Food and Agriculture Organization of the United Nations

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TRANSFORMATION TO LOW CARBON AGRIFOOD VALUE CHAINS IN EGYPT

Lessons from the Sustainable Agriculture Investments and Livelihoods project

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by

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FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS

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FOREWORD

The agriculture sector in Egypt plays a crucial role in feeding the growing population of the country and contributing to its economy. However, the sector faces numerous challenges, including limited water resources, degraded land, unsustainable farming practices, and the negative impacts of climate change. These challenges pose a threat to both food security and environmental conservation goals. In response, the government has implemented several recent initiatives, such as the "Haya karima" programme and the "irrigation modernization programmeme". However, it is paramount to transform the agrifood system in Egypt towards sustainability, productivity, and resilience through informed policies, strategies, and interventions.

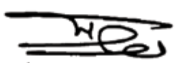
This study presents opportunities for transformation to low carbon agrifood value chain through scaling up successful climate-smart agriculture (CSA) practices. The study draws upon data from 173 farmer field schools (FFS) conducted by the Food and Agriculture Organization of the United Nations (FAO) as part of the IFAD-funded 'Sustainable Agriculture Investments and Livelihoods' (SAIL) project, implemented by the Ministry of Agriculture and Land Reclamation (MoALR) in Egypt.

The study assesses the potential for increasing farmers' incomes, decreasing greenhouse gas (GHG) emissions, and improving water-use efficiency (WUE) following the implementation of CSA interventions. It also analyses sustainable value chain production models for selected crops, with the goal of establishing climate-smart value chains that are economically feasible and present financial investment opportunities for small investors.

The conclusions and recommendations derived from this study emphasize the effectiveness of the FFS programme in promoting climate-smart agricultural practices in Upper Egypt. The study also highlights the significance of drip irrigation as a critical technique for water conservation in Upper Egypt, which not only leads to increased crop yield and income for small-scale farmers, but also contributes to reducing CO_2 emissions and mitigating the adverse impacts of climate change.

To promote and improve climate-smart agriculture value chain practices, the study recommends the establishment of comprehensive programmes that involve stakeholder consultations, partnerships, and a reliable support infrastructure. The study highlights the importance of establishing financial assistance programmes and low-interest loan schemes for smallholders, in collaboration with financial institutions. This will enable farmers to invest in climate-smart technologies and infrastructure.

This document serves as a valuable resource for policymakers, researchers, and stakeholders in the agriculture sector, providing insights into the challenges and opportunities for implementing climate-smart farming practices in Upper Egypt. It is our hope that the findings and recommendations presented here will contribute to the sustainable development of agriculture in Egypt, ensuring food security, environmental conservation, and improved livelihoods for small scale farmers.



Nasredin Hag Elamin

FAO Representative in Egypt

ABBREVIATIONS

AFOLU	Agriculture, Forestry, and Other Land Use
AFS	agrifood system
BCR	benefit-cost ratio
CAPMAS	Central Agency for Public Mobilization and Statistics
CSA	climate-smart agriculture
EGP	Egyptian Pound
EU	European Union
FAITC	Food and Agricultural Industry Technology Center
FAO	Food and Agriculture Organization of the United Nations
FFS	farmer field schools
GDP	gross domestic product
GHG	greenhouse gas
GIZ	German Agency for International Cooperation
IFAD	International Fund for Agricultural Development
IFPRI	International Food Policy Research Institute
IPCC	Intergovernmental Panel on Climate Change
IPM	integrated pest management
MAP	medicinal and aromatic plants
MoALR	Ministry of Agriculture and Land Reclamation
NEV	net present value
NGO	Non-Governmental Organization

NIB	net incremental benefit
NIC	net incremental cost
NWFE	Nexus on Water, Food, Energy
SAIL	Sustainable Agriculture Investments and Livelihoods project
SWOT	Strengths, Weaknesses, Opportunities, and Threats
WR	water requirement
WUE	water use efficiency
UNDP	United Nations Development Programme

UNITS OF MEASUREMENT

Feddan	0.42 hectare
M^3	cubic metre

CHEMICAL FORMULAE

CO_2	carbon dioxide
NO_2	nitrogen dioxide
Co_2-eq/Kg	CO_2 emission intensity equivalent 10
BCM Billion	cubic metre
CH_4	methane
N_2O	nitrous oxide

EXECUTIVE SUMMARY

EXECUTIVE SUMMARY

- **The purpose of this study is to investigate climate-smart farming in Upper Egypt.** The study utilized data from 173 farmer field schools (FFS) that were conducted by the FAO under the IFAD-funded 'Sustainable Agriculture Investments and Livelihoods' (SAIL) project, which was implemented by Egypt's Ministry of Agriculture and Land Reclamation (MoALR). This study has two objectives: evaluate current agricultural practices for major crops in Upper Egypt against recommended climate-smart agriculture (CSA) practices, and design sustainable value chain production models for selected crops. The goal is to increase farmers' incomes, decrease greenhouse gas (GHG) emissions, and improve water-use efficiency (WUE) while developing eco-friendly value chains that are economically feasible, and present financial investment opportunities for small investors. The study also aimed to assess the economic feasibility of such practices, with a focus on Upper Egypt.

- **The methodology** involved conducting a literature review on theagrifood system and the impact of climate change in Upper Egypt. Data from previous projects and existing research was analysed to determine the main challenges and opportunities for climate-smart agriculture practices in Beni Sueif, El Menya and Aswan. A team of experts was selected to study the value chain for four selected crops: pepper, tomato, medicinal and aromatic plants, and sugarcane. They identified traditional practices, and options for adapting to climate change. To examine the challenges and climate risks of the value chain, four workshops were organized in Beni Sueif and El Menia. The study identified significant players, service providers, and the ecosystem of the climate-smart value chain (CSVC). A SWOT analysis was conducted, and results from the FFS for the suggested CSA practices that reduce GHG and improve water use efficiency were analysed. An economic feasibility study was performed for each value chain model.

- **Egypt's agriculture sector is crucial, feeding over 100 million people and contributing 14.8 percent of the country's GDP.** However, the sector is facing several challenges such as limited water resources, degraded land, unsustainable farming practices and climate change. These challenges pose a threat to both food security and environmental conservation goals. In response, the government has launched initiatives such as Haya Karima and improved the irrigation network. Currently, water scarcity is the most significant obstacle to rural development, and the country relies on sources such as the Nile River and non-renewable groundwater. Smallholder farmers require technical and financial assistance to improve their productivity. and crop and livestock productivity are expected to be affected by climate change.

- **Upper Egypt is facing several challenges, including limited land resources, population growth, and significant land fragmentation.** The area is highly susceptible to the negative effects of climate change, with heat stress affecting wheat and maize crops. Other challenges include water scarcity, poor agricultural practices, and high poverty rates. To improve economic development and contribute more to the national GDP, Upper Egypt needs to enhance its productivity. Between 1990 and 2019, Egypt's greenhouse gas emissions have significantly increased. The Biennial Update Report of 2019 showed that its emissions rose by 31 percent between 2005 and 2015. However, the country has taken steps and implemented policies, institutions, and legislation to address this issue, and has invested in renewable energy and energy efficiency programmes, and launched initiatives to mobilize green finance both locally and internationally.

- **The first part of this study aimed to analyse the outcomes of FFSs conducted in Upper Egypt.** The focus was on corn, wheat, and sugarcane crops, which are crucial strategic crops for the country. The study compared traditional farming practices to those taught in the FFS programme and estimated changes in GHG emissions, water use efficiency, and economic benefits as a result of changing the approach. Although the data was observational, it provided valuable insights into the effectiveness of the programme.

- **Corn production in Egypt is facing significant challenges due to climate change,** in particular higher temperatures and the increased need for water for irrigation. Drip irrigation was introduced in Metobus in the Kafer El Sheikh governorate, resulting in a higher yield of 4.56 tonnes/feddan, compared to the 3.04 tonnes/feddan achieved with traditional surface irrigation. Drip irrigation saves water and increases yield, and despite higher installation costs, produces a greater return on investment. The method leads to a reduction in CO_2-e emissions, and increases income and net return by 50.0 and 54.5 percent respectively. Corn farmers in Egypt combat fall armyworm infestations by utilizing the Gold 21 hybrid cultivar, which is less susceptible to the pest. This variety not only improves yield and water use efficiency but also reduces CO_2-e emissions. To further enhance crop resiliency and promote sustainability in the corn agrifood system, farmers use drip irrigation and CSA techniques customized to their specific challenges.

- **Climate change has had an impact on wheat cultivation in Egypt.** FFSs have been experimenting with different wheat varieties and irrigation methods such as drip and sprinkler systems. Among the tested varieties, Gemeza 11, which is rust-resistant, has been shown to be the most productive under sprinkler irrigation. On the other hand, Beni Sueif 1 and 5 perform well under drip irrigation. Furthermore, Gemeza 11 is also effective in reducing GHG emissions, whereas traditional surface irrigation has the highest GHG values. In Western El-Fashn, the Beni Sueif wheat FFS adopts various techniques, such as using manure as organic fertilizer, drip irrigation, and planting heat-resistant wheat, to enhance productivity and reduce expenses. The results show that drilling Giza 171 wheat seeds can improve yield by 20 percent, generate higher income, and reduce GHG emissions by 17 percent compared to broadcasting the wheat seeds.

- **Sugarcane is a significant crop in Upper Egypt, requiring plenty of water and fertilizer to cultivate one feddan of land.** FFSs evaluated the advantages of implementing CSA practices in sugarcane production in the Aswan governorate. It was found that using drip irrigation with seedlings as a planting method led to higher yields and net profits. FFS suggests that drip irrigation is the most crucial CSA technique for sustainable sugarcane production in Upper Egypt. Another FFS was conducted in Aswan to find most sustainable way to cultivate sugarcane in the newly reclaimed land. The yield was lower than on old clay land, but using CSA interventions with drip irrigation improved water efficiency and led to higher yields. This method also reduced GHG emissions compared to traditional surface irrigation.

- **The second part of the study examines climate-smart practices for selected agricultural product value chains in Upper Egypt,** focusing on pepper, tomato, sugarcane, and medicinal and aromatic plants. It analyses the commercial value of these crops, conducts a SWOT analysis, and proposes climate-smart interventions for various stages of the value chain. The study also assesses the economic feasibility of these interventions for each crop.

- **Egypt's yearly fresh pepper production is around 837 000 tonnes, with 77 percent of it being consumed locally.** Nevertheless, Egypt faces tough competition from other countries and needs to enhance its pepper value chain to expand its market share. The average annual loss of peppers during production is 22 percent, which can be reduced by ensuring quality seedlings and minimizing pesticide overuse and surface irrigation. Pepper production has a carbon footprint of 0.33kg CO_2/Kg, with 80 percent of emissions occurring during production, and the remaining 20 percent during harvesting, processing, and packaging. **This study suggests CSA interventions** for the pepper value chain, including using reliably-sourced seeds before planting and implementing composting, bio-fertilization, and integrated pest management techniques at the production stage, as well as ensuring adequate storage conditions, packaging, protection, and grading in the post-harvest stage. Analysis of the economic feasibility of introducing a new chili pepper variety, which is tolerant to high temperatures as a CSA intervention, revealed a higher economic return at both the farm and aggregate levels.

- **Egypt is the sixth largest producer of tomatoes globally and has a cultivated area of 357 000 fed,** producing a total of about 6.4 million tonnes. A SWOT analysis for the tomato value chain has revealed that export opportunities are its main strength, while a high percentage of loss and waste (about 47 percent) is its biggest weakness. There is an opportunity to improve tomato products such as sauces, pastes, and canned and dry tomatoes. The carbon footprint of tomatoes is 0.95 kg CO_2e/kg, with most of it being generated during the post-harvesting stage. A study recommends CSA interventions, including selecting tomato varieties that are resistant to extreme temperatures, implementing an integrated pest management (IPM) system to limit chemical pesticides, using drip irrigation and renewable energy sources, and handling and transporting tomatoes carefully during the post-harvesting stages to prevent loss and waste. **Two CSA interventions have been recommended:** the first involves replacing traditional tomato varieties with ones that tolerate low temperatures and produce high quality crops. The second intervention aims to reduce post-harvest losses and waste, which are estimated to be around 10 percent. Economic feasibility analysis suggests that these interventions can provide higher economic returns at both the farm and aggregate levels.

- **Sugarcane is a valuable crop in Egypt, with a well-established infrastructure supporting its production.** However, its high water demand poses a challenge in the face of climate change. A recent study in Upper Egypt predicted that, by 2040, traditional sugarcane irrigation will lead to a 16 percent increase in water demand and a 14 percent decrease in yield. **Furthermore, the production of sugar has a carbon footprint of 0.55 kg CO_2e/kg due to the use of fossil fuels, fertilizers, and biomass burning.** While 30 percent of byproducts are generated during production, only 4 percent (molasses) are used in fermentation processes to make bread, fodder yeast, vinegar, perfumes, and medical solutions. A SWOT analysis of the sugarcane industry reveals that its main strength is an established infrastructure, whilst its weakness is its high demand for irrigation water. Opportunities for growth include exporting and expanding sugarcane-based ethanol production. However, global competition and price fluctuations pose threats to the industry, as does climate change and its adverse impact on sugarcane production. The study recommends the seedling technique and a drip irrigation system as primary interventions to mitigate these challenges. Using drip irrigation can reduce water usage from 12 000 to 6000 m^3/fed. The seedling technique can save up to 96 percent of the sugarcane previously used for cultivation, boosting average productivity from 33 to 55 tonnes per feddan, while reducing chemical fertilizers by 35 percent and saving about 30 percent of irrigation water. An economic feasibility analysis suggests that implementing these interventions across all sugarcane cultivation areas can save up to 12 billion cubic metre of water over six years.

- **Over the last 15 years, the global demand for medicinal and aromatic plants (MAP) has tripled.** The most commonly cultivated MAPs in Egypt are coriander, chamomile,marjoram, basil, anise, mint, henna, dill, and hibiscus. The production of MAPs provides employment to around 140 000 people, with women playing a significant role. Chamomile is cultivated in about 14 000 feddans, Marjoram covers 4143 feddans and Hibiscus is cultivated in about 13 000 feddans. A SWOT analysis shows that MAP are high-value crops with high productivity and a rapid return on investment. They are relatively easy to export to markets. However, weaknesses include the difficulty of adopting modern techniques and quality standards. The main opportunities are the growing global demand for natural and organic goods, whilst the main threat is the need to comply with changing domestic and international regulations such as quality standards, certifications, and export requirements. **CSA interventions for the MAP value chains were identified,** including improving access to weather and climate information, promoting IPM to reduce reliance on chemical pesticides and improving post-harvest handling. This extends the shelf life of MAP products, reduces waste, and accordingly reduces GHG emissions. For the economic and financial analysis, the study focuses on chamomile due to its relative importance in the MAP value chain. The economic feasibility analysis for replacing current surface irrigation for chamomile with drip irrigation powered by solar energy shows water savings from 1500 m^3/feddan to 1125 m^3/feddan, with an aggregated value savings of 15 million m^3 of water over the model period of 5 years, as well as a 36.6 percent increase in financial returns to the farmer.

- Land fragmentation is a major constraint when implementing a climate-smart value chain in agriculture. Encouraging cooperative farming arrangements among small-scale landholders can help consolidate fragmented land. This study shows that collaborative approaches can allow farmers of tomato, pepper and medicinal and aromatic plants to collectively adopt sustainable practices, share costs, and ensure better market access and bargaining power for smallholders.

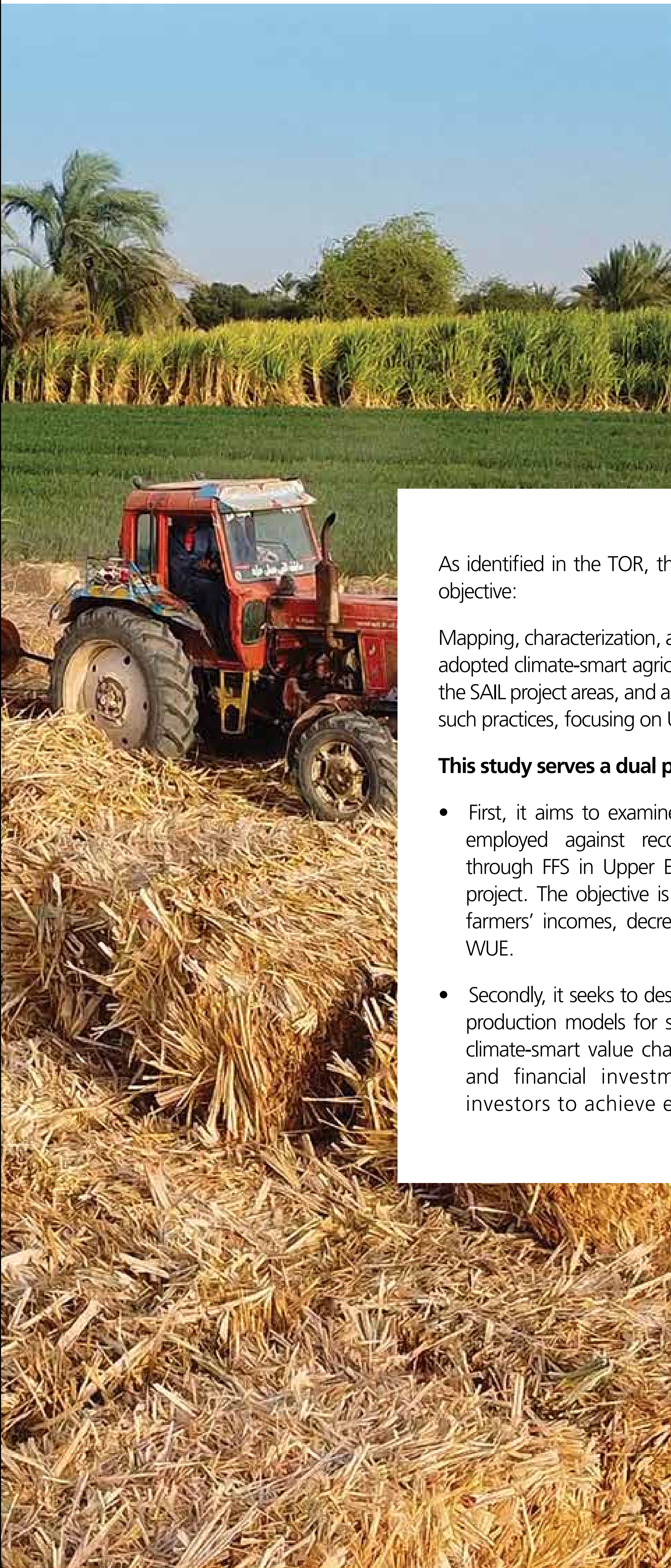
- Farmers require technical support and guidance to implement climate-smart practices effectively. A limited availability of agricultural extension workers can hinder the dissemination of climate-smart practices. Stakeholder consultations within the study revealed that most of the farmers acquire information about the selection of varieties, pesticides, and fertilizers from pesticide vendors. Strengthening extension services and promoting farmer field schools can help overcome this barrier.

- Adopting climate-smart agricultural practices in the value chain may require changes in production systems, post-harvest handling, processing methods, and exporting. During the stakeholder consultations for this study, it was found that a lack of communication between different stakeholders in the production system resulted in higher losses and waste in tomato production, and limited opportunities to export medicinal and aromatic plants. To address these issues, it is crucial to involve all stakeholders across the value chain, including processors, retailers, and consumers. This will help create market incentives and develop supportive infrastructure.

- Implementing climate-smart practices often requires investment in new technologies and infrastructure; as a result, these costs may be unaffordable for smallholders who have limited financial resources. For example, in this study, it was difficult to suggest investment into small tomato paste processing machines at farms to reduce tomato waste. This is because it would be too expensive an investment for a single farmer to undertake, and because the small farm would not be able to make use of such a machine economically. To facilitate the adoption of climate-smart practices, the government, financial institutions, and development organizations can help by providing financial assistance or low-interest loans.

ANALYTICAL FRAMEWORK AND OBJECTIVES OF THE STUDY

OBJECTIVES AND EXPECTED OUTPUTS



As identified in the TOR, the study aims to achieve the following objective:

Mapping, characterization, and identification of locally adapted and adopted climate-smart agriculture value chains of selected crops in the SAIL project areas, and assessment of the economic feasibility of such practices, focusing on Upper Egypt.

This study serves a dual purpose:

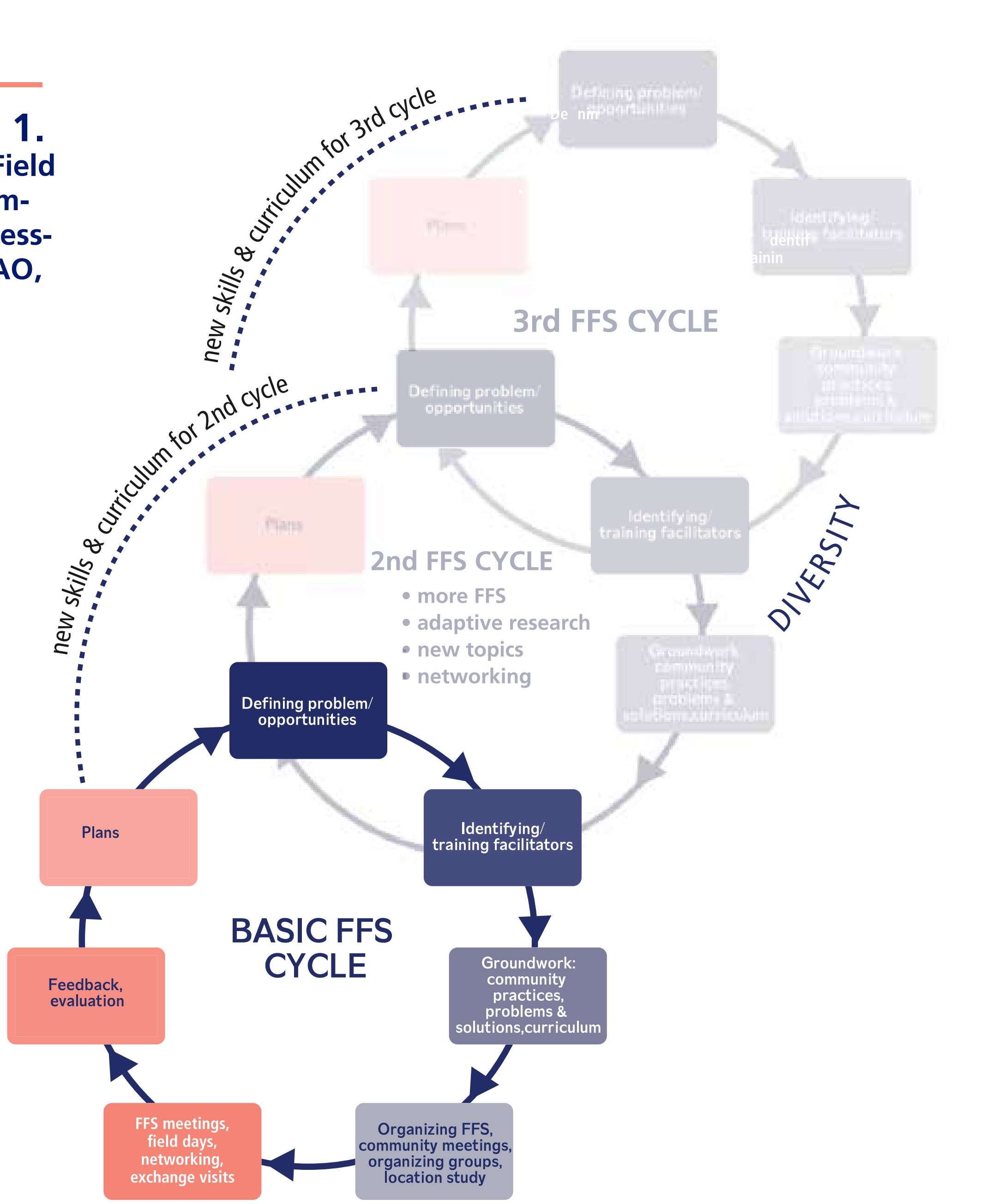
- First, it aims to examine the agricultural techniques currently employed against recommended CSA practices adopted through FFS in Upper Egypt for major crops under the SAIL project. The objective is to assess opportunities for increasing farmers' incomes, decreasing GHG emissions, and improving WUE.

- Secondly, it seeks to design robust and sustainable value-chain production models for selected crops. The aim is to establish climate-smart value chains and develop economic feasibility and financial investment options systems for small investors to achieve eco-friendly value chains.

METHODOLOGY FOR COLLECTING, ANALYSING, AND INTERPRETING DATA

The farmer field schools (FFS) method is a group-based approach to adult learning. It teaches farmers how to experiment and solve problems independently (Figure 1) .The goal is to transfer knowledge and promote sustainable agricultural practices. Each FFS is designed to bring together a group of 15-25 farmers who cultivate a specific crop. During each session, the participants engage in agricultural environmental analysis. This involves monitoring, recording, and analysing soil conditions, plant health, pest infestations, weather patterns, and other factors. There are also dynamic and interactive activities to stimulate critical thinking and foster innovation. Practical experiments are conducted to address challenges. In this study, farmers tested different CSA practices and compared them to traditional methods. The tested interventions included new varieties, different irrigation methods, cultivation techniques, non-chemical fertilization, and IPM techniques. At the end of the FFS programme, participants harvest the experimental crop and record yield data for each segment. The programme concludes with a set of comprehensive recommendations to guide sustainable agricultural practices. These recommendations are essential to the method and provide valuable guidance for implementing sustainable agricultural practices.

Figure 1.
Farmer Field School Impact Assessment (FAO, 2016)



Under the SAIL project, the selection process for participants in FFSs was inclusive. Women, landless farmers, and young farmers were actively involved in the decision-making process for the selection of crops and even the specific varieties to be cultivated. This inclusivity ensured that a diverse range of perspectives were considered, making the decision-making process more holistic and reflective of the community's needs and capabilities. Furthermore, separate FFSs were designed for women, each tailored to their unique needs, interests, and capacities. These women-specific FFSs focused on empowering and supporting them in their agricultural pursuits. The curriculum for these schools addressed crop production, financial literacy (through farmer business schools), sustainable agricultural practices, and entrepreneurship to enhance their overall engagement and contribution to the agriculture sector. In addition, some FFSs were dedicated to individuals with special needs and disabilities and were fully equipped with the necessary facilities and resources to accommodate and support participants with disabilities. The curriculum was adapted to their specific requirements and capabilities, ensuring their full participation in the learning and practical activities. These tailored programmes allow a broader and more diverse group of participants to be included, expanding the inclusivity of the FFSs.

Data and information collected from the FFSs under the SAIL project were used to identify sustainable and innovative climate-smart agriculture practices in the three governorates covered by the project (Beni Sueif, El Menya, and Aswan), and a literature review was conducted. Data and information were gathered from research studies conducted in various governorates with unique climate and economic conditions at both a local and national level, as well as that produced from previous projects. Analysis primarily focused on the differences between traditional, conventional practices and the introduced climate-smart agricultural (CSA) interventions that have been applied through the FFS. Specifically, we examined variations in productivity, farmer's income, carbon footprint (using the IPCC methodology), and water use efficiency for the major crops cultivated.

Experts across diverse fields - ranging from agricultural research and universities to marketing specialists, NGOs, and select farmers - were engaged through interviews and focus group discussions. Our goal was to gather and analyse information on the value chain of the four crops. The aim was to provide comprehensive insights into prevalent practices and various options for adapting to adverse impacts of climate change.

Four workshops were organized in Beni Sueif and El Menia to ensure that all relevant stakeholders were included. Each workshop focused on one of the four crops under study and provided a platform for meaningful discussions, analyses, and comparisons of ongoing practices with proposed sustainable practices across all elements of the value chain. The workshops had specific goals, which include: 1) outlining in detail the entire process of producing, processing, cooling, transporting, marketing, and exporting of the four selected crops; 2) documenting the challenges, constraints, losses, and climate risks of the selected value chain; 3) defining and documenting the climate smart practices of mitigation and adaptation measures used or potentially used by various climate actors; 4) identifying the overall impact on productivity, income, carbon footprint, and water use effi ciency; and 5) evaluating the economic feasibility of the proposed interventions at both the small-scale farmer and national levels.

A comprehensive analysis of climate-smart value chains was conducted. This involved identifying key players, service providers, and the ecosystem that supports these chains. In addition, the governance structure of the value chains was assessed, and a SWOT analysis was conducted. Furthermore, models for each value chain with indicators for profitability and income was developed, as well as innovative technologies and practices to reduce carbon footprints and improve water use efficiency.

METHODOLOGY FOR ASSESSING THE ECONOMIC FEASIBILITY FOR CLIMATE-SMART AGRICULTURE VALUE CHAINS:

A financial feasibility analysis was conducted at the farm level for a unit area (one feddan) based on the recommended interventions to transform to CSA Value Chain. It is important to note that not all interventions require capital investment, and hence, some of them might prove financially feasible to the farmer without requiring significant financial support in terms of debt. Other interventions, however, require significant capital investment that might not be financially feasible for smallholder farmers.

Accordingly, aggregation and economic feasibility analysis captured total net incremental costs (NICs) and benefits (NIBs) of those specific interventions on a wider scale (the three specific governorates in Upper and Middle Egypt). This analysis will add externalities and economic prices, where required, to ensure that the total economic impact is assessed. The economic evaluation of the entire programme is based on the aggregated net incremental benefits for the target population. All the technical assumptions considered in the models are sourced from field surveys, national statistics, international and national expert consultation and technical studies. Those interventions that prove to be economically feasible but not financially feasible for smallholder farmers would require additional support (trade-offs) from the government and/or development partners in the form of offering access to reduced debt financing, government infrastructure investment, and/or enabling the implementation of value-added projects to improve the financial feasibility of the smallholder farmers. Those recommendations will be then used as an input to the financial model to confirm the financial feasibility for smallholder farmers.

The general assumptions for the economic feasibility study include:

1) the figures used in the analysis were gathered from value chain experts during the value chain analysis stage and field workshops. This includes data collected from: a) interviews with farmers; b) official statistics from the Central Agency for Public Mobilization and Statistics (CAPMAS) and the Ministry of Agriculture; and c) academic papers and d) consultant estimates. Information on labor and input requirements for various operations, capital costs, prevailing wages, yields, farm-gate and market prices of commodities, input, and farm-to-market transport costs, were collected during the field workshops. Conservative assumptions were made both for inputs and outputs and took account of possible risks;

2) economic and financial assumptions: a) the exchange rate used in the analysis is fixed at 1 USD = 30.9 EGP. This was computed as the official exchange rate during the study period (2023) ; b) a fixed 10 percent annual inflation rate is used for the crop prices and input costs, both in the presence of the project or without it; c) for the financial model analysis at the farm level, a discount rate of 23 percent was used to assess the viability and robustness of the investments. To consider the profitability of the foreseen investments with market alternatives, the selected value is calculated as an average of the lending, deposit, and money market interest rates; and d) a reduced economic (development) discount rate of 15 percent for the aggregated model has been used.

CHAPTER 1

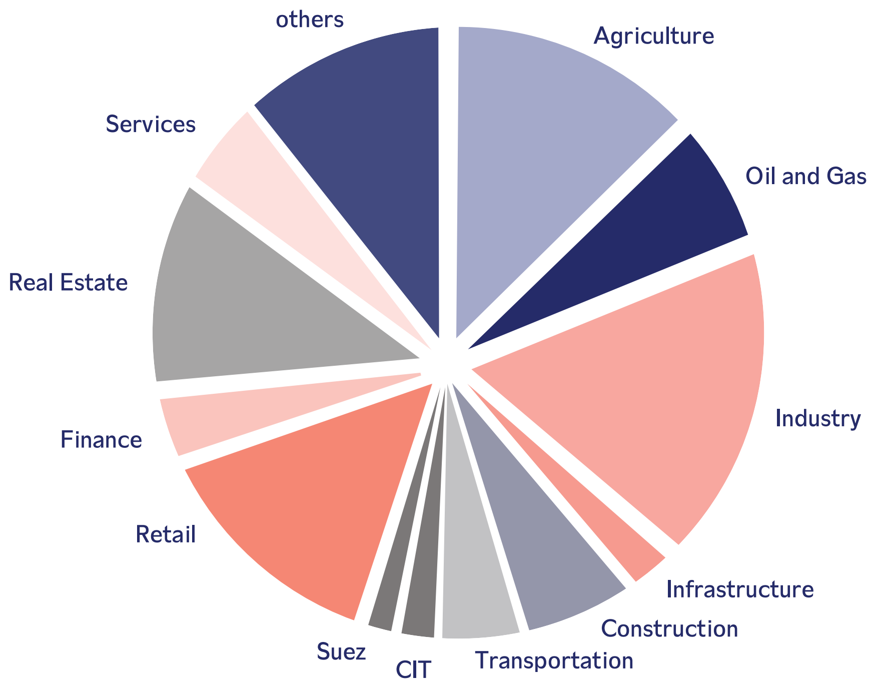
Introduction and background

1.1.

VULNERABILITY OF THE AGRIFOOD SYSTEM IN EGYPT

Egypt's agriculture sector plays a crucial role in providing food for over 100 million people. Based on data from 2020/2021, the agriculture sector accounted for 14.8 percent of the country's GDP and 28 percent of all jobs, making it the primary source of income for approximately 55 percent of the population. However, the sector is facing challenges due to limited water resources, degraded agricultural land, a rising population, unsustainable farming practices, climate change, and the fragmentation of land holdings, all of which threaten the sector's ability to achieve food security and environmental conservation.

Figure 2 Sectoral contribution to Egypt's GDP for the year 2020/2021



Source: CAPMAS, 2021.*Sectoral contribution to Egypt's GDP*. Central Agency for Public Mobilization and Statistics. https://www.capmas.gov.eg/.

Efforts are being made by the government to improve rural development through various initiatives such as Haya Karima ('decent life'), enhancing the irrigation network, utilizing wastewater, reclaiming desert land for productivity, and other similar projects to ensure food security. These efforts are being made to tackle challenges such as the undernourishment rate, which increased from 3.8 percent in 2010–2012 to 5.1 percent in 2019–2021, alongside a decrease in the average protein consumption per capita per day (Santos-Rocha *et al.*, 2023).

Egypt is heavily reliant on food imports, particularly wheat, making it the world's largest importer, which poses a significant challenge to the country's food security. The recent conflict between Russia and Ukraine has only intensified this situation. As a result, it is crucial to take immediate action to accelerate the transformation to a more sustainable, productive, and resilient agricultural system. This can be achieved through the implementation of policies, strategies, programmes, and projects that provide instruments, tools, measures, and practices aimed at improving agricultural productivity, adapting to climate change, and responding to potential risks and disasters.

Water scarcity is currently the biggest challenge to rural development in Egypt. The country relies on various sources, including 55.5 BCM/year from the Nile River, 1.3 BCM/ year from rainfall in the northern part of the Nile Delta, 2.1 BCM/year from non-renewable groundwater from the Western Desert and Sinai aquifers, and 0.35 BCM from desalination. To bridge the gap in water requirements, wastewater is being reused.

Egypt's food production has a water footprint of 50.2 km^3/year, while its food consumption has a water footprint of 76.2 km^3/year, the highest in the Near East and North Africa Region. The main productive areas in Egypt are the 'Old Lands' and 'New Lands'. The Old Lands, which depend mainly on the Nile for irrigation, have highly fertile soil and accommodate 85 percent of small farms in the country. However, around 40 percent of land resources in the Old Lands are of poor quality due to salinity constraints. On the other hand, the New Lands, which make up about 15 percent of the cropped area in Egypt, have less fertile soil and lower productivity.

Smallholder farmers in the New Lands require technical and financial support to improve their crop and livestock productivity. Many of them are new graduates with limited knowledge about agriculture practices, while others are traditional farmers who need guidance in adapting their methods to the newly reclaimed sand and calcareous soils. Practical guidance in improving soil fertility, water management, plant protection, and livestock productivity is essential for both groups of farmers.

The agriculture sector is under increasing pressure due to climate change, as projected temperature increases are expected to have a negative impact on crop productivity, particularly for major crops like wheat and maize. This loss in productivity can be attributed to crop-water stress and the emergence of new pests and diseases. In addition, rising sea levels are anticipated to lead to increased soil salinity in the Delta region due to seawater intrusion into coastal aquifers. Climate change is also expected to reduce livestock production due to heat stress and the emergence of new diseases. To mitigate these effects, it is important to improve resilience to climate change by addressing water scarcity, increasing land productivity, and diversifying livelihoods.

According to a study by the International Food Policy Research Institute (IFPRI) (Perez *et al.*, 2021), predictions for the impact of climate change on major crop productivity show that Egypt will be more severely affected by 2050 than the global average. Specifically, maize, sugar crops, and oilseeds are expected to see productivity decreases of more than 19 percent, 13 percent, and 12 percent respectively, due to the combined effects of heat stress, salinity, and water stress.

To address these challenges, Egypt has launched the Nexus on Water, Food, Energy (NWFE) programme, which aims to promote a resilient and sustainable agrifood system. The programme, launched in July 2022 by the government, is divided into three main pillars and includes various projects. As a national platform, NWFE offers opportunities to mobilize climate finance and private investments to support Egypt's green transition. It reflects the interlinkages between climate action and development efforts and aims to operationalize the National Climate Change Strategy 2050, moving from pledges to implementation.

Table 1 Changes in productivity due to climate change effects projected by 2050 in Egypt

	Biophysical effects, Egypt				Combined Biophysical and Economic Effects	
Commodities	Heat Stress	Water Stress	Salinity	Cumulative Effects	Egypt	Rest of World
	% change from a no climate change scenario					
All food crops	-4.94	-4.14	-1.55	-10.29	-6.17	-5.24
All cereals	-4.66	-2.57	-1.59	-8.59	-10.36	-7.74
Maize	-12.86	-2.46	-1.36	-16.16	-19.54	-17.66
Rice	-5.81	-1.59	-1.58	-8.78	-8.53	-5.61
Wheat	2.27	-3.25	-1.78	-2.81	-0.56	0.82
Fruits & vegetables	-4.73	-5.88	-1.48	-11.66	-8.28	-1.95
Oilseeds	-6.98	-3.18	-1.53	-11.31	-12.08	-6.69
Pulses	-5.46	0.04	-1.57	-6.92	-9.98	0.01
Roots & tubers	2.61	-0.29	-1.79	0.47	3.56	-4.58
Sugar crops	-6.66	-4.19	-1.56	-11.96	-13.28	-10.39

Source: Perez, N.D., Kassim, Y., Ringler, C., Thomas, T. S. & ElDidi, H. 2021. Climate Change and Egypt's agriculture. MENA Policy Note 17. Washington DC: International Food Policy Research Institute IFPRI. Available at https://doi.org/10.2499/p15738coll2.134318

Upper Egypt's cultivated land covers about 1.33 million feddans, representing 14.6 percent of the country's total agricultural land (Ministry of Environment, 2017). This area faces challenges including limited land resources, an increasing population, and high levels of land fragmentation, with 43 percent of farms falling below a one feddan land-holding size in Upper Egypt compared to 30 percent in the Delta. Saleh *et al.'s* study (2017) reveals the vulnerability of Upper Egypt to climate change, particularly heat stress affecting wheat in winter (-35 percent) and maize (-15.1 percent) in summer during heat waves. Other significant challenges include water scarcity, poor extension and advisory services, unsustainable agricultural practices, and land fragmentation.

Upper Egypt's poverty rate is the highest in Egypt, with rural Upper Egypt having 51.5 percent of the population living in poverty compared to the national average of 27.8 percent. Poverty incidence varies across governorates, with Assiut (66 percent), Sohag (65.8 percent), and Menya (56.7 percent) being the most affected. The agriculture sector provides livelihoods for 57.2 percent of the population and directly employs around 30 percent of the labor force, with over 55 percent of employment in rural Upper Egypt being agriculture-related (Breisinger *et al.*, 2019).

Economic development is hampered by various reasons, causing Upper Egypt's contribution to Egypt's national GDP to decrease from 15.9 percent in 2013 to 11.3 percent in 2018 (Santos-Rocha *et al.*, 2023).

Egypt's Ministry of Environment released the First Updated Nationally Determined Contribution (FUNDC) in 2022. This strategy aims to combat climate change in Egypt by reducing greenhouse gas emissions through the implementation of low-carbon energy systems. The plan involves promoting efficient energy usage, increasing the use of renewable energy, and utilizing more efficient fossil fuel technologies. FUNDC also includes action plans for adapting to the effects of climate change in sectors such as coastal zones, water resources and irrigation, agriculture, tourism, energy, and health.

BOX 1

The European Union's Carbon Border Adjustment Mechanism (CBAM)

In May 2023 the European Parliament established the European Union's Carbon Border Adjustment Mechanism (CBAM). As the European Union raises its own climate ambition, and as long as less stringent climate policies prevail in many non-European Union countries, there is a risk of so-called 'carbon leakage'. Carbon leakage occurs when companies based in the European Union move carbon-intensive production abroad to countries with less stringent climate policies than in the European Union, or when European Union products get replaced with more carbon-intensive imports.

The European Union's Carbon Border Adjustment Mechanism (CBAM) is a new landmark tool to put a fair price on the carbon emitted during the production of carbon intensive goods entering the European Union, and to encourage cleaner industrial production in non-European Union countries.

The CBAM will apply to carbon-intensive imports like cement, steel, aluminum, fertilizers, electricity, and hydrogen. The transitional period is a learning period for stakeholders, with importers only reporting GHG emissions without making payments. Indirect emissions will be added after the transitional period for some sectors. Starting 2025, only the EU method will be accepted.

The NDC 2023 listed only adaptation measures in relation to water resources, irrigation and agriculture sectors, overlooking mitigation actions needed, although inventory for the GHG emissions from the Agriculture, Forestry, and Other Land Use (AFOLU) was estimated and reported in the Third National Communications (2016) and updated and presented in the Egypt's first Biennial Update Report (2019) as well. It is true that adaptation measures have the potential to provide co-benefits for mitigation by increasing carbon sinks or reducing emissions, however there is a need to develop a low-carbon agrifood system/value chain in Egypt that will increase the resilience of small-scale farmers to climate pressures, and increase their productivity and income whilst reducing their carbon footprint.

1.2.

POLICIES AND PRACTICES FOR A LOW CARBON ECONOMY IN EGYPT

In 2023, the NDC report provided a detailed assessment of the actions taken to adapt to and mitigate climate change since the first NDC report in 2015. The report highlighted progress made in policies, institutions, and legislation, as well as in national-level measures. Notably, significant progress was made in the energy, transportation, and industry sectors. Here are some key actions taken:

1 Energy policy reforms: The Government implemented an energy policy reform programme that phased out energy subsidies, reducing them from 6 percent of the country's GDP in 2013 to 0.3 percent in 2020.

2 Renewable energy: Investments in renewable energy were encouraged under the Renewable Energy Law (Decree No 203/2014), resulting in the installation wind and solar power plants with a generation capacity of 3016 MW by 2020.

3 Energy efficiency and low carbon fuels: The government promoted energy efficiency and low-carbon fuels in the petroleum sector, with about 450 000 cars operating on natural gas nationwide.

4 Demand-side energy efficiency: Various energy efficiency programmes were implemented, leading to a reduction in electricity consumption in 2020. This included a transition to energy-efficient lighting, resulting in a significant drop in electricity consumption by 40 percent.

5 Low carbon transport: The expansion of the Greater Cairo underground metro network promoted low carbon mass transportation.

6 Solid waste management: The government implemented the new Waste Management Regulation Law in 2020, along with the Prime Minister's Decree 41/2019 on waste-to-energy feed-in tariff (October 2019), and Ministerial Decree 49/2021 for the mandatory partial replacement of alternative fuels in the cement sector (March 2021).

7 Green finance: National and international green finance was mobilized through various mechanisms and initiatives. Egypt's Ministry of Finance launched the first sovereign green bonds in the Near East and North Africa region in September 2020, valued at 750 million and listed on the London Stock Exchange to attract foreign investors.

The newly introduced Egyptian climate change strategy for 2050 is projected to cost 324 billion USD, and aims to reduce greenhouse gas emissions and help the country adapt to the impact of climate change (as indicated in the table). This presents a financing gap of 248.1 billion dollars (FAO and UNDP 2023). It is noteworthy that the overall cost of programmes and projects aimed at adapting to the effects of climate change on food security in Egypt is estimated at 111.7 billion USD. This amount includes 52.4 billion for the agriculture sector, 59.1 billion for water resources and irrigation, and 0.2 billion for biodiversity.

1.3.

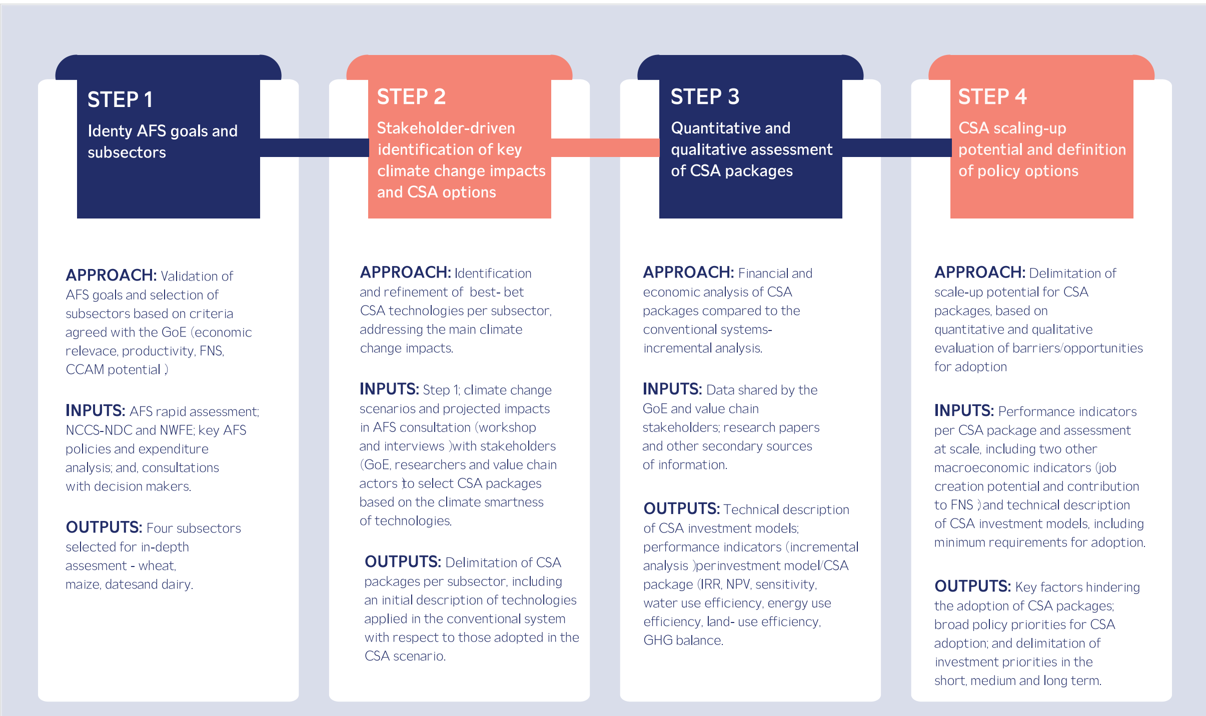
CLIMATE-SMART AGRICULTURE (CSA) FOR AGRIFOOD SYSTEMS TRANSFORMATION IN EGYPT

One solution proposed to combat climate change without compromising food security is climate-smart agriculture (CSA). According to FAO (2013), CSA is comprised of three pillars: sustainably increasing agricultural productivity and incomes, adapting, and building resilience to climate change, and reducing and removing greenhouse gas emissions through mitigation wherever possible. CSA practices are context-specific and tailored to local circumstances and the impact of climate change on theagrifood system (Table 2). To successfully transition to CSA, an enabling environment is necessary to support the development of appropriate institutional arrangements and structures, as well as increased access to credit, insurance, extension, and advisory services for small-scale farmers. This enabling environment would also promote gender equality and inclusive processes for stakeholder involvement (FAO, 2022a).

A study conducted by Abdel Monem *et al.* in 2022 explored the implementation of agricultural practices by small-scale farmers, the private sector, and the state in Egypt. The study examined how these practices contributed to the three pillars of climate-smart agriculture (CSA) towards building a more sustainable and resilient agrifood system. The selected CSA practices included intercropping, crop diversification, minimizing chemical fertilizer use, sustainable water management, renewable energy (solar and biogas), and agricultural waste recycling and management. The report suggests scaling up successful CSA models at both policy and technical levels to attract investment in programmes and projects that contribute to sustainable agrifood systems.

Santos-Rocha *et al.* (2023) provided a detailed explanation of the crucial steps in the CSA analytical framework in Egypt. These steps include: 1) identifying the goals and subsectors of the Agrifood system (AFS); 2) identifying climate change impacts and CSA options with the help of stakeholders; 3) assessing the CSA packages both quantitatively and qualitatively; and 4) determining the potential for scaling up CSA and defining policy options (Figure 3).

Figure 3 A climate-smart agriculture analytical framework for Egypt's AFS.



Research has identified various CSA technologies that can be advantageous to the agrifood value chain, some of which are highlighted in this study. Implementing these technologies across the entire value chain could potentially lead to improved land, water, and energy efficiency, as well as increased diversification. This can result in better-quality products, higher incomes in rural communities, and a smaller environmental footprint. To attain these benefits, it is crucial to consult with farmers, traders, processors, and government experts extensively. This will help in understanding the value chain and deciding which CSA interventions and technologies can be applied at each stage.

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CHAPTER 2

Assessing GHG emissions reductions and the economic benefits of CSA practices in FFS under the sustainable agriculture investments and livelihoods project

2.1.

RATIONALE

The Agriculture, Forestry, and Other Land Use (AFOLU) sector contributes to approximately 14.9 percent of GHG emissions in Egypt (48,390 Gg CO_2e), as reported by the Ministry of Environment (2019). The sector's emissions are caused by several processes, including: 1) enteric fermentation, which is a significant producer of methane from livestock; 2) manure management, which releases methane (CH_4) and nitrous oxide (N_2O); 3) burning of field residuals, which releases methane and nitrous oxide; 4) agricultural soil management, including fertilization; and 5) rice cultivation, which is a major contributor to methane and nitrous oxide. The report identified N_2O as constituting the highest percentage of emissions at 65 percent, followed by CH_4 at 32 percent, and CO_2 the lowest, at 3 percent.

In this study, GHG emissions were evaluated in the SAIL project areas in Upper Egypt under conventional practices and then with the climate-smart agricultural (CSA) practices that were introduced through the FFS programme and implemented by farmers in their fields. Additionally, the study assessed water-use efficiency, changes in productivity and income for small-scale farmers in the villages covered by the projects in Upper Egypt. The study focused on analysing data and information gathered from 173 farmer field schools located in select villages under the SAIL project.

It is worth noting that the data collected from the FFSs was observational, and not part of a controlled experimental design. The purpose was to demonstrate the specific agricultural practices implemented by the farmers and taught in the FFS programme. While the observational data provided initial insights into the potential outcomes of implementing climate-smart agricultural practices and techniques, further research utilizing robust experimental designs and larger sample sizes is necessary to establish stronger conclusions.

The attached Annex (1) presents a comprehensive dataset comprising of observed and calculated data for a set of 45 FFSs across various crops, including wheat, corn, sugarcane, sesame, tomato, pepper, bean, cucumber, onion, garlic, watermelon and several medicinal and aromatic plants. The dataset encompasses diverse parametres related to the performance and outcomes of these FFSs. The proposed interventions for CSA encompass a range of strategies aimed at enhancing agricultural practices. These interventions include the introduction of crop varieties that exhibit heat or drought tolerance as well as resistance to pests and diseases. Additionally, the evaluation of irrigation methods, such as drip irrigation in comparison to traditional surface irrigation, and the assessment of cultivation techniques, such as broadcasting versus drilling or utilizing high ridges versus flat seed beds, are considered. Furthermore, different approaches for plant protection, including the use of pesticides versus biological control methods, are being explored. It should be noted that some interventions involve modifications in multiple elements simultaneously.

The overarching findings reveal significant environmental and economic benefits resulting from the adoption of CSA practices. These benefits include a reduction in greenhouse gas (GHG) emissions, improvements in water-use efficiency (WUE), enhanced productivity, and increased income for farmers. While it is noteworthy that total income did not change significantly in certain cases following implementation of the proposed practices, substantial reductions in GHG emissions and increases in WUE were observed. The adoption of a combination of multiple sustainable practices as a comprehensive package has been shown to maximize both ecological and financial returns. Please refer to Annex (1) for detailed information on the observed and calculated data, as well as for the outcomes and impacts associated with the introduction of CSA interventions in the examined FFSs.

Three crops – namely wheat, corn, and sugarcane – have been selected as detailed case studies exploring and analysing the outcomes and results of the FFS programme executed under the designated FFSs. These three crops were chosen because of their importance to the national economy, as well as their significant role in generating employment opportunities. Based on data provided by FAO (2023), reports from the Economic Affairs Sector (MoALR 2022a) and (MoALR 2022b) indicate that during the winter season of 2022, wheat cultivation accounted for 26.3 percent of the total cultivated area, while during the summer season, 27.52 percent of the total cultivated area was dedicated to corn and sugarcane crops (23.87 percent for corn and 3.64 percent for sugarcane). These findings suggest the significance of the three selected crops in cultivated land in Egypt.

2.2.

WHEAT

In Egypt, climate change has had a negative impact on wheat production, necessitating the exploration of innovative techniques for climate-smart agriculture. One effective and easy-to-implement approach is to select wheat varieties that can adapt to local climates and irrigation methods. Farmers have been trained in sustainable soil improvement and pest and disease management, and have tested different wheat varieties and irrigation methods in FFSs under the scope of this study. Initially, crop rotation was used to manage wheat rust diseases by alternating wheat with non-host crops like legumes or oilseeds, which breaks the disease cycle and reduces the risk of infection. However, unsustainable irrigation methods such as surface irrigation pose a challenge to this strategy and reduce productivity. The key findings from the wheat FFSs conducted in Beni Souf and El Menia are analysed below.

Various strategies have been implemented in West Samalout, El Menia to improve wheat cultivation. Farmers in the region initially grew two varieties of wheat – Beni Sueif 1 and Beni Sueif 5 – using surface irrigation. However, through the FFS, a new variety called Gemeza 11 was introduced to test its resistance to local conditions and its potential for increasing yields. This variety was found to be more effective in preventing rust infections during the crop's susceptible stages, reducing the need for fungicides, and increasing yield.

The FFS conducted an observational and experimental field with three varieties: Beni Sueif 1, Beni Sueif 5, and Gemeza 11, tested under different irrigation systems (drip, sprinkler, and flood). The results showed that Gemeza 11, a rust-resistant variety, performed better than the other two, while Beni Sueif 1 and Beni Sueif 5 performed well under drip irrigation.

Under sprinkler irrigation, Gemeza 11 was found to be the most productive variety, and generated the highest income and yield per unit of water (Table 2) when compared to Beni Souf 1 and Beni Souf 5. However, when using drip irrigation, Beni Souf 1 and 5 showed greater productivity, income, and water use efficiency compared to surface irrigation. Introducing Gemeza 11 under modern irrigation techniques as a climate-smart agriculture intervention resulted in a positive impact on GHG emissions, leading to a decrease in carbon footprint to about 101 CO_2 g/kg. In contrast, using Beni Souf 1 under traditional surface irrigation, which was found to be the least favorable agricultural practice, resulted in the highest carbon footprint at 229.6 CO_2 g/kg.

Table 2 **Effect of changing wheat variety in El Menia governorate.**

Variety	Irrigation	CO_2 g/kg of wheat	WUE kg/m^3 of water	Yield/ tonnes/ feddan	Net income LE/feddan	Total income	Total cost
Gemeza 11	Sprinkler	100.6	1.84	4.41	38575	56700	18125
Beni Sueif 1	Drip	105.2	2.00	3.39	34229	50904	16675
	Sprinkler	145.6	1.13	3.05	20998	39123	18125
	Surface	229.6	0.97	2.62	14300	33075	18775
Beni Sueif 5	Drip	105.2	2.00	3.99	34229	50904	16675
	Sprinkler	132.0	1.40	3.36	24589	42714	18125
	Surface	197.9	1.13	3.05	19970	38745	18775

During the wheat FFS at western El-Fashn, Beni Sueif Governorate, various techniques were explored to enhance efficiency and lower costs. These techniques included using pigeon manure as a natural fertilizer, choosing appropriate planting dates, utilizing drip irrigation, and planting a heat-resistant wheat variety called Geza 171. The main focus was on testing and evaluating different land preparation and planting methods. An observational and experimental field was set up to compare the traditional broadcasting method utilized by farmers with the more precise seed drilling technique. The latter involves sowing seeds in uniform rows at a standard soil depth using specialized machinery.

Table 3 **Effect on wheat of changing cultivation method in the Beni Sueif governorate**

Practice	Yield (tonne/fed)	Total CO_2-e g/kg wheat	WUE kg/m^3	Total income LE/fed	Total production costs LE/fed	Net return LE/fed
T1: Giza 171 + Broadcasting	3.60	584	1.39	19 200	5500	13 700
P1: Giza 171 + Drilling	4.35	483	1.68	23 200	6000	17 200

Table 3 highlights the wheat production data showing that, by using the drilling method for planting the Giza 171 wheat variety, yield and total income increased by 20 percent, despite a slightly higher production cost. Additionally, WUE significantly improved. Furthermore, the drilling method contributed to fewer GHG emissions compared to broadcasting, with a reduction of about 17 percent.

2.3.

CORN

Conducting FFSs for corn growers showed that cultivating corn during the summer season poses multiple challenges for farmers. These challenges are mainly caused by climate change, leading to higher temperatures, increased evapotranspiration, and the need for more water for irrigation. However, FFSs have introduced new CSA A that have had a positive impact on yield, the environment, and the overall cultivation system.

Figure 4 **Farmers testing drip irrigation on the new land.**

In the FFS conducted in Metobus, Kafr El-Sheikh Governorate, corn hybrid SC Giza 10 white was planted using drip irrigation, which was introduced as a new method compared to traditional surface irrigation (Figure 4). Both systems used recommended agricultural practices such as land preparation, corn variety, fertilization, weed control, and harvest, except for the irrigation method. Drip irrigation positively impacted the yield and environment and helped farmers economically and environmentally.

Data collected from the corn fields established as part of the FFS shows that the drip irrigation system is more effective than surface irrigation. The yield under drip irrigation system is 4.56 tonnes/feddan compared to 3.04 tonnes/feddan under surface irrigation. Further calculations reveal that drip irrigation systems have not only potential environmental benefits but economic ones too. Table 4 shows that drip irrigation saves water, improving water use efficiency (WUE) from 0.95 to 1.82 kg/m^3 compared to surface irrigation, and increases yield and total income for the farmer. Although the cost of installing drip irrigation system is higher than that of surface irrigation, the return on investment is still higher in the former. It is worth noting that Abou Kheira (2009) found that WUE using drip irrigation was calculated at 1.64 kg/m^3 under similar conditions in corn cultivation in Egypt. The study showed that the proposed drip irrigation system reduced CO_2-e emissions from 579 g/kg to 364 g/kg of corn. According to a study by Farag *et al.* (2018), synthetic fertilizer contributed to the highest greenhouse gas emissions at 45.5 percent for corn, followed by manure fertilizer at 33 percent. Fuel consumption had the lowest emissions at 4.8 percent. This study estimated the carbon footprint to be 307 kg CO_2 eq/kg grain yield for corn.

Table 4 **Effect of changing the irrigation method for corn in the Kafr El-Sheikh governorate**

Practice	Yield (tonne/ fed)	Total CO_2-e (g/kg product)	WUE (kg/m^3)	Total income (LE/fed)	Total production costs (LE/fed)	Net return (LE/fed)
T1: SC Giza 10 white + surface irrigation	3.04	570	0.95	16 000	5000	11 000
P1: SC Giza 10 white + drip irrigation	4.56	364	1.82	24 000	7000	17 000

The proposed intervention increased total income and net return by 50.0 and 54.5 percent respectively compared to the traditional system. However, the Metobus region's proximity to the sea means that regular monitoring of salinity levels is necessary to determine the viability of surface irrigation. Salinity can significantly impact crop health, irrigation efficiency, and the choice of irrigation system.

Corn producers in Egypt have been dealing with the challenge of infestations of the fall armyworm (Spodoptera frugiperda) in recent years. To combat this problem, farmers are looking for alternative corn varieties that can resist or tolerate the fall armyworm. During their search, they identified the Gold 21 hybrid A, which has genetic traits that make it less susceptible to these infestations. By planting this variety, farmers can improve their yield whilst protecting their crops.

Data collected from the FFS fields shows that the Gold 21 hybrid corn yields better (3.36/feddan) than the traditional Pioneer 3444 hybrid (3.04 tonnes/feddan). Moreover, further calculations provided in Table 5 show that using the Gold 21 hybrid results in improved water use efficiency and reduced estimated CO_2-e emissions from 429.4 g/kg to 357.8 g/kg of corn. Although the total production cost is the same for both production systems, using the Gold 21 hybrid tends to increase the net return by 43.6 percent compared to the Pioneer 3444 hybrid.

Table 5 Effect of changing the variety of corn in the Beni Sueif governorate.

Practice	Yield (tonnes/fed)	Total CO_2-e (g/kg product)	WUE (kg/m³)	Total income (LE/fed)	Total production costs (LE/fed)	Net return (LE/fed)	ROI (percent)
T2: Pioneer 3444 hybrid + drip irrigation	2.80	429.4	1.17	24 000	13 000	11 000	85
P2: Gold 21 hybrid + drip irrigation	3.36	357.8	1.40	28 800	13 000	15 800	122

In conclusion, implementing CSA techniques customized to tackle specific challenges, like drip irrigation or growing corn varieties resistant to fall armyworm, can substantially improve farmers' ability to withstand and recover from difficulties by increasing their production and income. Moreover, these practices contribute to water conservation and a decrease in greenhouse gas emissions in the corn agrifood system.

2.4.

SUGARCANE

Sugarcane is a crucial crop in Upper Egypt and is primarily grown through the planting of its stalks, which are divided into segments known as stalk nodes. Each node has 3-4 buds or shoots. This traditional method of cultivation requires a substantial amount of water and fertilizers, with around 6-7 tonnes of sugarcane needed to cultivate one feddan of land. Due to the vast land area dedicated to sugarcane cultivation in Upper Egypt, innovative approaches are necessary to grow sugarcane sustainably. The next section of the report provides further details on the sugarcane value chain. In the Aswan governorate, two FFSs were set up to demonstrate and evaluate the advantages of implementing CSA practices in sugarcane production. The practices tested include the use of sugarcane seedlings for planting instead of conventional stalks, the evaluation of new sugarcane varieties, and the assessment of drip irrigation as a water-saving technique.

In Wadi El Noukra, Aswan, a FFS was conducted to evaluate a new sugarcane variety 'Geza 4' as an alternative to the well-known traditional variety (S9) in an observational field. Table 6 shows the performance of both varieties for each irrigation method used (drip or surface) and the planting methodology (seedlings or stalks).

Table 6 **Effect of changing sugarcane cultivation method in old fertile land in the Aswan governorate.**

Practice	Irrigation method	Net profit LE/feddan	Total profit LE/feddan	Total cost LE/feddan	kgCO_2 / tonne sugarcane	WUE	Yield tonnes/ feddan
Traditional method/S9	Flood	20375	50413	30038	17.8	6.37	45.83
Seedling of S9 30 cm distance	Drip	31790	76120	44330	11.8	18.02	69.2
Traditional method /Geza 4	Flood	29387	64625	35238	13.9	10.20	58.75
Seedling of Geza 4 30 cm distance	Drip	32160	76890	44730	11.7	18.20	69.9

The data presented in the abovementioned table has shown that using drip irrigation with seedlings as a planting method can increase yield and net profit, regardless of the sugarcane variety being used. Even if the cost of drip irrigation is higher than that of surface irrigation, it is still a more profitable option (Figure 5). Conversely, using surface irrigation with the S9 variety resulted in the lowest yield and profits. Drip irrigation has also been found to be the most water-efficient method, with an increased yield of 18.1 kg of sugarcane per cubic metre of water compared to 8.3 kg with flood irrigation . This highlights the need to adopt drip irrigation in sugarcane production in upper Egypt as a means of adapting to climate change and in order to save water. Comparing the GHG emissions of traditional practices versus CSA-introduced methods, it was discovered that using drip irrigation reduced emissions by 34 percent, regardless of the sugarcane variety being used. In contrast, the S9 variety using surface irrigation resulted in the lowest yield and profits

Figure 5 **Drip irrigation and planting with seedlings for sugarcane in the old land in Aswan**

In the newly reclaimed land of Aswan, a FFS for sugarcane was organized in Wadi El-Saida. This type of land is usually characterized by low fertility, high salinity, poor water retention, and high temperatures (Figure 6). The FFS aimed to overcome these challenges by testing and evaluating CSA techniques and comparing them to traditional methods.

Figure 6 **Drip irrigation and planting with seedlings for sugarcane in the old land in Aswan**

Table 7 Effect of changing sugarcane cultivation method in newly cultivated land in the Aswan governorate.

Variety	Irrigation method	Total cost LE/feddan	kgCO_2 / tonne sugarcane	WUE	Yield tonnes/ feddan	Total profit LE/feddan	Net profit LE/feddan
Seedling S9	Drip	36625	12.7	11.55	48.5	53350	16725
Traditional method S9	Surface	28373	14.9	7.00	42	46200	17827

Table 7 shows the performance of the most common crop variety (S9) in varying conditions in the newly reclaimed land of Aswan. As expected, the overall yield of this variety is lower when grown in the new land compared to the old clay land of Wadi El Noukra, Aswan (as shown in the table). This is mainly due to the lower fertility of the new land in Wadi El-Saida. However, the implementation of CSA interventions through the seedling method for planting with drip irrigation improved water efficiency. This is crucial in harsh conditions and leads to higher yields, although with a lower net profit due to the higher installation cost of the drip irrigation system. In terms of GHG emissions, growing S9 using the traditional surface irrigation method resulted in higher CO_2 emissions. However, introducing the aforementioned CSA practices reduced the emissions.

To summarize, drip irrigation is the most important CSA technique for sustainable sugarcane production in Upper Egypt both in the old and newly reclaimed land. Additionally, the seedlings method for planting reduces greenhouse gas emissions. The second part of the study examines CO_2 emissions at various stages of the sugarcane value chain and identifies the economic feasibility of the two suggested CSA interventions.

CHAPTER 3

Climate-smart value chain for selected agricultural products in Upper Egypt

3.1.

PEPPER

3.1.1. PEPPER PRODUCTION IN EGYPT

Pepper is a part of the Solanaceae family, which also includes important vegetables such as tomatoes, potatoes, and eggplants. It is grown for its flavor, color, taste, capsaicin, and oleoresin content, and has strong export potential. Depending on the capsaicin content of the fruit, it is classified as either sweet or hot. Adewoyin *et al.* (2023) reported that between 2009 and 2019, world pepper production was approximately 3.5 million tonnes, with Vietnam being the largest producer and exporter (at 35 percent of global production), followed by India and Indonesia. In Egypt, both sweet (bell) and hot (chili) peppers are grown as 'genus capsicum' for fresh consumption or for use in pickling. Chili peppers are used fresh or dried as whole fruit or crushed in flakes or powder for local consumption or export. Many pepper varieties fall into these two categories, varying in taste (sweetness, pungency, etc.), shape, length, color, yield, productivity, and resilience to climate, soil, and pests. Capsaicin and related compounds called capsaicinoids are the substances that give chili peppers their intensity when ingested or applied topically.

Pepper is a unique crop that can be grown in all governorates of Egypt throughout the year. It is the second most produced vegetable, with a total of 841 000 tonnes harvested in 2021 from an estimated 97 000 feddans, representing 5 percent of the land cultivated with vegetables. Capsicum pepper is mainly grown during the summer, with a total cultivated area of 65 000 feddans and a production of 473 000 tonnes, resulting in an average productivity of 7.3 tonnes per feddan. During the winter, the total cultivated area is 27 000 feddans, producing 215 000 tonnes, resulting in an average productivity of 8 tonnes per feddan. Sweet pepper, on the other hand, is mainly grown in greenhouses at medium to large-scale due to the cost of production. According to MoALR (2021), pepper cultivation in Upper Egypt made up around 16 percent of the total cultivated area and 24 percent of the total pepper yield in Egypt between 2016 and 2020. This equates to approximately 16 000 feddans of land and 173 000 tonnes of pepper production. The governorates of Beni Suef and Minya were the top producers of peppers in Upper Egypt during this period.

In Beni Suef and Minya, peppers are commonly grown in open fields . The seeds are transplanted between January and March, and crops are usually ready to harvest in the early summer from mid-May to late June. During the summer season, most of the crops are planted from local seeds and a few from imported seeds, which are strictly for local consumption. These seeds are transplanted between March and April, and the crops are usually ready to harvest in June and July. If the intention is to export cultivated hybrid types of peppers, it is best to plant them in mid-July to mid-August in a greenhouse, and to harvest them 110 to 120 days from planting.

Colored pepper is a highly valued greenhouse crop among producers due to its high price and strong demand in foreign markets. The most commercially sought-after color is red, which accounts for approximately 85 percent of cultivation, followed by yellow (10 percent) and orange (5 percent). To meet export requirements, European markets prefer cube-shaped peppers with thick flesh, a smooth surface, and bright colors. Colored peppers have become an important export crop and are typically grown in greenhouses in March, April, or September. After transplanting, the peppers start to mature in about 2-2.5 months and are usually harvested 2-4 months later depending on the variety and temperature.

Egypt consistently produced an average of 837 000 tonnes of fresh peppers every year between 2016 and 2021, with the quantity varying from 757 000 to 841 000 tonnes. The majority of the fresh peppers produced (about 77 percent on average) are consumed domestically within Egypt. Trends in fresh pepper production, consumption, wastage, and exports in Egypt can be seen in (Figure 7). Additionally, the value of Egypt's fresh pepper exports has been on the rise, increasing from 5.98 million USD in 2018 to 8.24 million USD in 2023 (General Organization for Export and Import Control, 2022)

Figure 7 Losses, exports, and consumption of peppers, 2016–2021

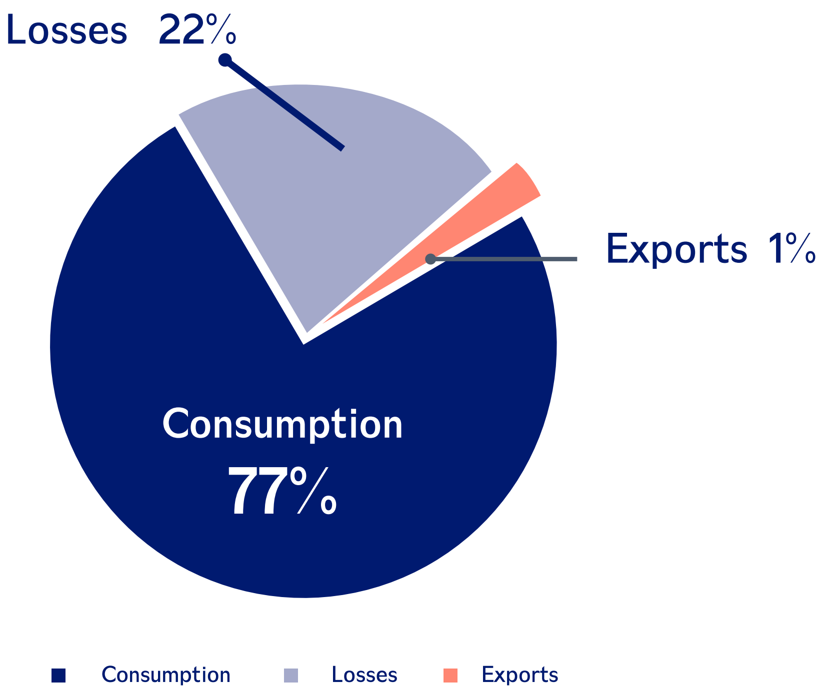
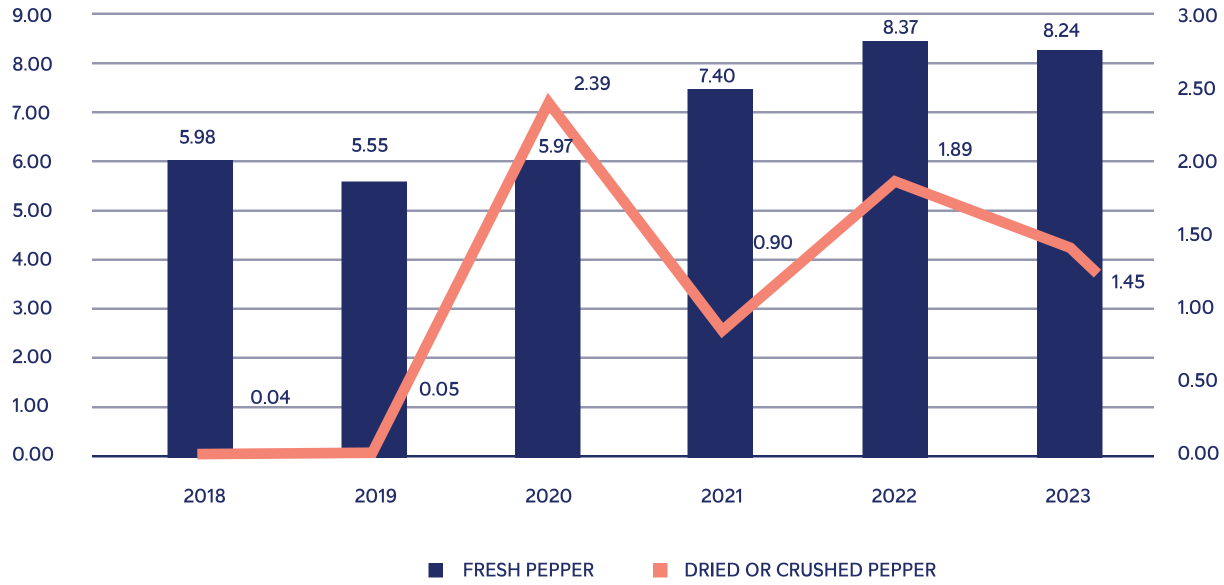


Figure 8 Egyptian pepper exports in million USD, 2018–2023

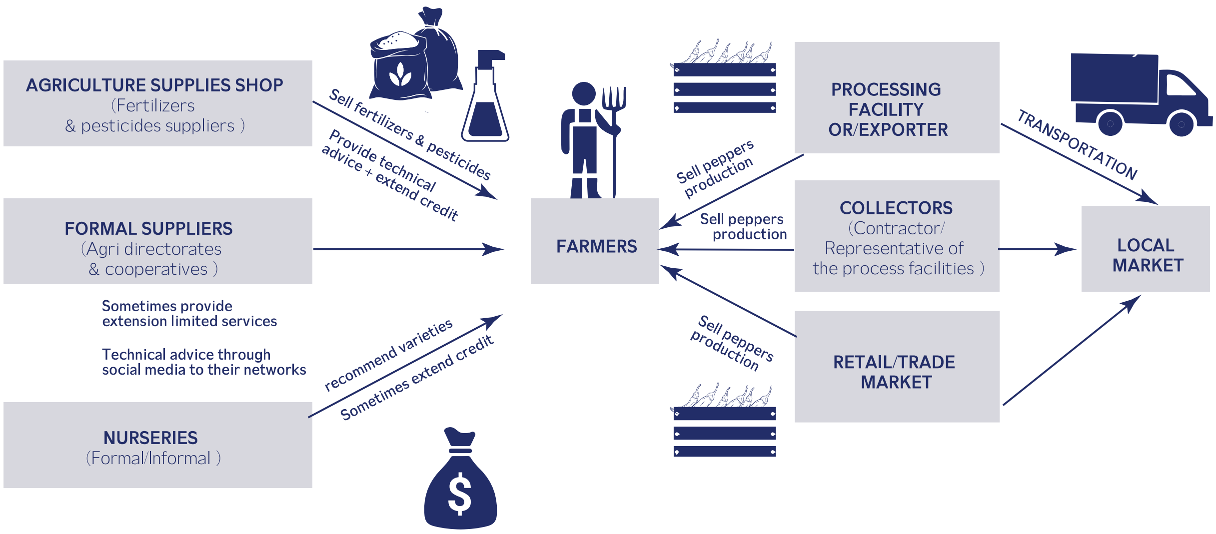


The percentage of peppers lost during production has been estimated at an average of 22 percent between 2016 and 2021, according to MALR (2021). Moreover, the ratio of exports to production remains relatively low. However, Egypt has a promising opportunity to increase its share of the global market, thanks to a gap in demand. One way to achieve this is by enhancing the pepper value chain, which includes fresh and processed varieties like dried chili peppers and high-end pickled options that are in high demand globally

3.1.2.

PEPPER VALUE CHAIN

Figure 9 Pepper value chain flowchart

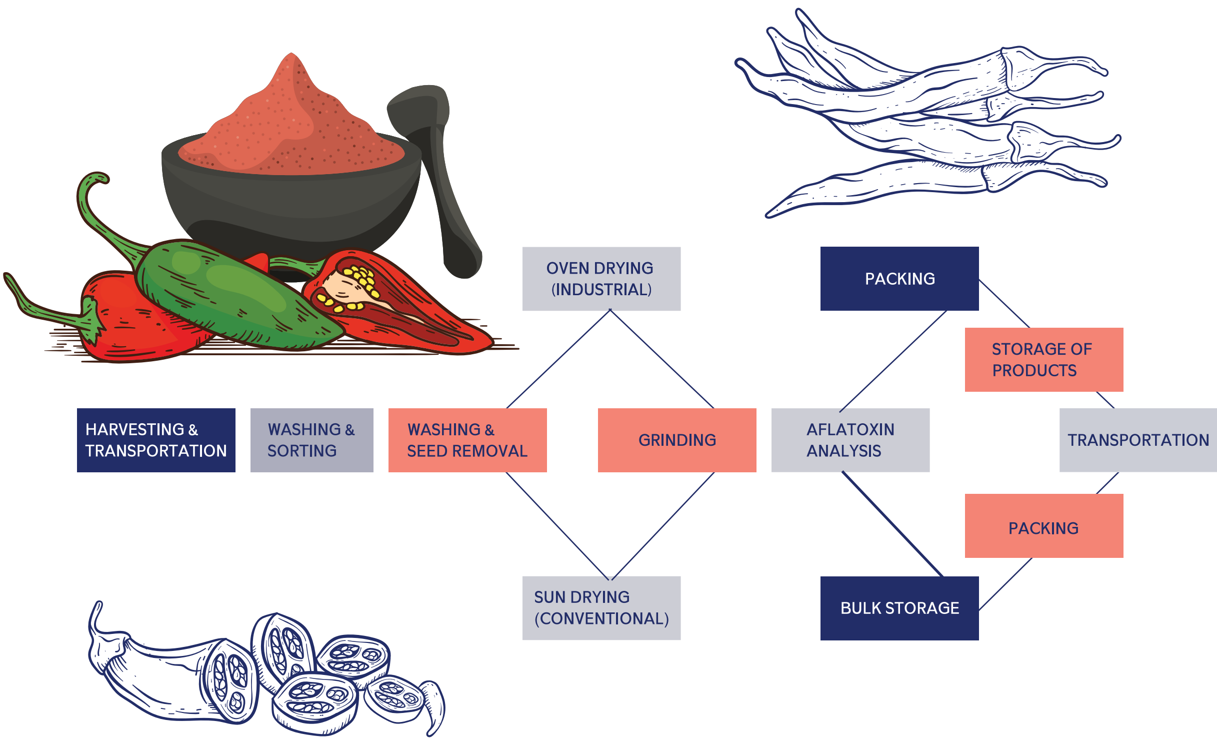


The pepper value chain consists of several activities, namely pre-farming, farming, post-harvest, processing, and trading, as shown in Figure 9. Each actor and stakeholder has a specific role in the value chain. Farmers, whether independent or contracted, can purchase seedlings from nurseries before beginning to farm. However, they may require assistance in ensuring the quality of the pepper seedlings they purchase, as the seedlings could be of lower quality or a different type. Smaller pepper growers typically prefer locally produced seeds over hybrids, which tend to be less productive and less resistant to pests and diseases, causing more issues for farmers.

Suppliers are the primary source of information for producers when it comes to fertilizers, pesticides, and crop management in farming activities. However, overuse of pesticides has resulted in their usage exceeding the recommended threshold. Most pepper growers in Minya and Beni Sueif make use of the flood irrigation method, while drip irrigation, though effective, is not widely used due to a lack of knowledge and awareness.

Pepper is often mishandled after harvest, leading to product wastage and a shorter shelf life, except for certain types produced by large exporters/processors. Contract farming post-harvest activities may include cleaning, sorting, grading, curing, and packing the produce. Beni Suef is a post-harvest facility situated in the village of Beni Soliman Al-Sharkia, within the Beni Suef District. It can process up to 30 tonnes of horticultural crops per day and operates for only eight months a year, catering to the European Union and Arab Gulf markets. The facility processes various crops such as fresh and dry garlic, onions, grapes, spring onions, and tomatoes. Another post-harvest facility is located in Minya, at the Agricultural Development Association in Bayhou Village, Samalout District. It has a production capacity of 40 tonnes per day.

Figure 10 Handling of dried hot peppers



Proper handling and processing of hot peppers is crucial for preventing contamination and minimizing losses. Unfortunately, due to poor post-harvest practices, high-end consumer markets often import peppers from other countries. This is because informal processing units do not comply with food safety and hygiene standards, rendering their produce unsuitable for export (Figure 10). Therefore, it is necessary to establish adequate infrastructure and low-cost solutions to improve pre-processing practices and address these issues effectively.

Women in Upper Egypt are playing a crucial role in different stages of the pepper value chain. Women participate in various aspects of pepper cultivation, including seedling preparation, transplanting, and harvesting, as well as in post-harvest activities, especially processing and packaging. An example of an initiative to engage women in the pepper value chain can be seen in Upper Egypt, where young girls are enrolled in a skill-building programme in post-harvest best practice.

3.1.3.

A SWOT ANALYSIS FOR THE PEPPER VALUE CHAIN

The purpose of this analysis is to provide a foundation for strategic planning and decision-making to enhance the sustainability and resilience of the pepper production value chain, aand to explore possible investment opportunities.

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3.1.3.

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Strengths

- Low production and labor costs, reasonable selling prices, proximity to markets, and favorable winter climates are all advantages Egypt enjoys in pepper production, with a view to exporting to the European Union and Gulf markets.
- Egypt has favorable exchange rate and a robust economic policy protecting this rate.
- Egypt enjoys favorable weather conditions which allow for pepper cultivation in three seasons of the year.
- Farmers are willing to expand pepper production in new land.
- Peppers are a high-value, high productivity crop that offer a fast return on investment.
- Production contract farming schemes embracing an inclusive business model are possible, proven by such enterprises as the Mozare company.
- The demand for peppers is growing both domestically and internationally.
- The market for peppers is available all year round.
- Egypt has established export routes and partnerships with neighboring countries.

Weaknesses

Nematodes and fungi pests can have a significant impact on productivity, leading to increased production costs as a result of the use of pesticides and fumigation.

The high initial cost of establishing greenhouses to improve quality for export.

Low-quality inputs, such as seeds, fertilizers, and pesticides with minimal support from extension services.

The price of peppers in the market can fluctuate, and sometimes revenues do not cover labor costs.

Small-scale farmers often lack appropriate equipment for production, land preparation, planting, harvesting, storage, and cold-chain facilities.

Inadequate post-harvest processing facilities and handling practices lead to high losses.

A lack of quality control and certification in the industry.

The use of surface irrigation systems on old land in Minya and Beni Sueif governorates leads to lower quality and productivity, as well as an increase in pests and diseases affecting the crop.

Lack of adoption of good harvest practices, inadequate post-harvest handling practices, sorting, grading, and packing for targeted markets, which contribute to a deterioration in product quality and shelf life.

Poor dissemination of production and marketing information regarding the timing of production and harvesting to market windows of opportunity.

Improper transportation and inadequate market facilities/infrastructure.

Lack of collective marketing and effective branding of Upper Egypt's peppers, along with infrastructure issues.

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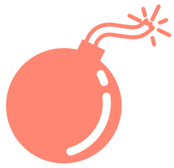

Opportunities

- There is a high demand for peppers in the export market, especially during the winter season.
- New desert lands are available for the expansion of pepper production.
- Donors are putting in efforts to improve the value chain.
- The productivity and quality of the land can be significantly improved by using protective cultivation methods, mulching, composting, and adopting drip irrigation systems.
- Several investments are being made in pepper processing, including in pickling, pepper paste production, and drying.
- International seed companies consistently introduce new varieties of higher quality and greater productive capacity. These varieties also tolerate different diseases and heat stresses.
- There is potential to expand into new export markets, particularly in Europe and the Near East.
- Implementing climate-smart practices can lead to sustainable production.

Threats

- The cost of inputs including seeds, fertilizers and petrol have been increasing yearly, but farm-gate and market prices remain low. At the same time, there are no formal agreements in place for local trade transactions.
- Pests and plant diseases attacking the pepper crop are becoming more intense, likely due to climate change.
- Climate change-related risks, such as extreme weather events and water scarcity, are also a concern. Changes in the EU regulations related to greenhouse gas emissions could also affect international trade.
- Competition from other countries and regions that produce peppers.

3.1.4.

CLIMATE-SMART PRACTICES FOR THE PEPPER VALUE CHAIN

Climate change and extreme weather events have had adverse effects on pepper production. When temperatures drop to 10°C, plant growth comes to a complete halt. Even slight frost is intolerable for plants. Moreover, if the temperature is excessively high during the initial stages of fruit growth, it can lead to the formation of small funnel-shaped or cuboid fruits with a large protrusion on top. This happens due to the thickening and enlargement of the stem, which fuses with the fruit at the top. If the temperature rises above 28°C during the coloring period, it can cause the color of red fruits to turn yellow or green fruits to turn black in some parts, and can increase the likelihood of their walls cracking.

It's important to note that bell pepapers have a high carbon footprint, emitting 0.331kg of CO_2e for every kg of pepper. This is due to factors such as land usage, long growth periods, and significant maintenance requirements during growth. According to Howarth (2021), the carbon footprint of bell peppers during the production stage accounts for 79.61 percent of the overall carbon footprint of this plant. They release 0.28 kg of CO_2e per kg of pepper, while the rest is released at the harvesting, processing, and packaging processes.

After consulting with various producers and stakeholders involved in the pepper value chain, several technologies and practices were recommended as CSA interventions. The main objective of these interventions is to increase agricultural productivity and income in a sustainable manner, whilst also building resilience and adapting to climate change. It is also important to focus on reducing greenhouse gas (GHG) emissions wherever possible.

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The following are the suggested CSA interventions that can be implemented in the stages of the value chain:

01. During the production stage, it is crucial to incorporate organic fertilizers, compost, and bio-fertilization techniques to enhance soil fertility and moisture retention. The use of nitrogen-fixing bacteria, phosphorin, and potassium-solubilizing bacteria can significantly reduce the utilization of chemical fertilizers and their associated greenhouse gas emissions.

02. Securing a reliable source of seeds and fertilizer to ensure higher yields and good quality peppers. In addition to this, selecting early-maturing, drought/heat/salinity tolerant pepper varieties that are appropriate for the characteristics of the soil, the availability of water, and the needs of domestic or international markets is crucial.

03. Post-harvest practices can be improved to minimize losses and enhance the quality of products. This includes harvesting at the optimal stage, proper handling and sorting, adequate storage conditions, packaging, protection, quality control, and grading.

04. Small-scale farmers can benefit from forming associations and groups to establish collection centers equipped with cold storage facilities at the village or district level. This will help minimize losses and waste whilst simultaneously increasing the value of the product.

3.1.5.

ECONOMIC FEASIBILITY OF CLIMATE-SMART INTERVENTIONS IN PEPPER VALUE CHAIN

- **Crop budget under current conditions**

The average time between plantation and harvesting is 5 months or 150 days. The below table represents the costs per feddan for the planting, drying and grinding of a local variety of hot pepper hybrid named 'Shushut'. The average yield per feddan is 2-3 tonnes of dried and ground pepper. The costs of pepper production per feddan without the suggested interventions are presented in Table 8.

Table 8 Hot Pepper crop budget under current conditions (without project)

Item	Quantity	Unit Cost (EGP)	Item Cost (EGP)
Land Rent	1	12 500	12 500
Plowing	1	670	670
Land Preparation	1	7 850	7 850
Labour preparation	4	150	600
Seedlings	55	150	8 250
Planting	3	150	450
Hoeing	9	150	1 350
Fertilizers	1	10 400	10 400
Pesticides	1	5 000	5 000
Irrigation	1	5 700	5 700
Drying Cost	2.5	4 000	10 000
Harvesting	2.5	800.0	2 000
Grinding	2.5	2 000	5 000
Transportation	1	5 000	5 000
Total Cost per feddan			**74 770**

*All costs are based on market prices.

- **Crop budget under suggested CSA interventions**

The suggested intervention for the transformation to CSA value chains is the replacement of the existing variety with a more advanced variety, named 'hot pepper Firebomb F1', that offers a 40 percent higher yield per feddan, and hence enhances food security and income to farmers, while also reducing water consumption per tonne of output. It is worth mentioning that no capital investment is required for this intervention. Investment in the new variety, which is more expensive than the old one by 73 percent (seedlings cost EGP 260 per tray rather than EGP 150), falls within the operational cost per feddan and is compensated by a much higher yield as shown in the financial analysis below (Table 9).

Table 9 Hot Pepper crop budget with CSA project

Item	Quantity	Unit Cost (EGP)	Item Cost (EGP)	Comment
Land Rent	1	12 500	12 500	No change
Plowing	1	670	670	No change
Land Preparation	1	7 850	7 850	No change
Labour preparation	4	150	600	No change
Seedlings	55	260	14 300	Same number of trays but higher price
Planting	3	150	450	No change
Hoeing	9	150	1 350	No change
Fertilizers	1	10 400	10 400	No change
Pesticides	1	5 000	5 000	No change
Irrigation	1	5 700	5 700	No change
Drying Cost	3.5	4 000	14 000	Similar for both
Harvesting	3.5	800.0	2 800	Varies due to change in yield - one time harvesting instead of 3-4 times for fresh products
Grinding	3.5	2 000	7 000	Dried Powder
Transportation	1	5 000	5 000	
Total Cost per feddan			**87 620**	

*All costs are based on market prices.

- **Crop budget under suggested CSA interventions**

The suggested intervention for the transformation to CSA value chains is the replacement of the existing variety with a more advanced variety, named 'hot pepper Firebomb F1', that offers a 40 percent higher yield per feddan, and hence enhances food security and income to farmers, while also reducing water consumption per tonne of output. It is worth mentioning that no capital investment is required for this intervention. Investment in the new variety, which is more expensive than the old one by 73 percent (seedlings cost EGP 260 per tray rather than EGP 150), falls within the operational cost per feddan and is compensated by a much higher yield as shown in the financial analysis below (Table 9).

- **Pepper model assumptions:**
  - Duration of the model is 5 years of growing and harvesting.
  - **Area:** unit area of one feddan, as it represents the most common ownership size for farmers in Upper and Middle Egypt.
  - **Crop prices:** The average market price of the dried and ground pepper is EGP 70 000 per tonne. This price is expected to increase yearly at a fixed annual inflation rate of 10 percent.

- Revenues: revenues are calculated based on an average annual yield per feddan which is equal to:

- 2.5 tonnes fixed over the model period for the 'without-project' model.

- 3.5 tonnes fixed over the model period for the 'with-project' model.

- **Pepper production financial model results:**

It is important to note that the financial return of the project is very high as illustrated in the below table (Table 10), due to the significant increase in yield without capital investment. All positive cash flows means that the project generates positive returns from the first year, hence the payback period is 0 years, and the Internal Rate of Return can't be calculated.

Table 10 Pepper Financial Model Results

Farm Level Financial Feasibility	Without Project	With Project
Area (Feddan)	1	1
Discount Rate	23%	23%
FNPV (EGP)	329 46	518 077
Payback (Years)	0	0
BCR		5.54

Table 11 Pepper detailed in-farm financial model with project

	Year 0	Year 1	Year 2	Year 3	Year 4
Farmer's Land Area (Feddans)	1	1	1	1	1
Yield per Feddan (Tonne)	3.5	3.5	3.5	3.5	3.5
Total Yield (Tonne)	3.5	3.5	3.5	3.5	3.5
Losses/Waste (Tonne)	0	0	0	0	0
Sales Price per (EGP per Tonne)	70 000	77 000	84 700	93 170	102 487
Sales Revenue (EGP)	245 000	269 500	296 450	326 095	358 705
Plowing	670	737	811	892	981
Land Preparation	7 850	8 635	9 499	10 448	11 493
Labour preparation	600	660	726	799	878
Seed	14 300	15 730	17 303	19 033	20 937
Plantation	450	495	545	599	659
Hoeing	1 350	1 485	1 634	1 797	1 977

Table 11 Pepper detailed in-farm financial model with project

	Year 0	Year 1	Year 2	Year 3	Year 4
Fertilizers	10 400	11 440	12 584	13 842	15 227
Pesticides	5 000	5 500	6 050	6 655	7 321
Irrigation	5 700	6 270	6 897	7 587	8 345
Drying Price per Tonne	4 000	4 400	4 840	5 324	5 856
Harvesting Price per Tonne	800	880	968	1 065	1 171
Grinding Price per Tonne	2 000	2 200	2 420	2 662	2 928
Drying	14 000	15 400	16 940	18 634	20 497
Harvesting	2 800	3 080	3 388	3 727	4 099
Grinding	7 000	7 700	8 470	9 317	10 249
Transportation	5 000	5 500	6 050	6 655	7 321
Rent per Feddan	12 500	13 750	15 125	16 638	18 301
Total Rent	12 500	13 750	15 125	16 638	18 301
Depreciation	0	0	0	0	0
Transportation	0	0	0	0	0
Total Operational Expenditures	87 620	96 382	106 020	116 622	128 284
Farmer's Profit/Loss	157 380	173 118	190 430	209 473	230 420
Taxes	0	0	0	0	0
After Tax Profit/Loss	157 380	173 118	190 430	209 473	230 420
Total Capex	0	0	0	0	0
Free Cash Flow	157 380	173 118	190 430	209 473	230 420
Cumulative FCF	157 380	330 498	520 928	730 401	960 821
Discount Rate	23%				
DFCF	127 951	114 428	102 334	91 518	81 845
NPV	518 077				
Payback (Years)	0				
IRR	#NUM!				
BCR	5.45				

- **Aggregation and economic model:**

The farm-level financial analysis per feddan is further aggregated into an economic model for the total area (Table 12) planted with dried and ground hot pepper in Beni Sueif and Minya, which is assumed to be **3000 feddans** to capture the total costs and benefits of the project. .
of **EGP 683 372** and a payback period of 0 years.

Table 12 Pepper Economic Aggregated Model Results

Aggregated Economic Feasibility	WP Scenario
Area (Feddan)	3 000
Discount Rate	15%
ENPV (kEGP) (net incremental)	683 372
EIRR (%) (net incremental)	N/A
Discounted Payback (Years)	0
BCR (net incremental)	5.45

Table 13 Pepper detailed Economic Aggregated Model

	Year 0	Year 1	Year 2	Year 3	Year 4
Farmer's Land Area (Feddans)	3 000	3 000	3 000	3 000	3 000
Yield per Feddan (Tonne)	3.5	3.5	3.5	3.5	3.5
Total Yield (Tonne 000's)	10.5	10.5	10.5	10.5	10.5
Losses/Waste (Tonne 000's)	0	0	0	0	0
Sales Price per (EGP per Tonne)	70 000	77 000	84 700	93 170	102 487
Sales Revenue (EGP 000's)	735 000	808 500	889 350	978 285	1 076 114
Plowing (EGP 000's)	2 010	2 211	2 432	2 675	2 943
Land Preparation (EGP 000's)	23 550	25 905	28 496	31 345	34 480
Labour preparation (EGP 000's)	1 800	1 980	2 178	2 396	2 635
Seed (EGP 000's)	42 900	47 190	51 909	57 100	62 810
Plantation (EGP 000's)	1 350	1 485	1 634	1 797	1 977
Hoeing (EGP 000's)	4 050	4 455	4 901	5 391	5 930
Fertilizers (EGP 000's)	31 200	34 320	37 752	41 527	45 680
Pesticides (EGP 000's)	15 000	16 500	18 150	19 965	21 962
Irrigation (EGP 000's)	17 100	18 810	20 691	22 760	25 036
Drying Price per Tonne	4 000	4 400	4 840	5 324	5 856
Harvesting Price per Tonne	800	880	968	1 065	1 171
Grinding Price per Tonne	2 000	2 200	2 420	2 662	2 928

Table 13 Pepper detailed Economic Aggregated Model

	Year 0	Year 1	Year 2	Year 3	Year 4
Drying (EGP 000's)	42 000	46 200	50 820	55 902	61 492
Harvesting (EGP 000's)	8 400	9 240	10 164	11 180	12 298
Grinding (EGP 000's)	21 000	23 100	25 410	27 951	30 746
Transportation (EGP 000's)	15 000	16 500	18 150	19 965	21 962
Rent per Feddan (EGP 000's)	13	14	15	17	18
Total Rent (EGP 000's)	37 500	41 250	45 375	49 913	54 904
Depreciation	0	0	0	0	0
Transportation	0	0	0	0	0
Total Operational Expenditures	262 860	289 146	318 061	349 867	384 853
Farmer's Profit/Loss	472 140	519 354	571 289	628 418	691 260
Taxes	0	0	0	0	0
After Tax Profit/Loss	472 140	519 354	571 289	628 418	691 260
Total Capex	0	0	0	0	0
8 (EGP 000's)	171 450	188 595	207 455	228 200	251 020
Cumulative FCF	171 450	360 045	567 500	795 699	1 046 719
Discount Rate	15%				
DFCF (EGP 000's)	149 087	142 605	136 405	130 474	124 801
NPV (EGP 000's)	683 372				
Payback (Years)	0				
IRR	#NUM!				
BCR	5.45				

3.2.

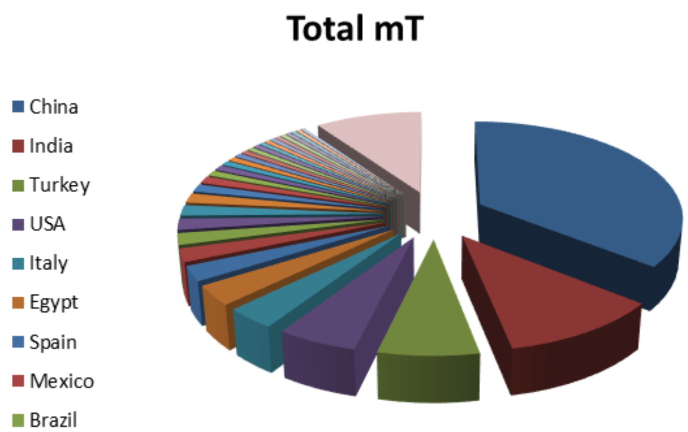
TOMATO

3.2.1. TOMATO PRODUCTION IN EGYPT

Tomatoes *(Lycopersicon esculentum)* are a crucial member of the Solanaceae family, widely cultivated for both fresh consumption and processing. They can be grown outdoors or in greenhouses, with different varieties preferred for each. Heirloom varieties are popular for their adaptability and use in grafting. However, tomato production faces several challenges, including, high costs, and a lack of marketing capability. Organic production is a niche but growing market driven by consumer awareness and environmental conservation. Adding value to tomato production can help address post-harvest challenges and increase profitability (Gatahi, 2020).

In Egypt, tomatoes are a vital part of the daily diet, used either fresh in salads or cooked in a variety of dishes (FAO, 2021). Egypt ranks sixth among tomato-producing countries in the world by volume, accounting for 3.3 percent of global production (Figure 11). Within the country, tomato cultivation takes up an area of 356 896 fed, with a total production of 6 389 295 tonnes. Tomato cultivation is prevalent in all governorates of Egypt, and the area of cultivation in Upper Egypt is 37,992 feddan (Figure 13).

Figure 11 **Global tomato production (mT). 2021.**



Source: Branthome, F. 2023. *Worldwide (total fresh) tomato production in 2021.* Tomato News. tomatonews.com/en/worldwide-total-fresh-tomato-production-in-2021_2_1911.html.

3.2.1.

Egypt has an estimated tomato cultivation area of 356 896 fed according to data released by the Sector of Economic Affairs Department of the Ministry of Agriculture for the year 2020/2021 (Table 13), with a total production of 6 389 295 tonnes of tomatoes throughout the winter, summer, and Nili growing seasons, in both old and new lands. Production is highest in the winter season, and the land area used for tomato cultivation was found to be higher in the old land than in the new land.

Table 14 **Tomato cultivation area (fed) and production (tonnes) in the three growing seasons.**

Winter season					
Old land		New land		Total	
area	production	area	production	Total area	Total production
58 927	1 304 019	115 999	2 209 592	174 926	3 513 611
Summer season					
Old land		New land		Total	
area	production	area	production	Total area	Total production
50 017	942 949	116 016	1 740 873	166 033	2 683 822
Nili season					
Old land		New land		Total	
area	production	area	production	Total area	Total production
5828	106 214	10 109	85 648	15 937	191 862

Source: MoALR 2021. Ministry of Agriculture and Land Reclamation Economic Affairs Sector of the MoALR (2022). Cairo, Egypt

In Table 14, a comparison of the three governorates - Beni Sueif, El Menia, and Aswan - shows that Beni Sueif has the largest tomato cultivation area in the winter season, whist El Menia is home to the largest area in the summer season.

Table 15 **Total tomato cultivation areas (fed) for the three governorates under the study**

Winter season									
Governorate	Beni Sueif			Menia			Aswan		
	Old land	New land	Total	Old land	New land	Total	Old land	New land	Total
	2561	8768	11 329	4902	5197	10 099	117	2317	2434
Summer season									
Governorate	Beni Sueif			Menia			Aswan		
	Old land	New land	Total	Old land	New land	Total	Old land	New land	Total
	1769	3034	4803	7315	4725	12 040	0	166	166
Nili									
Governorate	Beni Sueif			Menia			Aswan		
	Old land	New land	Total	Old land	New land	Total	Old land	New land	Total
	96	0	96	1028	0	1028	0	0	0

Source: MoALR 2021. Ministry of Agriculture and Land Reclamation Economic Affairs Sector of the MoALR (2022). Cairo, Egypt

3.2.2.

TOMATO VALUE CHAIN

Tomato production in Egypt is largely dominated by small-scale farmers who rely on traditional methods of cultivation on plots of land that are 5 feddans or smaller. Medium to large-scale farms account for only 20 percent of total tomato-growing land. The majority of the tomatoes produced are consumed locally, while the rest are exported or processed into sauce. The distribution system of tomatoes in Egypt (Figure 12) is informal and traditional, with intermediaries and traders playing a dominant role. Technology, handling practices, and marketing methods are also traditional. MoALR (2021) provides statistical data on tomato exports .

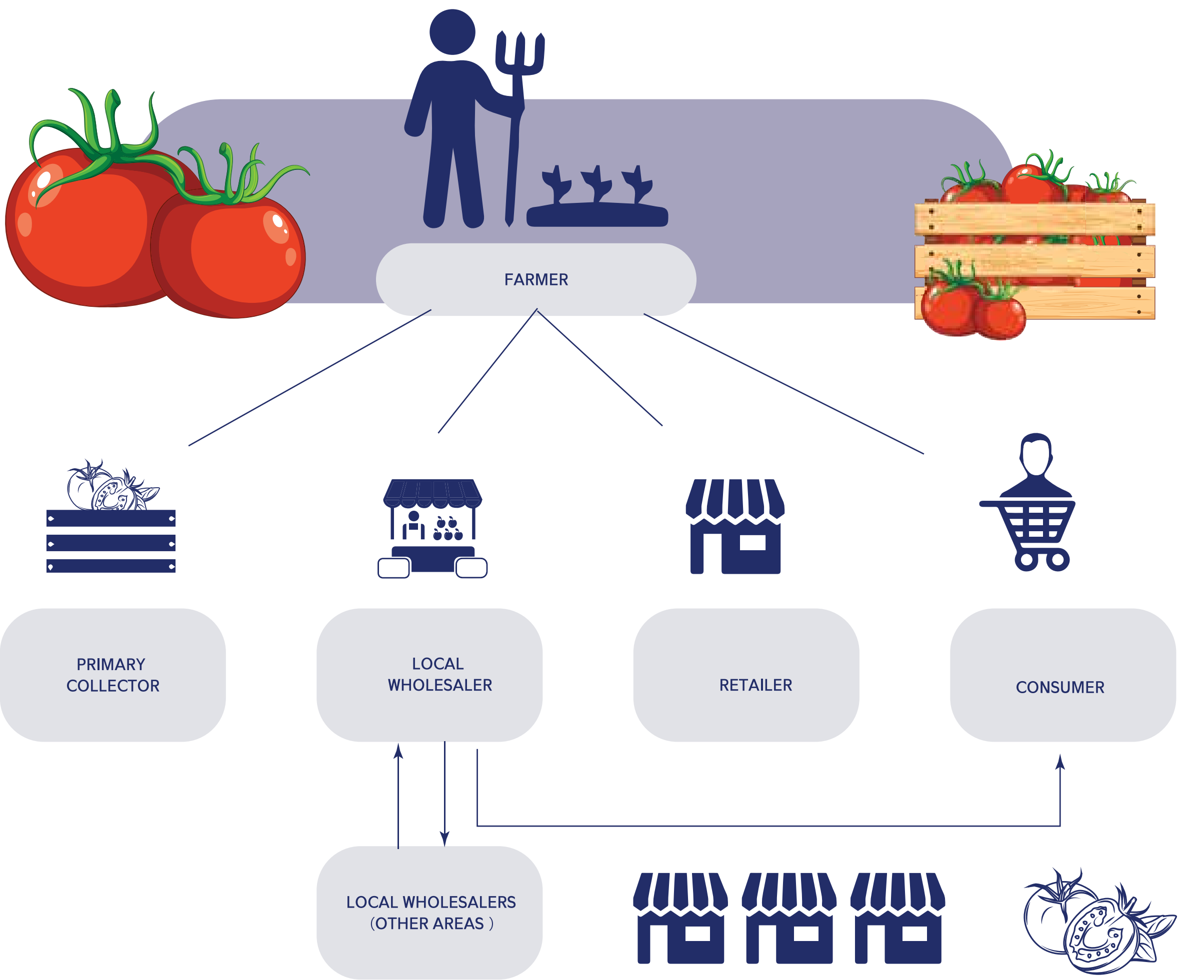
Producers: Most tomato farmers in Egypt own less than one feddan of land. They often face high production costs. However, there are also farmers outside the valley in new lands who grow tomatoes in greenhouses. These farmers invest in agriculture to gain high returns, as their product is also exportable. Additionally, there are some companies that have private farms where they grow special varieties for manufacturing purposes, producing solely for that purpose. Lastly, there are farmers who produce for export companies or factories under the contract farming system.

Labor: Most workers carry out tasks such as preparing the land for agriculture, applying fertilizers, irrigation, and adding pesticides. Most workers are men, and for those who carry out the harvesting process, some may be uneducated women with incomplete diplomas. In packing stations, sorting, grading, and packing operations are carried out by women.

Middlemen/traders: Brokers often buy crops directly from the farm and sell to wholesale or retail markets. They may also collect crops from more than one place and send them to collection centers for sorting before sending them to factory. Alternatively, they may collect crops from farms and send them to packing stations. The crop is marketed both by associations and by individuals. Merchants supply fertilizers, pesticides, and other production inputs to farms. Contract farming is also practiced in some areas.

Women in Upper Egypt are playing a crucial role in different stages of the tomato value chain. There is an increasing demand for processed tomato products in Egypt, as a way to reduce losses caused by transporting tomatoes to local markets. Sun-drying and dehydrating tomatoes, processing them into tomato paste, canning them, and making sauces are the most suitable options for preserving tomatoes. Young women in Upper Egypt are keen on establishing small-scale processing units as joint businesses. To build up their capacity to run the business, they require training and access to proper investment resources. Setting up microfinance or lending services that cater specifically to women involved in the tomato value chain can help expand their businesses and reduce tomato loss and waste.

Figure 12 **Tomato value chain flowchart.**



3.2.3.

SWOT ANALYSIS FOR THE TOMATO VALUE CHAIN

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3.2.3.

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Strengths

- **Favorable climate and geography:** Egypt's climate, with its abundant sunlight and warm temperatures, is ideal for tomato cultivation. The country's fertile soil and access to water resources support high yields and quality production.
- **Large-scale production:** Egypt has a significant capacity for tomato production, which allows for economies of scale and competitive pricing in both domestic and international markets.
- **Export potential:** Egypt's strategic location provides access to regional and international markets, creating opportunities for tomato exports.
- **Established infrastructure:** The tomato value chain in Egypt benefits from well-developed agricultural infrastructure, including irrigation systems, transportation networks, and processing facilities.

Weaknesses

- **Seasonal variations:** Tomato production is influenced by seasonal fluctuations in Egypt, peaking at specific times of the year. Because of this, there can be supply-demand imbalances, and it becomes challenging to maintain a year-round supply of tomatoes.
- **Post-harvest losses:** Inefficient practices in post-harvest handling, storage, and transportation of tomatoes can result in significant losses. Therefore, it is essential to improve post-harvest infrastructure and practices to minimize these losses.
- **Quality control:** Maintaining consistent quality standards throughout the value chain is challenging. Tomato quality and shelf life can be affected by variations in cultivation practices, pest and disease management, and post-harvest handling.

Opportunities

- There are several opportunities in the tomato industry that Egypt can take advantage of. Firstly, the demand for fresh and processed tomatoes is continuously growing both domestically and globally. By expanding production, Egypt can capture a larger market share and increase its revenue.
- There is an opportunity to diversify the product range and add value by producing processed tomato products such as sauces, pastes, and canned tomatoes. This will cater to different market segments and extend the shelf life of tomatoes, resulting in reduced waste.
- With the increasing consumer preference for organic and sustainably grown products, Egypt can tap into niche markets by promoting and certifying organic tomato production practices. This will not only create a new revenue stream but also contribute to the country's sustainable development goals.

Threats

- **Competition:** The global tomato market is highly competitive, with many major tomato-producing countries. Egypt faces competition in terms of price, quality, and market access. It is important for Egypt to remain competitive by maintaining high quality standards and exploring new markets.
- **Pests and diseases:** Tomato crops are vulnerable to various pests and diseases, which can reduce both yields and quality. To mitigate these threats, it is essential to implement effective pest and disease management practices and monitoring systems.
- **Price volatility:** Tomato prices can fluctuate due to factors such as supply-demand dynamics, weather conditions, and market forces. These fluctuations can impact tomato producers' profitability and the value chain's stability. To address this threat, it is important to have a stable and diversified market and explore new opportunities for growth.
- **Changing consumer preferences:** Changing consumer preferences and demands, such as a shift towards locally sourced or organic tomatoes, can be a challenge for the value chain. It is important to adapt to these changing trends and preferences to remain competitive. This can be achieved by investing in research and development, improving production techniques, and developing new products that align with consumer demands.

3.2.4.

CLIMATE-SMART PRACTICES FOR THE TOMATO VALUE CHAIN

Tomatoes grow best in moderate weather conditions, with optimal temperatures between 20-26°C in the day and 18-21°C at night. Temperatures below 10°C delay seed germination and reduce fruit set, while temperatures above 35°C during the day and 28°C at night can reduce flowering and lead to lower yields. Fluctuations in temperature can cause malformation in fruits and poor coloration. If the temperature drops below 5 degrees, growth stops and cold damage can occur.

High temperatures can have a negative impact on the growth, yield, and quality of tomato fruits. They reduce carotenoid and lycopene content in the fruits. However, some genotypes like IIHR-2202 have been found to have high antioxidant capacity even under high-temperature stress. Tolerant genotypes also tend to have higher total phenols and flavonoid content under both control and high-temperature stress conditions. Genotypic variations have been observed in these biochemical parametres under high-temperature stress. (Lokesha et al, 2019). To avoid the harmful effects of high temperatures, climate-smart agriculture suggests using techniques like frequent tomato irrigation or shading with black net (thiram) and growth regulators.

Small-scale farmers need to have a good understanding of the different plant varieties that are suitable for each season. They may seek guidance from seed merchants to help them choose the best option from the wide range of varieties and hybrids available. To reduce waste during the growth process, farmers need to grow their crops according to their intended use, whether for fresh consumption or for manufacturing. Tomato varieties can be categorized based on where they are grown, such as open fields or greenhouses and tunnels, and according to their purpose, such as hybrids for manufacturing and processing or for fresh consumption. Choosing the right variety also depends on the planting date, as there are hybrids suitable for each season and planting date that match changes in temperature. For Upper Egypt, some recommended hybrids include Castle Rock, Beto 86, Hines 2710, Hines 8704, Brigid, Mader, Franco, Super Estrin B Hybrid, Heinz 137, Heinz 7155, Tumanur, Nemaruk, Beto Pride, Star Royal, 028-027-023, and 100Master.

Table 16 Tomato water requirements (m^3/fed) in open field farming

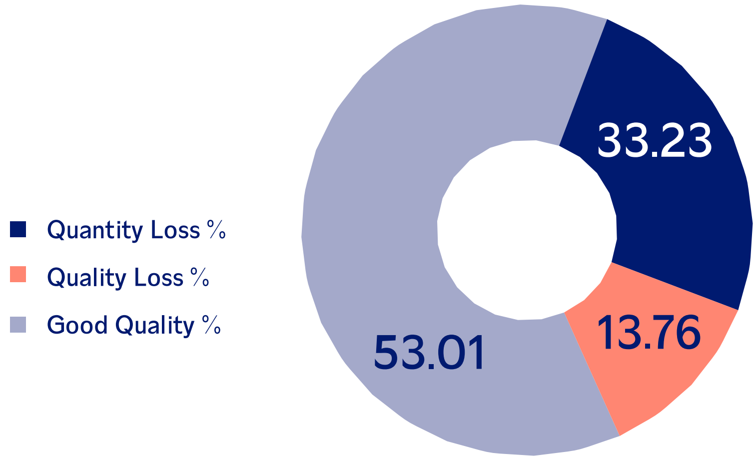
District	Season	Type of irrigation		
North Nile Delta	Winter	Surface	Sprinkler	Drip
		2117	1693	1494
	Summer & Nili	3188	2550	2250
Middle Egypt	Winter	3104	2483	2191
	Summer & Nili	4506	3605	3181
Upper Egypt	Winter	3873	3098	2734
	Summer & Nili	5676	4541	4007

Source: MoALR. 2022c. *The land and water institute report.* Cairo, Ministry of Agriculture and Land Reclamation.

Implementing a drip irrigation system can lead to increased tomato yield and better water productivity while reducing overall water usage. In comparison to surface irrigation methods, using drip irrigation showed an average reduction of 20 percent in total water input and a 22 percent increase in tomato yield, as per the findings of Mukherjee ***et al.*** (2023). According to the MoALR (2022c), water requirements for growing tomatoes are higher in Upper Egypt as compared to Middle Egypt and the Delta regions, which is presented in table (15). The table also shows that using drip irrigation in Upper Egypt can reduce water requirements by 29.4 percent during both summer and winter seasons as opposed to surface irrigation.

The tomato value chain in Egypt is facing significant challenges due to the high percentage of the loss and waste, especially at the post-harvest stage. Concrete interventions are necessary to eliminate or at least reduce the percentage of losses. According to (Figure 13) in the Nubaria area of Egypt (FAO 2021), approximately 47 percent of produced tomatoes are lost or wasted (Figure 14). There are three types of losses: quantity loss, which occurs due to damage, rot, or a decrease in weight and renders the food unusable; qualitative loss, which refers to a deterioration in the commodity's standard specifications without affecting its mass; and economic loss, which reduces the crop's monetary value due to differences in degree of quality and wasted resources (Yasin *et al.*, 2019).

Figure 13 Loss and waste of the tomato yield in the Nubaria area



Source: FAO. 2021. *Food loss analysis for tomato value chains in Egypt*. Cairo, FAO. https://doi.org/10.4060/cb4733e

Figure 14 Tomato losses incurred as a result of exposure to the sun and overloading of trucks.

Tomatoes have a carbon footprint of 0.952 kg CO_2eq/k, with most of it occurring during the post-harvest stage (Wyngaard and Kissinger, 2022). To decrease this footprint, it is essential to minimize loss and waste throughout the tomato supply chain. Moreover, optimizing transportation, shifting to renewable energy like solar power, and promoting tomato drying techniques to preserve the product and increase its value are crucial steps.

Tomato cultivation in Egypt requires the incorporation of climate-smart agriculture practices to ensure sustainable production. Here are some recommended interventions to achieve this:

01. Selection of tomato varieties that are resistant to extreme temperatures, drought, and salinity while producing high quality and high-yield crops.

02. Purchase of seeds, seedlings, fertilizers, and pesticides only from accredited sources to avoid various risks. Poor-quality products can result in lower crop yields, reduced produce quality, and incur financial losses for farmers. They also present a risk of introducing pests, diseases, or invasive species into agricultural systems. The use of low-quality fertilizers can also lead to excessive amounts of harmful chemicals or heavy metals that may accumulate in soils and water bodies, posing a risk to human health and the environment.

03. An effective integrated pest management (IPM) system, which utilizes biological enemies as a substitute for chemical pesticides, such as Trichogramma for Tuta absoluta insects, should be implemented. Crop rotation can also help mitigate pests and diseases and limit the use of chemical pesticides.

04. Efficient irrigation systems, such as drip irrigation, should be implemented to improve water-use efficiency. The use of renewable energy sources, such as solar-powered irrigation systems, should also be explored.

05. Handling and transporting tomatoes with care during the post-harvesting stages is crucial to prevent loss and damage. It is advisable to schedule harvest dates that align with factory capacity.

06. Sun-dried tomatoes are recommended to minimize waste, reduce carbon emissions, and create employment opportunities and profitability for growers. Egypt has great potential for exporting sun-dried tomatoes.

3.2.5.

ECONOMIC FEASIBILITY FOR CLIMATE-SMART INTERVENTIONS IN THE TOMATO VALUE CHAIN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- **Crop Budget under current conditions**

Tomatoes are planted in different seasons in Upper and middle Egypt; however, the most suitable season is the Winter season planted from late September to early October for this region. The average duration between plantation and harvesting is 3 months or 90 days. The below table represents the costs per feddan for the plantation, harvesting and transportation to the wholesale market. The average yield per feddan using traditional varieties is between 12 and 20 tonnes of fresh tomatoes. For the purpose of the study, 18 tonnes per feddan is used.

Table 17 **Tomato crop budget under current conditions**

Item	Quantity	Unit Cost (EGP)	Item Cost (EGP)	Comments
Land Rent	1	20 000	20 000	
Plowing	1	1 000	1 000	
Land Preparation	1	3 000	3 000	
Labour preparation	4	150	600	
Seedlings	35	250	8 750	
Planting	10	150	1 500	
Fertilizers	1	14 550	14 550	
Pesticides	1	20 000	20 000	
Irrigation	1	7 000	7 000	
Harvesting	1	12 000	12 000	
Subtotal Farm			**88 400**	
Post Harvesting - crates	800	5	4 000	Crates for 30 EGP used for 6 times and paid by the trader
Transportation	2	2 000	4 000	Paid by the trader
Total Cost per feddan			**96 400**	

*All costs are based on market prices.

- **CSA projects**

The following two projects were selected for the transformation to CSA value chains:

- Replace traditional varieties with varieties that tolerate low temperatures and give a high quality crop such as (014, 010, Brivio, Basimo, 017,4 647, Yara and Albion)
- Add carton lining to the palm crates to reduce post-harvesting losses.

The replacement of the existing variety with a low-temperature variety increases the yield significantly by almost 100 percent. Lining palm crates with carton also reduces food waste resulting from post-harvest transport damage.

Capital Investment Required

No capital investment is required for these interventions. The investment in new variety which is more expensive than the old one by 60 percent (Seedlings cost EGP 400 per tray instead of EGP 250) falls within the operational cost per feddan and is compensated by the much higher yield as shown in the financial analysis below.

Carton lining is also considered an operational cost and is compensated for with the savings in food wastage.

- **Crop Budget – CSA**

Table 18 Tomato crop budget with CSA projects

Item	Quantity	Unit Cost (EGP)	Item Cost (EGP)	Comments
Land Rent	1	20 000	20 000	No change
Plowing	1	1 000	1 000	No change
Land Preparation	1	3 000	3 000	No change
Labour preparation	4	150	600	No change
Seedlings	35	400	14 000	Same number of trays but different price
Planting	3	150	450	No change
Fertilizers	1	14 550	14 550	No change
Pesticides	1	20 000	20 000	No change
Irrigation	1	7 000	7 000	No change
Harvesting	1	12 000	12 000	
Subtotal Farm			**92 600**	
Post Harvesting - crates	1600	5	8 000	Crates for 30 EGP used for 6 times paid by the trader
Crates Lining	1600	5	8 000	Intervention-2
Post harvesting Losses		-10%	-	Saved losses due to lining crates
Transportation	3	2 000	6 000	Higher yield
Total Cost per feddan			**114 600**	

*All costs are based on market prices.

- **Tomato Model Assumptions**

Duration of the model is 5 years of growing and harvesting.

Area: Unit area of one feddan as it represents most of the ownership size of farmers in Upper and Middle Egypt.

Crop Prices

The average wholesale market price of fresh tomatoes produced in the winter season is **EGP 6000** per tonne. This price is estimated to increase yearly at a fixed annual inflation rate of 10 percent in revenue calculations.

Revenues

Revenues are calculated based on an average annual yield per feddan which is equal to:

- Eighteen tonnes fixed over the model period for the 'without project' model.

- Losses of 10 percent fixed over the model period for the 'without project' model.

- Thirty-five tonnes fixed over the model period for the 'with-project' model.

- Post harvesting losses of 10 percent assumed to be fully saved over the model period for the with-project model.

- **Tomato Financial Model Results**

It is important to note that the financial return of the project is very high as illustrated in the below table, due to a significant increase in yield without capital investment. All positive cash flows means that the project generates positive returns from the first year, hence the payback period is 0 years, and the internal rate of return cannot be calculated.

Table 19 Tomato in-farm financial model results

Farm Level Financial Feasibility	Without Project	With Project
Area (Feddan)	1	1
Discount Rate	23%	23%
NPV (EGP)	3 456	208 705
FIRR (%)	N/A	N/A
Discounted Payback (Years)	0.0	0.0
BCR (incremental)		4

Table 20 Tomato detailed in-farm financial model with CSA projects.

	Year 0	Year 1	Year 2	Year 3	Year 4
Farmer's Land Area (Feddans)	1	1	1	1	1
Yield per Feddan (Tonne)	30	30	30	30	30
Total Yield (Tonne)	30	30	30	30	30
Losses/Waste (Tonne)	0	0	0	0	0
Sales Price per (EGP per Tonne)	6 000	6 600	7 260	7 986	8 785
Sales Revenue (EGP)	**180 000**	**198 000**	**217 800**	**239 580**	**263 538**
Plowing	1 000	1 100	1 210	1 331	1 464
Land Preparation	3 000	3 300	3 630	3 993	4 392
Labour preparation	600	660	726	799	878
Seed	14 000	15 400	16 940	18 634	20 497
Plantation	450	495	545	599	659
Fertilizers	14 550	16 005	17 606	19 366	21 303
Pesticides	20 000	22 000	24 200	26 620	29 282
Irrigation	7 000	7 700	8 470	9 317	10 249
Harvesting	12 000	13 200	14 520	15 972	17 569
Harvesting Crates	8 000	8 800	9 680	10 648	11 713
Crates Lining	8 000	8 800	9 680	10 648	11 713
Transportation	8 000	8 800	9 680	10 648	11 713
Rent per Feddan	20 000	22 000	24 200	26 620	29 282
Total Rent	**20 000**	**22 000**	**24 200**	**26 620**	**29 282**

Table 20 Tomato detailed In-Farm financial model With CSA projects.

	Year 0	Year 1	Year 2	Year 3	Year 4
Depreciation	0	0	0	0	0
Total Operational Expenditures	**116 600**	**128 260**	**141 086**	**155 195**	**170 714**
Farmer's Profit/Loss	**63 400**	**69 740**	**76 714**	**84 385**	**92 824**
Taxes	**0**	**0**	**0**	**0**	**0**
After Tax Profit/Loss	**63 400**	**69 740**	**76 714**	**84 385**	**92 824**
Total Capex	**0**	**0**	**0**	**0**	**0**
Free Cash Flow	63 400	69 740	76 714	84 385	92 824
Cumulative FCF	63 400	133 140	209 854	294 239	387 063
Discount Rate	23%				
DFCF	51 545	46 097	41 225	36 868	32 971
NPV	208 705				
Payback (Years)	0				
IRR	#NUM!				
BCR	**4.05**				

- **Sundried tomato intervention**

This section aims to analyse the impact on financial feasibility of expanding the production of sundried tomatoes in farms as a value-added product. It is hence assumed for this model that the crop yield per feddan will not be sold fresh, but rather be completely sundried within the farm.

Investment Required

- No capital investment is required for these interventions.
- The tables, plastic and other costs are considered operational costs and are compensated by added-value.

Table 21 Sundried Tomato farm level costs

Item	Quantity	Unit Price	Cost
Subtotal Farm			***92 600***
Drying			
Conversion Rate		12	
Packaging material	-	1 500	-
Rent of Tables	35	370	12 950
Labour	10	600	6 000
Plastic & Others	1	20 000	20 000
Subtotal Drying			***38 950***
Total Cost (Feddan)			**131 550**

This intervention, as seen in the below table, demonstrates the increased financial return of the project as a result of the significant increase in value without capital investment.

All-positive cash flows means that the project generates positive returns from the first year. Hence, the payback period is 0 years, and the internal rate of return cannot be calculated.

Table 22 Sundried Tomato financial model results

Financial Feasibility	Sundried
Area (Feddan)	1
Discount Rate	23%
NPV (EGP)	398 839
FIRR (%)	N/A
Discounted Payback (Years)	0.0
BCR (incremental)	3

- **Aggregation and economic model**

The farm level financial analysis per feddan is further aggregated into an economic model below. The total area planted with fresh tomato in Minya, Beni Sueif and Aswan in Winter is around 25 000 feddans (60 percent of the total area planted with tomato in those governorates in 2020/2021) (CAPMAS, 2018) to capture the total costs and benefits of the project.

This is a huge economic benefit the surpasses the investment costs yielding a high net incremental NPV of EGP 6 billion and a payback period of 0 years.

For comparison, and to avoid double-counting, the sun-drying intervention is assumed to cover the same total area.

Table 23 Economic Aggregated Model Results

Aggregated Economic Feasibility	Fresh WP Scenario	Sundried WP Scenario
Area (Feddan)	25 000	25 000
Discount Rate	15%	15%
ENPV (Mn EGP) (net incremental)	6 213	11 968
EIRR (%) (net incremental)	N/A	N/A
Discounted Payback (Years)	0.0	0.0
BCR (net incremental)	4	3

Notes

- The net incremental benefit for both projects exceeds the net incremental costs.
- The net incremental ENPV is higher for the sundried tomato project compared to the fresh tomato ENPV. However, the percentage increase in the NIBs for the Sundried tomatoes is lower than that of the NICs, leading to a lower BCR.

3.2.5.

Table 24 Tomato detailed Economic Aggregated Model

	Year 0	Year 1	Year 2	Year 3	Year 4
Farmer's Land Area (Feddans)	25 000	25 000	25 000	25 000	25 000
Yield per Feddan (Tonne)	30.0	30.0	30.0	30.0	30.0
Total Yield (Tonne 000's)	750.0	750.0	750.0	750.0	750.0
Losses/Waste (Tonne 000's)	0	0	0	0	0
Plowing (EGP 000's)	25 000	27 500	30 250	33 275	36 603
Land Preparation (EGP 000's)	75 000	82 500	90 750	99 825	109 808
Labour preparation (EGP 000's)	15 000	16 500	18 150	19 965	21 962
Seed (EGP 000's)	350 000	385 000	423 500	465 850	512 435
Plantation (EGP 000's)	11 250	12 375	13 613	14 974	16 471
Fertilizers (EGP 000's)	363 750	400 125	440 138	484 151	532 566
Pesticides (EGP 000's)	500 000	550 000	605 000	665 500	732 050
Irrigation (EGP 000's)	175 000	192 500	211 750	232 925	256 218
Harvesting (EGP 000's)	300 000	330 000	363 000	399 300	439 230
Packaging Material (EGP 000's)	109 375	120 313	132 344	145 578	160 136
Table Rent (EGP 000's)	323 750	356 125	391 738	430 911	474 002
Labour (EGP 000's)	150 000	165 000	181 500	199 650	219 615
Plastic (EGP 000's)	500 000	550 000	605 000	665 500	732 050
Other Expenses (EGP 000's)	500 000	550 000	605 000	665 500	732 050
Rent per Feddan (EGP 000's)	20	22	24	27	29
Total Rent (EGP 000's)	**500 000**	**550 000**	**605 000**	**665 500**	**732 050**
Total Operational Expenditures	**3 898 125**	**4 287 938**	**4 716 731**	**5 188 404**	**5 707 245**
Dried Yield per Feddan (Tonne)	2.92	2.92	2.92	2.92	2.92
Total Yield (Tonne)	73	73	73	73	73
Losses/Waste (Tonne)	0	0	0	0	0
Sales Price per (EGP per Tonne)	95 000	104 500	114 950	126 445	139 090
Sales Revenue (EGP)	**6 927 083**	**7 619 792**	**8 381 771**	**9 219 948**	**10 141 943**
Farmer's Profit/Loss	**3 028 958**	**3 331 854**	**3 665 040**	**4 031 544**	**4 434 698**
Taxes	**0**	**0**	**0**	**0**	**0**
After Tax Profit/Loss	**3 028 958**	**3 331 854**	**3 665 040**	**4 031 544**	**4 434 698**
Total Capex	**0**	**0**	**0**	**0**	**0**
NIB (EGP 000's)	3 002 708	3 302 979	3 633 277	3 996 605	4 396 265
Cumulative FCF	3 002 708	6 305 688	9 938 965	13 935 569	18 331 835
Discount Rate	15%				
DFCF (EGP 000's)	2 611 051	2 497 527	2 388 939	2 285 072	2 185 721
NPV (EGP 000's)	11 968 309				
Payback (Years)	0				
IRR	#NUM!				
BCR	**3.01**				

3.3.

SUGARCANE

3.3.1. SUGARCANE PRODUCTION IN EGYPT

Sugarcane *(Saccharum officinarum)* is one of the most important and cost-efficient sources of sugar in the world. The top sugarcane-producing countries are listed in Table 21. According to Plate Number 1, the use of sugar crops for sugar production is expected to decrease from 81 percent in the last decade to 76 percent by 2032. Around 81 percent of the world's sugarcane production is used for making cane sugar, while the remaining is converted into biofuel. It is interesting to note that the sugarcane sector's market value exceeded USD 56 billion in 2022 (Voora *et al.*, 2023). The Food and Agriculture Organization (FAO) reports that sugarcane production has increased from 1.71 billion tonnes in 2008 to 1.87 billion tonnes in 2020 due to the cultivation of 26 million hectares (FAOSTAT, 2022). However, the ongoing Russia-Ukraine war and weather-related difficulties have caused significant disruptions to the sugar cane market and international prices. As a result, energy and fertilizer prices have increased due to the war, leading to higher input costs for sugarcane growers and lower fertilizer use (Voora *et al.*, 2023). This is due to the rise in competition for ethanol production. By 2032, Brazil will remain the top producer of sugar and sugarcane-based ethanol, responsible for 40 percent of the world's sugarcane. Their sugarcane is expected to contribute to 23 percent of global sugar production and 76 percent of global sugarcane-based ethanol production. This is in comparison to 21 percent and 88 percent, respectively, during the base period of 2020–2022.

Table 25 Top 10 sugarcane-producing countries globally

Ranking	The country	Production in millions of tonnes
1	Brazil	746.8
2	India	376.9
3	China	108 1
4	Thailand	104.4
5	Pakistan	67.2
6	Mexico	56.8
7	Colombia	36.2
8	Guatemala	35 5
9	Australia	33 5
10	USA	31 5

Source: FAOSTAT. 2022. *Crops and livestock products*. Rome, FAO. https://www.fao.org/faostat/en/#data/QCL.

Sugarcane is an essential crop in Egypt, with a significant value chain that includes various industries with refined sugars the main product . According to the Egyptian Sugar Company's report in 2023 (Figure 22) , the estimated area cultivated with sugarcane in 2022 was 245 668 feddan, with an average productivity rate of 31.64 tonne/feddan. The report notes that the cultivated area has remained relatively stable since 2004, except for minor fluctuations in some years, indicating the stability of the sugarcane production system and its related industries. However, Egypt is facing an increasing demand for sugar due to the rise in global sugar prices and population growth. To address these challenges, Egypt plans to increase sugar beet planting and to adopt improved seed varieties.

Sugarcane is predominantly cultivated in Upper Egypt, notably in El Menia, Sohag, Qena, Luxor, and Aswan (as shown in Table 22), which are also the locations of sugar factories. The table provides information about farming area sizes and productivity in these regions. However, the production of sugarcane in Egypt poses a significant challenge due to its high water consumption, which is expected to increase further due to climate change and rising temperatures. Therefore, it is essential to transform the current sugarcane production system and implement different CSA interventions to counteract the impact of climate change. A study conducted by Taha and Zohry (2018) in the primary sugarcane production areas of Upper Egypt outlined the actual water requirement (WR) for the conventional surface irrigation system, as well as the predicted water requirement in 2040. Their research suggests that there will be a 16 percent increase in the WR and a 14 percent decrease in yield by 2040.

Figure 15

Gated pipe irrigation for sugarcane.

Table 26 Areas and productivity of sugarcane in Upper Egypt

Governorates	Area	Yield	Production
	feddan*	tonne/feddan	Tonne
Minya	36 505	45	1 659 846
Sunag	14 439	47	677 892
Q.ena	119 665	50	5 952 975
Luxor	67 699	48	3 277395
Aswan	87 258	49	4 267302
Total Governorates	**325 566**	**47.8**	**15 835 810**
Total Egypt	**333 496**	**47.4**	**16 097 018**

To address the challenges posed by climate change on sugarcane cultivation and its water requirements, it is crucial to adopt water-saving techniques and to mitigate any potential temperature increases as a result of climate change. Typically, 18-20 irrigations with 10 000-13 000 m^3 of water per season are given under laser leveling with a developed surface irrigation system. Taha and Zohry (2018) found that using gated pipe irrigation in sugarcane cultivation in Upper Egypt saved about 21 percent of irrigation water compared to traditional surface irrigation. Gated irrigation diverts water into furrows through pipes or hoses connected to a hydrant fitted on buried pipes (Figure 15). The results of sugarcane FFSs conducted in Aswan under this study revealed that the drip irrigation method (Figure 16) is an effective technique for saving water in sugarcane production. It had the highest WUE compared to traditional surface irrigation, increasing from 8.3 to 18.1 kg of sugarcane per cubic metre of water.

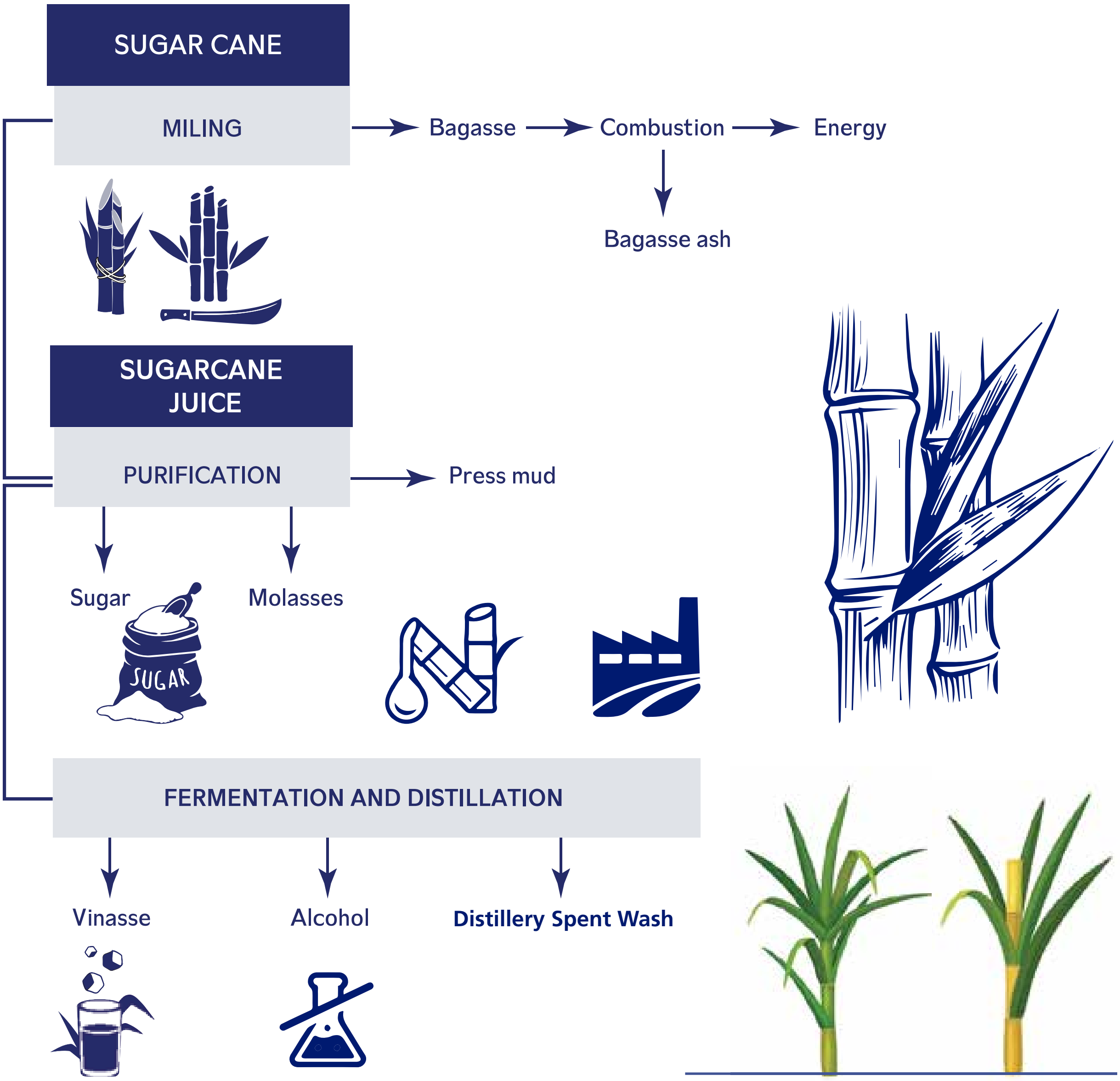
Figure 16 Drip irrigation in the new lands.

3.3.2.

SUGARCANE VALUE CHAIN

Sugarcane's value chain involves various processes that lead to the production of high-value products. Figure 17 illustrates flowcharts for the sugarcane value chain. In the agricultural stage, different methods are used to apply water, but modern irrigation systems such as gate pipes and drip irrigation are recommended. Chemical fertilizers are used to meet the soil's NPK requirements (nitrogen, phosphorus, and potassium). However, to reduce the use of synthetic fertilizers such as urea and ammonium nitrate and reduce the system's carbon footprint, CSA interventions such as using organic fertilizers like animal waste and compost should be implemented. Implementing IPM techniques allows for the sustainable management of sugarcane pests and diseases. The sugarcane borers, Chilo species, which are moths in the Crambidae family, can be biologically controlled by releasing the natural parasite Trichogramma evanesces at a rate of 20 000 individuals/feddan. This intervention has significantly reduced the infestation rate to 17 percent (EEAA, 2005).

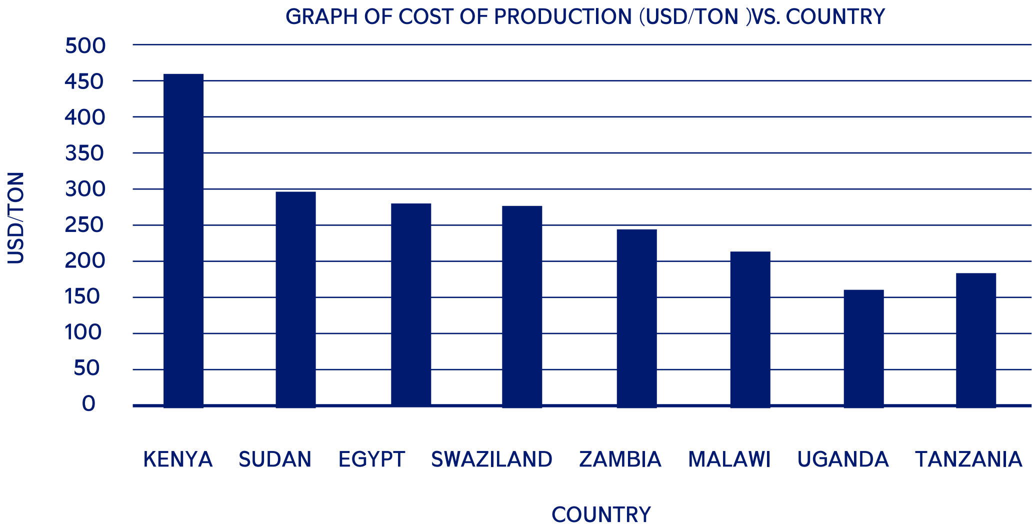
Figure 17 Flowcharts of sugar and ethanol production and byproducts.



Source: Guillermo *et al.* (2012)

Once harvested, sugarcane is transferred to one of eight mills located in the governorates of El Menia, Sohag, Qena, Luxor, and Aswan in Upper Egypt. These mills process the sugarcane to produce sugar crystals which are then cooled, packed, and stored. During the sugar production process in Egypt, 30 percent of by-products and co-products are generated, with 4 percent being molasses. Molasses have a sugar content of 50-55 percent of solid matter and are a valuable co-product, which can be used in fermentation processes such as in the production of fodder yeast, carbon dioxide, vinegar, perfumes, and medical solutions. Figure 18 illustrates the cost of producing one tonne of sugar in different countries, showing that the cost of production in Egypt is about USD 270 (Kabeyi and Olanrewaju, 2023). Additionally, several by-products and residues are generated during the sugar production process, including bagasse, the fibrous material remaining after juice extraction, filter mud/cake resulting from cane juice filtration, and furnace ash produced when bagasse is burned in a boiler for steam and electricity generation.

Figure 18 Cost of producing one tonne of sugar.



Source: Kabeyi, M. & Olanrewaju, O. 2023. Bagasse Electricity Potential of Conventional Sugarcane Factories. *Journal of Energy Volume*, 2023. https://doi.org/10.1155/2023/5749122

In Egypt, molasses is produced from sugarcane, and is often referred to as 'black honey.' This byproduct is usually generated in small mills located near sugarcane cultivation areas, primarily by private companies. The production process has traditionally been reliant on the knowledge and experience of individuals in the industry, with no standardized quality control measures in place beyond chemical compositions. To improve the industry, more effective, hygienic, and eco-friendly processes are required to produce high quality 'black honey'. The Food and Agricultural Industry Technology Center (FAITC) of the Ministry of Industry and Trade is implementing a new programme to introduce such a production system, which aims to address the current challenges and obstacles. Figure 19 shows some of the traditional practices that are used in the production of molasses.

Figure 19. Traditional molasses production practices in Upper Egypt

3.3.3.

SWOT ANALYSIS OF THE SUGARCANE VALUE CHAIN

3.3.3.

S

W

Strengths

1 **Favorable climate and geography:** Egypt's climate and fertile soil provide ideal growing conditions for sugarcane, resulting in high yields and quality sugar production.

2 **Established infrastructure:** The sugarcane industry in Egypt benefits from well-developed irrigation systems, transport networks and processing facilities, making operations throughout the value chain more efficient.

3 **Large domestic market:** With significant demand for sugar and sugary products, Egypt provides a stable market for local producers.

Weaknesses

1 **Water scarcity:** Limited water resources in Egypt pose a challenge for sugarcane cultivation, which requires substantial amounts of water. The industry needs to address water management and sustainability to overcome this challenge.

2 **High production costs:** Mechanized cultivation and processing methods used in the industry can lead to relatively high production costs, affecting competitiveness, especially in the global market.

3 **Limited diversification:** The sugarcane value chain in Egypt is primarily focused on sugar production, with limited value-addition and diversification into other sugarcane-based products.

O

Opportunities

1 **Export potential:** Egypt is strategically located and can expand its sugar and sugary products export market, creating potential for increased trade with regional and international markets.

2 **Ethanol production:** As the world focuses on renewable energy and sustainable fuels, Egypt could explore sugarcane-based ethanol production to diversify its product portfolio and contribute to energy security.

3 **Value-added products:** The sugarcane industry in Egypt can explore the production of value-added products such as molasses, bio-plastics, and animal feed to enhance profitability and market opportunities.

T

Threats

1 **Global market competition:** The global sugar market is highly competitive, with fluctuating prices and changing trade policies. Egypt faces competition from other sugar-producing countries with lower production costs.

1 **Environmental concerns:** Sugarcane cultivation can have environmental impacts such as soil degradation, water pollution, and greenhouse gas emissions. Compliance with environmental regulations and sustainability practices is crucial to mitigate these threats.

2 **Price fluctuations:** Volatility in sugar prices can pose risks to the profitability of sugar producers and impact the overall viability of the value chain.

3 **Changing consumer preferences:** Evolving consumer preferences, including the demand for healthier alternatives to sugar, can pose challenges to the sugarcane industry in Egypt. The industry needs to adapt and diversify its product offerings to cater to changing consumer demands.

3.3.4.

CLIMATE-SMART PRACTICES FOR THE SUGARCANE VALUE CHAIN

Figure 20 **Cultivating sugarcane with seedlings and a drip irrigation system in Qena.**

Source: MoALR. 2023. *Cultivating sugarcane with seedlings*. Report number 1431. Agriculture Research Center. Cairo, Ministry of Agriculture and Land Reclamation

Sugar production has a carbon footprint of 0.55 kg CO_2e per kg of sugar. This carbon footprint is made up of 0.49 kg CO_2e per kg of sugar from sugarcane cultivation and 0.06 kg CO_2e per kg of sugar from the milling process. Most greenhouse gas emissions from sugarcane cultivation come from fertilizer, fossil fuel use, and biomass burning. Specifically, nitrogen fertilizers contribute the most to carbon emissions (Yuttitham *et al.* 2011).

To enhance the resilience of the sugarcane value chain, the following CSA interventions are suggested.

01. **Cultivation using the seedlings technique** (Figure 20), which offers numerous benefits compared to traditional cultivation methods. This results in higher yields per unit area, increased land productivity, and improved profitability for small-scale farmers.

Additionally, this method helps to conserve water and reduce greenhouse gas emissions. A MoALR report (2023) identified several advantages of using sugarcane seedlings:

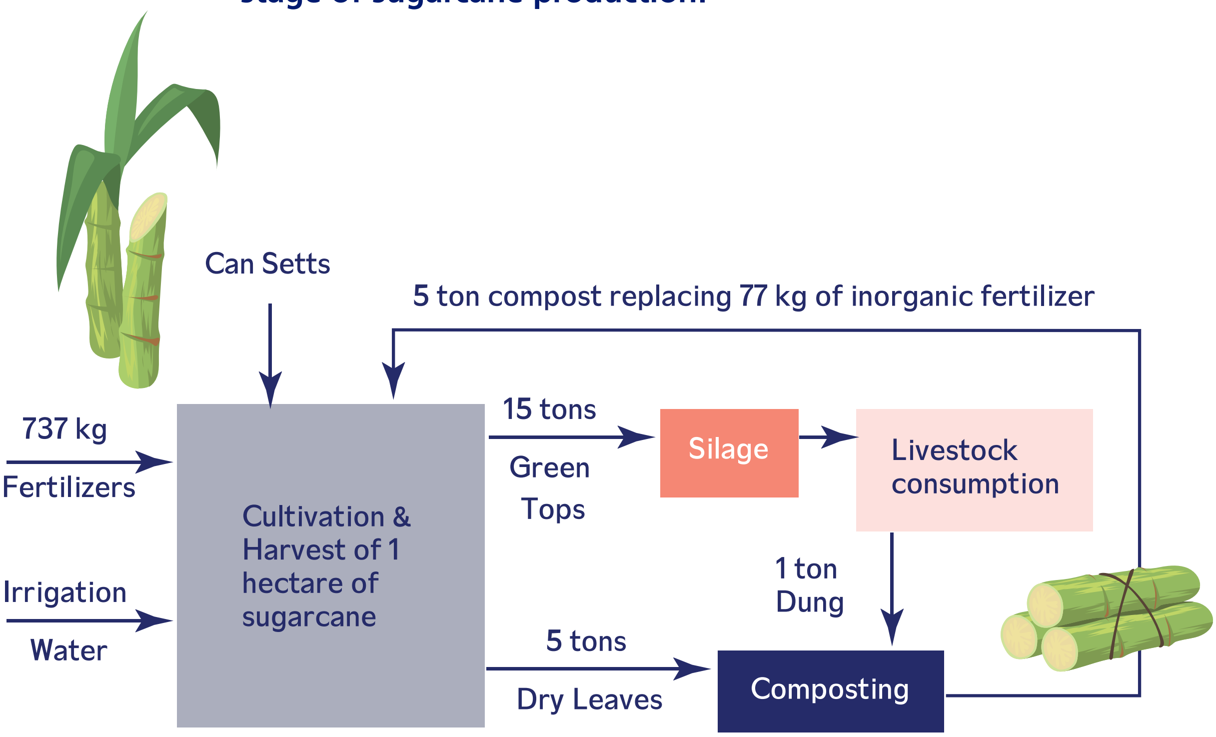
- Saves around 96 percent of the sugarcane previously used for cultivation, and tonnes of raw material that can be used for extracting sugar rather than being buried in the soil as seed.
- Provides more uniform planting material, resulting in more consistent crop establishment and growth.
- Planted at higher densities compared to conventional planting methods, which increases the average land productivity from 33 to 55 tonnes per feddan.
- Reduces the use of chemical fertilizers by 35 percent.
- Saves about 30 percent of irrigation water. a
- Reduces the risk of disease transmission compared to using whole sugarcane stalks as planting material.
- Seedlings can be grown in nurseries where they can be protected from weed competition during the early growth stages. This helps establish a strong crop stand and reduces the need for extensive weed control measures after transplanting.

02. Reduce the adverse environmental impact of sugar production. The primary contributor to this in the agricultural stage is the practice of burning sugarcane in fields after harvest, which accounts for 60 percent of the environmental impact. Additionally, the use of inorganic fertilizers and fuel for irrigation and transportation also contribute to the impact. During the industrial stage, the generation of steam and electricity using bagasse and heavy oil start-up are the primary sources of environmental impact.

03. **Use of renewable energy sources such as solar energy or biomass to power sugarcane processing facilities that** greatly reduce the greenhouse gas emissions associated with energy consumption. This not only contributes to the overall sustainability of the industry but also has a positive impact on the environment in the agricultural stage by preventing the combustion of dry leaves. Composting these dry leaves and utilizing them as soil additives further enhances environmental sustainability by substituting certain NPK inorganic fertilizers. This approach reduces the need for fertilizer production and mitigates the effects of nutrient leaching from inorganic fertilizers.

04. **Developing interventions for waste management and utilization of sugarcane byproducts.** This can include the production of bioenergy from bagasse (the fibrous residue after juice extraction), composting of organic waste, and exploring innovative uses for byproducts, such as the production of bioplastics or animal feed. The process of composting bagasse has minimal effects on greenhouse emissions, but it offers significant environmental benefits. By using the resulting organic fertilizer in agricultural fields, it reduces the need for inorganic fertilizers. This, in turn, helps to decrease the negative impact of manufacturing inorganic fertilizers on the environment presented in (Figure 21) as reported by Nakhla (2015).

Figure 21 **Proposal for zero waste in the agricultural stage of sugarcane production.**



Source: Nakhla, D. 2015. *Achieving Environmental Sustainability of Sugarcane Industry in Egypt: An Application of Life Cycle Assessment.* Doctoral disssertation, the American University in Cairo]. AUC Knowledge Fountain. https://fount.aucegypt.edu/etds/31

3.3.5.

ECONOMIC FEASIBILITY OF CLIMATE-SMART INTERVENTIONS IN SUGARCANE PRODUCTION

- **Crop budget under current conditions**

The duration between planting and harvesting is 12 months for the spring season and 16 months for the autumn season. The sugarcane trees last for 5 years and then need to be replaced. Hence, the costs of planting are only incurred in the first year while the costs of growing, including fertilizers, pesticides, labor etc. are incurred during the 5 years.

3.3.5.

Table 27 Sugarcane crop budget under current conditions

Item	Current Value Chain	Comment
Planting Expenses (First Year Only)	**EGP per feddan**	
Plowing	1 200	
Sub-soil deep plowing	400	
Leveling	500	
Seeds	9 000	6 tonnes x 1500 EGP per ton
Seed transportation and perpetration	1 800	
Plantation	1 200	12 worker x 100 EGP
Hoeing	3 000	Two times per year
Subtotal plantation	**17 100**	
Growing Expenses (5 years including first year)	**EGP per feddan**	
Nitrogen fertilizer	3 200	
Phosphorus fertilizer	1 600	
Potassium fertilizer	2 000	
Fertilization (labor)	250	
Irrigation	4 500	Cost of fuel
Tying (labor)	1 000	
Harvesting & transportation	11 060	350 EGP per ton x 31.6 tonnes
Land Rent	10 000	
Subtotal annual operational expenses	**33 610**	

*All costs are based on market prices.

CSA projects

The following two projects were selected for the transformation to CSA value chains:

- Planting using sugarcane seedlings instead of traditional methods.
- Drip irrigation to replace the current surface irrigation.

Capital Investment Required

The cost of installation of drip irrigation pipes **at the farm level** is estimated at **USD 1000 per feddan** based on estimates from the Ministry of Agriculture and Land Reclamation (MoARL). This is accounted for in the financial feasibility study assuming that the cost will be allocated to the farmers.

Aggregated Level

The drip irrigation infrastructure investment cost including pumps, pipes and solar power station is estimated, according to MoARL to be:

- Branch canal **USD 1500/feddan**
- Mesga/marwa level intervention **USD 2500/feddan**

This cost is added to the economic aggregated model assuming that such infrastructure is to be implemented through a government led development project.

The **outcome** of those interventions include:

- Higher yields per unit area (the yield increases from 31.6 tonnes to feddan to 55 tonnes per feddan) resulting from the use of sugarcane seedlings.
- Increase in the cost of seedlings by 17 percent
- Savings in seeds transportation, planting and hoeing during the first year resulting from the use of seedlings.
- Savings in the irrigation cost of fuel and hence electricity as a result of using solar power to operate the irrigation pumps.
- Saving in fertilization activities due to using drip irrigation piping.
- Water conservation
    - 6000 m^3/feddan instead of 12 000 m^3/feddan as a result of the implementation of drip irrigation.
    - An additional saving of 25 percent in the first year due to reduced irrigation for 3 months (nursery period) when using seedlings. Water consumption of only 4500 m^3/ feddan in the first year as a result.
- The financial analysis uses market prices and hence the price of water is 0 EGP since farmers do not pay for any water used.

- **Crop budget – CSA**

Table 28 Sugar Cane crop budget with CSA projects

Item	CSA Value Chain	Comment
Planting Expenses (First Year Only)	**EGP per feddan**	
Plowing	1 200	No change
Sub-soil deep plowing		Eliminated
Leveling		Eliminated
Seeds	10 500	7000 seedlings x 1.5 EGP per seedling
Seed transportation and perpetration	200	
Plantation	700	7 workers x 100 EGP
Hoeing	1 500	Only once
Subtotal plantation	**14 100**	
Growing Expenses (5 years including first year)	**EGP per feddan**	
Nitrogen fertilizer	3 200	No change
Phosphorus fertilizer	1 600	No change
Potassium fertilizer	2 000	No change
Fertilization (labor)	-	Eliminated - pumped through drip irrigation pipes
Irrigation	-	Eliminated fuel cost based on the use of solar energy
Tying (labor)	1 000	
Harvesting & transportation	19 250	Increased due to increase in the yield
Land Rent	10 000	
Subtotal annual operational expenses	37 050	

*All costs are based on market prices.

- **Sugarcane model assumptions**

Duration of the model is **6 years** (one cycle) including the first year (planting) and 5 years of growing and harvesting.

Area: Unit area of one feddan as it represents the most common ownership size for farmers in Upper and Middle Egypt.

Crop Prices

The price of sugarcane is set by the government at **EGP 1500** per tonne. This price is estimated to increase yearly at a fixed annual inflation rate of 10 percent in revenue calculations.

Revenues

The revenues are calculated based on an average annual yield per feddan which is equal to:

- 31.6 tonnes fixed over the model period for the without project model,

- 31.6 tonnes fixed over the model period for the drip irrigation only project model,

- 55 tonnes fixed over the model period for the seedlings only project, and

- 55 tonnes fixed over the model period for the implementation of both projects.

• Sugarcane financial model results

It is important to note that the financial return of the seedlings-only project is highest as illustrated in the below table due to the significant increase in yield without capital investment.

On the other hand, the drip irrigation-only project has a positive NPV from farmers only due to the savings in fuel costs of irrigation as a result of the use of solar power to operate pumps, and assuming that farmers only pay for the in-farm drip irrigation network, without having to invest in the drip irrigation infrastructure, including pipes, pumps and solar power stations. Changes to these assumptions – especially to the assumption that the financial cost of water is 0 for agriculture – will yield significantly different results.

Table 29 Sugar Cane Financial Model Results

Farm Level Financial Feasibility	Without Project	Drip Irrigation Only	Seedlings Only	Both
Area (Feddan)	1	1	1	1
Discount Rate	23%	23%	23%	23%
NPV (EGP)	8 361	-4 445	88 803	75 996
FIRR (%)	34%	19%	124%	80%
Discounted Payback (Years)	4.7	> 6yrs	1	2.7
BCR (incremental)		0	4.51	2.89

- The seedlings project is financially feasible at the farm level and should be attractive to farmers even without financial incentives.
- The drip irrigation alone is not financially feasible at the farm level and hence requires additional incentives.
- Both projects are financially feasible and yield higher financial returns compared to the WOP scenario indicating that they can be linked to incentivize farmers to implement drip irrigation at the farm level.

3.3.5.

Table 30 Sugarcane Detailed Financial In-Farm Model for both CSA projects

	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5
Farmer's Land Area (Feddans)	1	1	1	1	1	1
Yield per Feddan (Ton)	0	55	55	55	55	55
Total Yield (Ton)	0	55	55	55	55	55
Losses/Waste (Ton)	0	0	0	0	0	0
Sales Price per (EGP per Ton)	1 500	1 650	1 815	1 997	2 196	2 416
Sales Revenue (EGP)	**0**	**90 750**	**99 825**	**109 808**	**120 788**	**132 867**
Plowing	1 200	0	0	0	0	0
Sub-soil deep plowing	0	0	0	0	0	0
Leveling	0	0	0	0	0	0
Seed	10 500	0	0	0	0	0
Seed transportation and Perpetration	200	0	0	0	0	0
Plantation	700	0	0	0	0	0
Hoeing	1 500	0	0	0	0	0
Nitrogen fertilizer	3 200	3 520	3 872	4 259	4 685	5 154
Phosphorus fertilizer	1 600	1 760	1 936	2 130	2 343	2 577
Potassium fertilizer	2 000	2 200	2 420	2 662	2 928	3 221
Fertilization	0	0	0	0	0	0
Irrigation	0	0	0	0	0	0
Tying	1 000	1 100	1 210	1 331	1 464	1 611
Harvesting Price per Ton	350	385	424	466	512	564
Harvesting	0	21 175	23 293	25 622	28 184	31 002
Rent per Feddan	10 000	11 000	12 100	13 310	14 641	16 105
Total Rent	**10 000**	**11 000**	**12 100**	**13 310**	**14 641**	**16 105**
Depreciation	5 150	5 150	5 150	5 150	5 150	5 150
Transportation	0	0	0	0	0	0
Total Operational Expenditures	**37 050**	**45 905**	**49 981**	**54 464**	**59 395**	**64 819**
Farmer's Profit/Loss	**-37 050**	**44 845**	**49 845**	**55 344**	**61 393**	**68 048**
Taxes	**0**	**0**	**0**	**0**	**0**	**0**
After Tax Profit/Loss	**-37 050**	**44 845**	**49 845**	**55 344**	**61 393**	**68 048**
Drip Irrigation Pipes	30 900	0	0	15 450	0	0
Drip Irrigation Infrastrucure	0	0	0	0	0	0
Total Capex	**30 900**	**0**	**0**	**15 450**	**0**	**0**
Free Cash Flow	-62 800	49 995	54 995	45 044	66 543	73 198
Cumulative FCF	-62 800	-12 805	42 190	87 233	153 777	226 974
Discount Rate	23%					
DFCF	-51 057	33 046	29 553	19 680	23 636	21 138
NPV	75 996					
Payback (Years)	2.00					
IRR	79.8%					
BCR	**2.89**					

- **Aggregation and economic model**

The farm-level financial analysis per feddan is further aggregated into an economic model for the total sugarcane farmland area in Upper and Middle Egypt (325,000 feddans) to capture the total costs and benefits of the project.

In the economic model analysis, it is assumed that the government will invest in drip irrigation infrastructure in one phase at the beginning of the project using a reduced discount rate aiming to maximize savings in water consumption.

For the total area, implementing the drip irrigation projects lead to savings amounts to **12 billion m³** of water over the model period of 6 years.

For the economic model, the most significant saving is the financial cost of water. Accordingly, the financial cost of water is estimated based on the total cost of treatment (1 m³) of wastewater for restricted irrigation and is **USD 0.34,** based on a study published by the Water Pollution Research Department, National Research Centre in 2022 (Nasr et. Al, 2022). This is a huge economic benefit the surpasses the investment costs yielding a high net incremental NPV of **EGP 76 billion** and a discounted payback period of 1.2 years.

Table 31 Sugarcane Economic Aggregated Model Results

Aggregated Economic Feasibility	WP Scenario
Area (Feddan)	325 000
Discount Rate	15%
ENPV (MEGP) (net incremental)	76 871
EIRR (%) (net incremental)	143.5%
Discounted Payback (Years)	1.2
BCR (net incremental)	5

Table 32 Sugarcane Detailed Economic Aggregated Model

	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5
Farmer's Land Area (Feddans)	325 000	325 000	325 000	325 000	325 000	325 000
Yield per Feddan (Ton)	0	55	55	55	55	55
Total Yield (Ton 000's)	0	17 875	17 875	17 875	17 875	17 875
Losses/Waste (Ton 000's)	0	0	0	0	0	0
Sales Price per (EGP per Ton)	1 500	1 650	1 815	1 997	2 196	2 416
Sales Revenue (EGP 000's)	**0**	**29 493 750**	**32 443 125**	**35 687 438**	**39 256 181**	**43 181 799**

3.3.5.

Table 32 Sugarcane Detailed Economic Aggregated Model

	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5
Plowing (EGP 000's)	390 000	0	0	0	0	0
Sub-soil deep plowing (EGP 000's)	0	0	0	0	0	0
Leveling (EGP 000's)	0	0	0	0	0	0
Seed (EGP 000's)	3 412 500	0	0	0	0	0
Seed transportation and Perpetration (EGP 000's)	65 000	0	0	0	0	0
Plantation (EGP 000's)	227 500	0	0	0	0	0
Hoeing (EGP 000's)	487 500	0	0	0	0	0
Nitrogen fertilizer (EGP 000's)	1 040 000	1 144 000	1 258 400	1 384 240	1 522 664	1 674 930
Phosphorus fertilizer (EGP 000's)	520 000	572 000	629 200	692 120	761 332	837 465
Potassium fertilizer (EGP 000's)	650 000	715 000	786 500	865 150	951 665	1 046 832
Fertilization (EGP 000's)	0	0	0	0	0	0
Irrigation (EGP 000's)	0	0	0	0	0	0
Tying (EGP 000's)	325 000	357 500	393 250	432 575	475 833	523 416
Harvesting Price per Ton	350	385	424	466	512	564
Harvesting (EGP 000's)	0	6 881 875	7 570 063	8 327 069	9 159 776	10 075 753
Rent per Feddan	10	11	12	13	15	16
Total Rent (EGP 000's)	**3 250 000**	**3 575 000**	**3 932 500**	**4 325 750**	**4 758 325**	**5 234 158**
Depreciation (EGP 000's)	8 368 750	8 368 750	8 368 750	8 368 750	8 368 750	8 368 750
Transportation (EGP 000's)	0	0	0	0	0	0
Total Operational Expenditures (EGP 000's)	**18 736 250**	**21 614 125**	**22 938 663**	**24 395 654**	**25 998 344**	**27 761 304**
Farmer's Profit/Loss (EGP 000's)	**-18 736 250**	**7 879 625**	**9 504 463**	**11 291 784**	**13 257 837**	**15 420 496**
Taxes (EGP 000's)	**0**	**0**	**0**	**0**	**0**	**0**
After Tax Profit/Loss (EGP 000's)	**-18 736 250**	**7 879 625**	**9 504 463**	**11 291 784**	**13 257 837**	**15 420 496**
Drip Irrigation Pipes (EGP 000's)	10 042 500	0	0	5 021 250	0	0
Drip Irrigation Infrastrucure (EGP 000's)	0	0	0	0	0	0
Rehabilitation of Branch Canal	15 063 750	0	0	0	0	0
Mesga/Marwa Level Intervention with Diesel Pump	25 106 250	0	0	0	0	0
Total Capex (EGP 000's)	**50 212 500**	**0**	**0**	**5 021 250**	**0**	**0**
Water Consumption (m^3 000's)	1 462 500	1 950 000	1 950 000	1 950 000	1 950 000	1 950 000
Economic Cost (Externality) of Water (EGP 000's)	15 365 025	20 486 700	20 486 700	20 486 700	20 486 700	20 486 700
Fuel Consumption (litre 000's)	0	0	0	0	0	0
Economic Cost (Externality) of Fuel (EGP 000's)	0	0	0	0	0	0
NIB (EGP 000's)	-22 085 375	31 805 150	32 936 995	29 160 775	35 551 557	37 058 043
Cumulative FCF	-22 085 375	9 719 775	42 656 770	71 817 545	107 369 101	144 427 144
Discount Rate	15%					
DFCF (EGP 000's)	-19 204 674	24 049 263	21 656 609	16 672 767	17 675 407	16 021 214
NPV (EGP 000's)	76 870 587					
Payback (Years)	1					
IRR	**143.5%**					

- **Sugarcane sensitivity analysis:**

A sensitivity analysis was conducted to assess the impact of the main risks and uncertainties on the project feasibility indicators. The main risks and uncertainties are listed below along with their respective impact on the project feasibility:

Table 33 Sugarcane sensitivity analysis

1. SUGARCANE PRICES ARE REGULATED BY THE GOE WHILE COSTS OF INPUTS INCREASE YEARLY DUE TO INFLATION.

Financial (Drip Only)

Output	Baseline	Fixed prices with 10% inflation in costs
NPV	-4 445	-35 953
Payback	4	N/A
IRR	19.1%	-34.0%
BCR	N/A	N/A

Financial (CSA)

Output	Baseline	Fixed prices with 10% inflation in costs
NPV	75 996	21 157
Payback	2	2
IRR	79.8%	44.6%
BCR	2.89	2.24

Economic (CSA)

Output	Baseline	Fixed prices with 10% inflation in costs
NPV (000's)	76 870 587	66 630 951
Payback	1	1
IRR	143.5%	134.1%
BCR	5.00	4.47

2. YIELD IMPROVEMENT AS A RESULT OF THE APPLICATION OF SEEDLINGS IS LOWER THAN ANTICIPATED.

Financial

Output	Baseline (55 ton/fed)	(50 Ton/ Fed)	(45 Ton/ Fed)	(40 Ton/ Fed)
NPV	75 996	59 068	42 141	25 213
Payback	2	2	2	2
IRR	79.8%	68.2%	56.2%	43.6%
BCR	2.89	2.66	2.33	1.83

Economic

Output	Baseline (55 ton/fed)	50 Ton/Fed	45 Ton/Fed	40 Ton/Fed
NPV (000's)	76 870 587	69 745 901	62 621 216	55 496 531
Payback	1	1	1	1
IRR	143.5%	133.3%	123.0%	112.6%
BCR	5.00	4.63	4.26	3.89

3. CAPITAL INVESTMENT IS SIGNIFICANTLY HIGHER THAN ESTIMATED.

Financial (Drip Only)

Output	Baseline 1000 USD	1400 USD/ fed	1800 USD/ fed	2000 USD/ fed
NPV	-4 445	-17 194	-29 943	-42 692
Payback	4	5	5	N/A
IRR	19.1%	9.9%	2.6%	-3.4%
BCR	N/A	N/A	N/A	N/A

Financial (CSA)

Output	Baseline 1000 USD	1400 USD/ fed	1800 USD/ fed	2000 USD/ fed
NPV	75 996	63 247	50 498	37 750
Payback	2	2	2	2
IRR	79.8%	64.0%	52.0%	42.5%
BCR	2.89	2.13	1.69	1.40

Economic (CSA)

Output	Baseline 5000 USD/fed	6000 USD/ fed	7000 USD/ fed	8000 USD/ fed
NPV (000's)	76 870 587	67 563 795	58 257 003	48 950 211
Payback	1	2	2	2
IRR	143.5%	96.3%	70.6%	54.1%
BCR	5.00	3.42	2.59	2.08

4. EXCHANGE RATE HIKES.

Financial (Drip Only)

Output	Baseline	35 EGP/USD	40 EGP/USD	45 EGP/USD
NPV	-4 445	-8 674	-13 832	-18 989
Payback	4	4	4	5
IRR	19.1%	15.8%	12.1%	8.8%
BCR	N/A	N/A	N/A	N/A

Financial (CSA)

Output	Baseline	35 EGP/USD	40 EGP/USD	45 EGP/USD
NPV	75 996	71 767	66 610	61 453
Payback	2	2	2	2
IRR	79.8%	74.0%	67.7%	62.1%
BCR	2.89	2.59	2.29	2.06

Economic (CSA)

Output	Baseline	35 EGP/USD	40 EGP/USD	45 EGP/USD
NPV (000's)	76 870 587	81 574 472	87 310 917	93 047 363
Payback	1	1	1	1
IRR	143.5%	135.1%	127.3%	121.3%
BCR	5.00	4.70	4.42	4.21

5. FINANCIAL COST OF WATER IS REDUCED DUE TO TECHNOLOGY ADVANCEMENT.

Economic (CSA)

Output	0.13 USD/ m^3	0.25 USD/ m^3	Baseline 0.34 USD
NPV (000's)	26 232 674	55 168 624	76 870 587
Payback	2	2	1
IRR	44.0%	89.0%	143.5%
BCR	1.80	3.20	5.00

3.4.

MEDICINAL AND AROMATIC PLANTS (MAP)

3.4.1. MAP PRODUCTION IN EGYPT

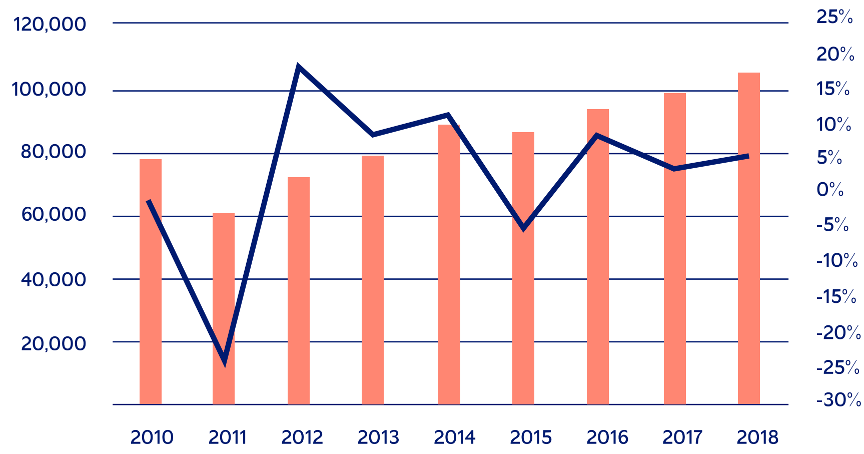
The global market for medicinal and aromatic plants (MAPs) totaled around USD 2.59 billion in 2016, with China dominating the market, followed by India. China alone has exported over 185 000 tonnes of raw MAPs annually since 2001, which is more than double the total volume of exports from India. Notably, the export of processed derivative products has increased, while the export of MAPs has decreased. This trend is evident in countries like China, India, and South Africa, which meet international standards on extracts (World Bank 2018).

The global demand for MAPs has tripled in value over the last 15 years. The steep rise in prices compared to volumes suggests a shortage in supply, indicating that demand is relatively inflexible. MAPs are essential inputs for several large global industries that require a consistent supply for business continuity. The top importers by value include the United States, Germany, Japan, China Hong Kong SAR, Taiwan Province of China, and Singapore, all of which imported over USD 100 million worth of MAPs in 2016. China and India are not only the world's largest exporters of MAPs by volume, but they are also the third and fifth largest importers by volume, respectively, as indicated by the World Bank (2018).

The popularity of natural products for health benefits has led to the growth of the MAP market. These products are considered safer and more cost-effective than synthetic pharmaceutical drugs. According to the World Health Organization (WHO), between 75 and 80 percent of the world's population relies on herbal medicines for their primary healthcare needs These plants are used in natural, cosmetic, medicinal, and pharmaceutical products and services. Value-added processing can create dry and liquid substances that are commonly used as inputs in pharmaceuticals, personal care products, processed foods and various natural health products.

For centuries, medicinal plants have been used as traditional remedies to treat and prevent various ailments. They contain bioactive compounds with therapeutic properties that are used in the production of pharmaceutical drugs. MAPs contribute to modern medicine by serving as a source of active pharmaceutical ingredients (APIs) for the development of new drugs or as natural alternatives to synthetic medications. One of the significant benefits of medicinal and aromatic plants is that they help overcome many difficult illnesses such as contagious diseases, cancer, and AIDS/HIV (Inoue *et al.* 2019).

Figure 22. Average area in feddan of cultivated MAPs in Egypt



Source: CAPMAS. 2019. *Annual bulletin of statistical crop area and plant production 2016/2027*

Egypt is a significant producer and exporter of medicinal and aromatic plants (MAP). According to official statistics from CAPMAS 2019, the average cultivated area for these plants is more than 98 570 feddans (Figure 22). The Egyptian agricultural strategy expects the area of land cultivated with medicinal and aromatic plants to increase to over 250 000 feddans by 2030. There are several reasons for this. First, Egypt exports substantial quantities of these plants and can increase this further, particularly in the winter months when demand increases in Europe and North America. Secondly, Egypt's mild climate allows for successful cultivation of these plants, resulting in good quality and high yields of the active ingredient. Additionally, these plants are high-yielding and are mostly commercialized in dry form, which reduces transportation costs and the risk of spoilage. They can also be stored until the optimal time for sale. Finally, medicinal and aromatic plants require less water than field crops, making them a suitable option for cultivation in Egypt's current water shortage conditions.

Egypt exports medicinal and aromatic plants (MAPs) worth an average of USD 87.17 million as reported by the Ministry of Trade and Industry. More than 30 types of MAPs are grown in Egypt, with over 90 percent of them cultivated for export as stated by the Ministry of Agriculture and Land Reclamation (MoALR). Some MAPs, such as marjoram, mint, and lemongrass grow as perennial plants, remaining in the soil for three years or more. Most species, however, are grown as annual plants, including winter plants such as aromatic grains like nigella, fennel, cumin, coriander, caraway, anise, and chamomile, and summer plants like basil, hibiscus, and chili.

The most extensively cultivated MAPs in Egypt, based on area, are coriander, chamomile, marjoram, basil, caraway, cumin, geranium, fennel, chili, anise, mint, henna, dill, and hibiscus. MAPs can be grown for their leaves and dry herbs like geranium, peppermint, fennel, mint, basil, coriander, dill, parsley, lemongrass, henna, and citronella, fruit like coriander, fennel, cumin, anise, caraway, and chili, flowers like, chamomile, hibiscus, and calendula, roots like licorice, Moghat, and carrots, and seeds like Guar, lupine, fenugreek, and senna.

medicinal and aromatic plants (MAPs) production is a significant source of employment in Egypt. It employs around 2 percent of agricultural workers, which amounts to approximately 140 000 people. Women are actively involved in the MAPs value chain, playing a significant role. The value chain involves several actors, including input suppliers, producers, producer organizations, local traders, wholesalers at different administrative levels (village, governorate, regional), processors, retailers, exporters, and foreign traders (importers, brokers, wholesalers, retailers, and caterers). Stakeholders in the MAPs industry in Egypt include associations such as the Egyptian Society for the Producers, Manufacturers, and Exporters of medicinal and aromatic plants (ESMAP), the Egyptian Spices and Herbs Export Development Association (ESHEDA), as well as initiatives like the Egyptian medicinal and aromatic plants initiative (EMAP). The MAPs value chain in Egypt is primarily governed by market forces, and cooperation among its actors is not very common. The upstream base, consisting of producers, is scattered and poorly organized, while the downstream actors, comprising large processors and exporters, are more organized and formally structured.

The governorates of Beni Sueif, Minya, and Aswan in Upper Egypt are known for producing medicinal and aromatic plants, with ideal growing conditions for such plants. Beni Sueif is known for its cultivation of chamomile, while marjoram is mainly concentrated in Minya, and hibiscus in Aswan. This information has been provided by the MoALR.

Figure 23 **Green chamomile, dried chamomile, and chamomile product in Egypt.**

In particular, chamomile *(Matricaria chamomilla)* is cultivated in Egypt on an average of 13 997 feddan, with 2 123 feddan being cultivated in Beni Sueif, accounting for 15.1 percent of the total chamomile cultivation in the country. The estimated average production of chamomile in Egypt is 13 186 tonnes, out of which 2927 tonnes are produced in Beni Sueif. Beni Sueif is known for growing 22.2 percent of Egypt's local varieties of German chamomile, known as the chamomile matricaria, as seen in (Figure 22), which shows chamomile both as a green plant and dried, as well as one of its products.

Chamomile cultivation is mainly concentrated in Fayoum, but Beni Sueif has a comparative advantage due to its cultivation of around 1255 feddan of chamomile on new lands, which indicates a higher potential for organic cultivation. Chamomile cultivation in Beni Sueif is mostly concentrated in Ahanasia, Biba, Sumosta, and Al-Fashn. From 2018 to July 2021, Egypt exported (Figure 23) an average of USD 3.16 million worth of chamomile (FAO 2015).

Figure 24 Total chamomile exports.

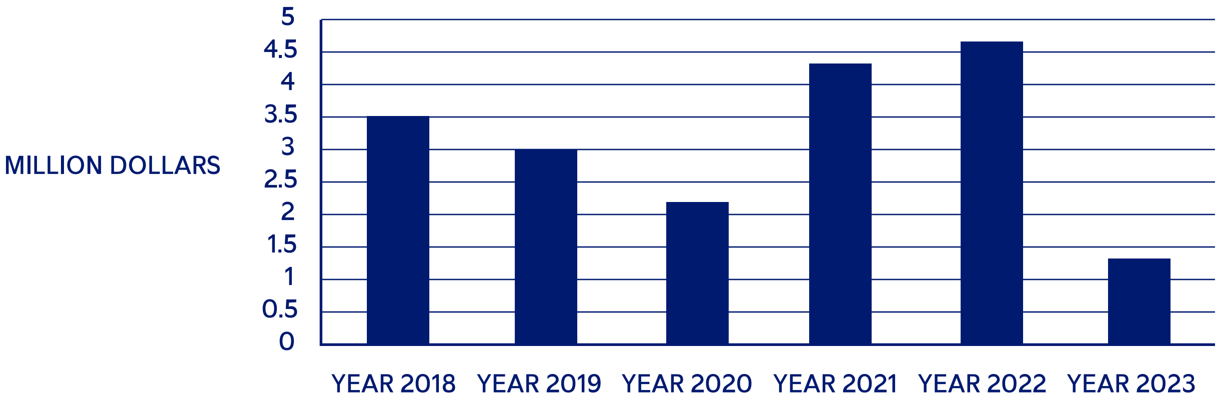


Figure 23 Green chamomile, dried chamomile, and chamomile product in Egypt.

Marjoram *(Origanum majorana)* is a herb that is primarily grown in Egypt, covering an average area of 4143 feddan. The majority of the cultivation area, accounting for 90.1 percent of the total, is located in El Minya governorate, with 3766 feddan. The estimated production of marjoram in Egypt is 13 369 tonnes, with Minya producing 12 380 tonnes. The major production regions in Egypt are Samalut, Beni Mazar, and Maghagha, which together account for 92.9 percent of the total production. From 2018 to July 2023, marjoram exports from Egypt have been valued at an average of USD 3.87 million (MoALR 2022). Figure 25 shows the green, dried, and processed products of Marjoram in Egypt. Exports is presented in (Figure 25).

Figure 25 Green marjoram, dried marjoram, and marjoram product.

Figure 26 Total marjoram exports.

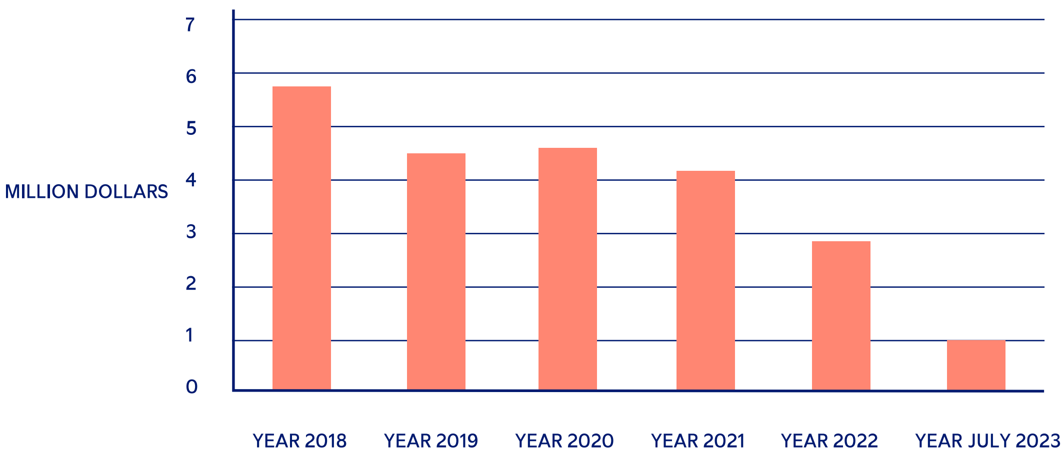


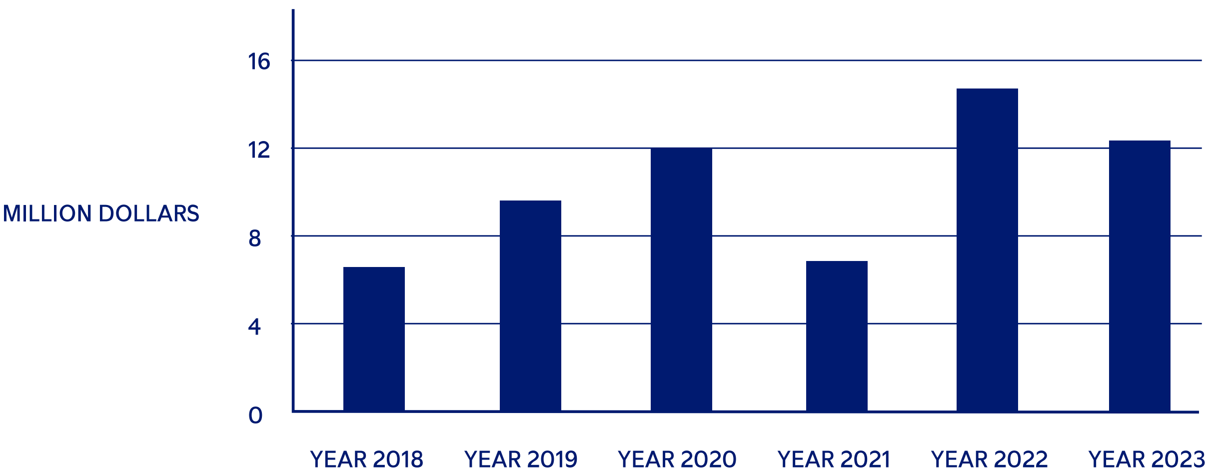
Figure 25 Green marjoram, dried marjoram, and marjoram product.

Hibiscus *(Hibiscus subdariffa)* is a crop that is grown in Egypt on an area of 13 556 feddan. Hibiscus cultivation in Egypt is concentrated in Aswan, where 9,019 feddan are used for cultivation, accounting for 67.46 percent of the total area. Figure 27 illustrates the green, dried, and processed products of hibiscus. In Egypt, the estimated average production of hibiscus is 13,968 tonnes, with 12,043 tonnes produced in Aswan alone, which accounts for 86.2 percent of the total production. Most of the hibiscus cultivation areas are located in Kom Ombo and Edfu. According to (Figure 27), from 2018 to July, the average export value of hibiscus in Egypt was USD 10.55 million (MoALR 2023).

3.4.1.

Figure 27 Fresh hibiscus, dried hibiscus, and final hibiscus product.

Figure 28 Total hibiscus exports.



3.4.2.

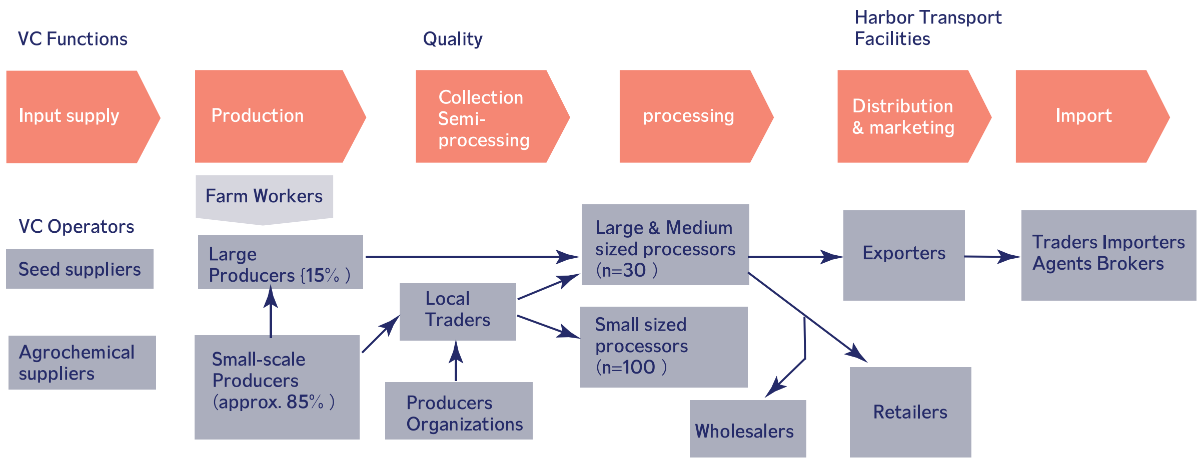
MAP VALUE CHAIN

Figure 29 illustrates a flowchart of the medicinal and aromatic plants value chain in Egypt (FAO, 2015) and can be summarized as follows:

- Cultivation: The value chain begins with the cultivation of MAPs. Farmers grow medicinal and aromatic plants either through traditional farming methods or specialized cultivation practices. This stage involves activities such as land preparation, planting, irrigation, fertilization, and pest management.
- Harvesting methods can vary depending on the plant species and the plant parts used (leaves, flowers, roots, etc.). Proper harvesting techniques ensure maximum yield and maintain the quality of the plant material.
- Plant material undergoes primary processing. This stage involves activities such as cleaning, sorting, and drying the harvested plant parts. Primary processing helps remove impurities, preserves the quality of the plant material, and prepares it for further processing.

- Plant material may undergo various extraction and processing methods to obtain desired compounds. Extraction techniques can include distillation, maceration, or solvent extraction to isolate essential oils, active compounds, or other valuable constituents. This stage may also involve grinding, refining, or further purification processes.
- The extracted or processed materials are used as ingredients in the manufacturing of various MAPs products. This can include pharmaceuticals, herbal medicines, herbal supplements, cosmetics, personal care products, aromatherapy products, and food additives. Product manufacturing involves formulation, blending, packaging, and labeling.
- MAPs products are distributed to wholesalers and retailers for local use or for export. Distribution channels can include pharmacies, health stores, online platforms, and specialized retailers.

Figure 29 **Flowchart for the medicinal and aromatic plants value chain in Egypt (FAO, 2015).**



Source: FAO. 2015. *Climate change and food security: risks and responses.* Rome, FAO. https://www.fao.org/3/i5188e/I5188E.pdf

3.4.3.

SWOT ANALYSIS FOR THE MAP VALUE CHAIN

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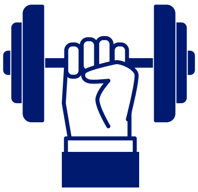
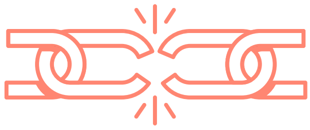
3.4.3.

S 

W 

Strengths

1 Egypt has a rich biodiversity and is home to a diverse range of flora, including several species of medicinal and aromatic plants. This provides a solid resource base for the cultivation of MAPs.

2 MAPs are high-value crops with high productivity and a rapid return on investment, especially when they benefit from value-added improvements.

3 Egyptian farmers possess significant traditional experience in growing MAP plants, and most of these plants are easy to cultivate.

4 The weather conditions in Egypt are generally favorable for the growth of MAPs. Most of these plants do not require greenhouse or tunnel cultivation, and many of them can even grow in reclaimed lands. Furthermore, some MAPs, such as chamomile and hibiscus, can tolerate salinity levels of up to 3000 ppm.

5 It is relatively easy to sell MAPs to export markets as long as they meet the required specifications.

Weaknesses

1 The adoption of modern cultivation techniques, processing methods, and quality standards pose challenges.

2 MAPs are prone to insect and fungi infestations, which can lower productivity and lead to increased production costs due to the necessity of pesticides and fumigation. This can also result in pesticide residue in the final product, lowering its marketability.

3 The quality of inputs, specifically fertilizers and pesticides, isn’t guaranteed, and there are no supplier controls in place. As a result, low-quality materials are prevalent, making it challenging for producers to predict crop quality. This can also lead to the presence of pesticide residue in the product and an increase in production costs.

4 Smallholder farmers rely mainly on information provided by input suppliers, pesticide dealers, and primary farmers with inadequate extension services.

5 Only larger producers can afford to hire consultants for production management guidance and support.

6 Small-scale farmers and producers lack the necessary marketing knowledge and skills to effectively promote their products in domestic and international markets.

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Opportunities

1 There is growing global demand for natural and organic items, particularly medicinal and aromatic plants. This presents a great opportunity for Egyptian manufacturers to expand their reach into the international market.

2 By improving infrastructure and providing modern tools to farmers and investors, the cultivation area for MAPs can be increased, leading to higher yields.

3 Investing in the production of pharmaceutical extracts that comply with pharmacopeia standards, rather than exporting raw materials, can result in significant profits. Encouraging medium-capital investments in this field would be a wise decision.

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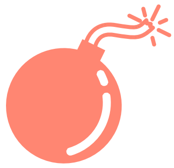

Threats

1 The global market for MAPs is highly competitive, and Egypt may face tough competition from other countries with established industries and lower production costs.

2 Climate change and extreme weather events can significantly impact the cultivation and production of medicinal and aromatic plants, thus affecting the quality and yield.

3 Complying with domestic and international regulations such as quality standards, certifications, and export requirements can be a challenge for producers in the value chain.

4 Protecting traditional knowledge and preventing unauthorized exploitation of Egypt's indigenous plant species can be a potential threat that needs to be addressed.

3.4.4.

CLIMATE-SMART PRACTICES FOR THE MAP VALUE CHAIN

Studies on the impact of climate change on medicinal and aromatic plants (MAPs) in Egypt are limited. However, temperature changes, particularly in Upper Egypt, can affect the physiology and chemical composition of plants. This can lead to changes in the production and concentration of bioactive compounds, ultimately affecting the medicinal properties and quality of MAPs. A study by Laftouhi et al (2023). revealed a decrease in the content of secondary metabolites in 90

MAPs during year four due to the continued deterioration of climatic conditions. This led to a similar trend in the yields of essential oils. Climate change can also cause a shift in pest populations and the emergence of new diseases, which farmers in Upper Egypt may need to adapt to by adjusting irrigation systems, planting schedules, and crop management practices. Taghouti *et al.* (2022) estimated the carbon footprint of some MAPs. The carbon footprint for organic rosemary was observed to be 0.051 kg CO_2-eq/kg, while for Damask rose it was 0.463 kg CO_2-eq/kg.

To enhance the resilience of the medicinal and aromatic plants (MAP) value chain, the following CSA interventions are suggested:

01. Integrated plant nutrition system to optimize fertilizer application, minimizing nutrient losses and reducing environmental impacts. This includes applying organic fertilizer and compost to enhance soil fertility and moisture retention. Intercropping with leguminous crops that have a nitrogen-fixing ability would provide the supplementary nitrogen requirement, reducing the inorganic nitrogen requirement.

02. Implement efficient irrigation systems such as drip irrigation to improve water-use efficiency and explore the use of renewable energy sources, such as solar-powered irrigation systems.

03. Promote the cultivation of a diverse range of MAP species that are suitable for Egypt's climate. Diversification can enhance resilience to climate variability and reduce the risk associated with relying on a single crop.

04. Improve access to weather and climate information to assist farmers in making informed decisions. Provide advisory services on climate-resilient farming practices, pest and disease management, and appropriate timing for planting and harvesting.

05. Promote integrated pest management (IPM), biological control methods, and organic farming practices. These approaches reduce reliance on synthetic pesticides and improve opportunities for exporting. This could include intercropping different crops, like pomegranate with sweet basil and rosemary, or grape with fenugreek, anise, parsley, and black cumin, at varying row ratios.

06. Improve post-harvest handling and storage practices to minimize losses and enhance product quality. Efficient drying techniques, proper packaging, and cold storage facilities can extend the shelf life of MAP products, reduce waste and reduce GHG emissions.

07. Provide training programmes and capacity-building initiatives to educate farmers about CSA practices, climate-resilient farming techniques, and sustainable resource management

3.4.5.

ECONOMIC FEASIBILITY OF CLIMATE-SMART INTERVENTIONS FOR MAP

- **Crop selection**

There are several medicinal and aromatic families and crops that are grown in Egypt. The technical practices and hence financials of each specific crop widely vary according to many factors. For the purposes of our economic and financial analysis, we have opted to focus on 91

chamomile due to its relative importance in the MAPs value chain. This choice enables us to conduct a comprehensive assessment of its value chain, covering not only farming practices but also value-added processes. This demonstrates the impact of the transition from the current status to the CSA value chain.

- **Crop budget under current conditions**

The average duration between planting and harvesting is 6 months. Planting usually starts in October and harvesting starts in December and lasts until April. The below table represents the cost per feddan for the planting, drying and grinding of chamomile in the Beni Sueif governorate.

Table 34 Chamomile crop budget under current conditions

Item	Quantity	Unit Price	Item Price	Comments
Rent	1	13 000	13 000	
Land Preparation	1	1 000	1 000	
Organic Fertilizers	1	2 000	2 000	
Seedlings			500	50-100 gm
Planting	4	150	600	one day
Ferilizers	1	8 000	8 000	
Service Labour	4	200	800	
Irrigation	1	2 000	2 000	Fuel for pump
Hoeing	3	1 000	3 000	2-3 times to remove harmful weed
Pesticides	1	2 000	2 000	
Yield (ton)	3.5			3-4 ton green fresh
Harvesting	3.5	5 000	17 500	1 kg for 5 pounds
Drying	1	2 000	2 000	Palm crates
Conversion	1	7		7 tonnes
Dry Yield (tonnes)	0.5			14%
Carton Packaging	100	7	700	5-6 kg per carton
Grinding	1	1 000	1 000	labor and threshing
Dried Remains Yield	0.5			Crushed stems and leaves
Sacks	34	3	102	
Total Cost			54 202	

*All costs are based on market prices in 2023.

- **CSA projects**

The selected project for the transformation to CSA value chains is the replacement of the current surface irrigation, especially in old land, with modern drip irrigation powered with solar energy. This transformation aims to reduce water consumption by 25 percent from 1500 m^3 to 1125 m^3 per feddan, in addition to reducing fuel consumption by replacing diesel pumps with electric pumps powered by solar energy. Table 29 lays out CSA-enabled production costs for chamomile in the Beni Sueif governorate.

Capital investment required

The cost to install a drip irrigation system powered by solar energy **at the farm level** in chamomile cultivation is **EGP 60 000 per feddan** based on experts' estimates, and are distributed as follows:

- Dripline with flexible pipes: EGP 15 000 depreciated and replaced every three years.
- Underground pipes, pump and hoses: EGP 10,000 to be depreciated over 10 years.
- Solar energy station: EGP 25 000 to be depreciated over 15 years.

This is accounted for in the financial feasibility study, with an assumption that the cost will be allocated to the farmers.

Aggregated Level

- The drip irrigation infrastructure investment cost for branch canals and mesga/marwa level (excluding solar energy) is estimated by MARL.
- 50 percent of such cost is allocated to the chamomile.

This cost is added to the economic aggregated model assuming that such infrastructure is to be implemented through a government-led development project.

The **outcomes** of this intervention include:

- Twenty to twenty-five percent higher fresh yields per feddan due to fewer crop diseases.
- A reduction of both hoeing the use of pesticides by 25 percent.
- Increased output of dried chamomile by 40 percent due to lower humidity and higher dry matter.
- A 20 percent increase in dry matter output due to a reduction in crop infection and disease.
- Fuel and electricity savings in irrigation as a result of using solar power to operate irrigation pumps.
- Water conservation: 1125 m^3/feddan with a drip irrigation system compared to 1500 m^3/feddan with surface irrigation.
- The financial analysis uses market prices, hence the price of water is 0, as farmers do not pay for water used.

- **Crop Budget – CSA**

Table 35 Chamomile crop budget with CSA project

Item	Quantity	Unit Price	Item Price	Comments
Rent	1	13 000	13 000	No change
Land Preparation	1	1 000	1 000	No change
Organic Fertilizers	1	2 000	2 000	No change
Seedlings	15000		500	No change
Planting	4	150	600	No change
Ferilizers	1	8 000	8 000	Reduction in quantity but higher price due to the use of soluble fertilizers
Service Labour	4	200	800	No change
Irrigation	0	450	-	Solar energy
Hoeing	2	1 000	2 000	One time less due to lower hasha2esh
Pesticides	0.75	2 000	1 500	25% less
Yield (ton)	4.375			20%-25% higher due to no diseases
Harvesting	4.375	5 000	21 875	
Drying	1.1	2 000	2 200	10% increase in crates
Conversion	1	6		6.2 tonnes per ton due to lower humidity and higher solids
Dry Yield (tonnes)	0.71			
Carton Packaging	142.00	7	994	
Grinding	1	1 000	1 000	No change
Dried Remains Yield	0.6			Due to less diseases
Sacks	40	3	120	
Total Cost			**55 589**	

*All costs are based on market prices in 2023.


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- **Chamomile model assumptions**
- Duration of the model is **5 years** of growing and harvesting.
- **Area:** Unit area of one feddan, as it represents the most common ownership size for farmers in Upper Egypt.
- **Crop prices:** The average market price for dried and ground chamomile is between EGP 90 000 and EGP 120 000 per tonne for European Union certified products. An average of **EGP 105 000** per tonne was used for the study. Additionally, crushed stems and leaves are sold as by-products for around **EGP 45 000** per tonne. This price is estimated to increase yearly at a fixed annual inflation rate of 10 percent in the revenue calculation.
- **Revenues:** The revenues are calculated based on an average annual yield per feddan which is equal to:
- 0.5 tonnes of dried and ground chamomile fixed over the model period for the 'without project' (WoP) model.
- 0.5 tonnes of crushed stems and leaves fixed over the model period for the WoP model.
- 0.71 tonnes of dried and ground chamomile fixed over the model period for the 'with project' (WP) model.
- 0.5 tonnes of crushed stems and leaves fixed over the model period for the WP model.
- **Chamomile financial model results**
  It is important to note that the financial return of the project resulting from the increased yield and the savings in pesticides and hoeing activities outweighs the initial investment needed for the installation of the drip irrigation system at the farm level. Accordingly, the FNPV of the WP model is equal to EGP 92 000 per feddan and the FIRR is very high.

Table 36 Chamomile in-farm financial model results

Farm Level Financial Feasibility	Without Project	With Project
Area (Feddan)	1	1
Discount Rate	23%	23%
NPV (EGP)	68 465	92 290
FIRR (%)	N/A	349%
Discounted Payback (Years)	0.0	1.6
BCR (incremental)		1.38

Table 37 Chamomile detailed in-farm tomato model with project (WP)

	Year 0	Year 1	Year 2	Year 3	Year 4
Farmer's Land Area (Feddans)	1	1	1	1	1
Yield per Feddan (Ton) Chamomile	0.71	0.71	0.71	0.71	0.71
Total Yield (Ton) Chamomile	0.71	0.71	0.71	0.71	0.71
Losses/Waste (Ton) Chamomile	0	0	0	0	0
Sales Price per (EGP per Ton) Chamomile	105 000	115 500	127 050	139 755	153 731
Sales Revenue (EGP) Chamomile	**74 093**	**81 502**	**89 652**	**98 617**	**108 479**
Yield per Feddan (Ton) By-Product	0.60	0.60	0.60	0.60	0.60
Total Yield (Ton) By-Product	0.60	0.60	0.60	0.60	0.60
Losses/Waste (Ton) By-Product	0	0	0	0	0
Sales Price per (EGP per Ton) By-Product	45 000	49 500	54 450	59 895	65 885
Sales Revenue (EGP) By-Product	**27 000**	**29 700**	**32 670**	**35 937**	**39 531**
Total Sales Revenue (EGP)	**101 093**	**111 202**	**122 322**	**134 554**	**148 010**
Land Preparation	1 000	1 100	1 210	1 331	1 464
Service Labour	800	880	968	1 065	1 171
Seed	500	550	605	666	732
Plantation	600	660	726	799	878
Organic Fertilizers	2 000	2 200	2 420	2 662	2 928
Chemical Fertilizers	8 000	8 800	9 680	10 648	11 713
Pesticides	1 500	1 650	1 815	1 997	2 196
Hoeing	2 000	2 200	2 420	2 662	2 928
Irrigation	0	0	0	0	0
Harvesting	21 875	24 063	26 469	29 116	32 027
Drying	2 200	2 420	2 662	2 928	3 221
Carton Packaging	994	1 093	1 203	1 323	1 455
Shewela	120	132	145	160	176
Grinding	1 000	1 100	1 210	1 331	1 464
Rent per Feddan	13 000	14 300	15 730	17 303	19 033
Total Rent	**13 000**	**14 300**	**15 730**	**17 303**	**19 033**
Depreciation	8 333	8 333	8 333	8 333	8 333
Total Operational Expenditures	**63 922**	**69 481**	**75 596**	**82 322**	**89 721**
Farmer's Profit/Loss	**37 170**	**41 721**	**46 726**	**52 232**	**58 289**
Taxes	**0**	**0**	**0**	**0**	**0**
After Tax Profit/Loss	**37 170**	**41 721**	**46 726**	**52 232**	**58 289**
Dripline flexible pipes	15 000	0	0	19 965	0
Underground pipes	10 000	0	0	0	0
Solar Energy	35 000	0	0	0	0
Total Capex	**60 000**	**0**	**0**	**19 965**	**0**
Free Cash Flow	-14 496	50 054	55 060	40 600	66 622
Cumulative FCF	-14 496	35 558	90 617	131 218	197 840
Discount Rate	23%				
DFCF	-11 786	33 085	29 588	17 738	23 664
NPV	92 290				
Payback (Years)	1				
IRR	348.9%				
BCR	**1.38**				

- **Aggregation and Economic Model**

The farm-level financial analysis per feddan is further aggregated into an economic model for the total area planted with dried and ground chamomile in Beni Sueif and Minya, which is assumed to be 8000 feddans to capture the total costs and benefits of the project.

In the economic model analysis, it is assumed that the government will invest in drip irrigation infrastructure in one phase at the beginning of the project using a reduced discount rate aiming to maximize savings in water consumption. For the total area, implementing the drip irrigation projects lead to savings amounting to 15 million m^3 of water over the model period of 5 years.

For the economic model, the most significant saving is the financial cost of water. Accordingly, this is estimated based on the total cost wastewater treatment for restricted irrigation (1 m^3) at **USD 0.34** as per section 1.13 of this report.

This is a huge economic benefit the surpasses the investment costs yielding a high net incremental NPV of **EGP 62 million** and a discounted payback period of 4.6 years.

Table 38 Chamomile Economic Aggregated Model Results

Aggregated Economic Feasibility	WP Scenario
Area (Feddan)	8 000
Discount Rate	15%
ENPV (kEGP) (net incremental)	62 291
EIRR (%) (net incremental)	20.6%
Discounted Payback (Years)	4.6
BCR (net incremental)	1.77

Note: The project is likely to be completed in phases over a number of years which will negatively impact the economic indicators.

Table 39 Chamomile detailed Economic Aggregated Model

	Year 0	Year 1	Year 2	Year 3	Year 4
Farmer's Land Area (Feddans)	8 000	8 000	8 000	8 000	8 000
Yield per Feddan (Ton) Chamomile	0.7	0.7	0.7	0.7	0.7
Total Yield (Ton 000's) Chamomile	5.6	5.6	5.6	5.6	5.6
Losses/Waste (Ton 000's) Chamomile	0	0	0	0	0
Sales Price per (EGP per Ton) Chamomile	105 000	115 500	127 050	139 755	153 731
Sales Revenue (EGP 000's) Chamomile	**592 742**	**652 016**	**717 218**	**788 940**	**867 833**
Yield per Feddan (Ton) By-Product	0.6	0.6	0.6	0.6	0.6
Total Yield (Ton 000's) By-Product	4.8	4.8	4.8	4.8	4.8
Losses/Waste (Ton 000's) By-Product	0	0	0	0	0
Sales Price per (EGP per Ton) By-Product	45 000	49 500	54 450	59 895	65 885
Sales Revenue (EGP 000's) By-Product	**216 000**	**237 600**	**261 360**	**287 496**	**316 246**
Total Sales Revenue (EGP 000's)	**808 742**	**889 616**	**978 578**	**1 076 436**	**1 184 079**
Land Preparation (EGP 000's)	8 000	8 800	9 680	10 648	11 713
Service Labour (EGP 000's)	6 400	7 040	7 744	8 518	9 370
Seed (EGP 000's)	4 000	4 400	4 840	5 324	5 856
Plantation (EGP 000's)	4 800	5 280	5 808	6 389	7 028
Organic Fertilizers (EGP 000's)	16 000	17 600	19 360	21 296	23 426
Chemical Fertilizers (EGP 000's)	64 000	70 400	77 440	85 184	93 702
Pesticides (EGP 000's)	12 000	13 200	14 520	15 972	17 569
Hoeing (EGP 000's)	16 000	17 600	19 360	21 296	23 426
Irrigation (EGP 000's)	0	0	0	0	0
Harvesting (EGP 000's)	175 000	192 500	211 750	232 925	256 218
Drying (EGP 000's)	17 600	19 360	21 296	23 426	25 768
Carton Packaging (EGP 000's)	7 952	8 747	9 622	10 584	11 643
Shewela (EGP 000's)	960	1 056	1 162	1 278	1 406
Grinding (EGP 000's)	8 000	8 800	9 680	10 648	11 713
Rent per Feddan (EGP 000's)	13	14	16	17	19
Total Rent (EGP 000's)	**104 000**	**114 400**	**125 840**	**138 424**	**152 266**
Depreciation	66 667	66 667	66 667	66 667	66 667
Total Operational Expenditures	**511 379**	**555 850**	**604 768**	**658 578**	**717 770**
Farmer's Profit/Loss	**297 363**	**333 766**	**373 810**	**417 857**	**466 310**
Taxes	**0**	**0**	**0**	**0**	**0**
After Tax Profit/Loss	**297 363**	**333 766**	**373 810**	**417 857**	**466 310**
Dripline flexible pipes (EGP 000's)	120 000	0	0	159 720	0
Underground pipes (EGP 000's)	80 000	0	0	0	0
Solar Energy (EGP 000's)	280 000	0	0	0	0
Government Insfrastructure (EGP 000's)	370 800	0	0	0	0
Total Capex	850 800	0	0	159 720	0
Water Consumption (m^3)	9 000	9 000	9 000	9 000	9 000
Economic Cost (Externality) of Water	94 554	94 554	94 554	94 554	94 554
NIB (EGP 000's)	-621 636	248 929	270 670	134 865	320 891
Cumulative FCF	-621 636	-372 708	-102 038	32 827	353 718
Discount Rate	15%				
DFCF (EGP 000's)	-540 553	188 226	177 970	77 109	159 540
NPV (EGP 000's)	62 291				
Payback (Years)	3				
IRR	20.6%				
BCR	**1.77**				

- **MAPs sensitivity analysis**

A sensitivity analysis was conducted to assess the impact of the main risks and uncertainties on the project feasibility indicators. The main risks and uncertainties are listed below along with their respective impact on the project feasibility:

Table 40 Chamomile Sensitivity Analysis

1. CAPITAL INVESTMENT IS SIGNIFICANTLY HIGHER THAN ESTIMATED.

Financial (CSA)

Output	Baseline	CAPEX Increased +10%	CAPEX Increased +20%	CAPEX Increased +30%
NPV	92 290	86 540	80 789	75 039
Payback	1	1	1	1
IRR	348.9%	245.6%	188.2%	151.3%
BCR	1.38	1.27	1.17	1.08

Economic (CSA)

Output	Baseline	CAPEX Increased +10%	CAPEX Increased +20%	CAPEX Increased +30%
NPV (000's)	384 726	333 855	282 984	232 113
Payback	2	2	2	2
IRR	89.8%	71.2%	57.2%	46.2%
BCR	2.80	2.57	2.37	2.20

2. EXCHANGE RATE HIKES.

Economic (CSA)

Output	Baseline	35 EGP/USD	40 EGP/USD	45 EGP/USD
NPV (000's)	384 726	398 745	415 841	432 937
Payback	2	1	1	1
IRR	89.8%	93.5%	98.2%	103.0%
BCR	2.80	2.80	2.80	2.80

3. INFLATION RATE CHANGES.

Financial (CSA)

Output	Inflation Rate at 0%	Baseline	Inflation Rate at 15%	Inflation Rate at 20%
NPV	72 235	92 290	103 680	116 064
Payback	1	1	1	1
IRR	308.1%	348.9%	369.3%	389.7%
BCR	1.24	1.38	1.46	1.54

Economic (CSA)

Output	Inflation Rate at 0%	Baseline	Inflation Rate at 15%	Inflation Rate at 20%
NPV (000's)	282 191	384 726	443 244	507 078
Payback	2	2	1	1
IRR	74.9%	89.8%	97.3%	104.9%
BCR	2.49	2.80	2.97	3.13

4. FINANCIAL DISCOUNT RATE CHANGES.

Financial (CSA)

Output	Discount Rate Rate at 12%	Discount Rate Rate at 18%	Baseline	Discount Rate Rate at 27%	Discount Rate Rate at 30%
NPV	129 755	107 236	92 290	82 271	75 687
Payback	1	1	1	1	1
BCR	1.56	1.46	1.38	1.33	1.29

CHAPTER 4

Conclusions and Recommendations

CONCLUSIONS AND RECOMMENDATIONS

- The successful outcomes of the FFS programme in Upper Egypt demonstrate its effectiveness in promoting climate-smart agricultural practices. To further enhance the adoption of these practices, an expansion of the FFS programme is recommended in order to reach more farmers in the region. This can be done through partnerships between the MoALR, FAO, IFAD, and other relevant stakeholders.

- Drip irrigation has been designated as a critical technique for water conservation in Egypt, which has been substantiated by this study confirming its economic and environmental benefits. This technique is instrumental in not only conserving water at the farm and aggregate levels, but also augmenting the productivity of the water unit. It leads to a substantial increase in crop yield and income for small-scale farmers. Furthermore, this technique contributes significantly to reducing CO_2 emissions, thereby mitigating the adverse impacts of climate change.

- Selecting the appropriate variety plays a crucial role in transforming the agrifood system in Egypt. To achieve this transformation, it is necessary to invest in and support an agricultural research programme that focuses on the development of new crop, vegetable, and orchid varieties. The research should take into account the impact of climate change, including not only a rise in temperatures but also weather fluctuations and extreme events. It should also take into account the decrease in water availability in the country due to limited water resources and the ever-increasing population.

- In order to tackle the issue of land fragmentation, it is crucial to encourage small-scale landowners to come together and create cooperatives or associations. This will help to consolidate fragmented land and enable farmers to adopt sustainable practices collectively. Moreover, these groups can offer support and incentives, such as access to training, credit facilities, and marketing assistance. By working together, small landowners can improve their bargaining power and enhance market access through collective marketing efforts.

- In order to promote and improve climate-smart agriculture (CSA) value chain practices, it is crucial to establish a comprehensive programme that includes stakeholder consultation, encourages partnerships, and provides a reliable support infrastructure. This objective can be achieved through the implementation of farmer field schools (FFS) or digital extension systems, which can aid in selecting high quality seeds and seedlings, composting, using bio-fertilization, and integrated pest management (IPM) techniques to reduce the need for chemical fertilizers and pesticides, as well as adopting irrigation-saving techniques. Additionally, it is imperative to enhance post-harvest handling, transportation, and processing to reduce food loss and waste.

- Establishing financial assistance programmes and low-interest loan schemes for smallholders is imperative to enable them to invest in climate-smart technologies and infrastructure. Collaboration with financial institutions is necessary to achieve this objective. The financial mechanisms that are designed and implemented should cater to the specific needs of farmers in the agriculture sector. It is important to provide capacity building and training in financial management and business planning to support farmers in this regard.

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Annex

ANNEX

Crop	Location of the FFS	Treatment	Yield (ton/fed)	Total income (LE/fed)	Total CO_2-eq (g / kg product)	WUE (kg / m³)
Wheat	Metobus, Kafr El-Sheikh	T: Misr1 + surface irrigation + broad-casting + 150 Kg Urea	2.18	11 600	345.8	1.53
		P: A mixture of Misr 1, Gemmayzeh 11 and Sakha 95 + surface irrigation + broadcast + 200 Kg ammonium nitrate	2.55	13 600	299.7	1.30
Wheat	Metobus, Kafr El-Sheikh	T: Giza 168 + surface irrigation + broadcasting + 100 Kg Urea + 150 Kg ammonium nitrate	2.40	12 800	436.8	1.47
		P: Egaseed + surface irrigation + raised beds + 100 Kg Urea + 150 Kg ammoni-um nitrate	2.85	15 200	367.4	1.75
Wheat	Western El-Fashn, Beni Sueif	T: Giza 171 + surface irrigation + broadcasting + 100 Kg Urea + 150 Kg ammonium nitrate	3.60	19,200	584	1.39
		P: Giza 171 + surface irrigation + drilling + 100 Kg Urea + 150 Kg ammo-nium nitrate	4.35	23 200	483	1.68
Wheat	Western El-Fashn, Beni Sueif	T: Giza 171 + Basin + broadcasting + 50 Kg Urea + 300 Kg ammonium nitrate	3.60	36 000	234.3	1.20
		P: Misr 3 + Raised beds + broadcasting + 50 Kg Urea + 300 Kg ammonium nitrate	4.65	46 500	181.4	1.55
Wheat	Western Samalout Menya	T: MISR-1 + surface irrigation + broad-casting + 100 kg Urea+ 150 Kg Ammo-nium nitrate	1.68	10 080	1465	0.73
		P: MISR-1 + drip irrigation + hills on raised beds + 100 kg Urea+ 150 Kg Ammonium nitrate	2.31	13 860	1786	3.09
Wheat	Western Samalout Menya	T: Beni Sueif 1 + surface irrigation + drilling using manual planter + 200 kg Urea+ 150 Kg ammonium nitrate	2.63	33 075	305.6	1.13
		P: Beni Sueif 5 + drip irrigation + drilling using manual planter + 150 kg Urea+ 90 Kg Ammonium nitrate	3.99	50 904	160.8	2.00
		P: Sids 14 + surface irrigation + planting in hills with planter on raised beds + 75 kg urea+ 100 Kg ammonium nitrate	3.75	18 700	147	1.67

Crop	Location of the FFS	Treatment	Yield (ton/fed)	Total income (LE/fed)	Total CO_2-eq (g / kg product)	WUE (kg / m³)
Wheat	Wadi El-Nuqra Aswan	T: Beni Sueif 5 + surface irrigation + planting in hills manually on raised beds + 75 kg urea+ 150 Kg ammonium nitrate	2.7	15 300	240	1.14
		P: Beni Sueif 5 + surface irrigation + planting in hills with planter on raised beds + 75 kg urea+ 150 Kg ammonium nitrate	3.0	17 000	216	1.26
Wheat	Wadi El-Saida Aswan	T: Beni Sueif 5 + surface irrigation + basins + 150 kg urea + 150 Kg ammonium nitrate	1.80	18 000	281	1 25
		P: Beni Sueif 5 + surface irrigation + raised beds + 150 kg urea + 150 Kg ammonium nitrate	3.30	33 000	153	1.38
Wheat	Wadi El-Saida Aswan	T: Sids 14 + surface irrigation + manual drilling on flat soil + 150 kg urea + 150 Kg ammonium nitrate	2.55	25 500	198.3	0.94
		P: Giza 171 + surface irrigation + manual drilling on flat soil + 150 kg urea + 150 Kg ammonium nitrate	3.30	33 000	153.3	1.21
Corn	Metobus Kafr El-Sheikh	T: SC Giza 10 white + surface irrigation + hills on rows + 200 Kg Urea	2.00	14 300	274	1.09
		P: SC Giza 168 yellow + surface irrigation + hills on rows + 250 Kg Ammonium nitrate	2.24	16 000	232	1.22
Corn	Metobus Kafr El-Sheikh	T: SC Giza 10 white + surface irrigation + hills on rows + 250 Kg Urea	3.04	16 000	570	0.95
		P: SC Giza 10 white + drip irrigation + hills on rows + 150 Kg Urea	4.56	24 000	364	1.82
Corn	Western El-Fashn Beni Sueif	T: D99 hybrid + surface irrigation + hills on rows + 50 Kg Urea + 250 Kg Ammonium nitrate	2.52	21 600	264.4	0.86
		P: Gold 21 hybrid + drip irrigation + hills on rows + 50 Kg Urea + 250 Kg Ammonium nitrate	3.92	33 600	258.9	1.85

Crop	Location of the FFS	Treatment	Yield (ton/fed)	Total income (LE/fed)	Total CO_2-eq (g / kg product)	WUE (kg / m³)
Corn	Western El-Fashn Beni Sueif	T: Pioneer 3444 hybrid + drip irrigation + hills on rows + 200 Kg Urea + 200 Kg Ammonium nitrate	2.80	24 000	429.4	1.17
		P: Gold 21 hybrid + drip irrigation + hills on rows + 200 Kg Urea + 200 Kg Ammonium nitrate	3.36	28 800	357.8	1.40
Corn	Western Samalout Menya	T: TWC Giza 368 + planting distance of 30 cm + drip irrigation + hills on rows + 50 kg Ammonium sulphate + 50 Kg Ammonium nitrate	3.36	36 000	127	2.30
		P: Pioneer 3444 + planting distance of 30 cm + drip irrigation + hills on rows + 50 kg Ammonium sulphate + 50 Kg Ammonium nitrate	4.20	43 200	75	1.04
Corn	Western Samalout Menya	T: Pioneer K9 + surface irrigation + hills on rows + 100 kg Ammonium sulphate + 100 Kg Ammonium nitrate	1.61	13 824	1668	0.45
		P: Hytech + drip irrigation + hills on rows +100 kg Ammonium sulphate + 100 Kg Ammonium nitrate	4.03	34 560	482	1.44
Corn	Wadi El-Saida Aswan	T: Yellow Kahraman + surface irrigation + hills on rows + 100 kg urea + 200 Kg ammonium nitrate + controlling armyworm with pesticides	4.76	40 800	320.5	1.8
		P: Yellow Kahraman + surface irrigation + hills on rows + 100 kg urea + 200 Kg ammonium nitrate + controlling armyworm with garlic and chili extractions	4.76	40 800	320.5	1.8
Fava bean	Metobus Kafr El-Sheikh	T: Giza 716 + surface irrigation + hills on rows + 150 Kg Ammonium nitrate	1.04	27 000	470	0.98
		P: Giza 716 + drip irrigation + hills on rows + 66 Kg Ammonium nitrate	1.44	39 000	163	2.50
Fava bean	Metobus Kafr El-Sheikh	T: Sakha 1 + surface irrigation + hills on rows + 7m³ manure + 150 Kg ammonium nitrate	1.28	24 000	302	0.83
		P: Sakha 1 + surface irrigation + hills on rows + 7m³ compost + 100 Kg ammonium nitrate	1.44	28 000	221	0.94

Crop	Location of the FFS	Treatment	Yield (ton/fed)	Total income (LE/fed)	Total CO_2-eq (g / kg product)	WUE (kg / m^3)
Fava bean	Wadi El-Nuqra Aswan	T: Unknown + surface irrigation + hills on rows + 250 Kg ammonium nitrate	0.96	23 100	373.2	0.53
		P: Unknown + sprinkler irrigation + hills on rows + 150 Kg ammonium nitrate	1.44	34 650	171.3	0.94
Fava bean	Wadi El-Nuqra Aswan	T: Local variety + surface irrigation + basins + 200 Kg ammonium nitrate	0.96	23 100	408.5	0.43
		P: Sakha 1 variety + surface irrigation + rows + 200 Kg ammonium nitrate	1.6	38 500	245.1	0.89
Fava bean	Wadi El-Nuqra Aswan	T: Local variety + surface irrigation + hills on rows with manual planter + without inoculation + 50 kg urea + 50 Kg ammonium nitrate	1.0	20 000	236.9	0.69
		P: Sakha 1 variety + surface irrigation + hills on rows with manual planter + inoculation with Rhizobia + 50 kg urea + 50 Kg ammonium nitrate	1.6	32 000	148.1	1.11
Fenu-greek	Wadi El-Nuqra Aswan	T: Local variety + surface irrigation + 200 Kg ammonium nitrate + without fertilizing with potassium sulphate humic acid or spraying with micronu-trients	0.90	15 950	476.8	0.56
		P: Local variety + surface irrigation + 200 Kg ammonium nitrate + 50 Kg potassium sulphate + 1Kg humic acid + spraying with micronutrients (0.5 Kg Fe + 0.5 Kg Zn + 0.5 Kg Mn)	1.26	22 330	340.6	0.78
Sesame	Metobus Kafr El-Sheikh	T: Shandawel 3 + surface irrigation + hills on rows + 50 Kg Ammonium nitrate + 100 Kg Urea	0.32	10 880	415	0.13
		P: Giza 32 (Del El-Jamal) + drip irrigation + Biofertilizers (Nova plus) + hills on rows + 25 Kg Ammonium nitrate + 50 Kg Urea	0.48	16 800	275	0.25
Sesame	Western El-Fashn Beni Sueif	T: Balady + surface irrigation + hills on rows + 100 kg Urea+ 100 Kg Ammonium nitrate	0.60	20 000	983.9	0.28
		P: Shandwell 3 + surface irrigation + hills on rows + 100 kg Urea+ 100 Kg Ammonium nitrate	0.84	28 000	703.1	0.39

Crop	Location of the FFS	Treatment	Yield (ton/fed)	Total income (LE/fed)	Total CO_2-eq (g / kg product)	WUE (kg/m3)
Sesame	Western Samalout Menya	T: Shandwell 3 + surface irrigation + hills on rows + mixing seeds with 5Kg sand at planting & fertilizing with 25 kg Urea + 125 Kg Ammonium nitrate	0.522	18 270	1021	0.18
		P: Shandwell 3 + surface irrigation + hills on rows + mixing seeds with 5Kg ammonium nitrate at planting & fertilizing with 25 kg Urea + 25 Kg Ammonium nitrate + 20 L Biofertilizers (Nova plus)	0.390	13 650	1138	0.14
Onion	Western El-Fashn Beni Sueif	T: Giza 6 + drip irrigation + hills on rows + 200 Kg Ammonium nitrate + Chicken manure	20	20 000	206.3	13.3
		P: Giza 6 + drip irrigation + hills on rows + 150 Kg Ammonium nitrate + Pigeon manure	20	20 000	202.7	13.3
Onion	Western Samalout Menya	T: Unknown variety (Maqour) + surface irrigation + hills on flat land + 50 kg Urea+ 100 Kg Ammonium nitrate	10	50 000	42.5	6.94
		P: Unknown variety (Maqour) + drip irrigation + hills on raised beds + 25 kg Urea+ 100 Kg Ammonium nitrate	16	80 000	20.3	17.39
Sugar-cane	Wadi El-Saida Aswan	T: S9 variety (cuttings) + surface irrigation + 100 kg urea + 300 Kg ammonium nitrate	42.0	46 200	27.5	7
		P: S9 variety (seedlings at 30cm spacing) + drip irrigation + 100 kg urea + 300 Kg ammonium nitrate	48.5	53 350	26	11.55
Tomato	Metobus Kafr El-Sheikh	T: Cristiano + surface irrigation + raised beds + 25 Kg ammonium sulfate + 50 Kg urea + 50 Kg ammonium nitrate	24.96	36 000	600	14.2
		P: Cristiano + drip irrigation + raised beds + 25 Kg ammonium sulfate + 50 Kg urea + 50 Kg ammonium nitrate	32.6	54 000	446	30.2

Crop	Location of the FFS	Treatment	Yield (ton/fed)	Total income (LE/ fed)	Total CO_2-eq (g / kg product)	WUE (kg / m^3)
Tomato	Western Samalout Menya	T: Sole culture of Jaara 023 + drip irrigation + hills on raised beds + 100 kg Urea+ 200 Kg Ammonium nitrate	30	80 000	26.28	12
		P: Intercropping Zucchini with Jaara 023 + drip irrigation + hills on raised beds + 100 kg Urea+ 200 Kg Ammonium nitrate	T=30 Z=0.2	80 200	26.11	12.08
Tomato	Western Samalout Menya	T: 086 + + drip irrigation + hills on raised beds (planting distance of 60 cm) + 6 kg Urea+ 75 Kg Ammonium nitrate + 75 Kg Ammonium sulphate	15.6	62 400	29.4	4.33
		P: Habeba + drip irrigation + hills on raised beds (planting distance of 30 cm) + 6 kg Urea+ 75 Kg Ammonium nitrate + 75 Kg Ammonium sulphate	20.4	81 600	38.5	5.67
Tomato	Western Samalout Menya	T: 010 + drip irrigation + hills on raised beds +50 kg Urea + 100 Kg Ammonium nitrate	16.8	56 532	76.9	5.6
		P: Habeba + drip irrigation + hills on raised beds +50 kg Urea + 100 Kg Ammonium nitrate	19.8	66 627	65.3	6.6
Cucum-ber	Western El-Fashn Beni Sueif	T: Bhai hybrid + drip irrigation + hills on raised beds + 200 kg Urea+ 200 Kg Ammonium nitrate	9	27 000	866	3.85
		P: Bhai hybrid + Sakr hybrid + drip irrigation + hills on raised beds + 200 kg Urea + 200 Kg Ammonium nitrate	13	39 000	600	5.56
Cucum-ber	Wadi El-Saida Aswan	T: Local variety + drip irrigation + hills on raised beds + 100 kg urea + 100 Kg ammonium nitrate	4	10 000	374	2
		P: Sakata + drip irrigation + hills on raised beds + 100 kg urea + 100 Kg ammonium nitrate	5	17 500	299	2.5
Pepper	Wadi El-Nuqra Aswan	T: Yellow (Local) + surface irrigation + hills on rows + 200 kg urea + 200 Kg ammonium nitrate	12	57 600	68	5.33
		P: Green (Hybrid) + surface irrigation + hills on rows + 200 kg urea + 200 Kg ammonium nitrate	9.24	36 960	88	4.11

Crop	Location of the FFS	Treatment	Yield (ton/fed)	Total income (LE/fed)	Total CO_2-eq (g / kg product)	WUE (kg / m³)
Pepper	Wadi El-Nuqra Aswan	T: Nourhan + surface irrigation + hills on rows + without spraying + 600 Kg ammonium nitrate	4.6	23 600	211	1.83
		P: Nourhan + surface irrigation + hills on rows + Spraying 3 times with K and micronutrients + 4 Kg Humic acid + 600 Kg ammonium nitrate	7.9	41 200	123	3.13
Garlic	Western El-Fashn Beni Sueif	T: Balady (White) + drip irrigation + hills on rows + 150 Kg Urea + 400 Kg Ammonium nitrate	12	48 000	131.8	7.73
		P: Egaseed (Red) + drip irrigation + hills on rows + 150 Kg Urea + 400 Kg Ammonium nitrate	17	85 000	93	5.45
Garlic	Western El-Fashn Beni Sueif	T: Egaseed (Red) + drip irrigation + hills on rows + 400 kg Urea+ 400 Kg Ammonium nitrate	16	80 000	125.6	6.40
		P: Egaseed (Red) + drip irrigation + hills on rows + 200 kg Urea+ 200 Kg Ammonium nitrate + 200 Kg Pigeon manure	19	95 000	70.2	7.60
Garlic	Western El-Fashn Beni Sueif	T: Egaseed (Red) + drip irrigation + hills on rows + 300 kg Urea+ 300 Kg Ammonium nitrate	18	81 000	77.6	7.2
		P: Egaseed (Red) + drip irrigation + hills on rows + 150 kg Urea+ 150 Kg Ammonium nitrate + 100 Kg pigeon manure	20	90 000	44.6	8
Water-melon	Metobus Kafr El-Sheikh	T: Scata + drip irrigation + hills on raised beds + 150 Kg Urea	20	22 000	371	8.33
		P: Scata + drip irrigation + hills on raised beds + 200 Kg Ammonium nitrate	22	24 200	360	9.17
Marjo-ram	Western Samalout Menya	T: Unknown variety + drip irrigation + hills on flat land + 24 m³ FYM + 50 kg Urea + 50 Kg Ammonium nitrate + 50 Kg Ammonium sulphate	2	18 000	212	0.7
		P: Unknown variety + drip irrigation + hills on raised beds + 20 m³ chicken manure + 50 kg Urea + 50 Kg Ammonium nitrate + 50 Kg Ammonium sulphate	4	36 000	106	1.3

Crop	Location of the FFS	Treatment	Yield (ton/fed)	Total income (LE/fed)	Total CO_2-eq (g / kg product)	WUE (kg / m³)
Fennel	Western Samalout Menya	T: Local variety + surface irrigation + hills on 60 cm row distance with 20 cm plant distance using manual planter + 200 Kg Ammonium nitrate	15.00	75 000	19.1	7.25
		P: Local variety + surface irrigation + hills on 45 cm row distance with 10 cm plant distance using manual planter) + 200 Kg Ammonium nitrate	19.20	96 000	14.9	9.28
Hibiscus	Wadi El-Saida Aswan	T: Local variety + drip irrigation + hills on raised beds + 150 Kg ammonium nitrate	2.10	16 800	102	0.833
		P: Saudi variety + drip irrigation + hills on raised beds + 150 Kg ammonium nitrate	3.675	27 200	58	1.458
Hibiscus	Wadi El-Saida Aswan	T: Saudi variety + surface irrigation + basins + 300 Kg ammonium nitrate	0.205	17 425	2097	0.10
		P: Saudi variety + surface irrigation + rows + 300 Kg ammonium nitrate	0.600	51 000	716.5	0.32
Hibiscus	Wadi El-Nuqra Aswan	T: Red hibiscus + surface irrigation + basins + 130 Kg ammonium nitrate	0.150	13 500	1241.9	0.089
		P: Red hibiscus + surface irrigation + rows + 130 Kg ammonium nitrate	0.200	18 000	931.4	0.198
Mint	Wadi El-Nuqra Aswan	T: Local variety + surface irrigation + hills on rows + 75 kg urea + 150 Kg ammonium nitrate + chemical control	0.70	42 000	329	0.39
		P: Local variety + surface irrigation + hills on rows + 75 kg urea + 150 Kg ammonium nitrate + (hand hoeing for weeds + spraying with agricultural soap for aphids + spraying copper oxychloride for leaf rust disease)	0.64	96 000	360	0.36

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