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Market Study on Protected Cultivation in Egypt: Road toward a consortium on Climate and Water Smart Protected Cultivation

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Rijksdienst voor Ondernemend Nederland (RVO)

Delphy

Market Study on Protected Cultivation in Egypt

Road toward a consortium on Climate and Water Smart Protected Cultivation

Abstract

This comprehensive study provides a detailed exploration of Egypt's strategic adoption of protected cultivation, navigating challenges such as limited water resources and technological complexities. A key case study, which includes collaborations with the Arab Organization for Industrialization (AOI) and insights from Dutch and Egyptian growers, illuminate the intricate dynamics between technology, government, and private-sector engagement. The case study highlights the landlord concept as a model, exemplified in military-led infrastructure leasing in protected cultivation. The study meticulously analyzes risks, encompassing currency fluctuations and regulatory uncertainties, emphasizing the necessity for strategic planning. Beyond the agricultural scope, the broader vision encompasses socio-economic goals such as rural development and job creation. Aligned with global trends, the commitment to producing high-quality, pesticide-free crops underscores Egypt's dedication to sustainable and healthy food production. In addition, this study highlights Egypt's adoption of protected cultivation as pivotal for enhanced food security and economic development. The insights derived from challenges and risks offer valuable guidance for stakeholders and policymakers about agriculture and sustainable development. Moreover, the project proposes a shift to a dynamic knowledge transfer program to showcase Dutch technology, providing practical insights on initiating a Partners for International Business (PIB) program to further fortify Dutch -Egyptian collaborations.

Delphy BV

Delphy BV is an independent agricultural consultancy and knowledge company headquartered in the Netherlands. Our professionals are a strong team of entrepreneurial, independent advisors with leading global knowledge and expertise, enabling us to offer optimal solutions and guide clients in realizing their ambitions. An essential component of our commitment to innovation is research. Our research locations are dedicated to the development and presentation of novel growing concepts and technical installations. In collaboration with our esteemed business partners, we conduct diverse trials, leveraging the expertise gained to empower our consultants in transferring this newfound knowledge to our clients. Our comprehensive services encompass crop advice, on-site or research unit-based applied research, tailor-made training programs, and (turnkey) projects, extending our support to farmers, agricultural companies, and investors across the globe.

Disclaimer

Attribution

This comprehensive market study, titled 'Protected Cultivation in Egypt,' was conducted by Delphy BV and commissioned by Rijksdienst voor Ondernemend Nederland (RVO). The research encompassed extensive field visits, data collection from key greenhouse industry players, and a thorough analysis of diverse factors influencing the protected cultivation market in Egypt.

We express our sincere appreciation to the organizations and companies that generously opened their doors for our field visits, sharing invaluable insights into their business models, input materials, and the challenges they navigate. Their contributions, including details on economic challenges and the complexities of the importing and exporting process, have played a pivotal role in enhancing the depth and richness of our study. We are particularly grateful for their openness and cooperation, which have significantly enriched our understanding of the protected agricultural landscape in Egypt. Special thanks are extended to Mr. Seif M. Salama, Consultant and Director at Tulima Farms; Mr. Walid Rady, Chief Executive Officer at AgriT; and Mr. Ahmed Mokhtar, Technical Office Manager at AgriT, for their direct contributions to the study. Gratitude is also extended to Rijk Zwaan Egypt, Cultivech, Nabatat, Zein for Greenhouse Construction, Hydrofarms, Bio Egypt, SEKEM, Renile, Plug'n'Grow, CherryLand for Import & Export, EGYBerry, Uniproducers, St Mark Farm, Ain Shams University, and Heliopolis University for sharing valuable information and contributing to enriching the study.

We would also like to express our gratitude to the agricultural team at the Netherlands Embassy in Cairo for their insights and support, as well as to the consortium of partners of Dutch Greenhouse Delta (DGD) and The Netherlands African Business Council (NABC) for their support within the project "Road toward a consortium on Climate and Water Smart Protected Cultivation in Egypt".

Contents

1 Introduction

1.1 Background of Agriculture in Egypt

Egypt, with its ancient agricultural legacy spanning over 8,000 years, has continually transformed its farming practices (See Figure 1). The historical dependence on the annual inundation of the Nile River laid the foundation for a flourishing agricultural civilization. The introduction of irrigation marked a significant milestone, enabling the controlled movement of water from rivers and creeks to fields through carefully designed ditches and canals, both ancient and modern, shaping its agricultural landscape. [1].

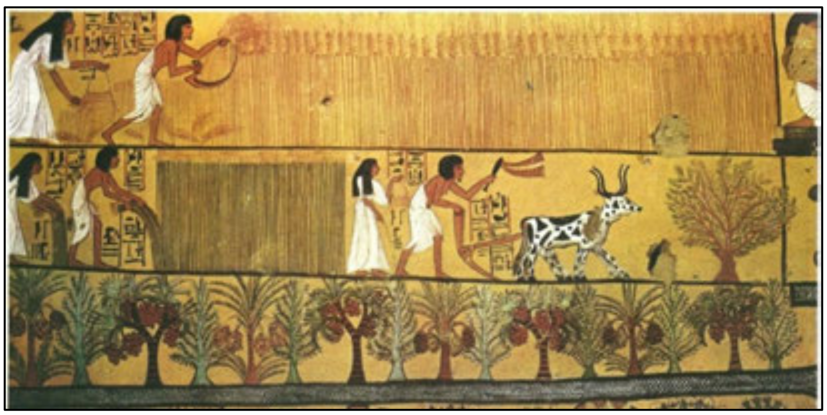

Figure 1: Agriculture in Ancient Egypt [2]

At the heart of this transformation lies the iconic Aswan Dam—a monumental feat in engineering and a crucial player in the nation's agricultural evolution. Situated on the River Nile just south of Aswan, the Aswan Dam comprises two distinct structures—the Aswan Low Dam, completed in 1902, and the more recent and extensive Aswan High Dam, completed in 1970 [3]. The Aswan High Dam represents a pivotal modern advancement aimed at increasing hydroelectric power, regulating Nile River flooding, and enhancing agricultural production [4]. Its construction effectively curbed the destructive floods that previously characterized the Nile, ensuring a stable water supply for agriculture. However, the Aswan High Dam has not been without challenges. Sedimentation in Lake Nasser, while reducing downstream flow, decreases the soil fertility in the Nile Delta [5] [6] [7].

In the contemporary context, Egypt is poised for another leap in agricultural innovation through the ambitious national project for protected agriculture. The country's objective is clear—achieving self-sufficiency in vegetables, fortifying food security, and increasing agricultural exports. Protected agriculture harnesses cutting-edge technology, utilizing greenhouses to control environmental factors, safeguarding crops from external elements, and resulting in higher yields of superior quality. This marks a modern chapter in Egypt's agricultural journey, combining ancient wisdom with technological advancements to ensure a sustainable and prosperous future for the nation's agriculture sector.

Egypt's rich agricultural heritage, contributing 11% to the GDP and employing 22% of the workforce in 2021 [8]. The sector faces formidable challenges, particularly in maintaining food security, given Egypt's heavy dependence on food imports for its population nearing 111 million [9]. This dependence renders the nation susceptible to global market fluctuations, impacting the accessibility and affordability of food [9]. This vulnerability is heightened by acute water scarcity, falling per capita availability below the "water poverty level," compounded by a growing population and climate change [10].

Despite challenges, Egypt's agriculture has expanded beyond the traditional confines of the Nile Valley and Delta, playing a pivotal role in the national economy by significantly contributing to employment, GDP, and food security. The sector's increases in wheat harvests highlight Egypt's potential not only for domestic food production but also as a potential agricultural export powerhouse. However, the sector grapples with growing water demand, a fixed supply, and risks posed by climate change, such as increased water loss and reduced crop yields. Egypt's status as the world's largest wheat importer exposes its food security to international market volatility.

The agricultural sector in Egypt benefits from inherent advantages—abundant sunlight conducive to solar-driven agricultural technologies, fertile soil in the Nile Delta, strategic location as a bridge between Africa, Asia, and Europe, and the presence of the Suez Canal enhancing export capabilities [11]. Diverse agro-climatic zones across the country allow for year-round crop production, further supported by growing domestic and regional markets, driving the imperative for agricultural expansion and modernization. Governmental focus on agricultural development, coupled with international support, creates a conducive environment for the implementation of technological advancements. Research institutions and the emergence of an Agri-tech start-up ecosystem in Egypt bring innovative solutions to the agricultural sector, contributing significantly to its growth and modernization [11].

Recognizing the urgency to meet the growing demand for food amid population expansion, the agricultural sector is compelled to embrace innovative and sustainable solutions. Hydroponics and (protected) horticulture emerge as practical approaches to circumvent soil erosion and mitigate water loss through controlled conditions. Acknowledging the imperative for efficiency and sustainability, both the public and private sectors have embarked on initiatives to revolutionize agricultural practices.

1.2 Significance of Protected Cultivation

Over the past decade, under the leadership of President Abdel Fattah al-Sisi, the Egyptian government has made significant investments in protected cultivation for fresh fruits and vegetables. Managed primarily by the National Service Projects Organization (NSPO), an entity affiliated with the armed forces, these investments aimed to ensure self-sufficiency in food production. However, the outcome fell short of financial expectations, prompting a strategic reassessment. The establishment of the National Company for Protected Crops under the NSPO signaled a move towards private sector involvement [12]. Alongside these domestic efforts, Egypt has also embraced technological advancements from diverse sources, including Chinese and Spanish technologies, to enhance its protected agricultural landscape.

In response to the financial crisis and requirements from the International Monetary Fund (IMF), the government encourages private sector companies and investors to lease and manage the established greenhouse infrastructure for the production of fresh produce for export. Currently, the technology level of greenhouses in Egypt varies from low to medium, with limited high-technology facilities. Challenges, including a shortage of skilled workers in greenhouse operations, greenhouse management issues, and financial feasibility concerns, persist.

1.3 Objectives and Scope of the Study

In light of these challenges, the Rijksdienst voor Ondernemend Nederland (RVO) has initiated a limited tender under the name “Road toward a consortium on Climate and Water Smart Protected Cultivation in Egypt” to provide an inclusive opportunity for private sector alignment, emphasizing the need for a comprehensive investigation into mapping stakeholders and devising the right approach for addressing technological issues in Egypt's greenhouse horticulture sector. Further exploration is essential to understand the dynamics, challenges, and potential interventions for a sustainable and technologically advanced greenhouse sector in Egypt. Finally, the question remains How can the Dutch horticulture sector strategically leverage the current dynamics in Egypt's evolving greenhouse industry, marked by government encouragement for private sector involvement and technological challenges, to not only enter but also contribute significantly to the sector's sustainable growth and efficiency?

This study is seeking a comprehensive answer to the posed question. By delving into the dynamics of Egypt's evolving greenhouse industry, examining the challenges and opportunities, and understanding the implications of government encouragement for private sector involvement, the study aims to provide insights that can guide strategic decisions for the Dutch horticulture sector.

1.4 Research Methodology

1.4.1 Data Collection in the Egyptian Context

The data collection process for this market study in Egypt involved a comprehensive approach, primarily centered around field visits and meetings with key industry stakeholders. The following organizations and entities were instrumental in providing valuable insights (See Figure 2).

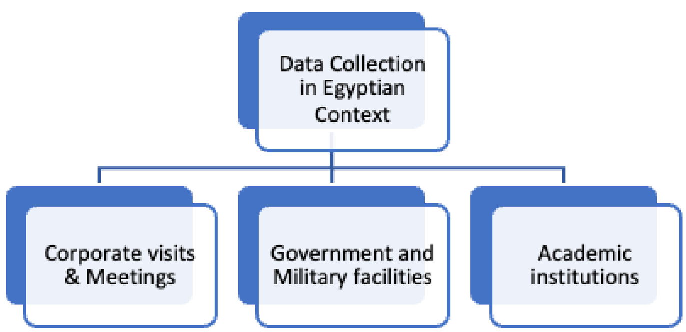

Figure 2: Schematic diagram of the data collection process

Corporate Visits:

- Rijk Zwaan Egypt;
- AgriT;
- Tulima;
- Nabatat;
- Zein for Greenhouse Construction;
- Hydrofarms;
- Bio Egypt;
- SEKEM;
- Renile;
- Plug'n'Grow;
- CherryLand For Import & Export;
- EGYBerry;
- Uniproducers;

- Cultivech.

Academic Institutions:
- Faculty of Agriculture at Ain Shams University
- Heliopolis University for Sustainable Development

The selection of organizations and entities for field visits was strategic, aiming for a representative sample that covers diverse aspects of the protected cultivation landscape in Egypt. This included visits to greenhouse farms, agricultural enterprises, military base projects, and academic institutions.

1.4.2 Limitations of the Study in the Egyptian Context

While efforts were made to obtain comprehensive data, certain limitations were encountered during the research process. These include:

1. Availability of Data: Some industry-specific data, especially pertaining to proprietary technologies and financial details of private companies, may have limitations due to confidentiality.

2. Time Constraints: The study's timeline constraints impacted the depth of field visits and meetings, potentially limiting the exhaustive coverage of all relevant stakeholders.

3. Internet-Accessible Data: Although internet-based sources, such as research reports like "Greenhouse Management and Best Practice in Egypt" by the Agriculture Research Center in Egypt and "Protected Horticulture in Egypt" by Wageningen University, were utilized, the availability and accuracy of online data were subject to the sources' reliability.

4. Statistical Data: The use of statistical data from the Central Agency for Public Mobilization and Statistics (CAPMAS) for the 2020/2021 period, published in January 2023, implies potential time lag and reliance on historical data.

5. Limited Access, Confidentiality, and Information Sharing Challenges: Access to facilities associated with military affairs is restricted due to the lengthy process of obtaining security clearance for a visit. Additionally, internet access to relevant data is very limited. Nevertheless, we have successfully connected with companies that either operate or lease some of the military-protected agriculture facilities. Moreover, we attempted to reach out to certain companies; however, our efforts were hindered by the confidentiality

of their data. The limitations originate from the restricted sharing of information, which is governed (generated) by the principles of business confidentiality and cultural considerations.

Despite these limitations, the research methodology aimed to provide a comprehensive and insightful analysis of the protected cultivation market in Egypt. The combination of field visits, stakeholder meetings, and diverse data sources enhances the reliability and relevance of the study's findings.

2 Agricultural Landscape in Egypt

2.1 Land Use in Egypt

Egypt exhibits a diverse range of land use patterns, encompassing agricultural land, barren land, urban areas, water bodies, and natural vegetation. The agricultural land is primarily concentrated in the Nile Valley and Delta regions, which have historically been cultivated for centuries (known as old land). These regions, as shown in Figure 13, benefit from fertile soils and a consistent water supply from the Nile River, rendering them exceptionally conducive to agricultural practices. Figure 3 provides a visual representation of Egypt's land use, with agricultural land denoted by

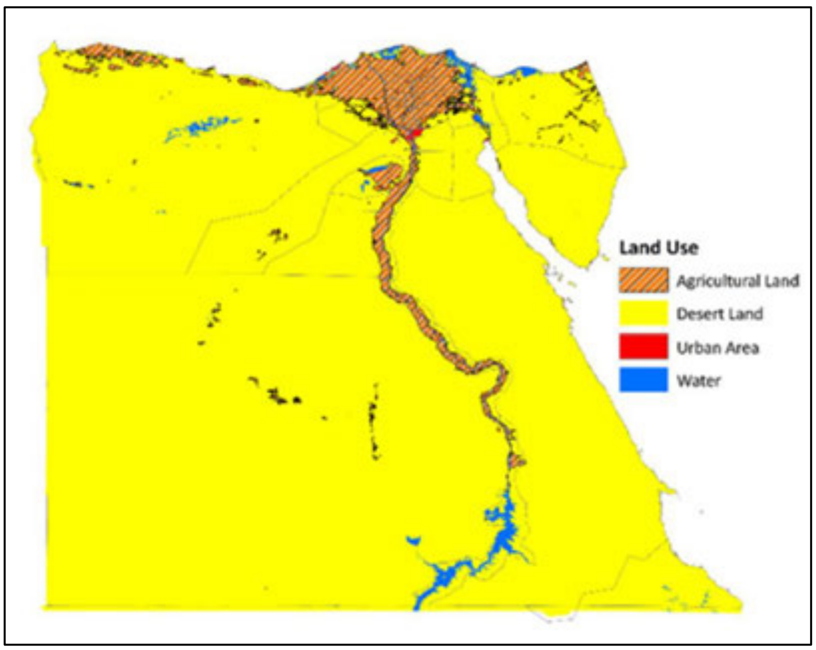

Figure 3: Land use in Egypt

the hatched pattern, desert areas highlighted in yellow, urban zones depicted in red, and water distribution shown in blue. The predominant cultivation of agricultural land in the Nile Valley and Delta by smallholder farmers underscores the importance of inclusive land-use policies. This approach, initiated by the Free Officers after the 1952 Revolution, aimed to broaden opportunities and break the monopoly of a narrow elite [13]. After the 1952 revolution, the government redistributed rich agricultural lands from large areas to farmers, withholding five acres per the Agrarian Reform Law [14]. Subsequently, family inheritance laws led to the subdivision of these smallholdings into even smaller plots, resulting in land fragmentation over the years. The challenge of land fragmentation, with small plots dispersed among various owners, has driven investors to consider new development areas in the desert. This trend allows for more comprehensive projects, overcoming the limitations posed by fragmented land. Investors are drawn to these new development areas as they offer the opportunity to implement larger-scale agricultural projects with greater operational efficiency and potentially higher returns.

2.2 Climate Conditions in Egypt

Egypt, being predominantly arid and semi-arid, is characterized by a desert climate. However, there are notable climate variations across different regions of the country. As a result, six locations have been chosen to represent the diverse climate conditions in Egypt.

As showed on climate data (See Figure 4) for various governorates in Egypt reveals distinctive regional patterns. Coastal areas, such as Marsa Matrouh, exhibit moderate temperatures with limited precipitation and moderate humidity. Inland regions, including Dakahlia and Giza, experience minimal rainfall, moderate temperatures, and decreasing humidity levels. As one moves southwards, towards Minya, Qena, and Aswan, temperatures rise significantly, reaching high peaks in summer, accompanied by low precipitation, low humidity, and abundant sunshine. These variations emphasize the diverse climatic conditions across different parts of Egypt. This highlights the importance of climate-controlled greenhouses in providing optimal growing conditions despite these climatic challenges.

Figure 4 Selected locations have been chosen to represent the diverse climate conditions.

2.2.1 Natural radiation

Substantial variations in solar radiation levels are evident across the Giza, Minya, Marsa Matrouh, Dakahlia, Qena, and Aswan Governorates in Egypt (Figure 5), as illustrated in the provided data. This diverse range of sunlight exposure has significant implications for agricultural practices within each region.

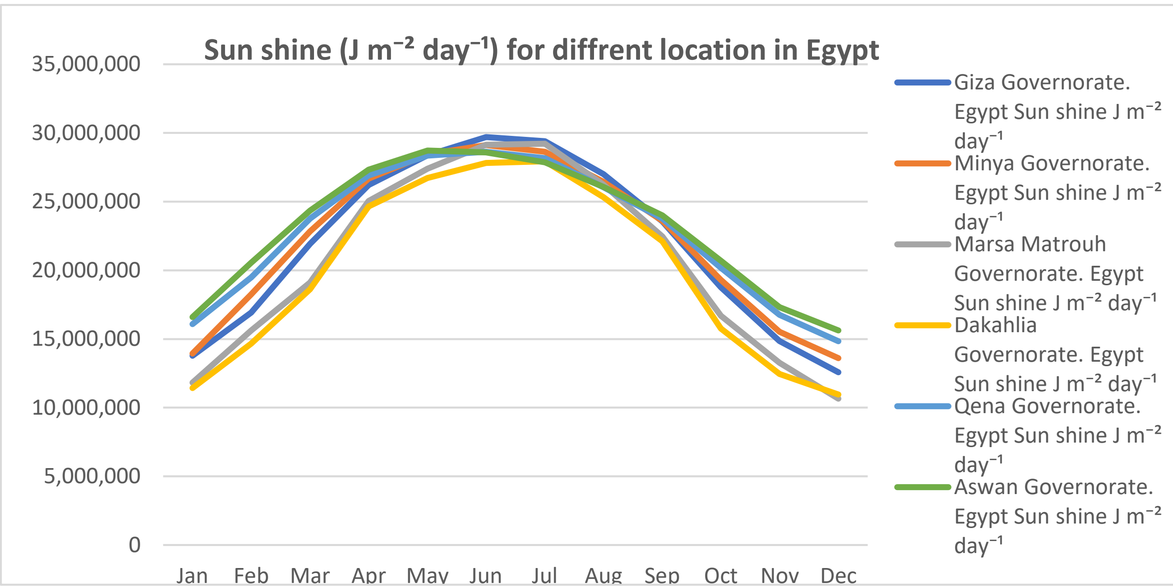

Figure 5: Solar radiation levels per month per governorate [23]

Examining the solar radiation levels during the summer months in these governorates, it becomes apparent that the intensity varies, with some regions experiencing higher levels than others. Notably, the data suggests that, for certain governorates, solar radiation surpasses a threshold of 20,000,000 J/m2, indicating that light is not a limiting factor during this period.

The natural quantity of solar radiation holds paramount importance in greenhouse cultivation, serving as a crucial source for both plant growth and heating. As the recommended value should be 20,000,000 J/m2, from this perspective, it is evident that certain regions, such as Qena and Aswan, exhibit consistently higher total radiation sums than others, potentially providing favorable conditions for agricultural production [24].

In the context of these Egyptian governorates, it is noteworthy that additional light in vegetable production may not necessarily lead to increased yields after a certain threshold, particularly beyond 25,000,000 J/m2 Per 24 hours from May 1st. Moreover, the data implies that too much direct radiation can potentially result in Sunscald (burn marks) on the fruit, emphasizing the need for careful management of light exposure, particularly in crops like bell peppers.

The consideration of shading screens to reduce sunlight in the summer months is very beneficial to achieve desired crop quality or to extend the production season [24].

2.2.2 Temperature

Optimal temperature control is essential for successful protected cultivation in greenhouses, and understanding the climatic conditions in Egypt is crucial for optimizing agricultural practices [23]. Figure 6 shows the maximum and mean temperatures recorded for each month in Giza, Minya, Marsa Matrouh, Dakahlia, Qena, and Aswan Governorates [24].

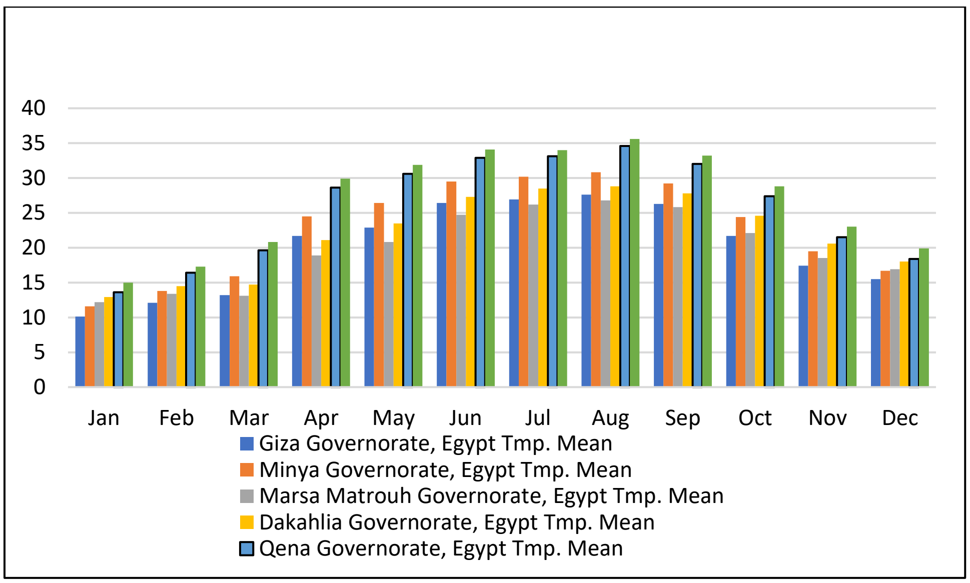

Figure 6: The maximum and mean temperatures recorded for each month per governorate.

For protected cultivation, the most favorable temperatures for vegetable growth generally range between 15 to 25°C, with the outside temperature ideally maintained between 21 to 24°C, as recommended by Joe, a greenhouses management expert. It is important to note that extreme inside temperatures can be detrimental to crops, resulting in reduced production. Greenhouses provide an effective means of temperature control; however, challenges may arise, especially during periods of extreme heat outside (> 30°C), leading to potential temperature spikes inside the greenhouses [24].

Prolonged exposure to temperatures higher than 25°C can negatively impact production, particularly in crops like tomatoes, where higher temperatures can cause fruit-setting problems. Additionally, outside temperatures exceeding 40°C can pose challenges for cultivating vegetables in greenhouses.(Figure 7)outlines the maximum temperatures recorded for each month in Giza, Minya, Marsa Matrouh, Dakahlia, Qena, and Aswan Governorates [24].

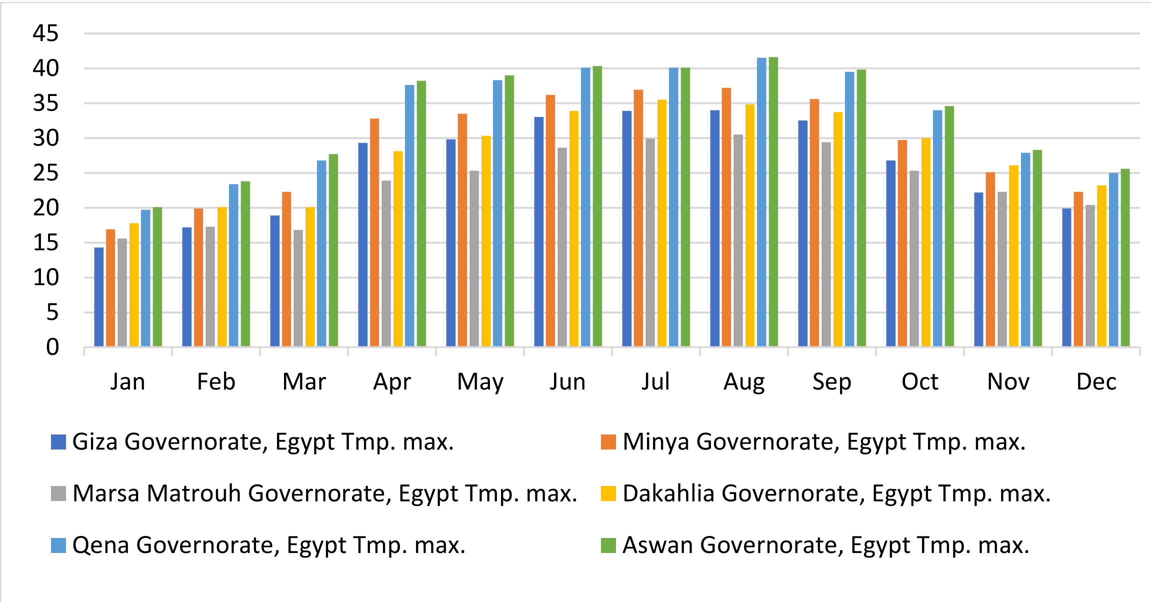

Figure 7: The maximum temperatures recorded for each month per governorate.

The temperature data highlights variations across regions, from the coastal Marsa Matrouh to the southern Aswan Governorate. To counteract high temperatures, implement cooling systems, such as Pad and Fan greenhouses or greenhouses with shading screens & high-pressure misting systems, both these systems will not only reduce the temperature but will also increase the humidity to better levels as explained below [24].

2.2.3 Humidity

Protected cultivation in greenhouses is an effective approach for maintaining the optimum relative humidity (RH) range of 60 to 80% required for vegetable growth (recommended by the author). In Egypt, where agricultural activities are concentrated along the Nile River, creating unique microclimates, greenhouse cultivation becomes even more crucial (Figure 8).

During summer, growers in Egypt may encounter low daytime humidity levels, which can stress plants and lead to suboptimal growth conditions. This can be mitigated by utilizing greenhouses, where humidity levels can be controlled and maintained within the desired range. Greenhouses provide a protective environment that helps retain moisture and prevent excessive evaporation, ensuring plant health and optimizing growth. Conversely, winter nights in Egypt can experience excessively high humidity levels. This heightened humidity increases the risk of mold and pathogen growth, posing a threat to plant health and crop yields. Greenhouses equipped with proper ventilation systems and climate control mechanisms can regulate humidity levels and reduce the risk of disease outbreaks, creating a favorable environment for crops.

Figure 8: High humidity fog is prevalent in the Egyptian winter.

The relative humidity data for different governorates in Egypt (Figure 9) further emphasizes the importance of greenhouse cultivation. For example: Giza Governorate witnesses a fluctuation in relative humidity, ranging from 55.8% in January to 57.8% in December. In Minya Governorate, the relative humidity spans from 44.4% in February to 48% in December. Marsa Matrouh Governorate exhibits a broader range, varying from 42.2% in April to 60.6% in December.

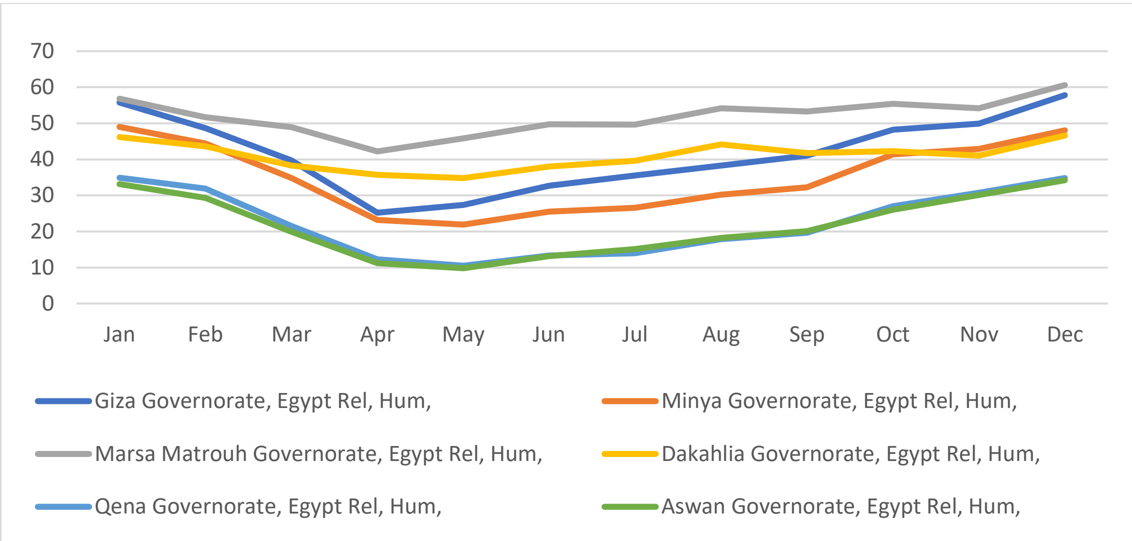

Figure 9: The relative humidity data per governorate.

These variations in relative humidity levels underscore the importance for growers to adapt their greenhouse practices accordingly. By utilizing innovative climate control solutions tailored to Egypt's unique conditions, growers can strike a balance between providing open environments for cooling purposes and maintaining optimal humidity [24].

2.3 Egypt's Water Resources

Egypt has limited natural water resources. Nile River, groundwater from both renewable and non-renewable (fossil) aquifers, sporadic rainfall along the Northern Coast, and flash floods in the Sinai Peninsula are available freshwater resources throughout the country.

As shown in Figure 10, since 1997 Egypt fell below the international standard of water scarcity 1,000 m3/person/year. The following figure highlights various contributing factors according to the Egyptian Ministry of Irrigation and Water Resources, including rapid population growth, climate change, the Grand Ethiopian Renaissance Dam (GERD), and inappropriate water resource utilization, all impacting Egypt's water sources. To guarantee Egypt's water security and the country's population in the future, all this calls for a strict set of rules based on empirical research [15].

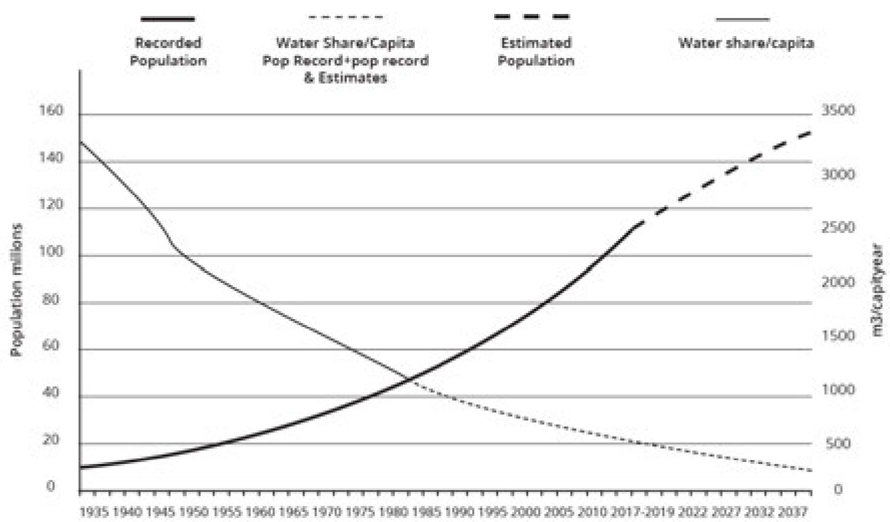

Figure 10: Population vs water records and estimates (1935-2037) [15]

Error! Reference source not found. shows the water supply from each water source and water concumpation by each sector in Egypt in year 2010, as given in the 2050 water strategy of the Ministry of Water Resources and Irrigation [15]. Egypt is currently using agricultural wastewater to meet its water demand, which is currently more than 20% greater than its available resources. Around 83 %of the water from the Nile is used for agriculture, with the remaining 2 and 5 percent going to municipal and industrial purposes, respectively. Crops retain excess water, infiltrating through the soil and drainage system [15].

Table 1: Egypt's Water Uses and Available Resources (MWRI, 2016)

Water supply	Volume (billion m3/year)
Conventional water sources	
River Nile (AHD)	55.5
Deep groundwater	2
Rainfall and flash floods	1.3
Desalination	0.2
Total supply conventional	59
Unconventional sources	
Shallow groundwater (Delta)	6.2
Reuse of agricultural drainage water	16
Total supply nonconventional	22.2
Total water supply	81.2

Egypt now experiences a 13.5 billion cubic meter per year (BCM/yr) water shortage, and this number is predicted to keep rising. As mentioned before that, currently, drainage reuse is used to make up for this water shortage, which negative impact the quality of the water [23].

In this context, protected cultivation offers a sustainable approach to agriculture, optimizing water usage while maximizing crop productivity. By implementing controlled environments in greenhouses, growers can minimize water wastage, reduce reliance on conventional irrigation methods, and mitigate the negative impacts of water scarcity on agricultural production. Thus, embracing protected cultivation practices becomes essential for Egypt's agricultural sustainability amidst growing water challenges.

Groundwater is Egypt's second source of freshwater, contributing around 12% of the nation's total water supply [16]. Groundwater resources in the Nile valley and delta and desert aquifers are few and difficult to replenish [17]. Illustrated in Figure 11 and detailed in **Error! Reference source not found.** are Egypt's six primary aquifer systems [18]. The effects of the mineral components on soil and plant life determine whether water is suitable for irrigation.

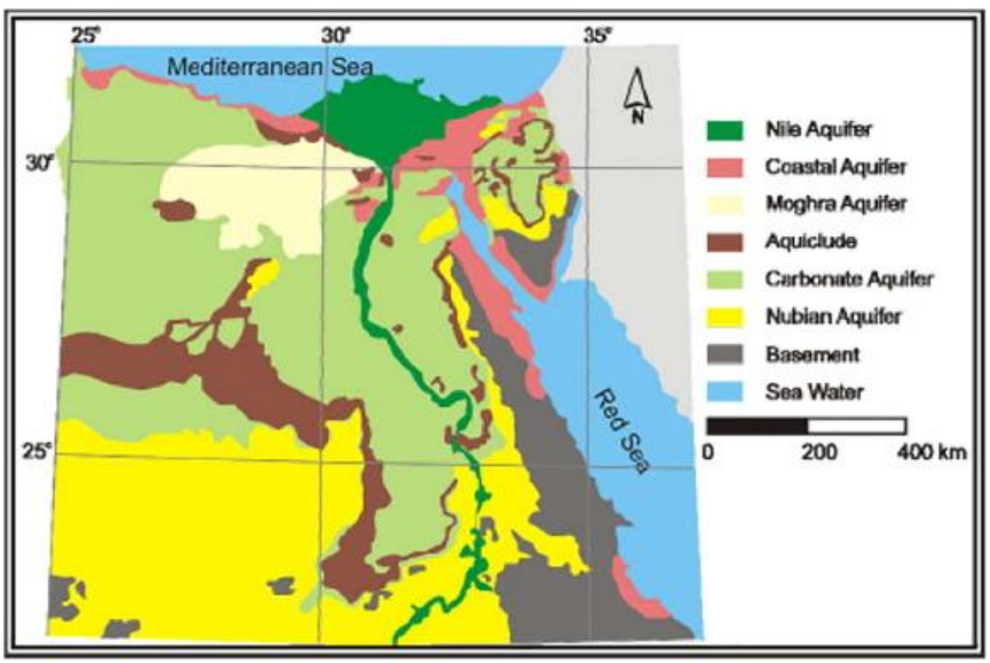

Figure 11: Aquifer systems in Egypt [18]

Table 2: The six main aquifer systems in Egypt

The Nile Aquifer System	The Nile River, its tributaries, and channels, as well as extra irrigation water, infiltrate these aquifers and replenish them. According to abstraction rates and aquifer accessibility, the Nile Valley and Delta aquifer systems—which make up over 87% of the country's utilised groundwater—are the most significant aquifers in Egypt [19].
The Moghra aquifer system	Takes up a significant part of the Northwestern Desert. The 50,000 km2 Moghra Aquifer, which extends from Wadi Farigh to the Qattara Depression, is reachable at the surface. The thickness of the aquifer, which dips beneath more recent layers to the north, ranges from 75 to 700 meters [20].
The Coastal aquifer system	Water is supplied to several coastal locations in the Sinai Peninsula and Western Desert through the small-scale exploitation of shallow wells at abstraction rates of under 100 MCM/y. Depending onssss their position and hydrological environment, the coastal aquifers are refilled by meteoric water, upward leakage, or cross flow from the underlying and adjacent aquifers.
The Nubian Sandstone Aquifer System	Stretches from Egypt into Libya, Chad, and Sudan. It was formed throughout the Paleozoic and Mesozoic periods, covering 2 million km2. [21]. This aquifer, which contains vast quantities of groundwater, is without a doubt the most significant source of fresh water outside the Nile system. [22].
The fractured carbonate aquifer system	Located in the central part of the Western Desert in central Sinai. It belongs to the Eocene period
The fissured crystalline basement aquifer system	Located in the Eastern Desert and South Sinai and underlies the NSAS. It has a higher productivity and shallow depth to water table. It belongs to the Precambrian period

As shown in Figure 12, the intensity of precipitation rapidly drops in places distant from coastal areas and becomes extremely rare in Upper Egypt (2 mm/yr to nil) [23]. The Sinai Peninsula, the Western and Eastern deserts, and other regions may experience prolonged periods of utter dryness, yet sporadic, abrupt, high-intensity rainstorms have the potential to cause devastating flash floods. Rainfall harvesting, a low-cost method, is crucial for capturing surface water for irrigation along the Mediterranean coast, where there is no access to Nile River water and only a small supply of groundwater. The process of groundwater recharging might be improved to some extent by drilling shallow recharge wells [24]. The total amount of rainwater is about one billion m3 per year [25].

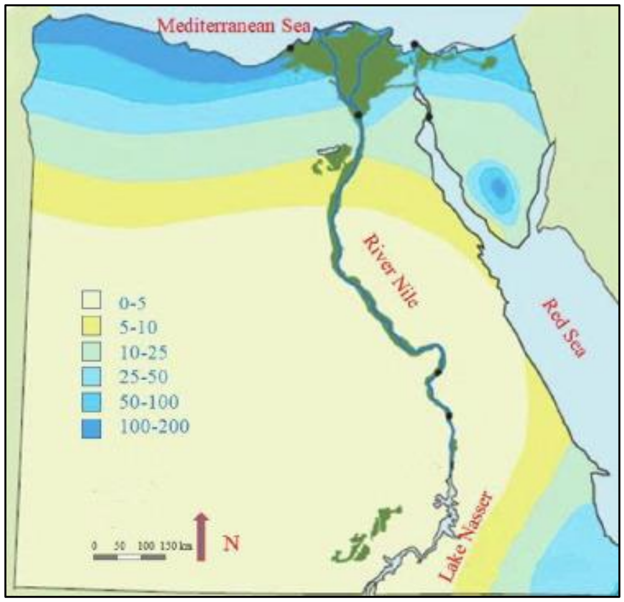

Figure 12: The intensity of precipitation (mm/yr)

2.4 Investment Climate and Legislative Reforms and Agricultural Transformations

Egypt's investment landscape is undergoing significant transformation through legislative reforms, combined with ongoing social and economic challenges [26]. Egypt has exhibited robust growth in recent years, although the pandemic has tempered this progress. Notably, in 2020, Egypt saw its first decline in poverty rates in almost two decades [26]. The proportion of the population living below the national poverty line decreased from 32.5% in 2017/2018 to 29.7% in 2019/2020, with a similar drop observed in extreme poverty.

In relation to these developments, public spending on essential services has seen substantial growth, with increased allocations for healthcare, logistics, and education sectors. The introduction of Investment Law No. 72 of 2017 and its Executive Regulations signifies a monumental shift in Egypt's investment landscape, aiming to foster a conducive environment for investment while aligning with the nation's development goals [27]. However, despite these advancements, some companies have reported challenges in accessing information about the implementation of this law, particularly because it is new for some individuals within the government. Nonetheless, the government remains committed to creating a business-friendly environment. The ongoing efforts include streamlining procedures, providing investment

guarantees and incentives, and promoting governance in key sectors, particularly in agriculture [27].
Egypt's substantial and skilled labor force, exceeding 29 million, with 60% under the age of 30, presents a dynamic workforce crucial for attracting investments [8]. However, in high-technology agricultural sectors for example, specialized training becomes imperative to meet the evolving demands of the industry. Therefore, investing in training programs and vocational education tailored to the needs of the agricultural sector is essential to ensure that Egypt's labor force remains competitive and capable of driving innovation and productivity in high-tech agriculture.

In addition to labor force, competitive tax rates, notably a 25% income tax rate for more than 400,000 EGP income and a 27.5% income tax rate for more than 1,200,000 EGP income, position Egypt as potentially a cost-effective investment destination [28]. The availability of abundant natural resources provides diverse investment opportunities, particularly in sectors such as agriculture, mining, and renewable energy. Furthermore, extensive infrastructure development, including transportation networks, contributes to improving logistics and connectivity, thereby facilitating successful business operations in the country [29].

Egypt's strategic location as a trade hub is reinforced by its memberships in key trade blocs such as COMESA and GAFTA, which facilitate efficient import-export activities. The Egypt-European Union Association Agreement plays a crucial role in offering preferential access to EU markets, reducing tariffs, and simplifying customs procedures, ultimately enhancing market access for businesses [29] [30].

Despite these favorable conditions, the agriculture sector in Egypt is undergoing transformative changes to address challenges posed by climate change. Innovative solutions, such as 'smart agriculture' incorporating AI, robots, sensors, and sustainable practices like soilless and vertical farming, are being adopted. The shift from traditional flood to efficient drip irrigation signifies a move towards sustainable farming, presenting potential solutions to existing challenges. This transformative approach underscores Egypt's commitment to creating a resilient and forward-looking agricultural sector capable of addressing evolving challenges and contributing to sustainable economic development. Egypt has implemented a comprehensive set of strategies and initiatives to address climate change and reduce disaster risks as shown in Figure 13.

These strategies cover key sectors such as agriculture, water resources, health, urban areas, and tourism. Notable strategies include the National Strategy for Climate Change Adaptation, and the Climate Change Adaptation Strategy for Water Resources [31]. The Sustainable Agricultural Development Strategy, launched in 2009, focuses on modernizing Egyptian agriculture for food security and improved rural livelihoods. This involves increasing agricultural productivity, expanding cropping areas with high-yield crops, and enhancing the efficiency of irrigation water use to reach 80%.

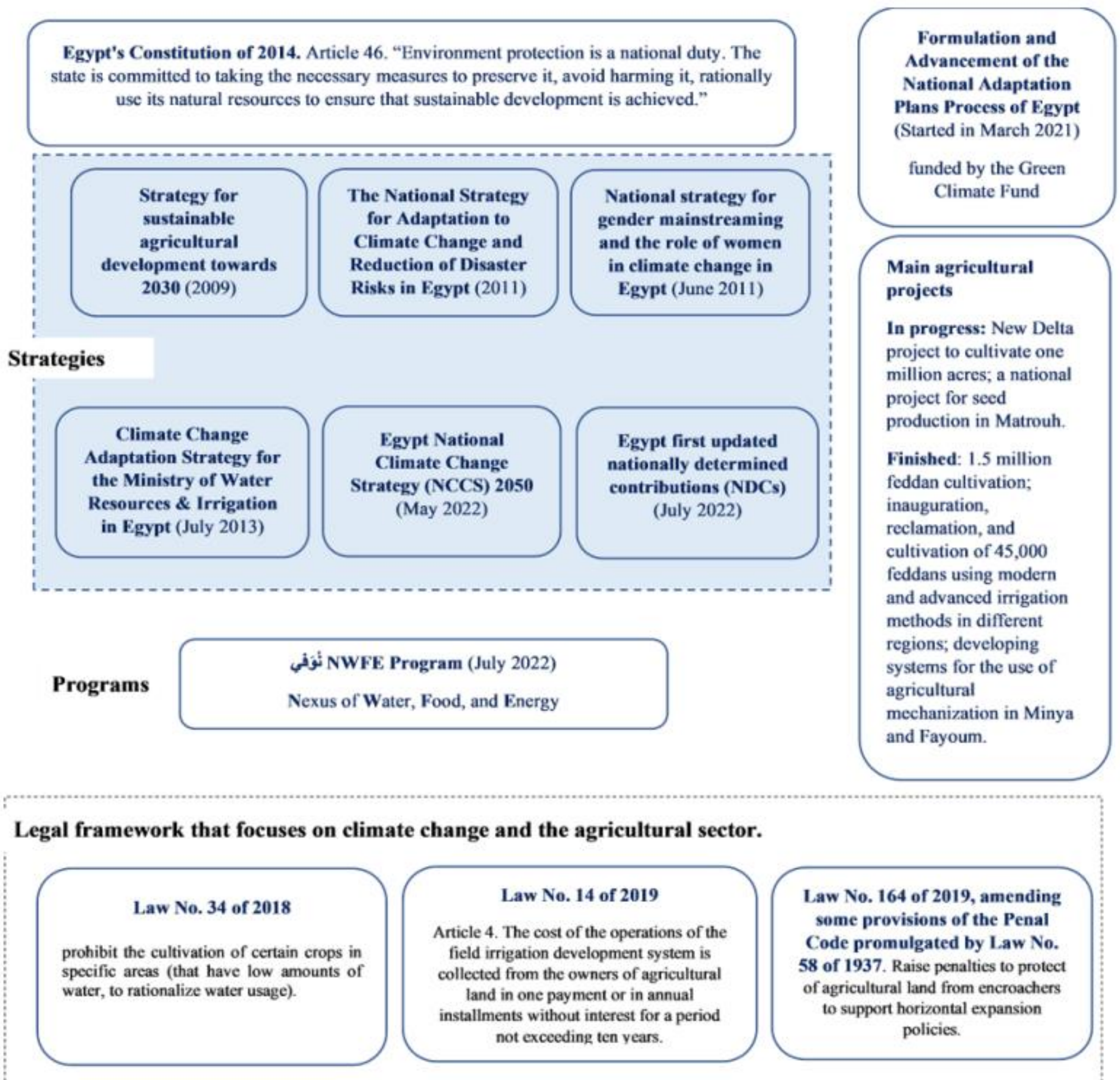

Figure 13: The main past and current governmental policies and approaches to adapting agriculture to climate change [31]

In May 2022, Egypt launched the Egypt National Climate Change Strategy (NCCS) 2050, emphasizing a long-term commitment to mitigating greenhouse gas emissions and adapting to climate change, particularly in the critical agricultural sector. However, the updated Nationally

Determined Contributions (NDCs) in July 2022 highlight the financial challenges associated with achieving ambitious climate targets, explicitly stating that implementation depends on adequate international finance [32].

A portfolio of around USD $500 million worth of national-level projects is currently underway across 27 governorates, with a focus on agriculture. Noteworthy projects include the National Canal Lining Project, one of the largest water initiatives in Egypt, and the NWFE Program, a National Platform for Green Projects connecting water, food, and energy initiatives [33].

Additionally, the government initiated the Formulation and Advancement of the National Adaptation Plans Process in March 2021, aiming to enhance institutional and technical capacity for climate resilience. The NWFE Program, launched in July 2022, focuses on promoting green development projects aligned with the National Strategy for Climate Change 2050, addressing both mitigation and adaptation to climate change [32] [33].

2.5 Gender

In Egypt, women have historically played a crucial yet often overlooked role in agriculture, contributing significantly to both food production, food processing and household food security, whether through paid or unpaid labor [34]. Despite their important involvement, with over 50% of the total labor force in agriculture, women remain largely invisible in national statistics. This invisibility is caused by cultural and social challenges, where it is difficult to accurately capture data on the specific contributions of women. In many cases, men are the ones who speak for the household and are more visible, making it challenging to estimate the true extent of women's involvement [34]. Traditionally, Egyptian farmers, particularly women, have been among the lowest-income earners and least educated members of society. To cope with economic challenges, families have relied heavily on home-based production methods to reduce household expenses and promote self-sufficiency. Each family member, regardless of gender or age, has been assigned specific roles aimed at maximizing productivity and minimizing dependence on external goods [34].

Inclusivity is a key aspect, within the National Strategy for Gender Mainstreaming emphasizing gender equality in adaptation and mitigation efforts. The strategy is designed to empower women in agriculture by amplifying their voices, facilitating access to modern agricultural technologies, and ensuring their effective participation in decision-making processes. Through these initiatives, the strategy seeks to create a more equitable and inclusive agricultural sector, acknowledging the vital role that women play in sustainable and resilient agriculture.

2.6 Egypt's Business Landscape:

Egypt grapples with the repercussions of a collapsing Egyptian pound (Figure 14), and foreign currencies are increasingly scarce [35]. Despite these economic challenges and the existence of a black market for foreign currencies, selling them at notably higher prices than the official exchange rate, there is a cautious exploration of Egypt's current economic landscape as a potential prospect for businesses and investors. This perspective is shaped by various strategic factors that have influenced Egypt's evolution over recent decades. At the core of this appeal lies Egypt's cross-continental positioning, acting as a trade bridge to Africa, the Middle East, Asia, and Europe. Infrastructure projects like the Suez Canal contribute to this image, positioning Egypt as a hub for the flow of goods, services, and investments across vital regions. Demographic shifts, characterized by significant population growth, add a layer to Egypt's attractiveness, creating a potentially lucrative domestic consumer market. While these shifts are acknowledged, it's essential to navigate the challenges posed by economic instability.

Egypt's engagement with the IMF has been instrumental in shaping its economic policies. Notably, on December 16, 2022, the IMF Executive Board approved a 46-month arrangement under the Extended Fund Facility (EFF) for Egypt, totalling approximately US$3 billion. Moreover,

Figure 14: US Dollar to Egyptian Pound Exchange Rate Chart (5 years) [35]

the EFF is expected to catalyse additional financing from Egypt’s international and regional partners, further supporting the country's economic objectives and development efforts. The IMF support inspires confidence among stakeholders in the Egyptian business community, stability and facilitating investment opportunities.

The analysis of Egypt's business appeal is presented with a measured tone, recognizing both strengths and challenges. The discussion emphasizes solid structural foundations but acknowledges the economic realities and uncertainties that Egypt faces. In conclusion, while Egypt positions itself as a potentially business-friendly destination, the overall assessment considers the nuanced interplay of advantages and challenges, urging a cautious approach for businesses and investors.

3 The Egyptian Protected Cultivation

Protected cultivation has emerged as a cornerstone of Egypt's agricultural landscape, fostering innovation and sustainability in crop production. According to data from the annual bulletin of statistical crop area and plant production for the 2020/2021 period, as reported by the Central Agency for Public Mobilization and Statistics in January 2023, the country boasts a diverse array of greenhouses across various governorates [36].

Figure 15 illustrates a comprehensive overview of greenhouse distribution, (Table 3) showcasing the substantial range from as low as 32 greenhouses in Matruh to an impressive 53,268 in Dakahlia. Noteworthy concentrations are observed in governorates such as Sharkia, Gharbia, and Ismailia, reflecting a strategic emphasis on protected cultivation. In total, Egypt hosts an extensive network of 108,947 greenhouses, underscoring the sector's vitality and its pivotal role in ensuring year-round, controlled-environment crop production [36].

This data illuminates the concerted efforts to leverage modern agricultural practices, fostering increased productivity and resilience in the face of evolving environmental and economic challenges [36].

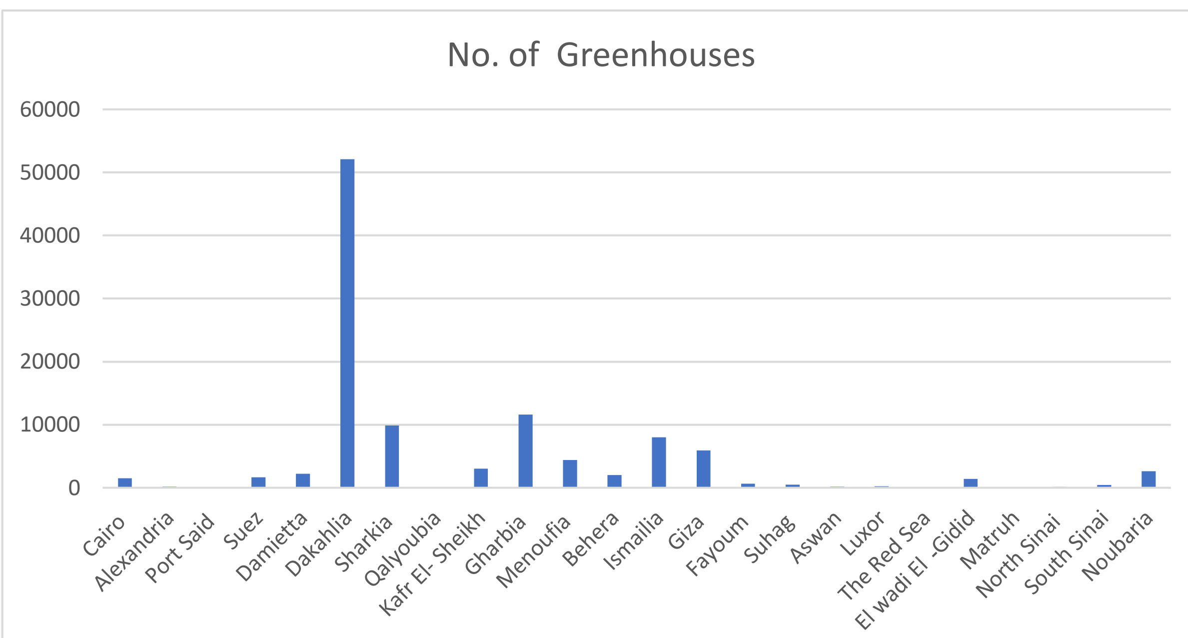

Figure 15 Total Number of Greenhouses per Governorates 2020/ 2021 [36]

Table 3 Total Number, Area, and Production of Greenhouses per Governorates 2020/ 2021 [36]

Number	Governmenate	Production (tons)	Area (m2)	No. of Greenhouses
1	Cairo	5867	634325	1527
2	Alexandria	400	88200	180
3	Port Said	36	9600	12
4	Suez	3643	595992	1656
5	Damietta	7227	1009912	2220
6	Dakahlia	192919	20260940	52098
7	Sharkia	51098	5873234	9888
8	Qalyoubia	486	50850	111
9	Kafr El- Sheikh	10091	966968	3005
10	Gharbia	42578	2862004	11615
11	Menoufia	11703	1368970	4418
12	Behera	32140	1245788	2029
13	Ismailia	32203	4104450	8018
14	Giza	35112	3183095	5947
15	Fayoum	1470	333025	620
16	Suhag	784	197067	469
17	Aswan	262	115997	172
18	Luxor	1107	81200	234
19	The Red Sea	460	39200	85
20	El wadi El. Gidid	3536	455680	1424
21	Matruh	133	26040	32
22	North Sinai	389	42350	121
23	South Sinai	2056	184632	443
24	Noubaria	18892	1311500	2623
Total		**454592**	**45041019**	**108947**

Table 4 provides a comprehensive overview of vegetable production in Egypt, showcasing the types of crops cultivated, their production quantities, yield per square meter, cultivated area, and the number of greenhouses utilized for their cultivation. Among the notable crops, tomatoes emerge as a significant contributor to agricultural output, with a production of 47,810 tons and a yield of 12.99 kg/m2 across an expansive cultivated area of 3,681,175 square meters spread over 7,248 greenhouses. Eggplants, squash, cabbage, and green beans also feature prominently, each with substantial production figures and varying yields per square meter. Cucumber production has a high production amount of 269,686 tons, covering an extensive area of 24,524,493 square meters utilizing 64,122 greenhouses. Peppers, including both regular and colored varieties, also make a significant contribution to vegetable production in Egypt, with production quantities exceeding 100,000 tons for each type. The table underscores the diversity and scale of vegetable cultivation in Egypt, highlighting the country's agricultural prowess and its importance in meeting domestic demand and contributing to export markets [36].

Table 4: Total Number, Area, Yield and Production of Greenhouses [36]

Type	Type (Arabic)	Production (Ton)	Yield (kg/ m2)	Area (m2)	No. Greenhouses
Tomato	طماطم	47810	12.99	3681175	7248
Eggplant	باذنجان	2535	10.22	248135	478
Squash	كوسة	1747	5.49	318017	725
Cabbage	كرنب	2521	10.16	248120	465
Green Beans	فاصوليا خضراء	7587	7.46	1016385	2258
Green Peas	بسلة خضراء	100	3.97	25200	50
Jews	ملوخية	267	8.29	32200	92
Okra	بامية	4	2.52	1589	5
Tomato Cherry	طماطم شيرى	1545	9.04	171000	613
Pumpkin	قرع عسلى	80	25.4	3150	4
Egyptian Leek	كرات	434	18.72	23188	62
Broccoli	بروكلى	1	1.92	520	2
Cauliflower	قنبيط	4	5.13	780	3
Strawberry	فراولة	2990	31.18	95910	230
Lettuce	خس	629	14.58	43144	67
Cucumber	خيار	269686	11	24524493	64122
Pepper	فلفل	111593	8.05	13863723	30562
Pepper's Coular	فلفل ألوان	4142	6.54	633527	1654
Papricka	فلفل حلو	251	11.13	22548	64
Chilly	فلفل حار	666	7.55	88215	243

Table 5 provides a detailed breakdown of Tomato, Pepper and cucumber production across various governorates in Egypt. Dakahlia emerges as a major contributor to vegetable production, particularly in tomato cultivation, with 1,540 tons produced over 162,000 square meters utilizing 444 greenhouses [36].

Table 5: Number, Area and Production of Greenhouses of Tomatoes, Pepper and Cucumber, according to Governorates

Governorate	Tomato			Pepper			Cucmber		
	Production (Ton)	Area (m2)	No. Greenhouses	Production (Ton)	Area (m2)	No. Greenhouses	Production (Ton)	Area (m2)	No. Greenhouses
Cairo	800	71400	200	0	0	0	2150	189000	380
Alexandria	350	68600	140	20	9800	20	30	9800	20
Port Said	9	2400	3	6	1600	2	6	1600	2
Suez	17	3960	11	11	2880	8	27	5592	16
Damietta	0	0	0	0	0	0	7227	1009912	2220
Dakahlia	1540	162000	444	66047	8037700	20101	125332	12061240	31553
Sharkia	2854	236860	456	20200	3161671	4583	29594	2395471	4648
Qalyoubia	124	12735	23	155	16510	36	91	10240	26
Kafr Sheikh	0	0	0	48	7268	24	10043	959700	2981
Gharbia	0	0	0	329	23183	94	41834	2808854	11438
Menoufia	1851	147120	613	896	92841	370	6903	876246	2566
Behera	7706	320082	411	6970	268291	444	12434	439483	758
Ismailia	7694	1071000	1838	8051	1169700	2598	16025	1770300	3397
Giza	18375	1164475	2165	1898	353950	671	8801	914655	1709
Fayoum	11	3500	5	415	102200	195	884	186900	352
Suhag	0	0	0	157	68999	163	627	128068	306
Qena	0	0	0	0	0	0	0	0	0
Aswan	42	18032	28	2	525	1	88	40264	57
Luxor	0	0	0	600	50400	150	507	30800	84
The Red Sea	177	10200	18	76	6950	17	97	10200	23
Wad Gidid	869	106240	332	295	61440	192	1642	198720	621
Matruh	75	14925	15	28	6259	7	30	4856	10
North Sinai	35	2800	8	76	6300	18	0	0	0
South Sinai	337	32821	74	475	25256	98	628	58092	146
Noubaria	5006	232000	464	5638	381000	762	6286	396500	793

3.1 Stakeholder Analysis for The Egyptian Protected Cultivation Market

The Egyptian protected cultivation market involves a diverse array of stakeholders, each contributing unique perspectives and capabilities to the sector's development.

Figure 16: Analysis of stakeholders

3.1.1 Government Entities

a. Ministry of Agriculture and Land Reclamation: Sets agricultural policies, regulates practices, and provides support to farmers.
b. Ministry of Water Resources and Irrigation: Critical for managing water resources, a key element in protected cultivation.
c. Ministry of Trade and Industry: Facilitates trade policies that can affect the export of agricultural products.

Interests: Food security, economic growth, sustainable agriculture.
Influence: High; policy-making and regulatory power.
Potential for Collaboration: Policy support, subsidies, and training programs.

3.1.2 Local Farmers:

They are the backbone of the industry, whether they are small-scale farmers or part of larger agricultural enterprises. They are the primary producers and are directly affected by market demands, climate conditions, and government policies.

a. Small-Scale Farmers: Key stakeholders in adopting protected cultivation methods.
   i. Hydroponics:
      1. *Nabatat*: https://www.nabatat-farm.com/
      2. *Tulima Farms*: https://www.tulimafarms.com/
      3. *AlGhanim* Agriculture: https://www.alghanimagri.com/
      4. *PlugnGrow*: https://www.plugngrow.me/
      5. Egyptian Hydrofarm: https://www.facebook.com/p/Hydrofarms-Agri-Solutions-100064184676375/
   ii. Protected Cultivation:
      1. *Sara's Organic Food:* https://www.sarasorganicfood.com/
   iii. Open Field:
      1. *Linah Farms*: https://linahfarms.com/
b. Large Agribusinesses: Have the capital and infrastructure to invest in high-tech protected cultivation.
   i. Open Field:
      2. *Maghrabi Agriculture:* https://www.magrabi-agriculture.com/
      3. *MAFA Organic:* https://mafaorganic.com/
      4. *Belco:* https://www.belco.com/
      5. *Agreen:* https://www.elbannagroup.com/
   ii. Protected + Open Field:
      6. *Dina Farms:* https://www.dinafarms.com/
      7. *El Roda:* https://www.elroda.com/
      8. *El Aguizy Farms*: https://www.elaguizyfarms.com
      9. *Sekem Farms*: https://www.sekem.com

Interests: Increased productivity, profitability, and sustainability.
Influence: Moderate; direct impact on agricultural practices and outputs.
Potential for Collaboration: Adoption of new technologies, feedback on policy effectiveness.

Figure 17: Tulima Farms Container Farming Unit (High tech farming in Egypt)

3.1.3 Private Sector Suppliers:

Companies that provide seeds, fertilizers, pesticides, and farming equipment are crucial. They influence farming practices and are often involved in research and development to produce better-yielding and disease-resistant crops

a. Suppliers of Farming Equipment: Provide the technology and equipment for protected cultivation.
    i. High-Tech / IOT:
        1. *Tamkeen:* https://agro-tamkeen.com/
        2. *Renile*: https://www.renile.net/
        3. *Tulima*: https://www.tulimafarms.com/
        4. *AgriT*: https://agrit.net/
b. Agrochemical Companies: Supply necessary fertilizers and pest control products.
    i. *Yara Egypt*: https://www.yara.com/
    ii. *EuroFert*: https://www.eurofert-egypt.com/
    iii. *Tradecorp*: https://arabic-tradecorp.com/
    iv. *Evergrow Fert*: https://evergrowfert.com/
c. Seed Suppliers / Pesticides / Crop Protection
    i. RijkZwaan: https://www.rijkzwaan.com.eg/home

ii. *Bayer (Seminis + De Ruiter):* https://www.vegetables.bayer.com/eg/ar-eg.html
iii. *Syngenta Egypt:* https://www.syngenta.com.eg/
iv. *Fine Seeds*: https://fineseeds.com/
v. *Techno Seeds*: https://technoseeds-eg.com/

Interests: Market expansion, long-term partnerships.
Influence: High; critical in supply chain and technology provision.
Potential for Collaboration: Technological advancement, supply chain efficiency.

3.1.4 Research Institutions:

Universities and research institutes contribute through agricultural research, development of new technologies, and training of the agricultural workforce.

a. Universities: Conduct research on agricultural practices and technology.
   i. *Heliopolis University:* https://www.hu.edu.eg/
   ii. *Ain Shams Univesity:* https://www.asu.edu.eg/
   iii. *Cairo University:* https://cu.edu.eg/Home
   iv. *Kafr El-Sheikh University*: https://kfs.edu.eg/
   v. *American University in Cairo: https://www.aucegypt.edu/*
b. Agricultural Research Centers: Develop new cultivation techniques and crop varieties.
   i. *Agricultural Research Institute:* http://www.arc.sci.eg/default.aspx?lang=en
   ii. *National Water Research Center:* https://www.nwrc.gov.eg/

Interests: Research advancement, practical application of findings.
Influence: Moderate; contribute knowledge and innovation.
Potential for Collaboration: Research partnerships, field trials.

3.1.5 Financial Institutions:

Banks and microfinance institutions offering loans and financial support to farmers and agribusinesses play a critical role. Their support can determine the scale and scope of cultivation projects.

a. Banks and Microfinance Institutions: Provide necessary funding and loans.
   i. *Agricultural Bank of Egypt:* https://abe.com.eg/
   ii. *Banque Du Caire:* https://www.bdc.com.eg/
   iii. *National Bank of Egypt:* https://www.nbe.com.eg/

b. Investors and Venture Capitalists: Offer capital for large-scale projects.
   i. *500 Ventures:* https://500.co/
   ii. *Global Ventures:* https://www.global.vc/
   iii. *A15 Ventures:* https://www.a15.com/
   iv. *Algebra Ventures*: https://www.algebraventures.com/
   v. *Egypt Ventures:* https://egyptventures.com/

Interests: Profitability, investment security.
Influence: High; control over financial resources.
Potential for Collaboration: Funding for technology adoption, financial management training.

3.1.6 NGOs and International Organizations:

NGOs often work in areas like sustainable agriculture, farmer training, and community development. They can influence practices and policies at the grassroots level.

a. Local and International NGOs: Work in agricultural development, farmer training, and sustainability.
b. UN Agencies and International Aid Organizations: Provide funding and expertise.

Interests: Sustainable development, poverty reduction.
Influence: Moderate; provide resources and support.
Potential for Collaboration: Development projects, training programs, sustainability initiatives.

3.1.7 International Bodies:

Organizations like the FAO (Food and Agriculture Organization) and the World Bank are involved in funding, policy advice, and technical assistance, particularly in sustainable agriculture and food security projects.

a. Trade Partners and Foreign Investors: Interested in the export potential of Egyptian produce.
b. International Regulatory Bodies: Influence trade policies that affect exports.

Interests: Stable trade relations, quality produce.
Influence: Moderate to high; dependent on international markets.
Potential for Collaboration: Market access, compliance with international standards.

3.2 Optimal Greenhouse Design for Egypt

In the context of greenhouse agriculture in semi-arid and arid regions, the following characteristics are deemed essential for maximizing productivity and ensuring sustainable practices [37].

1. **Effective Light Transmission:**
   Greenhouse construction and covering materials should allow for excellent light transmission to optimize sunlight exposure, promoting robust plant growth.

2. **Efficient Ventilation:**
   The greenhouse design must incorporate efficient ventilation systems to regulate temperature and create an optimal environment for plant development.

3. **High Volume and Insulation:**
   Robust construction with high volume is necessary to provide insulation, protecting crops from external factors like pests and sand, contributing to crop health.

4. **Windproof Construction:**
   The greenhouse structure should be designed to withstand strong winds, ensuring stability and durability in challenging weather conditions.

5. **Optimal Cooling Systems:**
   An effective combination of cooling systems is crucial to maintain suitable temperature levels within the greenhouse, fostering a conducive environment for plant growth.

6. **High Resource Use Efficiency:**
   Prioritizing resource use efficiency is vital, emphasizing the reduction of inputs while maximizing production and enhancing crop quality, particularly concerning water management in water-scarce regions.

7. **Conducive Enabling Environment:**
   Establishing a conducive enabling environment involves developing a maintenance industry, implementing rules and legislation supporting biological crop protection, and fostering a robust system of education, research, and extension services.

Addressing these characteristics is pivotal for the success of greenhouse agriculture in semi-arid and arid areas, ensuring resilience, resource efficiency, and long-term sustainability in agricultural practices.

3.3 Categorizing Greenhouses for Informed Investment Decisions

Investing in greenhouses is inherently a technology-driven venture, with the level of technology employed directly influencing the potential for maintaining precise growing conditions. The ability to tightly control these conditions is integral to the overall health and productivity of the crops. To assist stakeholders in selecting the most suitable investment based on their needs and budget, three distinct categories of greenhouses have been established:

3.3.1 Low Technology Greenhouses:

Low technology greenhouses, often less than 3 meters in height, include structures like tunnel houses that lack vertical walls and offer poor ventilation. While cost-effective and easy to erect, these structures present significant production and environmental limitations. Although they provide advantages over field production, the growing environment is suboptimal, limiting yields and necessitating chemical-intensive pest and disease control. Despite their limitations, low technology greenhouses serve as a cost-effective entry point to the industry (See Figure 18).

Figure 18 Low greenhouse structure (in Egypt) ©Delphy

We attempted to assess the costs associated with constructing such greenhouses and requested a quotation from two local greenhouse constructors in mid-January 2024. The quotation provided ranged from 150 to 220 LE/m2 (1 EUR = 33.865 EGP at the bank exchange rate). The specifications included a single half-moon structure with dimensions of 8–9 meters in width, 40 meters in length, and a height of 3 meters. The structure materials commonly used are galvanized iron, plastic, wood, steel, and stainless steel, with column thickness ranging from 1 to 2 inches. The cover material options include polyethylene or net. Cultivation is typically done in soil, with natural and side ventilation options (manual or with mechanisms). Cooling systems are not included, and shading is provided through netting. Irrigation is done using drip irrigation, with fertigation achieved through injection during irrigation. However, no control system is integrated into these greenhouses.

3.3.2 Medium Technology Greenhouses:

Medium technology greenhouses strike a balance between cost and productivity (see Figure 19)

Figure 19 Medium-Tech greenhouse (in Egypt) ©Delphy

Characterized by vertical walls of 2-4 meters and total heights typically less than 5.5 meters, they may feature roof or side wall ventilation. Cladding options include single or double skin plastic film, with varying degrees of automation. Offering a compromise between cost and efficiency, medium technology greenhouses provide a reasonable economic and environmental foundation for the industry. Although more efficient than field production, reaching the full potential of greenhouse horticulture remains challenging.

In order to provide financial estimate for capital investment, we collected quotations from two local constructors in mid-January 2024.They provided price estimates ranging between 800 and 1300 LE/m2 (1 EUR = 33.865 EGP at the bank exchange rate) for a greenhouse covering an area of 320 m2 for each span. These greenhouses can be designed as single or multi-span structures, featuring half-moon arc, sawtooth, or Gable shapes. The dimensions typically range from 8 to 9 meters in width and 40 meters in length, with a minimum height of 3 meters.

Specifications from the quotations:

- Structure shape: single or multi span greenhouse, half-moon.
- Greenhouse dimensions: Width ranging from 8 to 9 meters, length of 40 meters, and minimum height of 3 meters.
- Structure material: most commonly, galvanized iron with column thickness ranging from 1 to 2 inches.
- Cover material: Options include glass, fiberglass, acrylic, polyethylene, and polycarbonate.
- Cultivation media: Soil or substrate.
- Ventilation: Natural and side ventilation (manual or with mechanism), and/or fans
- Cooling system: Pad and fan system
- Shading: Net, shading screen.
- Irrigation: Drip irrigation.
- Fertigation: Injection through the irrigation system using a fertigation unit.
- Control system: Temperature and humidity control, along with timers for irrigation.

Figure 20 Medium-Tech greenhouse (in Egypt) ©Delphy

3.3.3 High Technology Greenhouses:

High technology greenhouses, with a minimum wall or gutter height of 4 meters and a roof peak up to 8 meters, deliver superior crop and environmental performance. These structures feature automated environmental controls, roof ventilation, and possibly side wall vents. Cladding options range from plastic film to polycarbonate sheeting or glass. While capital-intensive, high technology greenhouses offer significant opportunities for economic and environmental sustainability. Reduced pesticide use, increased productivity, and an impressive visual presence make them a compelling choice for advanced fresh produce industries. In investment decisions, prioritizing high technology greenhouses can lead to a highly productive and sustainable venture.

Figure 21: High-Tech greenhouse (in Egypt) ©Delphy

In our exploration, we wanted to acquire quotations for high-technology greenhouse installations. However, it was discovered that the necessary equipment and technology for such advanced setups are not fully available in Egypt.

Nevertheless. some farms, exemplified by Tulima Farm, showcase an innovative approach by seamlessly integrating elements from both mid-tech and high-tech technologies within their agricultural practices. High technology greenhouses, characterized by their superior structural design, automated controls, and advanced environmental features, are strategically combined with medium technology greenhouses. The synergy between the two technologies strikes a

Figure 23: Integrated model between both mid-tech and high-tech technologies at Tulima farm ©Tulima

Figure 22: Visual Representation of Growing Bags Cultivation at Tulima farm ©Delphy

balance between cost-effectiveness and enhanced productivity. The high-tech components offer precise environmental control, while the mid-tech features contribute to a more economical setup. This integrated model allows for a flexible and adaptive approach to greenhouse farming, capitalizing on the strengths of each technology.

3.4 Estimated Greenhouse Yield for Various Crops in Egypt

Figure 24 shows a general outline of estimated crop yields in Egypt, considering different crops cultivated in greenhouses categorized into three technological levels: high-tech, mid-tech, and low-tech. The production values are measured in kilograms per square meter per year. It is essential to note that these estimations are provided for guidance and are not definitive. Moreover, it is important to recognize that the technological categories are not mutually exclusive and can be mixed in practice. The diverse yields observed across these technological categories provide valuable insights into the potential productivity and efficiency of various greenhouse cultivation methods employed in Egypt.

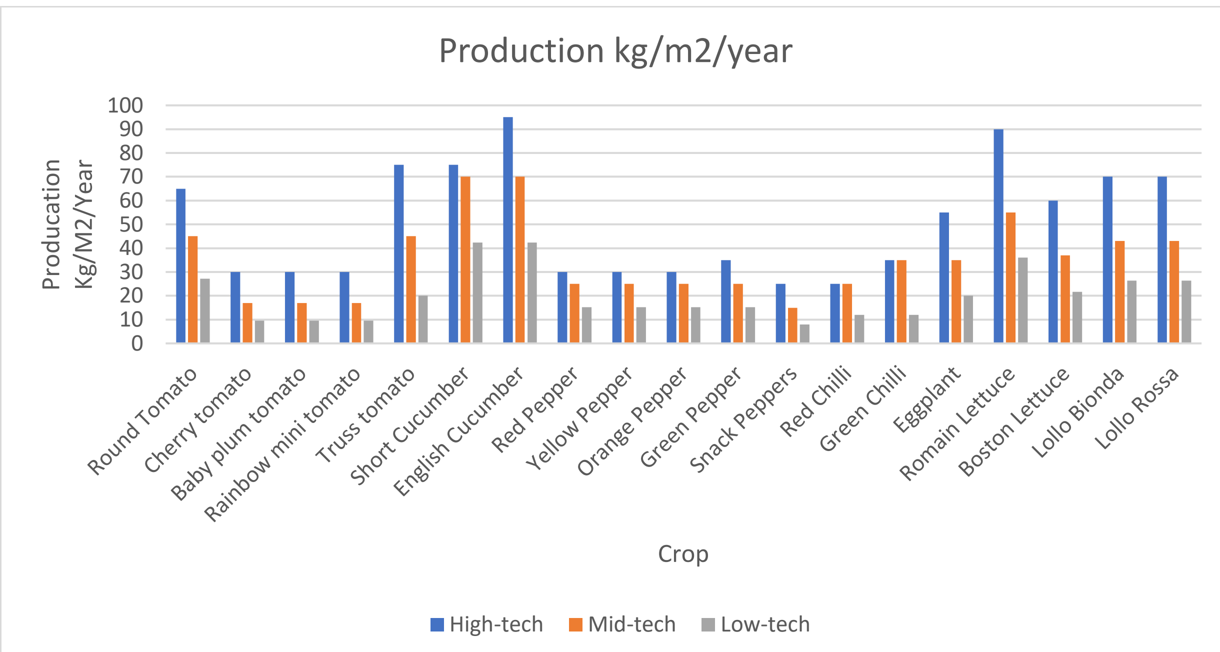

Figure 24 Estimated Greenhouse Yield for Various Crops in Egypt

4 Technical assessment: current greenhouse infrastructure

The technological landscape of existing greenhouses in Egypt exhibits a spectrum ranging from low to medium technology, with only a limited number featuring high-tech capabilities. A comprehensive technical evaluation of the current infrastructure within Egypt's protected cultivation sector was conducted through more than 12 meticulously organized site visits by the Delphy team. These visits have yielded valuable insights into the prevalent agricultural practices.

4.1 Greenhouse structure:

Protected cultivation appears in many forms, varying from plastic ground covers, cold frames and tunnel row covers, to tall structures covered with plastic or glass. This artificial protection may be used for the entire growth period of the crop, or for only a portion thereof. One could also define protected cultivation in a broader sense. Sometimes one wishes to protect the crop with materials to shield against damaging factors other than climate, such as birds and insects. In this sense, the covering of the crop with insect mesh or nets should also be included in the definition of protected cultivation. Each climate, tradition, availability for instance is modifying the type of structure.

With covering one should realize that the microclimate for the plants will differ from the external climate. The creation of this micro-climate is mostly the goal of protection, but it can sometimes lead to undesired side effects, such as light loss or a lack of ventilation. Looking at the range from low-tech to high tech greenhouses, the development of modern greenhouses has led to improved capacities to maximize the desired microclimate around the plants. The decision which greenhouse type is however also a balance of investments and return of better plant growth and production. In general, one can define single structures, chained (twin or trio) structures, mono-span and multi-span constructions. On the other hand, there are also shadow halls, wind screens, rain shelters and low tunnels.

The strong wind makes plastic films the most vulnerable covers to consider. Fiberglass, Polycarbonate and Glass covers are more popular in the Gulf area, while in Jordan there are very few with Fiberglass and Glass covers. In fact, Fiberglass, Glass and polycarbonate are more practical, but their cost at the initial investment might be prohibitive in Egypt, though it needs to be considered since it is proven to withstand strong wind threat.

4.2 Climate:

Water availability is an important limiting factor for agricultural operations. Egypt is one of the most water stressed countries in the world. The discussion on how to use the limited amount of water is ongoing and the question how to optimize the added value per cubic meter of water used is subject of a large number of research papers Due to the big differences in economic output per water unit, there is a constant discussion about the future use of the shrinking water resources in combination with a food security policy. Reducing water use and increasing water use efficiency in the agricultural sector is key and asks for continuous innovation (See Figure 25).

The Mediterranean climate of Egypt is dry and hot. It is characterized by long, hot, dry summers and short, cool winters. Greenhouses that are suitable for hot and dry climates should have the

Figure 25 Cooling systems (pad and Fans) ©Delphy

capacity to help create the optimal climate in the Egypt context. Other equipment and installations inside the greenhouse that are chosen should support this capacity, helping the grower to reach his goal for optimal growing conditions.

4.3 key considerations for Used Facilities:

The design and functionality of greenhouses play a crucial role in addressing the specific climatic requirements and common practices in Egypt. Here are some key considerations and examples:

1. Cooling in Summer cropping

In multi-span greenhouses effort needs to be addressed for natural cooling: i.e. the structure design with more spaces that can be open and closed. Also thermal reflective nets are an option. When choosing cooling systems: the Pad and Fans systems are the most common proven techniques in the area. A sprinkler or fogging might have the impact of increasing the relative

humidity inside the greenhouse causing more fungi challenges Fogging systems have to be carefully tested.
In the case of tunnels, the using strips of nets to replace the whole plastic cover is an option next to the making of so called “windows” by putting a piece of wood between the 2 plastic films and covering them with nets.

2. In multi-span where the Fans and cooling pads might not be the best solution, since the relative humidity might be too high. Other cooling systems should be evaluating the impact on humidity and fungi diseases. Botrytis is a big challenge in greenhouses (cucumber and tomatoes). Most farmers struggle with Botrytis and spray pesticides. However, there is an opportunity for improved Botrytis management through effective greenhouse structure management. This approach would be welcomed by farmers, contingent upon its cost-effectiveness and practicality in implementation.
3. Ventilation in any greenhouse is a continuous challenge, while it interacts with the cooling practices. In the Egypt farmers tend to close the doors of the tunnels when temperature goes down at night. This is a widely used practice adopted by many farmers to keep them warm at night. It is putting a huge pressure on the humidity, thus diseases like Botrytis and powdery mildew are increasing.
4. Reducing the number of plants per tunnel is a recommended practice to have a better humid environment inside the greenhouse. Keeping the right LAI, by crop handling, such as picking leaves is a better recommendation. Although not directly a structure issue, it allows and helps the structure to have better capacity.

4.4 Crop protection:

Pest and disease outbreaks pose significant challenges for growers in Egypt, primarily due to the reliance on chemical pesticides, which is not a sustainable approach to cultivation. The presence of biological pesticide companies in Egypt, notably Koppert through Bio Egypt (See Figure 26), is gaining recognition among growers. However, there is a crucial need to enhance product availability, emphasizing the selection of predators that can thrive in the region's warmer

Figure 26 Pollination inside greenhouses ©Delphy

climates. Developing and promoting sustainable alternatives will be pivotal for effective and environmentally conscious crop protection strategies.

4.5 Substrate

In Low-Tech greenhouses, crops are cultivated directly in the native soil. However, in medium and high-tech greenhouses, there is a shift toward soilless cultivation systems (See Figure 27), such as hydroponics, gaining increasing attention. Despite this, the variety and quality of substrates used in these systems may be limited compared to advanced markets and are not consistently available locally.

Figure 27 Soilless culture systems ©Delphy

Rockwool is occasionally used, along with perlite and vermiculite. Coco peat is a widely used substrate, but a significant challenge arises from the inconsistent quality of coco-peat across farms. Often, the material observed in Egypt has fine texture, leading to high water-holding capacity and insufficient oxygen supply to the root zone. Typically, a blend of two or three of these soil types is customized for cultivation purposes.

4.5.1 Summary for comparative Analysis of Greenhouse Technologies: Egypt and the Netherlands

Table 6 presents a comprehensive comparative analysis between greenhouse practices in Egypt and the Netherlands across various key dimensions. Each aspect is examined to highlight the contrasting approaches and advancements in technology, resource efficiency, crop diversity, research, and development (R&D), climate adaptation, training and knowledge transfer, greenhouse structure, climate control, cooling systems, crop protection, nutrient management, automation technologies, seed technology, and shade screens.

Table 6: Comparative Analysis of Greenhouse Technologies: Egypt and the Netherlands

Item	Egyptian Context	Dutch Advancements
Technology and Innovation	The focus on basic greenhouse structures in Egypt is evident, with a gradual shift towards modernization. Prevailing technologies lack advanced features compared to Dutch systems.	The Netherlands stands out for cutting-edge technologies in greenhouse construction, utilizing automated climate control, advanced hydroponics, and incorporating AI for precision agriculture.
Resource Efficiency and Sustainability	In Egypt, the primary goal is to maximize yield per unit area per season, with less emphasis on resource efficiency and sustainability. Adoption of advanced water-saving technologies is limited.	Dutch technologies excel in resource efficiency, particularly in water and energy use. Closed-loop systems recycle water and nutrients, and renewable energy sources are integrated for sustainable operations.
Crop Diversity and Quality	Protected cultivation in Egypt is generally limited in terms of crop diversity, focusing mainly on a few high-demand crops. While there is an emerging trend towards diversification, it is still in the early stages.	The Netherlands boasts a wide range of crops grown in protected environments, including exotic and high-value varieties. Dutch greenhouses are renowned for producing high-quality produce meeting stringent European standards.

Research and Development (R&D)	R&D in Egypt's protected cultivation sector is growing but still relatively limited compared to global leaders. Collaboration between academia and industry is less prevalent.	The Netherlands has a robust R&D infrastructure supporting its protected cultivation sector. There is a strong synergy between universities, research institutes, and the greenhouse industry, driving continuous innovation.
Climate Adaptation	While Egypt faces significant climate challenges, especially water scarcity, the adaptation of protected cultivation technologies to these challenges is still developing.	Dutch greenhouse technologies are highly adapted to various climatic conditions and are designed to minimize environmental impact. They include features for climate control, tailored to different environmental conditions.
Training and Knowledge Transfer	There is a growing need for training and knowledge transfer in Egypt to effectively utilize and maintain advanced protected cultivation technologies.	The Dutch agricultural sector benefits from a highly skilled workforce trained in the latest agricultural technologies, with extensive programs for training and knowledge transfer both domestically and internationally.
Greenhouse Structure	Varied structures are observed in Egypt, often focusing on cost-effectiveness. Basic materials like polyethylene and plastics are commonly used, with limited adoption of advanced cladding materials.	Dutch greenhouses are engineered with a holistic approach, integrating structural, mechanical, electrical, and computer engineering. State-of-the-art cladding materials like diffused glass and ETFE are employed for enhanced efficiency.
Climate	The Mediterranean climate of Egypt is dry and hot, posing challenges for water availability. Ongoing discussions on water use optimization and climate adaptation are crucial.	Dutch greenhouse designs are tailored to create optimal climates. Advanced cooling, ventilation, and climate control systems ensure the greenhouse's capacity to withstand various climatic conditions.
Cooling system Used	Cooling challenges are faced in multi-span greenhouses, with practices affecting humidity. Ventilation practices impact humidity levels. Dutch greenhouses feature advanced cooling systems and dynamic ventilation control.	Dutch greenhouses feature advanced cooling systems, dynamic ventilation control, and emphasize structure management for optimal humidity environments.
Crop Protection	Pesticide reliance is common in Egypt, with a growing interest in biological control methods.	The Netherlands leads in integrated pest management, with a focus on biological predators, reducing reliance on chemical

	Challenges exist in adapting to warmer climates.	pesticides and promoting sustainable pest management.
Nutrients and Fertilizers	Use of conventional fertilizers is common in Egypt, with limited integration of precision fertilization techniques. Dutch practices include precision fertilization, often integrated with irrigation systems.	Dutch practices include precision fertilization, often integrated with irrigation systems (fertigation), ensuring efficient nutrient use and reducing environmental impact.
Smart and Automation Technologies	Adoption of smart technologies is growing but not widespread in Egypt. Automation in irrigation and climate control is still emerging.	Dutch greenhouses extensively use automation and smart technologies, including AI and IoT, for precision agriculture, climate control, and resource management.
Grafting Houses, Germination Houses, and Seed Technology	Conventional practices in seedling development and grafting are predominant in Egypt.	Advanced seed technologies, along with sophisticated germination and grafting houses, ensure high-quality plant production in the Netherlands.
Shade Screens	Basic shade screens are used in Egypt, with less focus on advanced automated screening. Dutch greenhouses feature advanced automated shade screen systems.	Advanced automated shade screen systems are standard in Dutch greenhouses, allowing for dynamic control of light and temperature based on real-time environmental conditions.

4.6 Indicative Cost of Farm Operation and Price of Sale (given by a grower, Dec 2023)

4.6.1 Cost of Operation

The Cost of Operation in protected cultivation encompasses various components that are essential for effective management and financial planning. These costs, collected directly from a grower, provide valuable insight into the economic dynamics of greenhouse operations. Due to confidentiality, the name of the grower is not mentioned.

4.6.1.1 Fuel Costs

- **Price of Fuel 95 Octane:** As of December 18, 2023, the price of 95 octane fuel in Egypt is EGP 12.50 per liter, equivalent to approximately USD 0.40 per liter. This price point is significantly lower than the global average, which stands at around USD 1.21 per liter (1 USD = 30.89850 EGP).
- **Price of Diesel**: The latest information on the price of diesel in Egypt indicates that it remains at EGP 6.75 per liter. Diesel prices are a critical factor for transportation and logistics costs.

4.6.1.2 Consumer Electricity Costs (July 2023):

The below data shows the prices for consumers and residential areas. Commercial and Industrial users price differ approximately 50% higher.

1. First Tier (0 to 50 kW/month): 58 piasters per kW.
2. Second Tier (51 to 100 kW/month): 68 piasters per kW.
3. Third Tier (0 to 200 kW/month): 83 piasters per kW.
4. Fourth Tier (201 to 350 kW/month): 111 piasters per kW.
5. Fifth Tier (351 to 650 kW/month): 131 piasters per kW.
6. Sixth Tier (651 to 1,000 kW/month): 140 piasters per kW.
7. Seventh Tier (above 1,000 kW/month): 145 piasters per kW.

4.6.1.3 Material Costs

- Price of Perlite: Average cost of 200L of perlite is 430 EGP.
- Avg. Price of 1,000 good quality pepper seeds: $296 (imported)
- Avg. Price of 1,000 Liters of liquid fertilizer from a well-known local producer:
    1. Nitromag: (12,0,0 + 15mg) = 14,050 EGP
    2. Amber II: (6, 3, 6) = 13,800 EGP
    3. Yakour: (19,0,0) = 7,200 EGP

4.6.1.4 Labor Costs

- **Minimum Wage in Private Sector**:
  From January 2024: 3,500 EGP per month

4.6.2 Price of Sale (given by a grower)

The Price of Sale, as provided by the grower, is an important aspect of evaluating the financial performance and market dynamics within protected cultivation. Due to confidentiality, the name of the grower is not mentioned. This data, collected directly from growers, offers valuable insights into the pricing strategies and market conditions prevalent in the industry. Two primary categories of sale prices are examined:

1. The Wholesale Price: This represents the prices at which agricultural produce is sold in bulk to retailers or other intermediaries. The price is typically negotiated based on factors such as volume, quality, and market demand. An Example is Obour wholesale market.

2. The Supermarket Price: This refers to the retail prices of agricultural produce when sold directly to consumers through supermarkets or other retail outlets. The prices are influenced by factors such as packaging, branding, and marketing strategies, in addition to the wholesale cost. Two prominent examples of supermarkets in Egypt are Hyper One and Carrefour Egypt.

4.6.2.1 The Wholesale price:

The below prices are indicative of prices in December 2023, during the winter season and at the cheapest local prices.

Table 7: Average wholesale price for selected crops

Product	***Average Wholesale Price (LE/Kilo)***
Tomatoes	4 - 7
Potatoes	6 - 13
Onions	11 - 23
Zucchini	6 - 12
Carrots	3 - 5
Eggplant	2.5 - 4.5
Green Bell Pepper	8 - 12
Colored Bell Pepper	20 - 34
Okra	40 - 45
Peas	22 - 28
Garlic	40 - 70

4.6.2.2 Price of Sale (Supermarket)

The following prices, listed in Egyptian Pounds (LE), depict the retail costs of these items when purchased from supermarkets. This table serves to elucidate the pricing dynamics encountered by consumers in Egypt's retail agricultural produce market.

Table 8: Average Price of Sale at the Supermarket

Product	***Supermarket Price (LE/Kilo)***
Tomatoes	32
Potatoes	29
Onions	36
Zucchini	29.45
Carrots	27
Eggplants	10.95
Green Bell Pepper	50
Colored Bell Peppers	100
Onion	72.95

5 Current situation for the greenhouses owned by the government.

Despite the challenge of being unable to physically visit the government-owned greenhouse (See Figure 28), our team successfully gathered data from operators at those facilities. However, It is crucial to note that the data could not be independently verified by our consultants, introducing the possibility of inaccuracies. The Egyptian government has strategically invested in greenhouse technology as part of the country's comprehensive development plan, with a specific focus on enhancing food security and agricultural productivity. The primary objective of the project is to optimize land utilization and water resources, aiming to establish modern, water-efficient greenhouses capable of producing high-quality crops for both local consumption and international markets. The following section provides detailed information on five specifics locations, as illustrated in the figure below.

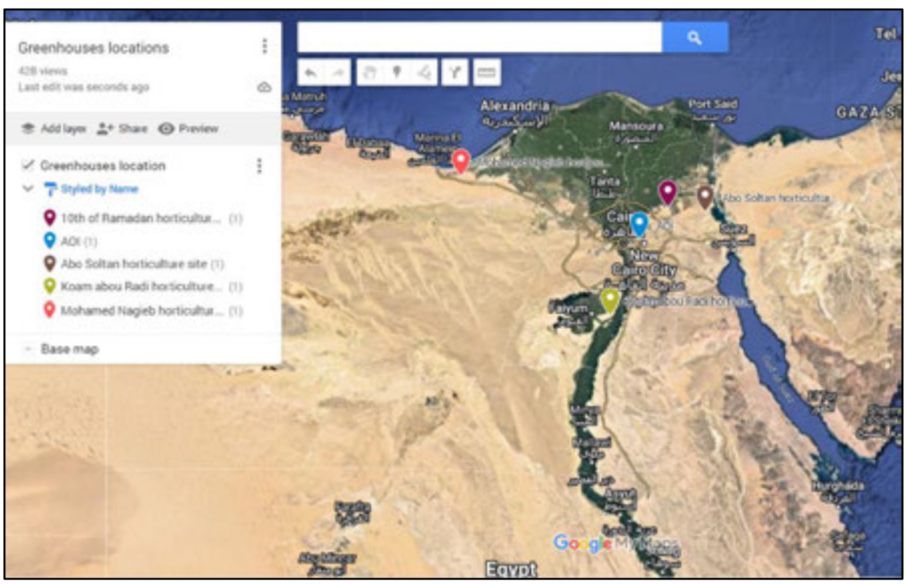

Figure 28: Locations of 5 projects of governmental owned greenhouses

5.1 The Mohamed Naguib project

The Mohamed Naguib project is located west of Hammam City, encompasses various greenhouse structures, primarily designed according to the Spanish system, and constructed by "Rufepa". The project consists of 25 clusters, each containing four greenhouses with an area of 1.25 hectares, covered by plastic. Among these, 10 clusters are classified as High-Tech greenhouses with water recycling capabilities, while the remaining 15 clusters are considered Mid-Tech greenhouses without water recycling. The Mid-Tech greenhouses allow cultivation in either soil or substrate without a draining system.

Each pair of clusters shares a service area, equipped with circulation tanks, irrigation units, fog systems, disinfection units, shared poll and tank recharge pump. A dedicated computer in the service area manages and monitors sensors for both greenhouses separately. Climate control systems include natural ventilation, air ventilation through fans, shading screens, and a high-pressure fog system from Rufepa company with climate control technology provided by "Ritec". Fertigation and irrigation control are also from "Ritec," tanks from Dutch company “Genap”, and the disinfection unit from Italian company “Sita”.

Additionally, there are eight clusters, each with two net greenhouses covering an area of 10 hectares, following the Spanish system. These greenhouses feature a service area, fertigation unit, climate control from "Ritec," low-pressure fog system from "Ritec," and automatic one-side ventilation system, along with shading screens.

Furthermore, the project includes 1,000 Mid-Tech Greenhouses across 126 clusters, each with an area of 1.25 hectares. These greenhouses allow cultivation in soil or substrate without a draining system and are equipped with fertigation units from "Ritec," natural ventilation automatic (Chinese company), shading screens, and climate control technology provided by the Dutch company "Hotraco Horti", along with motors from a Chinese company.

5.2 The 10th of Ramadan greenhouse project

The project is located in the 10th of Ramadan City, which is 65 KMs East Cairo, comprises 1,000 Chinese greenhouses with a height of approximately 5.5 meters. These greenhouses feature a manual shading screen, electric up ventilation with an on/off switch (manual), side ventilation (manual), and fertigation units, with 600-650 units from a Chinese company and the remainder from “Ritec.” The systems in these greenhouses operate manually without automatic control.

5.3 Abu Sultan greenhouse project

Located in the southern region of Abu Sultan city in Ismailia, the project encompasses approximately 2,350 Chinese greenhouses spread across 5,250 hectares of land. These greenhouses are outfitted with shading screens, manual up-and-side ventilation systems, and fertigation units controlled by a manual control panel. The systems within these greenhouses operate manually, without automated sensors or monitoring systems.

5.4 Al Lahoun Section, Future Egypt - Abu Radi, Beni Suef Governorate

The project comprises a total of 1,118 greenhouses, covering an expansive area of 2,136 hectares. Among these, 708 Spanish greenhouses sourced from Rufepa company covers 2,050 hectares, while approximately 410 Egyptian greenhouses contribute to the remaining area. Notably, the Spanish greenhouses boast features such as natural ventilation, air ventilation via fans, shading screens, and a low-pressure fog system. In contrast, the Egyptian greenhouses are characterized by shading screens, manual up and side ventilation, circular fans, fertigation units, and a manual control panel overseeing all internal systems, operated using on/off switches. Suppliers providing hardware for this project include Ridder, Ritec, and De Gier Drive Systems.

Figure 29: Google Earth Map of Al Lahoun Section in the Future Egypt Project

6 A Case Study in Egypt: Dutch Egyptian Growers' Collaboration

The Delphy team has conducted a site-visit to the project farm to provide valuable insights about this collaboration. The collaboration represents a successful partnership between Dutch company Kwekerij Roodpunt BV, CherryLand For Import & Export Company, and AOI in Egypt. Cherryland Egypte Company, established in Egypt since 2002, has recently entered a three-year contract with The Arab Organization for Industrialization (AOI) to lease their greenhouses. Currently focusing on cultivating peppers during the first production cycle, Cherryland Company benefits from the advanced greenhouse technology provided by AOI. With 75 dedicated personnel working in the greenhouses, Cherryland Company receives AOI's support for a smooth rental process and access to essential agricultural inputs. AOI, a governmental entity, facilitates the acquisition of crucial materials for greenhouse maintenance and cultivation preparation.

Background about AOI:
The Arab Organization for Industrialization (AOI) is responsible for military factories engaged in the production of both civilian and military goods. Originally co-owned by Egypt, Saudi Arabia, and the United Arab Emirates, AOI became fully owned by the government of Egypt in 1993. AOI has made substantial investments in greenhouse infrastructure, leveraging cutting-edge Dutch technology from Bosman van Zaal and expertise from Delphy between 2017 and 2019. Delphy's trainers played a crucial role in providing continuous training on greenhouse management, focusing on enhancing growing skills and overall company results from November 2018 to May 2019.

6.1 General farm Observations:

- Crop Cultivation: The entirety of the greenhouse area is dedicated to the cultivation of peppers.
- Desalination System: the farm is equipped with a Reverse Osmosis (RO) system.
- Circulation: All the drain water are collected in silos and disinfected with UV unit to be reuse again for next irrigation, this closed system saves up to 30% of water and fertilizer waste.
- Agricultural inputs are sourced from renowned Dutch and international companies.
- Post-harvest operations: the process of sorting and packing is efficiently conducted within the greenhouse.

6.2 Specification of the greenhouse facilities

The greenhouse facilities encompass a substantial net area of 8.2 hectares, all operating under a rental agreement. Below is a detailed breakdown of the various greenhouse structures:

6.2.1 Large Dutch Greenhouse (5 hectares):

Characteristics: This sizable greenhouse has heating system with warm water will be used with boiler system, however there is no cooling system (for summer months).

Purpose: Dedicated to the cultivation of peppers, and showcasing the adaptability of Dutch technology in a large-scale setting.

Figure 30: Impressions of the Greenhouse and sorting & packing equipment

6.2.2 Dutch Greenhouse from Bosman van Zaal (1.5 hectares):

Characteristics: This Dutch greenhouse, spanning 1.5 hectares, is equipped with a cooling system. Its unique composition comprises half glass and half plastic. The greenhouse features an irrigation unit with a frequent irrigation cycle, and cooling is facilitated through a high-pressure misting system, enhancing humidity as needed.

Purpose: Primarily utilized for pepper cultivation, it highlights the versatility of Dutch technology in various construction configurations. Additional information about this greenhouse can be found via Bosman van Zaal's website.

6.2.3 Spanish Greenhouse (1.7 hectares):

Characteristics: Equipped with a cooling system, this Spanish greenhouse contributes to the diversified portfolio of greenhouse structures. The cooling system used is pad and fan system. The cultivation is done in the soil and in substrate

Figure 31: Spanish greenhouse dual cultivation methods - both in soil and in substrate.

6.2.4 Egyptian Greenhouses:

Specifications: Unfortunately, no specific details were provided for these greenhouses.

7 Risk Analysis for Market Entry and Growth in Egypt

In navigating the agricultural protected landscape, it is important to discern and comprehend the multifaceted risks that shape the industry's trajectory. This comprehensive overview delves into the intricacies of the risk landscape, systematically categorizing potential challenges across various domains. From the dynamics of currency fluctuations to the complexities of labor, regulatory frameworks, and market intricacies, this analysis aims to offer a nuanced understanding of the factors influencing the Egyptian agricultural sector. Unveiling specific risks highlighted by recent data, including aspects like local supply chain weaknesses, environmental considerations, and the role of state-owned enterprises, provides a holistic perspective. This approach sets the stage for developing informed strategies and resilient practices in response to the dynamic nature of the agricultural sector in general and protected cultivation sector in particular (See Table 9).

Establishing a company in Egypt entails a potential risk due to unclear procedures, potentially exposing investors to scams or fraud, particularly as the process mandates involvement of an Egyptian lawyer. However, the General Authority for Investments (GAFI) is addressing this concern by assigning a Country Account Manager, currently Ms Ola M. Mamdouh, specifically for the Netherlands. This dedicated representative aims to streamline the establishment process and provide guidance to Dutch investors, enhancing transparency and reducing the risk of fraudulent activities. To obtain reliable information, investors are encouraged to contact the Egyptian Embassy in Den Haag and/or the Netherlands Embassy in Cairo. Proactive engagement with these official channels ensures accurate and up-to-date information, offering a trustworthy source to navigate the establishment process and mitigate the associated risks in the Egyptian market.

The risk category of currency fluctuations, particularly the depreciation of the Egyptian Pound, exerts a substantial impact on multiple facets of the market. This high-level risk directly influences the cost of imports, introducing fluctuations that reverberate through pricing structures and profitability considerations for businesses operating in Egypt. Depreciation creates a scenario where the stability of exchange rates becomes precarious, significantly complicating the accurate estimation and prediction of prices. This unpredictability adds a layer of complexity to financial planning and decision-making processes, demanding strategic acumen from businesses to navigate the uncertainties introduced by currency depreciation. In response to this challenge, growers within the Egyptian market actively seek export opportunities, leveraging the strategic location of Egypt. The proximity to large market demands in the neighboring European Union and the Gulf region provides a viable avenue for growers to mitigate the adverse effects of currency fluctuations on their cost structures and overall financial performance. This strategic approach allows businesses to harness external market dynamics and maintain resilience in the face of currency-related uncertainties.

The challenges associated with currency fluctuations in Egypt are further compounded by the intricate dynamics of obtaining foreign currencies [38]. This difficulty, coupled with the coexistence of official and black-market exchange rates, adds an additional layer of complexity to the economic landscape. The dual-market scenario creates opportunities for businesses and individuals to strategically exploit the price differentials, potentially leading to increased revenue for those adepts at navigating the system. This situation intensifies the challenges faced by businesses, making it arduous to accurately anticipate and manage financial exposures. The uncertainty introduced by the presence of parallel markets necessitates a strategic approach from businesses, demanding agile financial planning and risk management. However, governmental officials have provided assurances that measures will be taken to mitigate these challenges soon, with a particular focus on addressing these issues following the results of the presidential elections in December 2023. This commitment from the government instills a degree of confidence, indicating a proactive stance in addressing the complexities associated with currency fluctuations and their impact on the market dynamics.

The risk of skills shortages, categorized at a medium level, is particularly relevant in the context of advanced agricultural techniques. The demand for specialized skills in modern and innovative farming practices creates a gap that may hinder the sector's productivity. To address this, strategic planning for skill development, training programs, and collaboration with educational institutions can be essential mitigating measures. On the other hand, the risk associated with labor regulations and unrest is deemed low but not negligible. This risk encompasses potential challenges such as wage inflation, strikes, and differences in cultural work practices. While the level is categorized as low, the consequences of such disruptions can be impactful.

Energy supply constraints pose a high-level risk for protected cultivation in Egypt, with a pronounced dependence on energy for greenhouse operations. Recent challenges in energy supply, evident since the last quarter of 2023, have escalated due to scheduled daily power cuts, lasting for one hour, particularly affecting residential areas. The extension of this power cut plan until March 2024, coupled with reported daily fuel supply shortages. Under the extended plan, the country experiences daily power cuts ranging from 600 to 800 megawatts, lasting for 10-minute intervals [39]. Nevertheless, government officials have assured the public that measures will be taken to address and resolve this energy supply problem soon before Ramadan 2024 in mid-March 2024 [39].

In summary, the Egyptian market presents a dynamic landscape with a complex interplay of risks. Successful market entry and growth requires a strategic approach, encompassing currency risk management, skill development, and responsive strategies to address labor-related challenges. The government's commitment to mitigating these challenges post-election instills confidence, underscoring the importance of adaptive strategies for sustainable growth in the Egyptian agricultural sector. Additionally, concerns about the establishment process are being addressed through initiatives like the appointment of a Country Account Manager for the Netherlands by the General Authority for Investments (GAFI), offering a streamlined approach and minimizing the risk of fraudulent activities. Proactive engagement with official channels, such as the Egyptian Embassy in Den Haag and the Netherlands Embassy in Cairo, remains crucial for obtaining reliable information and mitigating associated risks in establishing a company in Egypt.

Table 9 Risk Analysis for Market Entry and Growth in Egypt

Risk Category	Specific Risks	Impact Level	Details
Regulatory	Unclear procedures in establishing a company	Medium	Unclear procedures, potentially exposing investors to scams or fraud
Market and Economic Risks	Depreciation of the Egyptian Pound	High	Impact on cost of imports, affecting pricing and profitability
Foreign currencies	Difficulty to obtain foreign currencies from banks in Egypt	High	Causes challenges in cost prediction as well as importing and exporting
Labour Challenges	Skills shortages	Medium	Particularly in advanced agricultural techniques
	Labour regulations and unrest	Low	Potential for wage inflation, strikes, and cultural work practice differences
Regulatory and Political Risks	Unclarity in laws and political instability	Medium	Creates uncertain business environments, requiring monitoring of developments
Market Access and Trade Barriers	Trade barriers and tariffs	Medium	Necessity to navigate local regulations and possible need for partnerships

Logistical and Infrastructural Challenges	Transportation and infrastructure issues	Low	Inadequate transport facilities, weak cold-chain infrastructure affecting supply chain
Water Management and Scarcity	Water resource limitations	High	Water scarcity and the evolving policies on water usage, especially for intensive cultivation, can cause a significant risk.
Climate and Environmental Risks	Climate change impact	Medium (Open Field) Low (Protected)	Variability in climate conditions, including extreme weather events, could affect crop yield and quality.
Energy Availability and Cost	Energy supply constraints	High	Dependence on energy for protected cultivation and potential issues with energy availability and cost escalations.
Supply Chain and Logistics	Supply chain disruptions	Medium	Challenges in supply chain management due to logistical and infrastructural limitations.
Social and Cultural Factors	Labor management and cultural differences	Medium	Challenges in managing local labor, understanding cultural practices, and maintaining workforce stability.
Political and Security Risks	Political instability and security concerns	Medium	Political changes and potential unrest can affect the business environment and investment security.

8 Conclusion

In this comprehensive study of protected cultivation in Egypt, various facets influencing the contemporary agricultural landscape have been thoroughly described. Despite challenges such as limited water resources, climatic variations, and the complexities of integrating advanced technologies, Egypt strategically employs protected cultivation to enhance agricultural productivity and achieve broader developmental goals. It is noteworthy that the Egyptian horticulture sector has also integrated Spanish and Chinese technologies, often accompanied by loans, which could potentially become competitors to the established Dutch technology.

A key case study, exemplified by the collaboration with the Arab Organization for Industrialization (AOI) and insights from Dutch growers like CherryLand for Import & Export company, illuminates the intricate dynamics between technology, government, and private-sector engagement. The case study showcases the landlord concept as a model, demonstrated through military-led infrastructure leasing. This approach may have the potential to foster collaboration among government entities, private sector stakeholders, and agricultural producers within the sector, provided it is implemented effectively. Furthermore, the comprehensive examination of greenhouse facilities across diverse locations as well as governmental-owned greenhouses such as those in Mohamed Naguib to Abu Sultan, the 10^{th} of Ramadan city and Abu Radi, provides valuable insights into the diverse technologies and approaches employed in protected cultivation.

The risks associated with this initiative encompass a spectrum of challenges, including currency fluctuations, labour issues, regulatory and political uncertainties, and environmental considerations. A detailed risk analysis, notably emphasizing the impact of currency depreciation on costs, underscores the necessity for strategic planning and adaptability in navigating a dynamic economic environment. In addition, it is essential to note that the prices and costs of agricultural inputs are changing rapidly, and the quotations requested were very short in length. This was caused by the financial challenges that Egypt is currently facing, and further research will be advised to evaluate the changes once it stabilizes.

The broader vision of greenhouse projects in Egypt extends beyond immediate agricultural concerns, incorporating socio-economic objectives like rural development, job creation, and the establishment of integrated communities. The commitment to producing high-quality, pesticide-free crops aligns with global trends promoting sustainable and healthy food production.

In conclusion, the exploration of Egypt's protected cultivation landscape reveals a dynamic interplay of technology, socio-economic considerations, and environmental challenges. As Egypt pursues enhanced food security, economic development, and global competitiveness, the adoption and adaptation of protected cultivation practices emerge as pivotal components of a multifaceted strategy. The insights derived from case studies, risk assessments, and facility examinations contribute to a nuanced understanding of the intricate tapestry of protected cultivation in Egypt, offering valuable lessons for stakeholders, policymakers, and researchers in the realm of agriculture and sustainable development.

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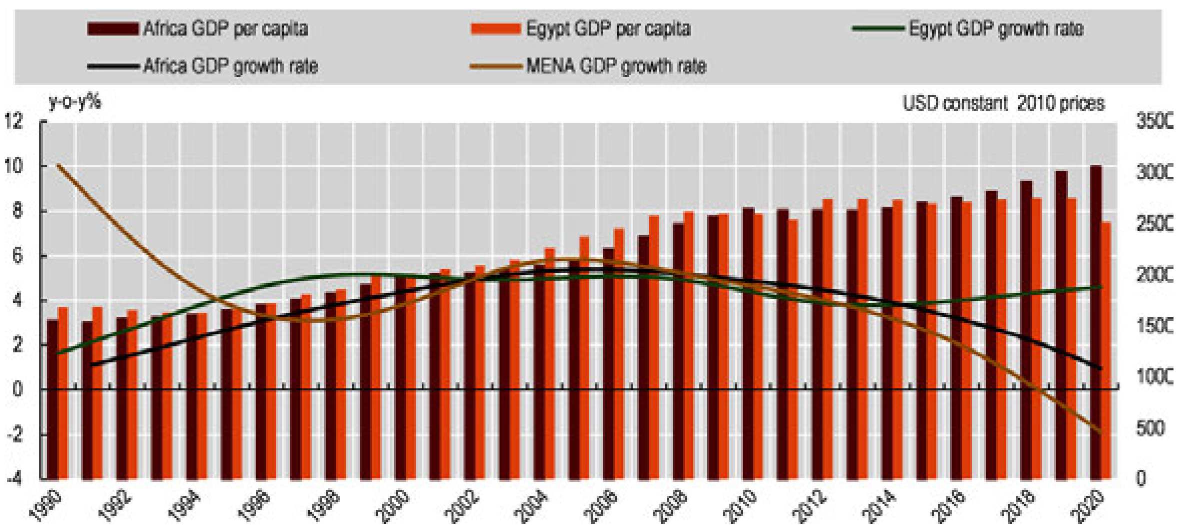
Appendixs

Appendix 1: The Egyptian Economy's growth and development



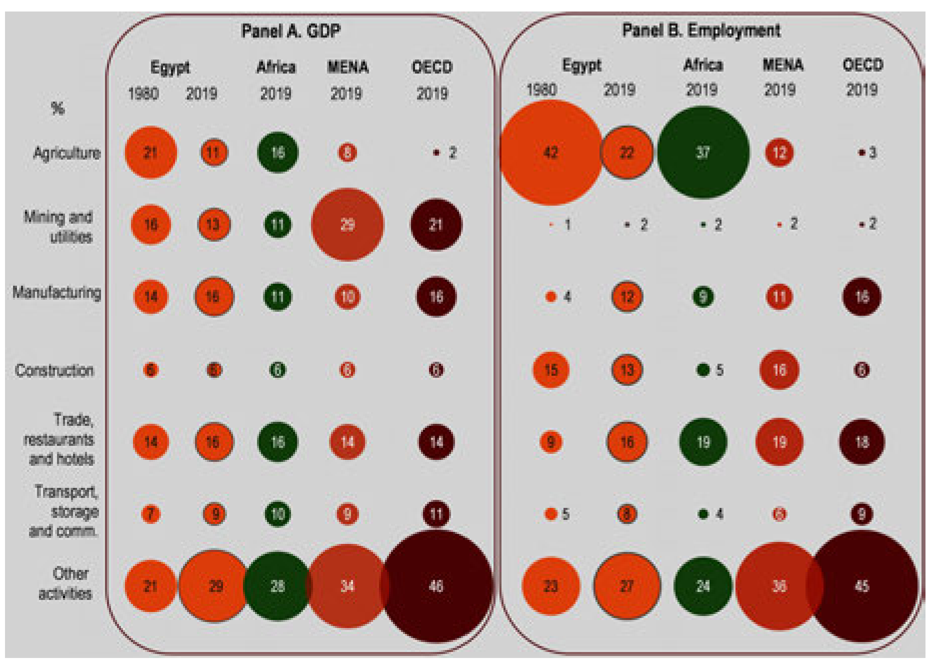


Figure 32: Egypt is among the fastest growing economies in North Africa and the Middle East (OECD et al., 2021)
Figure 33: Composition of GDP and employment in Egypt and selected areas, by economic activity, 1980-2019 (OECD et al., 2021)

Appendix 2: World Bank, World Trade Organization, and UN Statistics overview and analysis

In this section, we have meticulously analyzed a comprehensive dataset to map out Egypt's current export and import patterns, focusing specifically on fruits, vegetables, and technology-related products for imports. This analysis is tailored to the unique economic and trade dynamics of Egypt. Our data, encompassing a range of international trade partners, offers a clear picture of where Egypt is successfully exporting its agricultural produce and machinery and, conversely, which countries are key sources for Egypt's technology imports. This targeted approach provides valuable insights into the intricacies of Egypt's trade relationships and helps identify strategic opportunities and challenges in the global market, particularly pertinent to the sectors we have highlighted.

1. **Product Code 07 (Edible Vegetables and Roots)**: This code suggests a focus on basic agricultural products.
2. **Product Code 08 (Edible Fruit and Nuts)**: Like code 07, this category highlights another area of agricultural strength for Egypt.
3. **Product Code 8424 (Mechanical Appliances for Spraying)**: High import values in this category could signal a growing demand in Egypt for advanced irrigation and crop management solutions, an area where Dutch technology could be highly beneficial.
4. **Product Code 8432 (Agricultural Machinery for Soil Preparation)**: Significant imports under this code might indicate a need for modernizing Egypt's agricultural infrastructure, where Dutch companies could offer advanced soil preparation technologies.
5. **Product Code 8433 (Harvesting or Threshing Machinery)**: The demand for these technologies could reveal the level of mechanization in Egyptian agriculture, and potential gaps that Dutch tech could fill.
6. **Product Code 8436 (Other Agricultural Machinery)**: This is a broad category that may encompass various types of agricultural equipment. High import volumes here could indicate a general openness in the Egyptian market to adopting new agricultural technologies.

Top 10 Countries for Egypt Exports by Product Code (2022): This stacked bar graph illustrates the top 10 countries to which Egypt exports the most, with each bar representing a country and the segments within each bar indicating the different product codes.

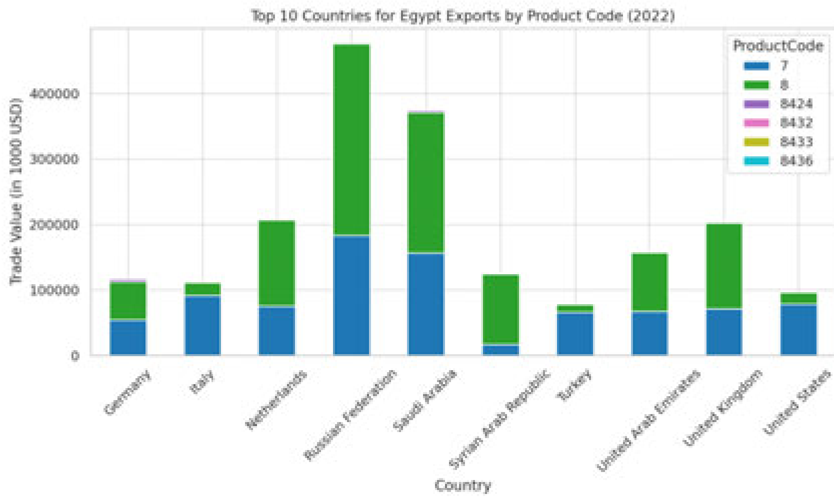


Figure 34: Top 10 countries for Egypt Exports by Product Code [40] [41]

Top 10 Countries for Egypt Agricultural Technology Imports by Product Code (2022): This graph specifically highlights the top 10 countries from which Egypt imports agricultural technology (HSProduct Codes: 8424, 8432, 8433, and 8436). Each bar represents a country, with segments indicating the specific agricultural technology products.

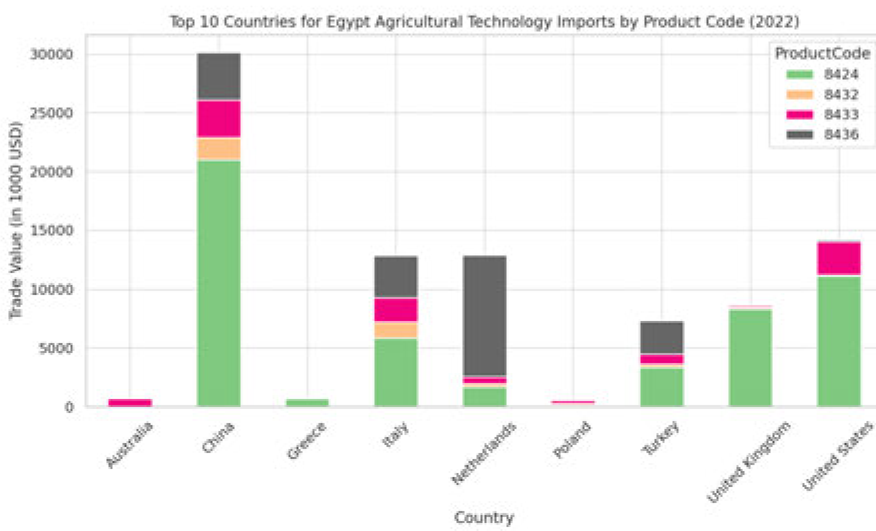


Figure 35: Top 10 countries For Egypt Technology Imports [41] [40]

Appendix 3: Egypt PESTLE Analysis

1. **Political:**
   - The Egyptian government is actively engaged in developing agricultural strategies to improve productivity. This includes establishing frameworks for agricultural extension services, veterinary services, and Disaster Risk Reduction (DRR) mechanisms. These efforts are directed toward sustainable agricultural practices and tackling challenges such as trans-boundary animal diseases and plant pests, which are crucial for the sector's resilience and long-term growth (FAO, TCP/EGY/3701).
2. **Economic:**
   - Economic measures are oriented towards enhancing food security, particularly for strategic commodities. The government's approach incorporates the development of multi-sectoral action plans aimed at reducing pre- and post-harvest losses and enhancing post-harvest management. Efforts are also focused on empowering agricultural co-operatives and smallholder producer groups as small agri-business entities, thereby boosting their economic viability. Additionally, the government is working on improving coordination among various stakeholders for agricultural investments and expanding social protection in rural areas to ensure a comprehensive economic development in the agricultural sector (FAO, TCP/EGY/3701).
3. **Social:**
   - Social initiatives in the agricultural sector are designed to create employment opportunities for youth and women, and to support the most vulnerable populations in agricultural value chains. These initiatives form part of a broader strategy that aims at ensuring food security and nutrition. This underscores the government's commitment to fostering inclusive growth within the agricultural sector, which is essential for social stability and development (FAO, TCP/EGY/3701).
4. **Technological:**
   - Technological advancement is a key area of focus, particularly in enhancing water productivity and adapting to climate change. Strategies are being developed to increase water supply through alternative freshwater sources and treated wastewater. Sustainable management of land, water, and biodiversity is also being prioritized. These technological interventions are vital for the long-term sustainability and resilience of the agricultural sector in Egypt (FAO, TCP/EGY/3701).
   - **Legal:** Legal frameworks supporting the agricultural sector are undergoing strengthening. This includes the enhancement of regulations and frameworks for sanitary and phytosanitary measures, sustainable agriculture, and good hygienic practices. Furthermore, the government is focusing on bolstering national capacities in research and development, particularly in modern technologies for inland and marine aquaculture production, which are essential for legal compliance and sectoral innovation (FAO, TCP/EGY/3701).
5. **Environmental:**

- Environmental challenges in Egyptian agriculture include high soil salinity and pest and pathogen management in protected farming, especially in arid and semi-arid regions. These challenges necessitate significant investments in infrastructure, skilled human resources, and technical knowledge for effective crop cultivation under protected structures. The environmental aspect is of critical importance, given Egypt's unique geographical and climatic conditions, which influence the agricultural sector's sustainability and productivity (FAO, TCP/EGY/3701).

Appendix 4: Egypt SWOT Analysis

1. **Strengths:**
   - **Diverse Agricultural Base:** Egypt's agricultural sector exhibits a wide range of activities, including small-scale dairy farming, horticulture, and more, contributing substantially to the country's economy. This diversity provides resilience and multiple avenues for growth (FAO, TCP/EGY/3701).
   - **Government Support and Strategic Initiatives:** The Egyptian government prioritizes agricultural productivity, food security, and sustainable resource use, indicating strong policy support. This commitment is evident in various strategic initiatives and plans aimed at bolstering the sector (FAO, TCP/EGY/3701).
   - **Innovative Technologies Adoption:** The focus on innovative technologies for water productivity and climate change adaptation is commendable. This forward-thinking approach positions Egypt to effectively tackle future environmental challenges (FAO, TCP/EGY/3701).
2. **Weaknesses:**
   - **Infrastructure and Technical Knowledge Gaps:** Challenges in protected farming, including high costs for infrastructure setup, lack of skilled labor, and technical knowledge, represent significant weaknesses. These factors can hinder the efficient operation and scalability of protected agriculture (FAO, TCP/EGY/3701).
   - **Water Management Issues:** Given its geographical positioning, Egypt faces significant challenges in water management, a critical factor for successful agriculture in its predominantly arid and semi-arid regions (FAO, TCP/EGY/3701).
   - **Pest and Pathogen Management:** Managing pests and soil-borne pathogens, especially in protected farming environments, is a persistent issue that impacts crop yield and quality, posing a risk to agricultural productivity (FAO, TCP/EGY/3701).
3. **Opportunities:**
   - **Expansion in Agri-Tech and R&D:** The sector has considerable opportunities for growth in research and development, especially in modern technologies related to aquaculture and post-harvest handling. This can lead to increased efficiency and productivity (FAO, TCP/EGY/3701).
   - **Food Security and Nutrition Programs:** Developing comprehensive national strategies and action plans for food and nutrition security can greatly enhance the overall health and well-being of the Egyptian population (FAO, TCP/EGY/3701).

- **International Cooperation and Investment:** Potential for international partnerships, particularly in technology transfer and investment in sustainable agricultural practices, offers vast opportunities for sectoral growth and innovation (FAO, TCP/EGY/3701).

4. **Threats:**

- **Climate Change Impacts:** The increasing impacts of climate change, particularly concerning water availability and extreme weather events, pose significant risks to agricultural productivity and sustainability (FAO, TCP/EGY/3701).
- **Global Market Fluctuations:** The agricultural sector's dependence on global markets for certain inputs and products makes it vulnerable to price fluctuations and supply chain disruptions, which can have far-reaching effects on economic stability (FAO, TCP/EGY/3701).
- **Land Degradation and Biodiversity Loss:** Issues related to land degradation and biodiversity loss threaten the long-term sustainability of agriculture in Egypt, necessitating concerted efforts for environmental conservation and sustainable practices (FAO, TCP/EGY/3701).

Appendix 5: Report on Solar Incidence in Comparison to 10 other Countries

Countries Compared

- Egypt
- Germany
- UK
- UAE
- USA (California)
- Canada (Ontario)
- Australia (Queensland)
- India
- China
- Brazil

Analysis Overview

1. Monthly solar intensity (in kWh/m²/day) was compared across the selected countries.
2. The data showed significant variations, reflecting different geographical and climatic conditions.
3. Egypt displayed consistently high solar intensity throughout the year, indicative of its strong potential for solar energy projects as well as a large prerogative on projected yield from agriculture.

Key Findings

1. **High Solar Intensity Regions**: Egypt, UAE, Australia (Queensland), and Brazil showed higher solar intensities, suitable for solar energy investments and high yield agricultural projects.
2. **Moderate to Low Intensity Regions**: Germany, UK, and Canada (Ontario) exhibited lower solar intensities.
3. **Seasonal Variations**: Most countries showed some seasonal variations, with intensities typically peaking during summer months.

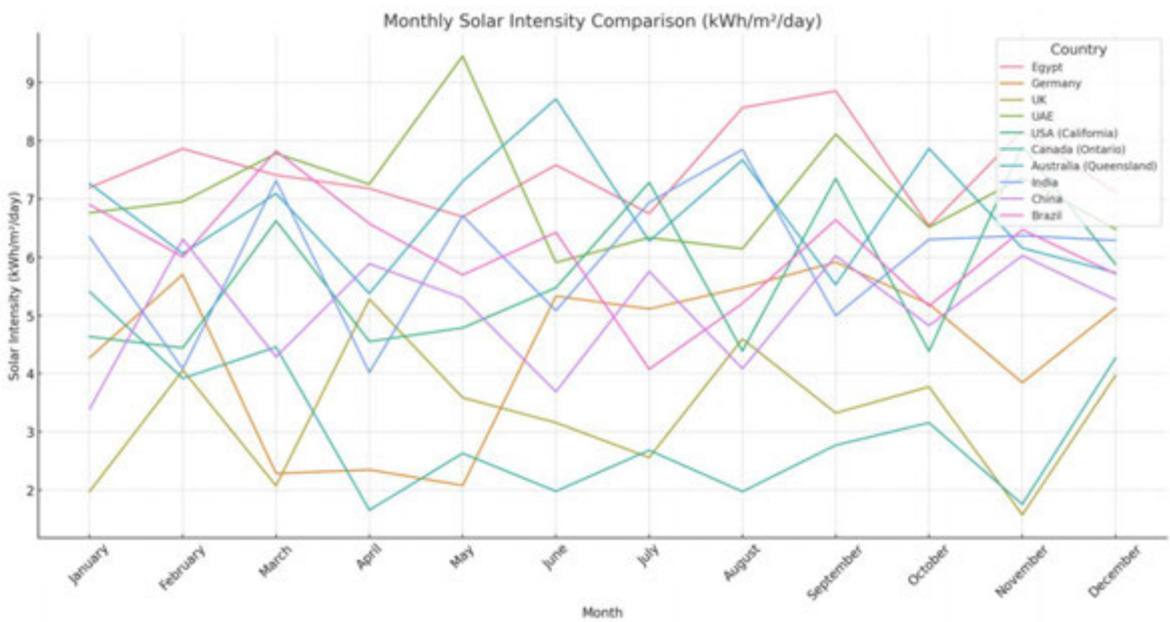


Figure 36: The monthly solar intensity comparison (in kWh/m²/day)

Here is the updated diagram showing the monthly solar intensity comparison (in kWh/m²/day) for Egypt and the selected countries, excluding Saudi Arabia. This graphical representation provides a visual comparison of how solar intensity varies across these countries throughout the year.

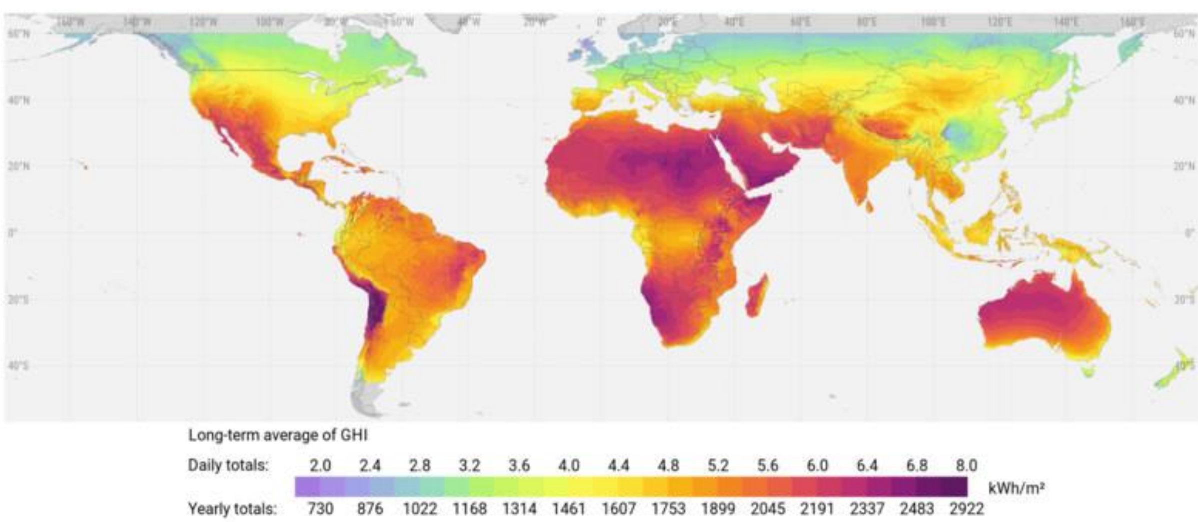


Figure 37: Global Horizontal Irradiation (GHI): Long-term yearly average of daily and yearly totals

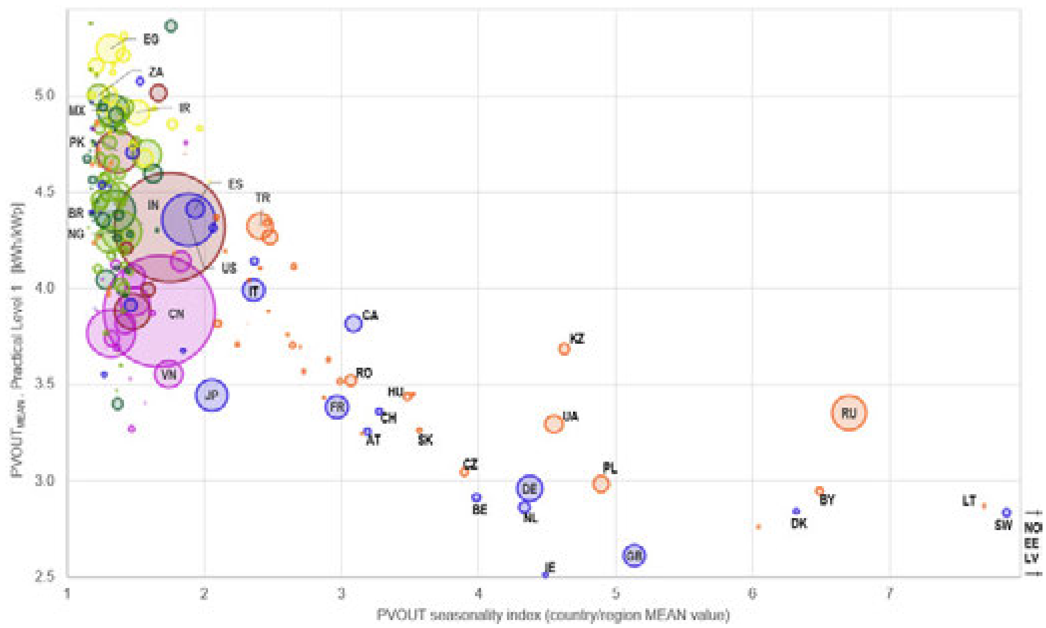


Figure 38: Absolute values of practical PV power potential (PVOUT) compared to PV seasonality index

Seasonality index, a new statistic defined as the ratio between the highest and the lowest monthly totals. The high-potential countries tend to have low seasonality (below 2) and vice versa.

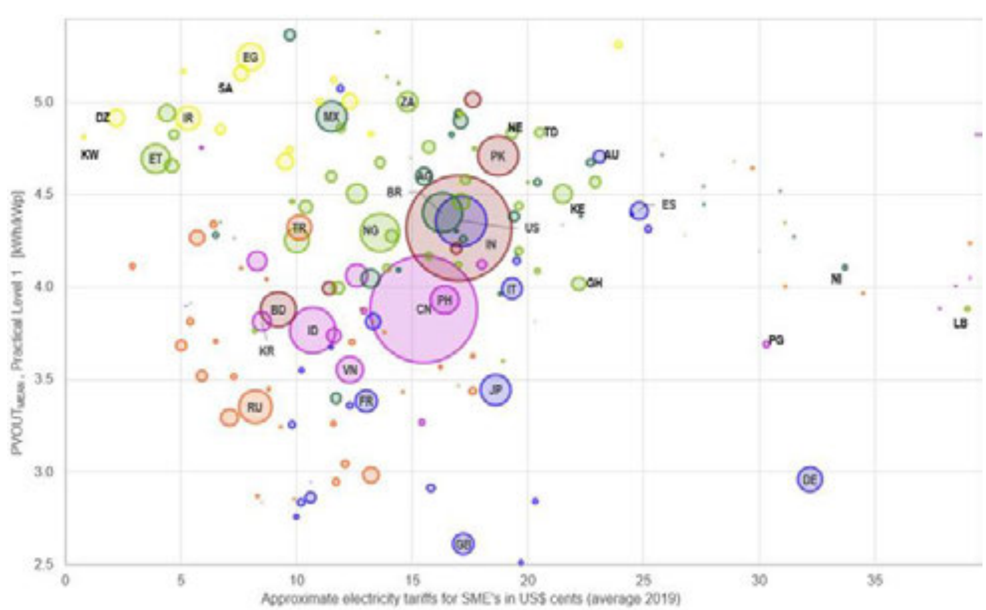


Figure 39: Practical PV power potential (PVOUT) vs. typical average electricity tariffs

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