Aswan Governorate demonstrates the highest CO2 emission rate at 35.62 tons per square meter per year. The emission rates gradually decrease:

Assiut Governorate at 33 tons per square meter per year,

Giza Governorate at 32.4 tons per square meter per year,

and Alexandria Governorate at 31.05 tons per square meter per year.

For the south orientation paired with green walls and dark double-glazed glass, Aswan Governorate again leads with the highest CO2 emission rate, registering 35.3 tons per square meter per year. Subsequent emission rates follow this pattern:

Assiut Governorate at 32.77 tons per square meter per year,

Giza Governorate at 32.4 tons per square meter per year,

and Alexandria Governorate at 30.94 tons per square meter per year.

Finally, in the north orientation with green walls and dark double-glazed glass, Aswan Governorate exhibits the highest CO2 emission rate at 34.5 tons per square meter per year,

followed by Assiut Governorate at 32 tons per square meter per year,

Giza Governorate at 31.5 tons per square meter per year,

and Alexandria Governorate at 30 tons per square meter per year.

Overall, this analysis underscores the notable influence of climatic conditions and building orientation on carbon emissions, highlighting the importance of region-specific design considerations to enhance energy efficiency and reduce environmental impact. These findings equip architects and designers with essential data to inform sustainable architectural decisions and emphasize the significance of tailored design strategies for achieving environmental objectives..

7 Results:

The utilization of computer programs in simulation during the design phase emerged as a crucial factor in evaluating and realizing the principles of green architecture. These programs played a pivotal role in identifying optimal strategies for reducing carbon dioxide emissions, thereby contributing significantly to sustainable architectural design.

Vegetation cover was identified as an indispensable component of ecological systems. Its diverse plant species harnessed solar energy through the process of photosynthesis, effectively absorbing carbon dioxide from the atmosphere. In addition to this, vegetation cover produced the vital oxygen necessary for supporting life on Earth, playing a vital role in mitigating the greenhouse effect.

The research focused on the critical role of design decisions in determining the rate of carbon dioxide emissions in buildings. Specifically, it examined three architectural dimensions: orientation and the incorporation of green walls. These dimensions were chosen due to their significance and potential impact on reducing carbon dioxide emissions, especially in the context of university classroom buildings.

The study's results demonstrated that the inclusion of green walls in university classroom buildings, combined with the use of dark glass, resulted in a notable reduction in the carbon dioxide emission rate. This finding underscored the effectiveness of green architectural features in achieving lower emissions in the model of classrooms within university buildings.

The research also explored the influence of building orientation on the carbon dioxide emission rate in university classroom buildings, with a particular focus on the Greater Cairo region. It was observed that building orientation played a significant role in emissions reduction. Notably, the north orientation exhibited the lowest carbon dioxide emission rate, showing a remarkable decrease of 12.1% compared to the west orientation. This outcome was visually represented in Figures 11, 12, 13, and 14.

These results collectively highlight the critical role of computer simulations in promoting green architecture principles and reducing carbon dioxide emissions. Moreover, they emphasize the importance of vegetation cover, green architectural elements, and thoughtful design decisions, such as building orientation, in achieving sustainable and environmentally responsible university classroom buildings, particularly in urban areas like Greater Cairo. These findings provide valuable insights for architects, designers, and policymakers working towards a greener and more sustainable built environment.

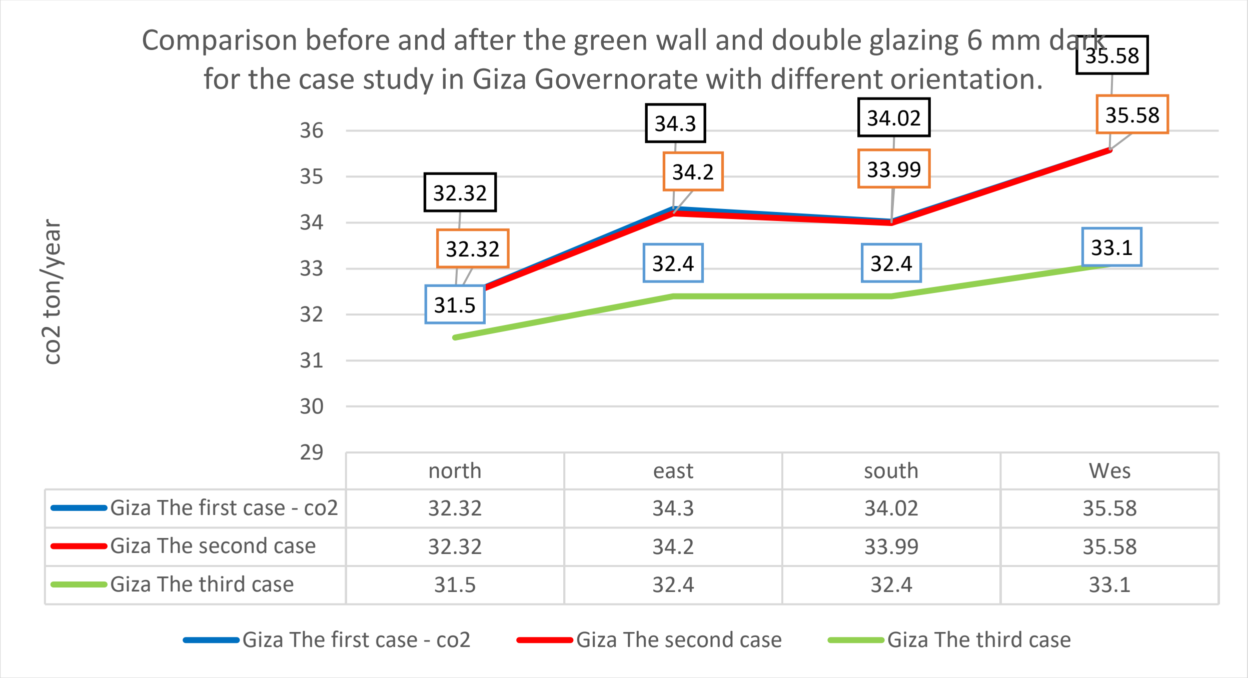
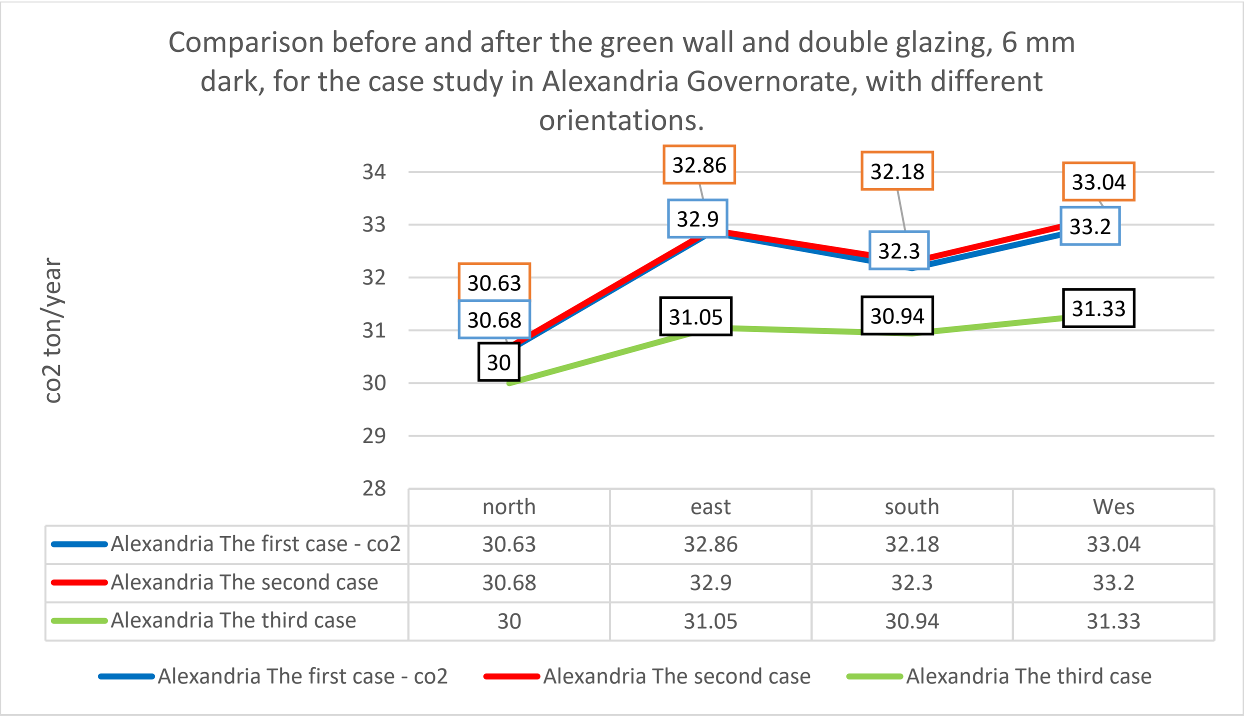
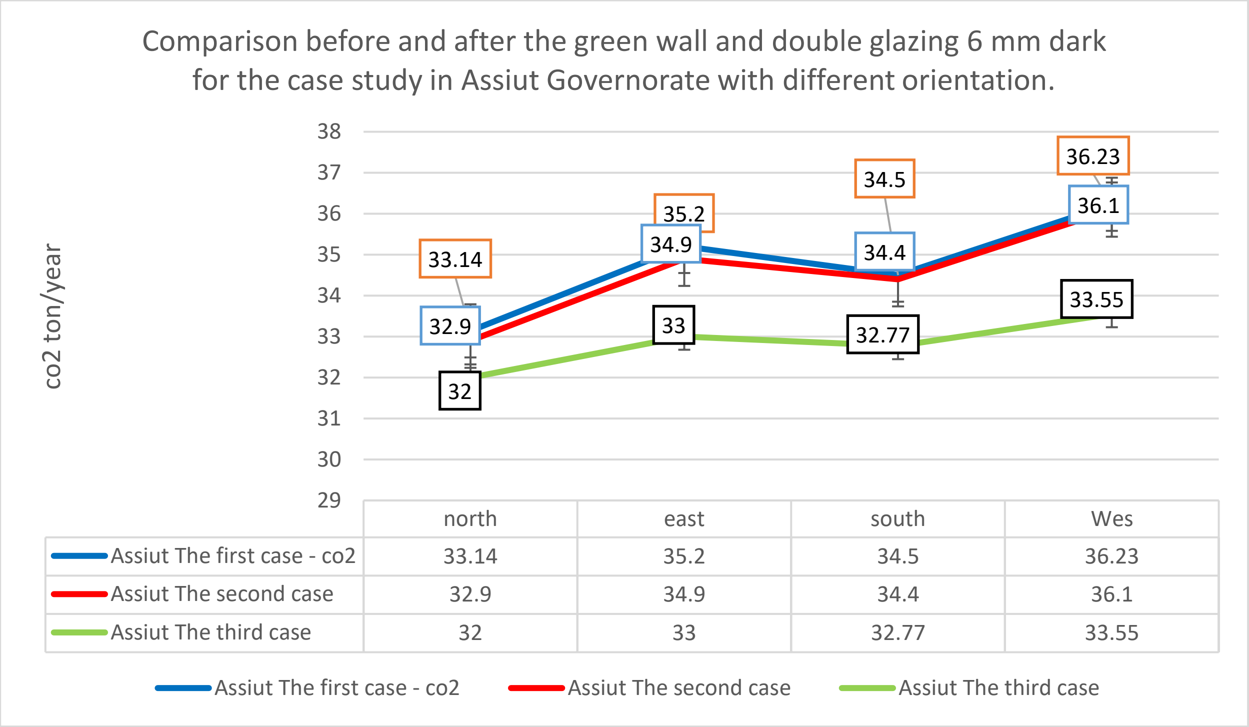


Figure (11) shows the decrease in the rate of CO_2 emissions in all three study cases on the northern façade and when using a green wall with dark glass for the Giza Governorate



	north	east	south	Wes
Alexandria The first case - co2	30.63	32.86	32.18	33.04
Alexandria The second case	30.68	32.9	32.3	33.2
Alexandria The third case	30	31.05	30.94	31.33

Figure (12) shows the decrease in the rate of CO_2 emissions in all three study cases on the northern façade and when using a green wall with dark glass for the Alexandria Governorate.



	north	east	south	Wes
Assiut The first case - co2	33.14	35.2	34.5	36.23
Assiut The second case	32.9	34.9	34.4	36.1
Assiut The third case	32	33	32.77	33.55

Figure (13) shows the decrease in the rate of CO_2 emissions in all three study cases on the northern façade and when using a green wall with dark glass for the Assiut Governorate.

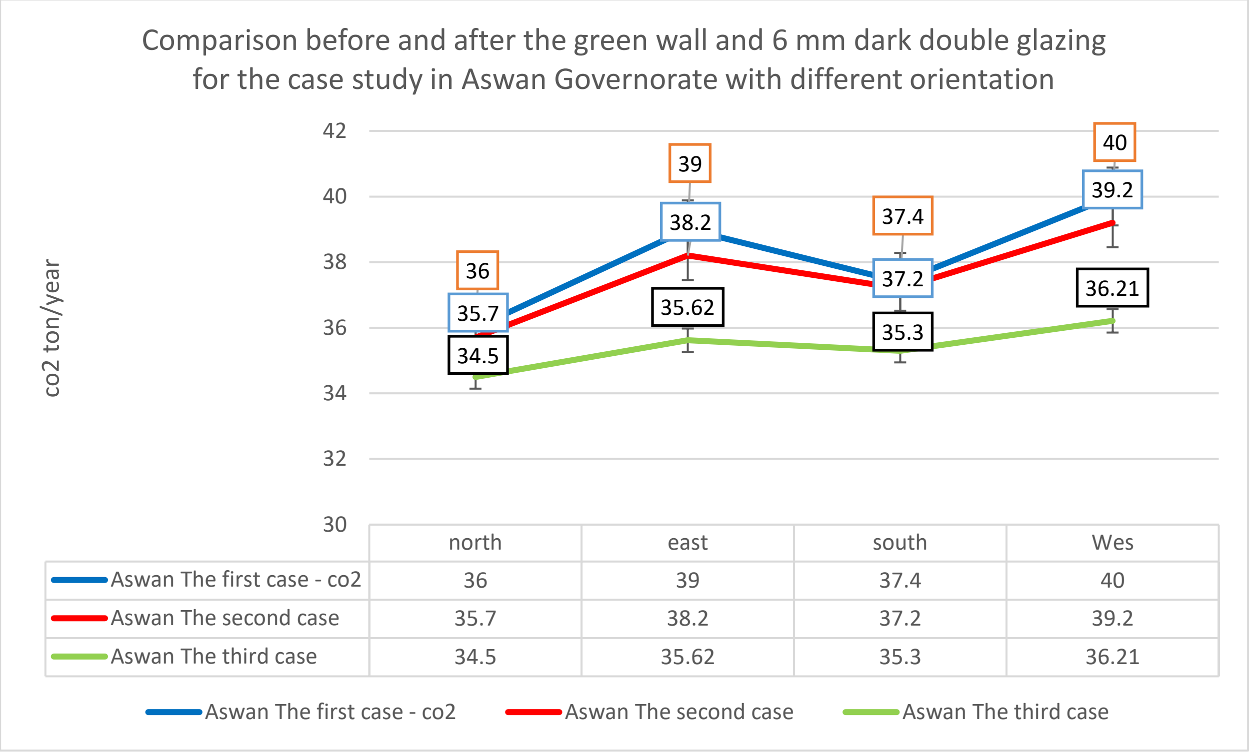


Figure (14) shows the decrease in the rate of CO_2 emissions in all three study cases on the northern façade and when using a green wall with dark glass for Aswan Governorate.

Conclusion:

The study's findings underscore the critical role of orientation in mitigating carbon dioxide emissions within the classroom models of university buildings, particularly in the Greater Cairo region. Notably, the north orientation emerges as a robust strategy for significantly reducing carbon dioxide emissions, with an impressive decrease of 12.1% in comparison to the baseline case of the west orientation. Moreover, the east orientation proves to be an effective alternative, yielding an 11.5% reduction when compared to the base case. These results highlight the importance of thoughtful architectural design, emphasizing the potential of green walls and specific orientations to contribute significantly to the reduction of carbon dioxide emissions in educational environments.

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