INITIATIVE ON
Fragility to Resilience in Central and West Asia and North Africa

An assessment and analytical report for integrated agriculture-aquaculture (IAA) systems in Egypt

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In partnership with

International Water Management Institute

An assessment and analytical report for integrated agriculture-aquaculture (IAA) systems in Egypt

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List of abbreviations

ACO	Aquaculture Consultant Office
AHRI	Animal Health Research Institute
ARC	Agriculture Research Center
AI	artificial intelligence
BMP	best management practice
CLAR	Central Laboratory Aquaculture Research
EEAA	Egyptian Environmental Affairs Agency
EUFC	Egyptian Union of Fishermen Cooperatives
GOVS	General Organization for Veterinary Services
HDPE	high density polyethylene
IFMA	Investor & Farmers of Moghra Association
IAA	integrated agriculture-aquaculture
ICT	information communication technology
IOT	internet of things
LFRPDA	Lakes and Fish Resources Protection and Development Agency
MFFA	Menia Fish Farming Association
MHESR	Ministry of Higher Education & Scientific Research
MOALR	Ministry of Agriculture and Land Reclamation
MWRI	Ministry of Water Resources and Irrigation
NIOF	National Institute of Oceanography and Fisheries
NGO	nongovernmental organization
PRAS	partial recirculating aquaculture system
RAS	recirculating aquaculture system
STREAMS	Sustainable Transformation of Egypt`s Aquaculture Sectors
SWOT	strengths, weaknesses, opportunities and threats
WP4	Work Package 4

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Executive summary

Integrated agriculture-aquaculture (IAA) is one of the most promising, and fastest-growing, food production systems in Egypt. IAA systems offer an excellent opportunity to optimize the use of water resources, increase fish production, decrease the use of chemical fertilizers in crop farming and reduce the impact of aquaculture on the environment. This assessment provides an in-depth analysis of IAA systems in Egypt. We identify and map the governance and stakeholders of IAA systems, outline knowledge gaps and opportunities for developing these systems, define current water use policy in the country and its limitations, and list supporting services for IAA stakeholders.

A sample of IAA farms was selected from WorldFish's database and network of experts. The study examined 18 farms adopting IAA in six governorates (Marssa-Matrouh, Menia, Beheira, Giza, Beni-Sweif and Alexandria). The IAA farms culture Nile tilapia, mullet, red tilapia, basa, eels and whiteleg shrimp. The IAA farms follow two main irrigation systems: drip and sprinkler. Field crops are alfalfa, maize, wheat, and barley; vegetable crops are onion, lettuce and herbs; and fruit crops include tomato, mango, date palm, olive, guava and fig, as well as shrubs and trees (jojoba and casuarina).

Currently, there are only a limited number of farmers in Egypt practicing IAA, mainly because of water management issues, including the increased labor and capital the system requires. Egyptian farmers understand that IAA systems use water more efficiently, which can lead to a wide range of social, economic and environmental benefits. However, they do not fully understand how to balance the water requirements between the fish farm component and the crop component within IAA systems.

Through various field visits, we used a strengths, weaknesses, opportunities and threats (SWOT) analysis of IAA systems to draw the following conclusions:

Strengths
- Government is helping integrate aquaculture into farming projects on new land by issuing different laws and decrees, which has allowed IAA to take hold.

Weaknesses
- Operational costs for projects are high.
- There is limited knowledge of groundwater resources to develop IAA.
- There is a lack of technical and management skills for optimizing resource use in IAA.
- High salinity levels in groundwater limit crop selection and increase soil salinity.

Opportunities
- Demand for fish consumption is growing.
- IAA generates employment opportunities in rural areas.
- Untapped water sources are available for aquaculture.
- Increasing fish production could meet the rising demand for fish.
- There are opportunities to establish seafood processing factories.

Threats
- There are conflicts between different authorities on how to use water resources.
- The increasing salinity of groundwater over time will make the water unsuitable for many crops.
- Newly reclaimed lands have adverse climate conditions for aquaculture.
- There is a lack of sufficient funding to support the infrastructure of the aquaculture value chain and to train farmers on how to use IAA systems.

This report is the first of its kind in Egypt. It brings together existing data, literature and analysis of the challenges, opportunities and governance of IAA in order to propose policy recommendations. The literature review and collection of secondary data began at the start of the study. Primary data sources were semi-structured interviews and focus group discussions. This data was collected during field visits from December 1 to 20, 2022, followed by 20 days to finalize the report. The report also contains primary data collected during the expert consultation workshop held during the study. The completed report was accepted by the International Water Management Institute, WorldFish and CGIAR in May 2023.

Feedback from experts during the workshop focused on the main constraints and obstacles facing IAA in Egypt. These include high prices for fish feed and seed, limited seed and water, poor water quality, limited knowledge of water management, limited data for aquaculture production, lack of technical training for aquaculture personnel, weak marketing knowledge, high production costs and lack of access to credit.

We used different tools and participation levels to define future development of IAA to support food security and economic development. This generated the following proposed actions for the planning period (2023–2032) under four guidelines:

1. Increase knowledge and innovation.
2. Build resilience and competitiveness.
3. Optimize and protect the environment.
4. Ensure social acceptance and consumer knowledge.

The study proposes an action plan for priority topics and areas of the program. To help meet the growing demand for fish in the country, the study recommends that fish production from IAA should reach 25,000 t by 2032, which is 10 times higher than the 2500 t that was produced in 2020.

The study concludes that successful development of innovative IAA and sustainable scaling in Egypt require creating innovative solutions to implement these systems. During the next 10 years, IAA will become an important approach for sustainable development. Recommended innovations include the following:

- Help stakeholders use information communication technology (ICT), smart sensing and the internet of things (IOT) for optimal use of resources.
- Adopt hybrid water management in the fish farm component of IAA by using both the flow-through system, partial recirculating aquaculture system (PRAS) and the recirculating aquaculture system (RAS) based on the requirements for crop irrigation.
- Support product network marketing and establish IAA pilot farms as demonstration farms for private farmers so that they can learn how to manage IAA systems.
- Help farmers learn how to adopt new techniques through applied research, training, interactions and shared knowledge.

1. Introduction

Desertification is one of the biggest environmental challenges Egypt suffers from. Over the past 20 years, land cover in Egypt has increased 11,976 km^2 (1.2 % of the total land area). However, 1817 km^2 (0.18% of the total land area) has been lost to degradation. This shows the need to increase wetlands and waterbodies while being aware of the consequent hazards to the Nile Delta croplands (Yossif 2019).
A government land reclamation program aims to increase agricultural land outside old delta land. In newly reclaimed land, water resources are limited, so optimizing the use of water is important for sustainable development in the country.

This study was conducted as part of Work Package 4 (WP4) of the CGIAR Initiative on Fragility to Resilience in Central and West Asia and North Africa: "Integrated food, land, water and energy systems for climate-resilient landscapes." It attempts to clarify the limits to growth and improve the long-term potential for sustainable livelihoods by strengthening inclusive policies and governance for integrated management across the food-land-water-energy nexus. One of WP4's expected outputs is: "Guidelines on the integration and scaling up of aquaculture (fish farming) and agriculture developed."

Most predictions concerning the rate of increase and potential to produce fish and related products through IAA are based primarily on resource considerations, such as the availability of land and water, trained personnel and investment capital. Little consideration is given to external constraints such as consumer demand, competition with other means of producing animal protein and fats, and the competing demands for space and other resources to meet other societal needs. It is with that in mind that this study assesses the potential growth of aquaculture production as realistically as possible to determine in what forms aquaculture is likely to be most competitive with other types of food production using IAA systems.

This study describes, in chronological order, the significant advances that IAA has made in commercial and small-scale activities. The main aspects of these advancements are related to integrating one or more plants and aquatic animals to optimize the use of land, water and energy. The study also addresses the main characteristics, advantages, disadvantages and successful examples of using flow-through and recycled water in fish farming systems. These types of integrated systems focus on using resources efficiently by complying with several criteria that bring them closer to sustainability. However, each one has its challenges, one of the most important being the biological compatibility between different cultivated plant and animal organisms.

2. Objectives

This assessment provides an in-depth analysis of IAA systems in Egypt in terms of actual status, future development and challenges. The objective is to provide recommendations to WorldFish and CGIAR on potential interventions and innovations for improving the performance of IAA farms. In addition, the study aims to build resilience of the aquaculture subsector for sustainable growth in rural and arid zones to develop and implement more IAA systems and recycle more water in fish farms using different available water salinities.

The study was completed over 20 days of office work, field activities and reporting. During the consultancy, we held a workshop to present our findings and receive feedback from experts. The purpose of the study's workplan is to provide the requested information of the terms of reference based on the expressed objectives of the chosen priorities.

The draft consultancy report focuses on the following:

- Provide a better understanding of IAA in Egypt and identify or map key stakeholders and governance.
- Identify and document knowledge gaps, bottlenecks and opportunities for developing IAA in Egypt.
- Identify related IAA technologies and innovations in Egypt and international lessons learned and best practices.
- Update and upgrade IAA guidelines to spread knowledge of better IAA practices throughout Egypt.

The consultancy delivered an assessment and an analytical report for IAA systems in Egypt. It also reviewed and updated the current manual of IAA technology, which includes the productivity of marginal and saline landscapes.

The assessment and analytical report covered the following objectives:

- Create an IAA assessment framework, including data, approach and analytical methods.
- Show the current status of IAA in Egypt through focus group discussions and field visits with different stakeholders.
- Describe water resources, water use policy and limits on water use in the country.
- Outline bottlenecks and opportunities in IAA systems.
- Identify and recognize nutrient management under a constant effluent water supply and variable fish and/or plant demand, including optimizing the use of fish nutrients.
- Provide materials for all training modules, including session plans, slides, exercises, handouts and evaluation forms, as well as a brief approach to capacity building.
- Makes recommendations and provide references. This includes making recommendations and strategic actions to improve the situation in Egypt, offering suggestions for an additional survey and providing a contact list of the targeted organizations and individuals through the survey.

2.1. Study approach

To conduct an in-depth analysis of IAA in Egypt within the study frame, we used a hybrid approach of semi-structured interviews and focus group discussions to collect primary and secondary data. Data sources included a literature review of previous studies and current regulations, expert interviews, field visits for the main integration farming area, and an expert consultation workshop.

The study team selected IAA farms from WorldFish's database and network of experts due to limited official data. The study sampled 18 of farms adopting IAA in six governorates (Marssa-Matrouh, Menia, Beheira, Giza, Beni-Sweif and Alexandria).

3. Implementation of the consultancy

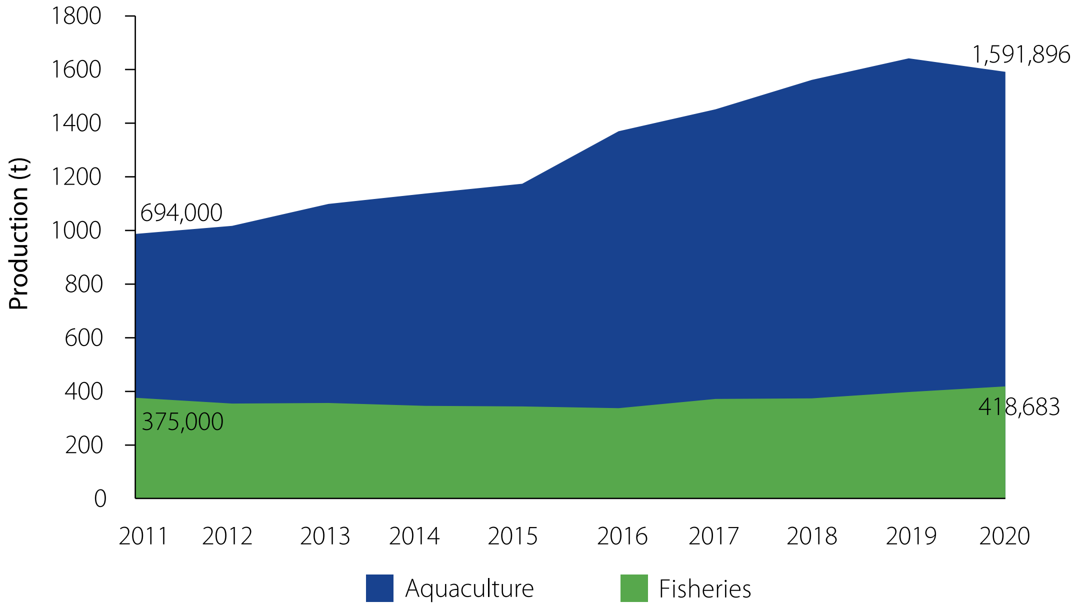
WorldFish requested the study team make field visits to various IAA stakeholders. All visits were made within a 10-day span and were conducted by the following staff from the Aquaculture Consultant Office (ACO):

- Sherif Sadek (PhD), CEO
- Nour Ahmed, Engineer, Operation Supervisor
- Salma Munir, Engineer, Technical Support
- Abdel-Rahman Mahfouz, Engineer, Operation Assistant Supervisor

4. Overview

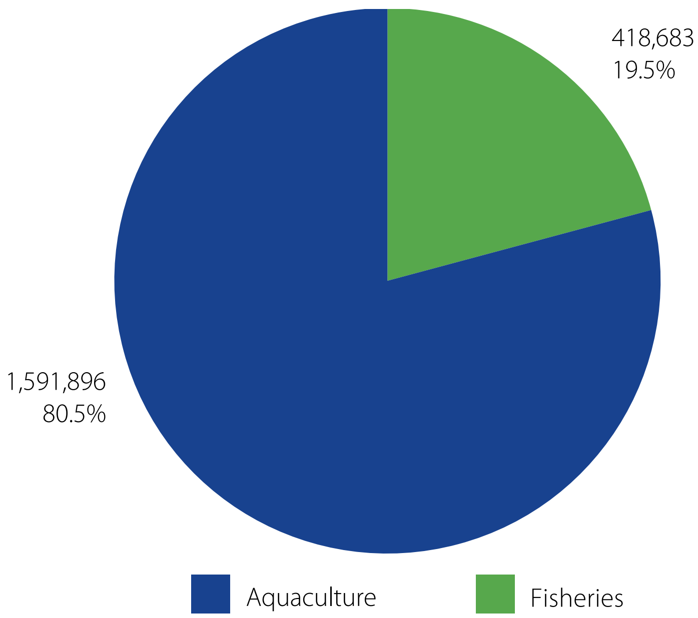
Fish provides a cheap source of protein for Egypt's 105 million people (CAPMAS 2019). In 2020, Egyptian fish farms produced 2.01 million metric tons of finfish and shrimp, almost all of which (99%) came from private production. About 1.592 million metric tons (79.18%) came from freshwater and marine fish production for a total market value of about USD 3.8 billion (USD 1 = EGP 16.22) (GAFRD 2022). The remaining 418,000 t (20.82%) were captured from the Nile, coastal and inland lakes, and the Mediterranean and Red seas.

From 2011 to 2020, aquaculture increased 62%, while fisheries only increased 12% (Figures 1 and 2).



Source GAFRD 2013 and GAFRD 2022.

Figure 1. Aquaculture and fisheries production in Egypt (2011–2020).



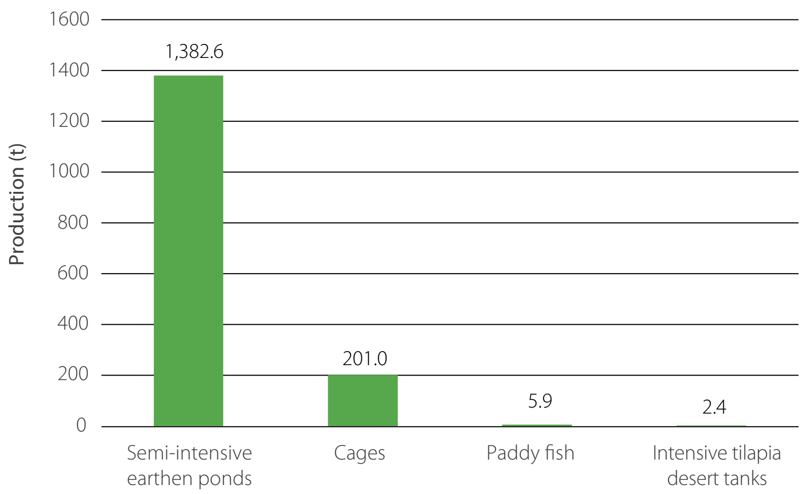
Source: GAFRD 2022.

Figure 2. Fish landing (t) in Egypt (2020).

From 2010 to 2020, average annual fish consumption in Egypt increased from 16.5 to 22.7 kg. Most fish farms are in the Delta region, and they use four different production systems. Earthen ponds make up 86.9% of production, cages 12.6%, paddy fields 0.4% and intensive tanks 0.1% (Figure 3). Production from intensive tank culture or desert culture, mostly in arid zones, is estimated at 2447 t. The main fish species farmed are tilapia (61%), mullet (20%) and carp (12%). The others (7%) are a mix of catfish, marine finfish and shrimp (Figure 4).

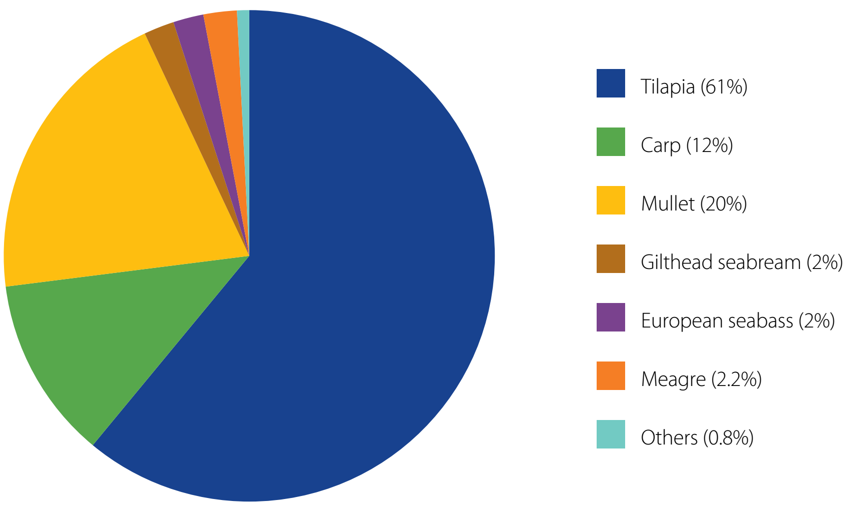
In 2020, hatcheries produced 674 million finfish/shrimp seeds, while 47 million mullet seeds were collected from the wild (GAFRD 2022). Although the total number of registered freshwater and marine hatcheries has reached 103, more than 500 tilapia hatcheries still are not registered. The number of registered freshwater seeds, mainly monosex tilapia and carp species, is 121 million. From 2011 to 2020, imports of fish and seafood increased 65%, from 182,000 to 300,000 t, while exports nearly tripled from 9500 to 28,000 t.

From 2011 to 2020, annual production from intensive fish culture projects in the desert more than tripled from 700 to 2447 t. The total water volume of intensive fish tanks is estimated at 165,000 m^3, with an annual production of 15 kg/m^3 (GAFRD 2022). During 2020, the General Authority for Fish Resources Development (GAFRD) licensed 12 IAA farms, with 46 feddans of fishponds. The governorates of El-Beheira and El-Menia ranked first at 56% (Annex 1). Figure 5 shows the licensed surface area of fishponds integrated into agricultural lands in different governorates in Egypt in 2020 (GAFRD 2022).



Source: GAFRD 2022.

Figure 3. Aquaculture production in Egypt (2020).



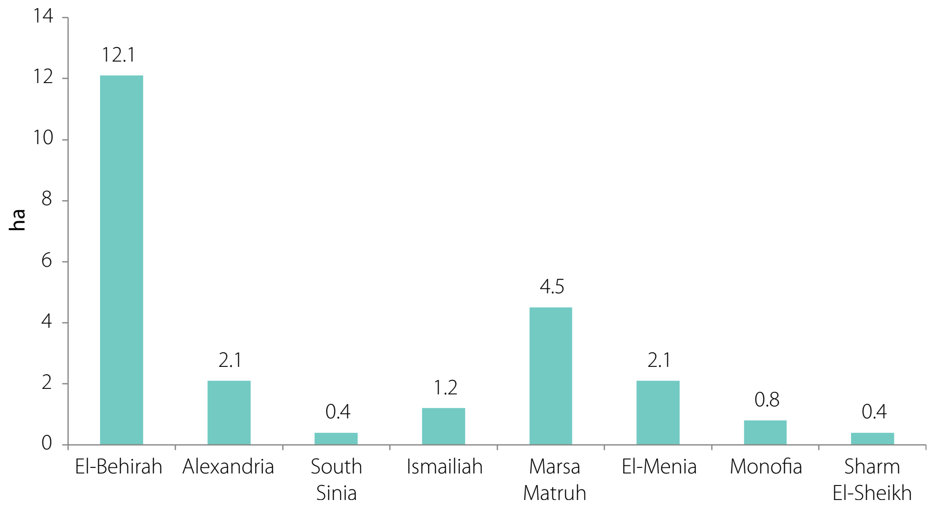
Source: GAFRD 2022.

Figure 4. Most farmed fish species in Egypt (2020).

During the past two decades, several studies have investigated the importance of IAA in Egypt: El-Guindy 2006; Ali and Talukder 2008; Verdegem MCJ and Bosma RH 2009; Sadek et al. 2011; Nasr Alla et al. 2012; Van der Hejden et al. 2013; Heijden et al, 2014; Corner et al. 2020; and Goda 2022. Between 2016 and 2019, WorldFish supported IAA in the governorates of Menia, Sharkia, Ismailia and Beheira through the Sustainable Transformation of Egyptian Aquaculture Market Systems (STREAMS) project (DPA 2019). End of project data indicated that there were 95 IAA farms with 137,000 m^2 (approximately 33 feddans) of surface area of freshwater reservoirs used for agriculture irrigation systems. Of these reservoirs, 69% were less than 1000 m^2 and 31% more than 1000 m^2. None exceeded 4000 m^2. Most of these reservoirs had a water depth of 3 to 5 m (Figure 6).

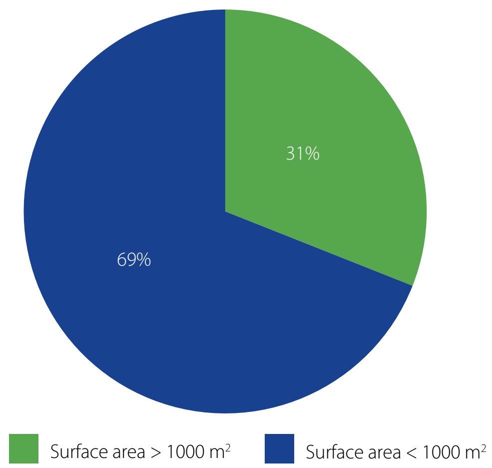
There is no accurate data on the number and distribution of IAA farms in Egypt. According to the final evaluation report for the STREAMS project, there are approximately 500 integrated small farms in operation in the governorates of Menia, Sharkia, Ismailia, Beheira and Aswan (DPA 2019). Recently, the government of Egypt, through the Egypt Countryside Development Company (El Reif El Masry), has been supporting the adoption of IAA in a 1.5 million feddan giga project. Many farms in the El-Moghra region have already started implementing IAA systems.

In a subsample, generated from STREAMS, more than two-thirds of the 95 integrated farms in the governorate of Menia have fishponds or tanks with a volume over 1000 m^3 (Figure 6). This shows that farmers are interested in applying IAA in their farms at scale.



Source: GAFRD 2022.

Figure 5. Distribution of licensed surface area of fishponds integrated into agricultural land in Egypt (2020).



Source: DPA 2019.

Figure 6. Surface area of 95 plant irrigation/fish culture reservoirs integrated into agricultural land in the governorate of Menia.

5. Alignment with national strategies

From 2002 to 2022, Egypt's total cultivated land area climbed from 8.1 million to 9.4 million feddans. However, this is still not enough to meet the needs of a growing population. Water is the main challenge for reclaiming land in Egypt, which needs 80 billion m^3 annually. However, the country's water resources only produce 60 billion (CAPMAS 2022a).

In December 2021, Egypt turned to wastewater treatment, when it opened the Bahr El Baqar plant, one of the world's largest wastewater treatment plants, at a cost of USD 1.14 billion. The plant, located on the eastern bank of the Suez Canal, is expected to produce 2 billion m^3 annually that will all go to the Sinai Peninsula. Meanwhile, Egypt will establish another USD 5 billion water plant in the northwest part of the country to produce 6 billion m^3 of water for reclaiming land in the New Delta region.

Nationwide, Egyptian projects are expected to reclaim nearly 3 million feddans of land from 2020 to 2024. This amounts to securing one-third of all cultivated land in Egypt for high production of food crops. Land reclamation includes different megaprojects by the government, which aims to reclaim 1.5 million feddans of desert in different rural areas as follows:

- 500,000 feddans in North Sinai and central Sinai to the east of the capital
- 500,000 feddans on the Dabaa Axis in northwestern Egypt
- 300,000 feddans in Toshka in southern Egypt
- 200,000 feddans in West Menia.

The reclaimed land will primarily be used for growing wheat as part of the government's import substitution program, which aims to makes the country self-sufficient in wheat production.

Law 147/2021 did not include the possibility of licensing the use of freshwater, whether from the Nile and its canals, or groundwater for aquaculture activities. However, the Ministry of Water Resources and Irrigation (MWRI) is permitting the use of freshwater for fish farming on the condition that it is stored in reservoirs at a specific volume, according to the amount of water needed for plant cultivation. Anyone using water for non-agricultural purposes or draining it must pay a charge for each cubic meter of water used in accordance with the conditions and controls specified by the executive regulations. The MWRI licenses fish farms for a period of 5 years based on their use of agricultural drainage water and semi-saline groundwater (MWRI 2021). However, this is only on condition of obtaining prior approval from the Ministry of Health and Ministry of Environment regarding the validity of water (Law 147/2021).

6. Policy supporting aquaculture and IAA in Egypt

This section describes the institutional involvement in organizing and managing the aquaculture sector in Egypt and the links between them.

There are five main decision-making government bodies in Egypt, which play different roles in the IAA process:

1. Lakes and Fish Resources Protection and Development Agency (LFRPDA)
2. Ministry of Agriculture and Land Reclamation (MOALR)
3. MWRI
4. Ministry of Higher Education & Scientific Research (MHESR)
5. Egyptian Environmental Affairs Agency (EEAA).

Under Law 146/2021, the LFRPDA controls the development of the fisheries and aquaculture sector in Egypt through the following measures (LERPDA 2021):

- granting approvals for establishing projects of public benefit carried out by other parties within the limits of their jurisdiction if they result in deducting parts of the lakes, their shores and their sanctuaries, after obtaining the approval of the EEA
- establishing pilot projects and drawing up training, extension plans and programs in the field of the sector and protecting development
- laying down rules, conditions and procedures for granting licenses for fish farms
- preparing an emergency plan to coordinate the concerned authorities for disaster response programs in lakes and to protect fisheries zones
- supervising cooperative fisheries and aquaculture societies.

There are two government bodies under the MOALR that support the fisheries and aquaculture sector for zootechnics, feeding, health and safety:

- Agriculture Research Center (ARC) along with two other organizations: the Animal Health Research Institute (AHRI) and the Central Laboratory Aquaculture Research.
- General Organization for Veterinary Services (GOVS).

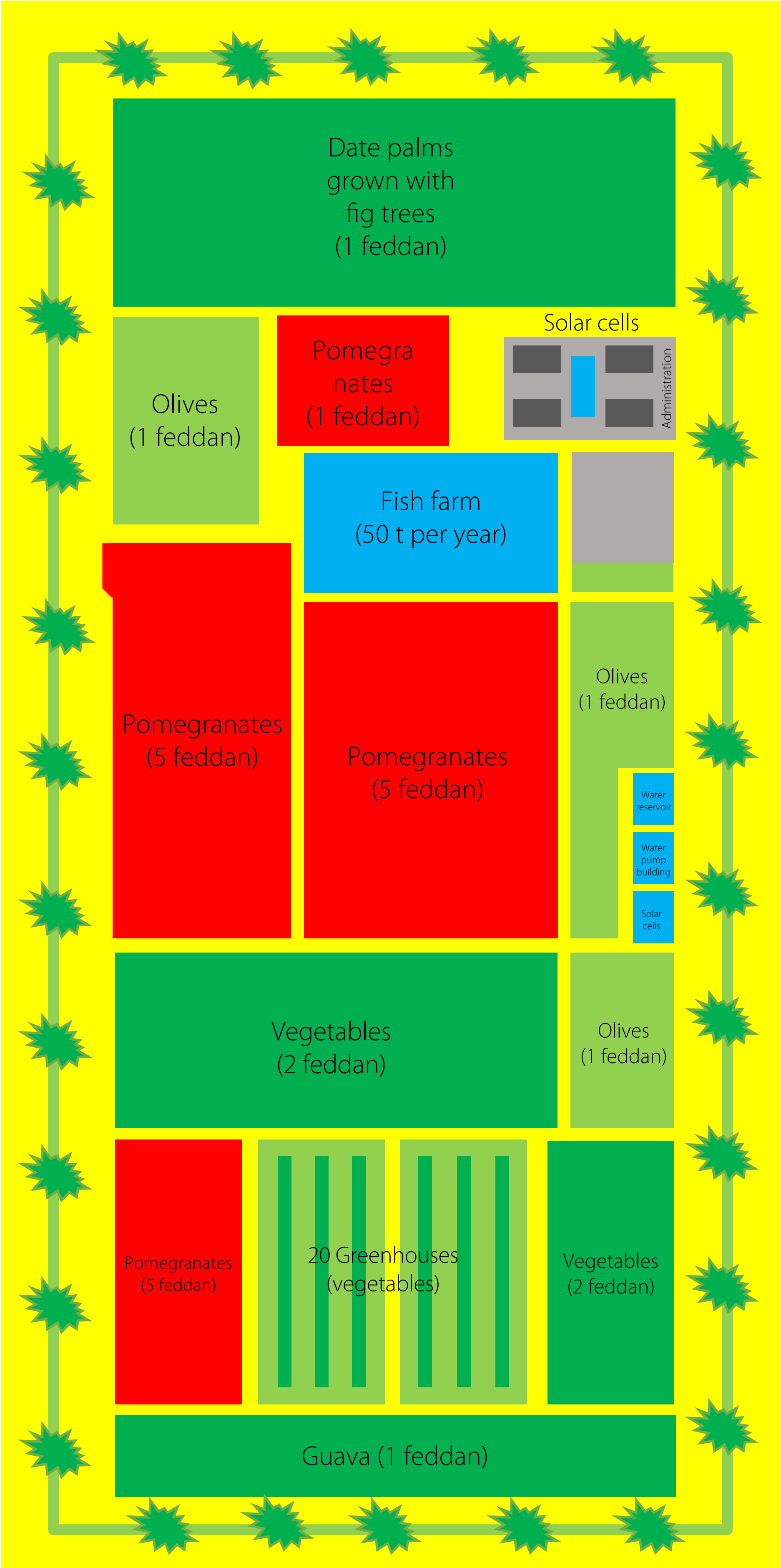
The MHESR is responsible for three research government bodies: the Academy of Scientific Research and Technology, National Institute of Oceanography and Fisheries (NIOF), and universities.

The Egyptian Union of Fishermen Cooperatives (EUFC) is a central nongovernmental organization (NGO) supporting the fisheries and aquaculture sector. The union consists of 13 aquaculture associations and 89 fisher associations that represent private farmers and fishers.

Many small, medium and large farmers, corporate farmers, cooperatives and government research organizations have adopted IAA in Egypt. Among these are NGOs such as the Investor & Farmers of Moghra Association (IFMA) and the Menia Fish Farming Association (MFFA) as well as companies from the private sector such as World of Pioneers, Go Green and KIWA Group. (CAPMAS 2019 and Corner et al. 2020) reported that the Executive Authority for Sinai Development implemented IAA development projects on 1500 feddans in the north and south of the province of Sinai in six community centers (Nekhel, El-Hassana, Abou-Zineam, Abour-Dess, Ras-Sedr and El-Tor) among 21 Bedouin communities (Figure 7). In addition, IAA projects were implemented for an indeterminable number of small fish farmers. A previous study (DPA 2019) identified 95 IAA farms that had different fish farm activities integrated with crop irrigation.

Many input and service companies and agents are playing important roles in IAA, including wholesale traders, retail traders, large supermarket chains, hypermarkets, fish fry collectors, hatcheries, nurseries, feed manufacturers, ice makers and aquatic drug manufacturers. The most important of their services are as follows:

- IAA extension and advisory services provided by the Government Department of Services, research bodies and NGOs
- Agricultural research and development provided by the Agricultural and Aquaculture Research Center
- IAA information provided by the economic department of the MOALR, and technical inspection and licensing provided by the National Food Safety Authority, MOALR and LFRPDA.

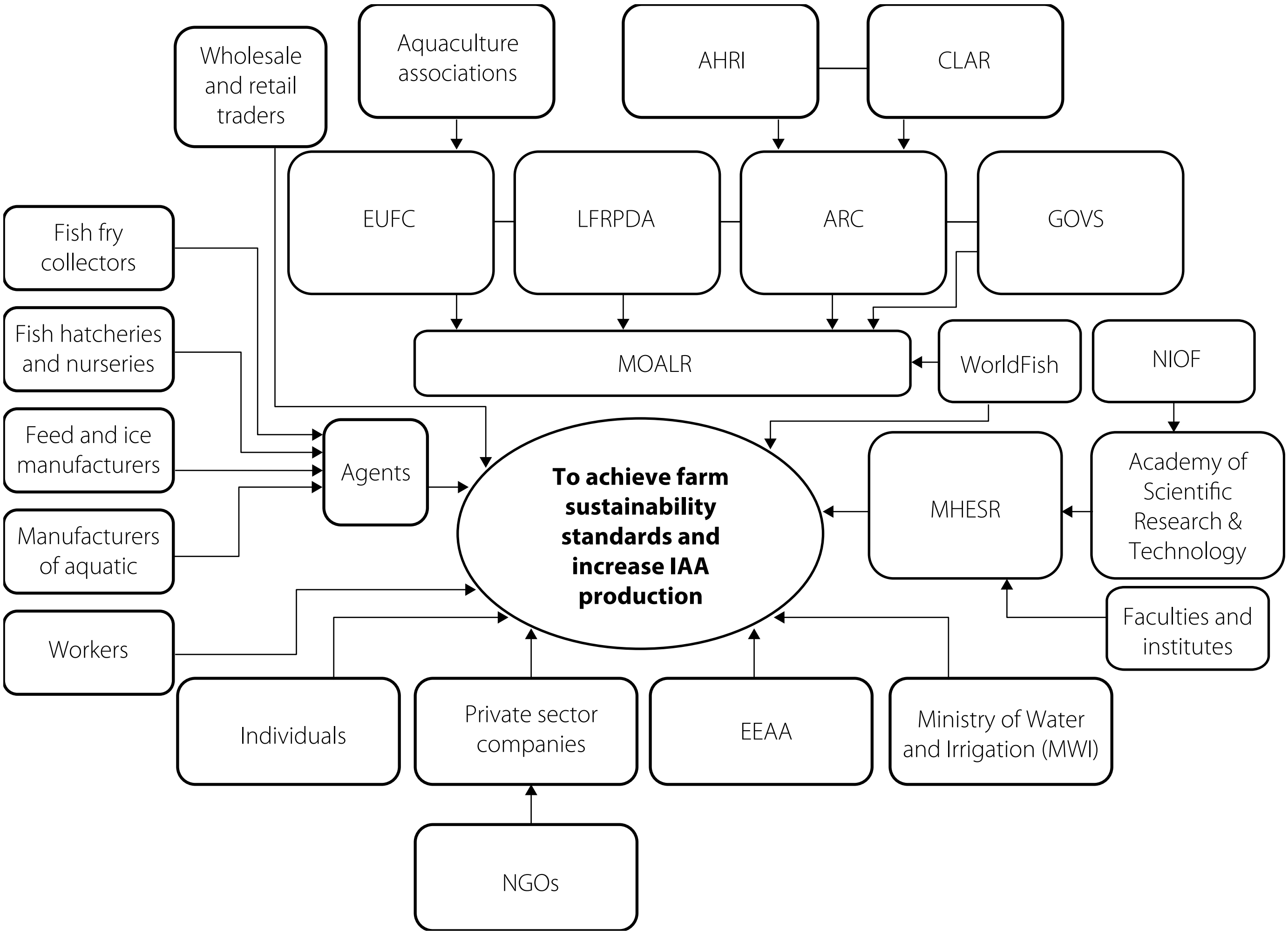


Source: amended from Corner et al. 2020.

Figure 7. Wadi Tal Village Farm IAA system on 32 feddans in Abu-Zneimah, South Sinai, Egypt.

7. Egyptian stakeholders

A stakeholder map is not an end in itself, but a means to understand the stakeholder structure and identify significant stakeholders at the bottom. To meet farm sustainability standards and increase production for IAA, value chain actors must maintain their functions across the value chain (Figure 8).



Source: amended from Corner et al. 2020.

Figure 8. Mapping of Egyptian stakeholders related to the IAA.

8. Mission statement of the field visit program

For the study, background investigations and reference checks were needed to secure information on the status of IAA and its impact on crops. A reference check generally involves contacting key stakeholders from relevant government authorities, private fish farmers and NGOs to obtain information about their knowledge, skills and abilities. The study included field visits to IAA activities in five governorates December 1–20, 2022 (Annex 2).

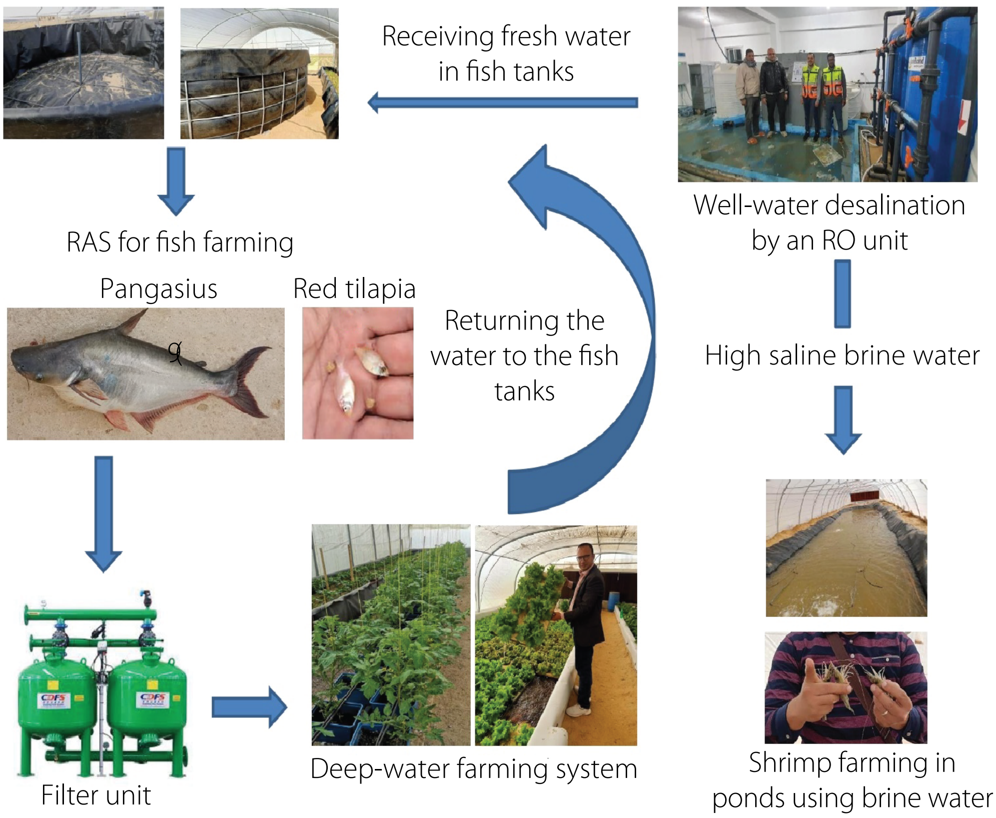
8.1. Moghra, Marssa-Matrouh

A representative from the ACO made a field visit to Moghra in the governorate of Marssa-Matrouh December 5–7, 2022. Four IAA farms were visited to determine their issues and to receive suggestions for development (Annex 3).

During these visits, we noticed the presence of the research applied station Academy of Scientific Research and Technology. The experimental and extension farm model (Dr. Ahmed Hamza, personal communication, 2022) derives knowledge through observation and research in the same environment it is meant to study.

Different key characteristics are needed to determine whether IAA projects are aquaponic or sandponic. Hamza et al. (2022) have started to study the use of aquaponic systems for vegetable production in arid and salinity affected areas in Al-Moghra by applying the following steps (Figure 9):

- The experimental station is receiving desalinated water (5 ppt) from a well that is pumped to the aquaponic and sandponic systems under a greenhouse system to grow different vegetable crops, such as tomatoes, peppers, lettuces and strawberries.
- Red tilapia, pangasius (*pasa*) and common carp are cultured in circular and raceway tanks, using fresh water from the desalination plant. The effluent water from fish tanks is pumped to irrigate the crops.



Source: Hamza et al. 2022.

Figure 9. Aquaponic systems for vegetable production in arid and saline areas in Moghra, Marssa-Matrouh.

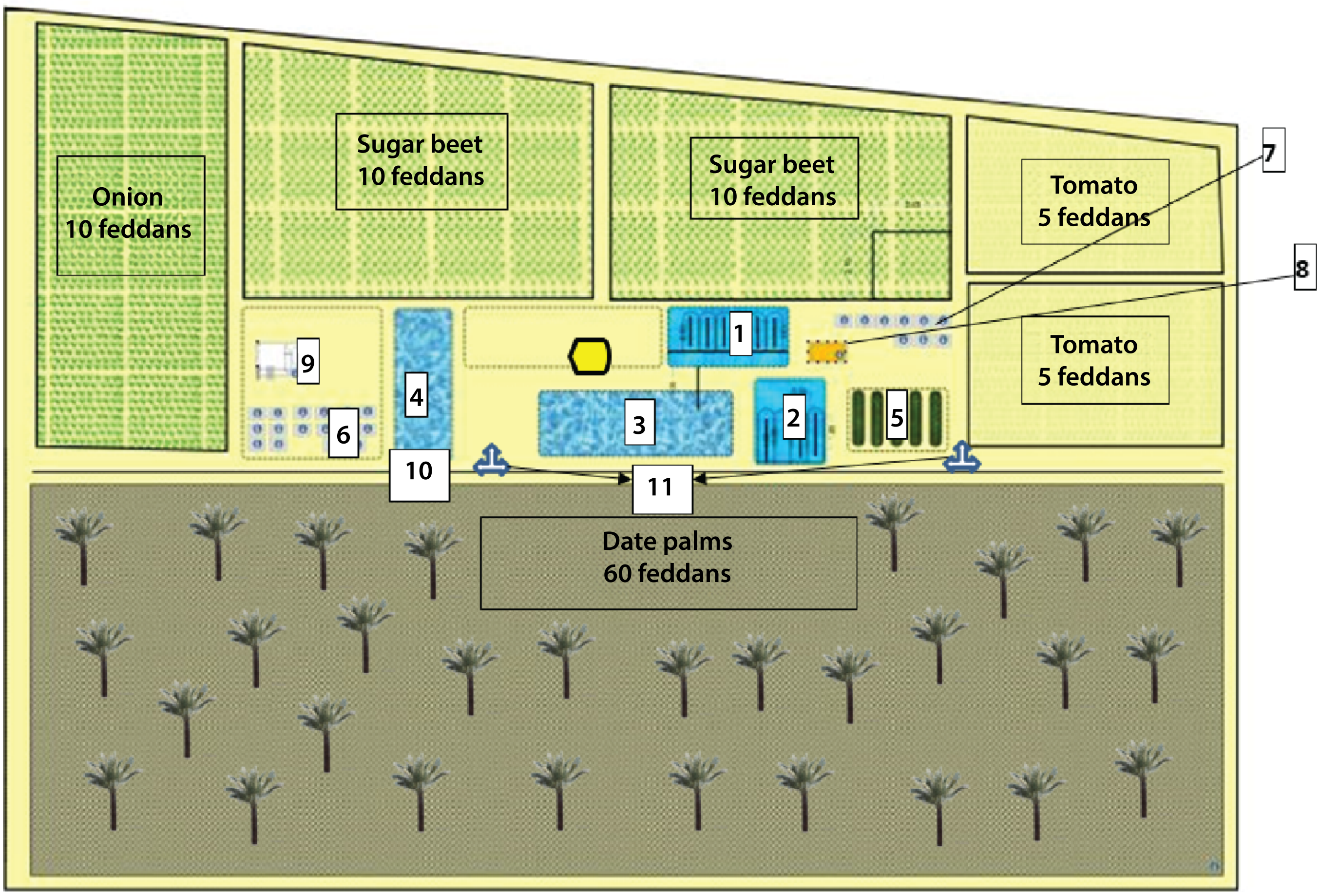
- The fish tanks can be developed into an RAS based on the water requirements of the crops and during winter when they need less water.
- Whiteleg shrimp (*L. vannamei*) is cultured in brine water (18 ppt) produced from the desalination plant (18 ppt).
- The best tank shape for an RAS is either circular or rectangular.

8.2. Beni-Sweif

The ACO representative visited the Arzak Company in the governorate of Beni-Sweif on December 8, 2022 (Annex 4).

8.3. Menia

The ACO representative visited four IAA farms in the governorate of Menia December 9–11, 2022: the Alam El-Awel Investment Company, the Abdel-Monem Omran farm, the Monastery of Anba Anthony, and the Korlos farm. Four other IAA farmers were contacted, but they were not interested in meeting the study team, as they were no longer farming fish. The main reasons were that effluent water from their fishponds had clogged the irrigation pipes, their fish were frequently stolen, fish farming had been prohibited on land suitable for agriculture, and the cost of production was too high, mainly because of tilapia feed and low fry quality (Annex 5 and Figure 10).



Alam El-Awel for Investment co., West Menia, Menia Governorate

1. D-ended fish tank (300 m^3/tank).
2. D-ended fish tank (400 m^3/tank).
3. Upper well water storage reservoir tank (20,000 m^3)
4. Lower effluent storage reservoir (15,000 m^3).
5. Azolla pond (100 m^2)
6. Solar station (200 Kw/hour)
7. Solar station (250 kw/hour)
8. Sand mechanical filter
9. Staff building
10. Fish farm effluent pumps to agriculture (600 m^3/hour)
11. Well pump (260 m^3/hour)

Source: designed by the ACO.

Figure 10. Layout of the 120 feddans of IAA of the Alam El-Awel for Investment Company on the Western Asyut desert road in the governorate of Menia.

8.4. Wadi-El-Natroun, Beheira

The ACO representative visited the El-Keram El-Alamiaa Company in the governorate of Wadi-El-Natroun, Beheira, December 9–11, 2022 (Annex 6 and Figure 11).

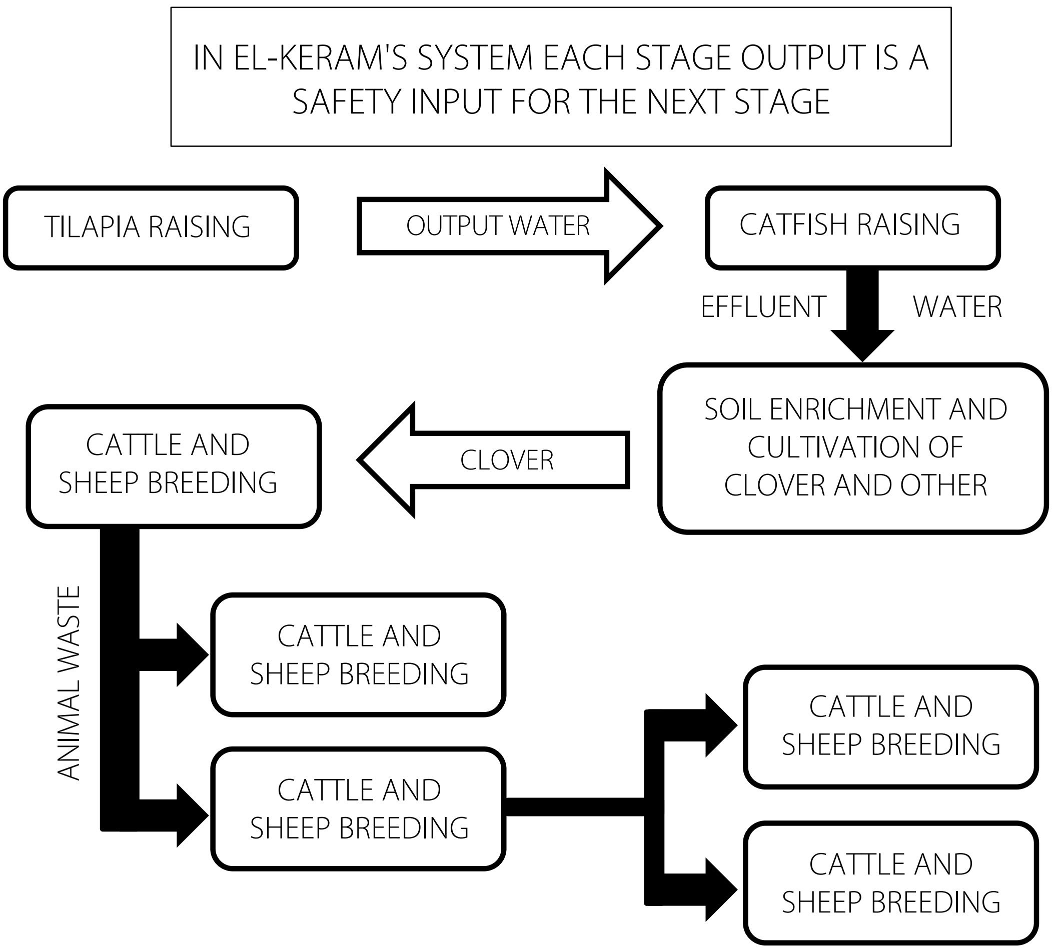
8.5. Alexandria

The ACO representative visited the Agromar for Agriculture Investment Company in the governorate of Alexandria December 14, 2022 (Annex 7).

8.6. Giza

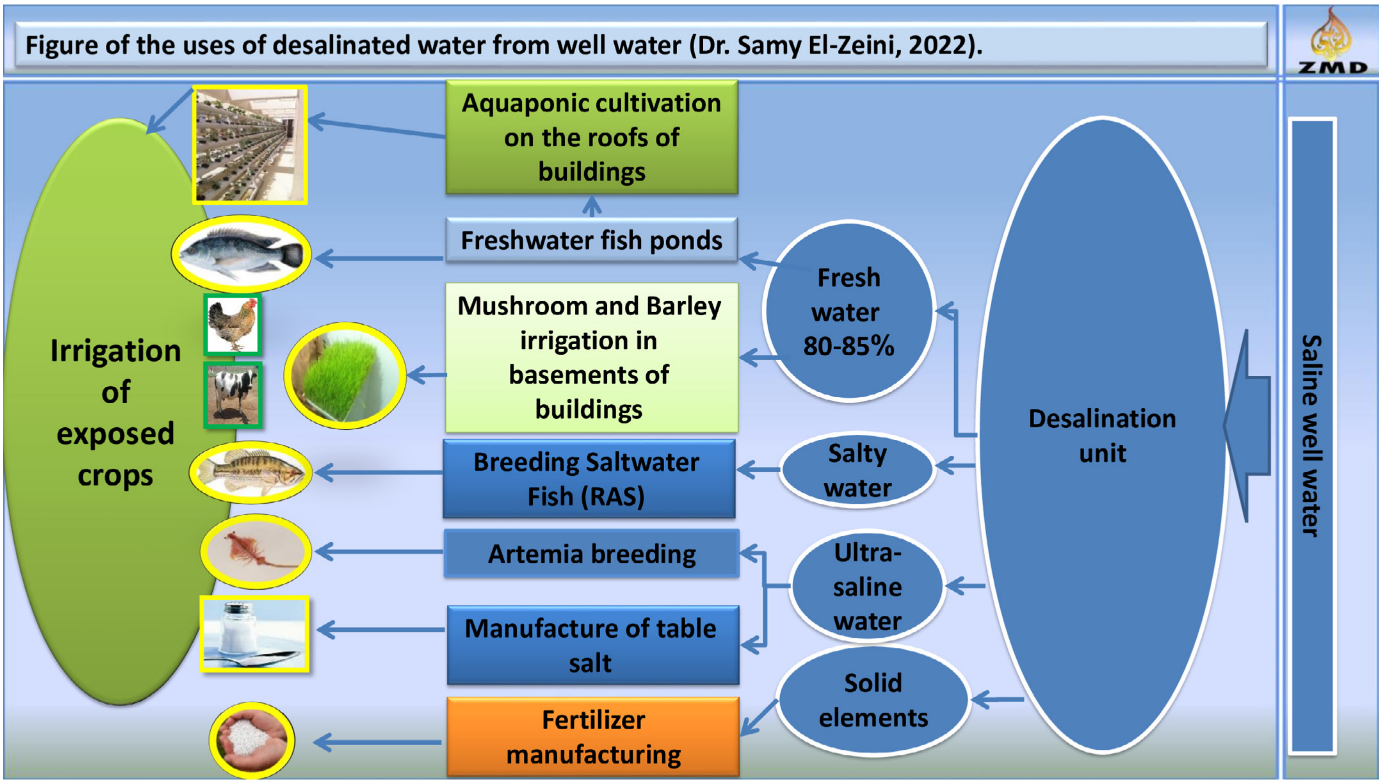
The ACO representative visited the El-Zeini Group for Agriculture Development Company in the governorate of Giza. The farm uses underground well-water with a salinity level of 1750 ppm pumped to two desalination stations with a daily well pumping capacity of 1100 m^3 and 700 m^3 respectively. There, water is desalinated at a rate of 1350 m^3 per day with a salinity level between 100 and 120 ppm. The water is then used to irrigate agricultural land through drip system networks and aquaponics. Brackish water (4500 ppm) is also produced from the desalination stations at a rate of 20%–25% of the total well-water, which is used to irrigate the Casuarina trees (windbreak trees) around the agricultural land. In future, brine water will be stocked in reservoirs to produce saline water for culturing marine fish in RASs and artemia (Figure 12).

On December 15–16, 2022, other field visits were made to Kiwa Grow. The company has Nile tilapia tanks and uses a sandponic system to grow green vegetables and herbs in 1500 m^2 of greenhouse space, using well-water with a salinity level of 900–1100 ppm. In addition, we also visited Nature Works. The company also has similar facilities. It has Nile tilapia tanks, and uses both aquaponic and sandponic systems to grow green vegetables and herbs in 1200 m^2 of greenhouse space, using well-water with a salinity level of 20 ppm (Annex 8).



Source: Corner et al. 2020.

Figure 11. El-Keram IAA farm in the Egyptian desert.



Source: El-Zeini 2022.

Figure 12. The IAA farm of El Zeini Group in the governorate of Giza.

9. SWOT analysis results and recommendations

The following are the results of an early SWOT analysis of IAA based on the field visits:

Strengths

- There is government support to develop the aquaculture sector, especially on new land.
- There are current projects in the aquaculture sector and an umbrella organization representing the sector.
- More Egyptians are eating fish.
- The private sector is interested in adopting IAA.
- There is greater awareness of the importance of fish as a healthy protein source for nutrition.
- Production inputs such as seed, feed and skilled laborers are available.
- Market demand for fish and crops has increased because of the country's growing population.

Weaknesses

- There is a lack of technical and management skills for optimizing resources in IAA.
- Integrated farming areas are far away from producers of fish seed and feed.
- Current statistics and databases are insufficient and unreliable to provide stakeholders with information on the status, practices and limitations of IAA.
- There is a lack of investment in IAA.
- Coordination between the public and private sectors in new areas is insufficient.
- There is no specialized supervisory body to monitor the quality of production from farm land and throughout the entire value chain.
- It is difficult to market IAA products. There is a lack of protective measures for local products against imported products.
- There is sufficient capacity to increase fish and shrimp production to meet the increasing demand (Plate 1).

Plate 1. A jojoba tree (left) and shrimp cultured in high density polyethylene (HDPE) tanks (right) in Moghra.

Opportunities

- Demand for aquatic food is growing.
- Domestic and international demand for jojoba seeds and oil is also growing (Plate 1).
- Tourism projects increase demand for fish consumption.
- There are opportunities to employ laborers in the aquaculture sector.
- Untapped water sources are available for aquaculture.
- Private companies have expressed interest in starting value addition businesses for aquatic food products. Using high quality water and feed or fertilizer produces premium products.

Threats

- There is conflict between different authorities on how to use water resources.
- Increasing salinity of groundwater over time means the water is unsuitable for many crops.
- There is limited knowledge of groundwater resources to develop IAA.
- Newly reclaimed lands have adverse climate conditions, such as wind or heat stress.
  There is not enough funding to support infrastructure along the aquaculture value chain. Egyptians lack confidence in local products and do not understand the nutritional value of aquatic organisms because of a lack of proper media coverage.

Plate 2. An HDPE pond out of production from 2020 to 2022 in Moghra.

10. IAA technologies

This section describes current IAA practices in Egypt, focusing on the fish farming component. It highlights the constraints and obstacles in marketing fish and other aquatic products in arid and desert zones and innovation opportunities under environmental sustainability development in the country.

10.1. Culture systems in IAA farms

10.1.1. Flow-through system

The most popular forms of tilapia production in IAA are an extensive method with a flow-through system (FTS) and an intensive method with an RAS. The FTS has been the fundamental technology since aquaculture began in Egypt.

When fish density at facilities starts to increase, the first measure is to aerate the ponds or tanks. The effluent water discharged from an FTS farm is used to irrigate cultivated crops.

In Egypt, water for crops is categorized geographically into three areas: North Delta, Middle Egypt and Upper Egypt. Fish farms using an FTS must calculate the total water volume and water exchange based on how much water plants require daily.

For alfalfa crops, for example, the water runs straight through the pond or tank without being reused or recirculated and is re-pumped to crops for irrigation (Plate 3). The water is either aerated or oxygen is added to it (Plate 3).

Plate 3. Pumping effluent from fish tanks to irrigate alfalfa crops in an IAA farm in West Menia (left), and Nile tilapia culture in an HDPE pond integrated with jojoba trees in Moghra (right).

Several underground water sources have a high concentration of iron and manganese, which can be toxic to aquatic animals. In Moghra, SOFEC, a company with the commercial name El-Radwan - Pangasius for Aquaculture (SOFEC) established an oxidation tank with a water-venture aeration system to oxidize iron in the water before pumping it to hatcheries and ponds (Plate 4).

10.1.2. Partial recirculating aquaculture system

To increase yields from the fish production component in IAA and to use water more efficiently, farmers tend to reuse water in their fish tanks. This helps reduce the demand on water resources and increases productivity per unit of water. Water recycling and the PRAS are the best options for farms close to urban areas with a reliable source of electricity. To ensure good water purification, recirculating systems consist of a number of components with specific functions. The system is an almost completely closed circuit in which effluent water is purified and reused continuously. Efficient PRASs can reuse 90% of culture water or more. Waste products include solid waste, ammonium and carbon dioxide, which are either removed or converted into non-toxic products. The purified water is then saturated with oxygen and returned to the fish tanks. Non-degradable waste products are removed, and evaporated water is replaced (Plate 5). Wastewater can be used as fertilizer for crops.

There are many advantages of using a PRAS:

- The environment is semi-controlled for fish growth.
- Water use is low.
- Energy and land are used efficiently.
- Feeding strategies are optimal.
- Waste and natural resources are better managed.
- Grading and harvesting fish is easier.
- Fish products are safer and of high quality.

Plate 4. Iron oxidation tank using water-venture aeration to treat groundwater in Moghra.

Plate 5. A D-ended pond in an intensive fish farm (top) and an aeration unit creating a water current and aeration in one of the ponds (bottom) in an IAA project in West Menia.

To scale PRAS grow-outs in any country requires certain infrastructure, feed and staff:

- Electricity is needed 24 hours a day, 7 days a week.
- A reliable water source, preferably borehole, is needed.
- Fish need to be fed quality feeds, preferably high in protein and fat, that are easy to digest.
- Staff must be technically skilled to operate the equipment.

10.1.3. Aquaponics and sandponics

10.1.3.1. Aquaponics

Aquaponics is a combination of aquaculture (the growing of fish and other aquatic animals) and hydroponics (the growing of plants without soil) in one recirculating environment. In aquaponics, the fish produce waste that nitrifying bacteria convert into nutrients for plants, which in turn absorb these nutrients to thrive. In return, the plant roots clean and filter the water for the fish to live (Plate 6).

10.1.3.2. Sandponics

Like aquaponics, sandponics uses fish to create ammonia that is then converted into nitrates by beneficial bacteria that serves as food for plants. The sand in a sandponic system acts both as a mechanical filter and a biofilter. The plants are cultivated on the ridges of the sand so that the roots get enough aeration as well as hydration (Plate 7). Pereira (2021), Go Green Aquaponics (2022), and Khaled Sherif from KIWA GROUP (Sherif, personal communication, 2022) compared the benefits of aquaponics and sandponics. They found that sandponics were better suited for IAA in Egypt because the system is less expensive to run, both the initial and total cost of production and the technology to operate it (Table 1).

Plate 6. An aquaponic deep-water culture tank with vegetable production in Moghra.

Plate 7. The Kiwa Group integrating sandponic ponds with fish tanks in the governorate of Giza.

Aquaponics	Sandponic s
It is expensive to set up and build because the system is more high-tech. It is also more intensive to manage.	It is less expensive and not as high-tech, so there are no mechanical filters and/or biofilters, and fewer water pumps are needed.
Accumulated fish feces can stress plant roots.	Fish feces are good for plants.
It is more water efficient, but daily maintenance is required.	There is less maintenance, as the microbes and beneficial bacteria do most of the work.
There is no soil involved, so weeding and digging are not needed.	It is easier and more efficient to grow root vegetables such as potatoes, carrots, garlic, beetroot, onion and fruiting plants.

Sources: Pereira 2021; Go Green Aquaponics 2022; Sherif, personal communication, 2022.

Table 1. Aquaponics versus sandponics.

10.1.4. Fertigation of biofloc wastewater exchange in crop irrigation

10.1.4.1. Biofloc

Biofloc is a fish farming system that recycles fish waste and uneaten feed nutrients into fish food. Specifically cultured microorganisms are introduced into the water to form microbial protein from fish waste and other organic matter in the water. This helps maintain water quality as well as lower costs. Candidate species must be resistant to environmental changes, be able to tolerate high stocking densities, adapt to changes in dissolved oxygen, and be able to take microbial protein as food. Biofloc is currently used in large-scale shrimp and finfish farms, mainly in Asia.

10.1.4.2. Fertigation

Fertigation is the application of fertilizers or nutrients into a farming system through an irrigation network in which the fertilizer is dissolved into the water and then absorbed directly by plants. The term combines the terms "fertilizer" and "irrigation" and has existed as a practice for hundreds of years. Fertigation is the most precise, controlled method of application, and typically uses less fertilizer than other techniques. It is also a common practice in hydroponic systems or other growing systems that do not use soil, as it is by far the easiest technique for administering precise doses of the proper nutrition that plants need in these systems. Although a number of compounds are used in fertigation systems, the most common are phosphorus, potassium and nitrogen because of their importance in the growth and development of many crop species.

The following are the advantages of fertigation:

- Nutrients and water are supplied near the active root zone through fertigation, which results in greater absorption by crops.
- As water and fertilizer are supplied evenly to all crops through fertigation, yields can increase as much as 25%–50%.
- Fertilizer use efficiency ranges between 80% and 90%, which helps save a minimum of 25% of the nutrients.
- It saves water while still increasing yield and profit.
- It requires less time, labor and energy.

10.1.4.3. Fertigation of biofloc wastewater exchange in conjunction with plant crop irrigation

Fertigation allows farmers to use biofloc effluent to fertilize their crops. There are many different types of irrigation, including sprinkler and soaker systems, but the drip system is the most compatible for crops. The JK for Agriculture Investment in El-Wahat El-Bahariya of the governorate of Giza uses this technology. The company uses waste water from its biofloc system to supply its irrigation system with fertilizer dissolved in water, including nitrates and phosphates. The company established an integrated project on reclaimed agricultural land in the Bahariya Oasis, where it grows palm crops on 1500 feddans of land using a drip system and cultivates alfalfa crops using pivot irrigation for an area of 240 feddans, divided into three areas of 80 feddans each.

The project has established 15 basins for culturing tilapia with its biofloc system (Figure 13). The system is irrigated using well-water in which iron is oxidized through two basins before pumping the water to the tilapia basins. This requires replacing 5%–20% of the water, according to the amount of bacteria present. The pond water is drained into a storage basin to irrigate the alfalfa crops, in addition to the drip network for palm trees. The amount of water required daily for irrigation is calculated according to seasonal needs, and the water that is replaced from the biofloc system is injected daily (Saluma, personal communication, 2022).

10.2. Constraints and obstacles facing fish farming in IAA

10.2.1. Fish feed

One of the biggest obstacles to sustainable aquaculture development in Egypt is the price and quality of fish feed. Feed makes up about 65%–75% of the running costs of fish production (Macfadyen et al. 2012; Kleih et al. 2013; Dickson et al. 2016), and prices have increased tremendously in the past few years. Distances for transportation are another problem. For example, it is 315 km from Kafr-El-Sheik to Moghra and 420 km from Kafr-El-Sheik to Menia.

10.2.2. Seed availability and price

There are two main sources of fish seed: hatcheries and the wild. Price and accessibility usually affect mariculture more than freshwater aquaculture (Sadek 2011). As with fish feed, distances are also long for transporting fish seed. Another problem is that suppliers often misrepresent the quality of their seed.

10.2.3. Good water quality availability

There is a scarcity of good sources of high quality water for IAA. There are two main sources: surface water and underground water. But there are problems with both types. Surface water is often polluted, while groundwater often has unacceptable levels of salinity, iron/manganese, ammonia, etc.

10.2.4. Poor water management in IAA systems

The main objective of IAA is to optimize water productivity by using it multiple times. In this system, water is used in fish production and then reused in crop irrigation. Farmers who use IAA need to know how much water is needed for both the fish and crop components to optimize integration. CAPMAS (2022b) reported that the average amount of water used in drip and sprinkling irrigation systems for field and vegetable crops varies depending where they are located in the country (Figures 14 and 15). The efficiency of drip systems is 64%–72% while for sprinkler systems it is 73%–83% (Figure 16). It is essential that IAA is based on the irrigation requirements for the location of the crops.

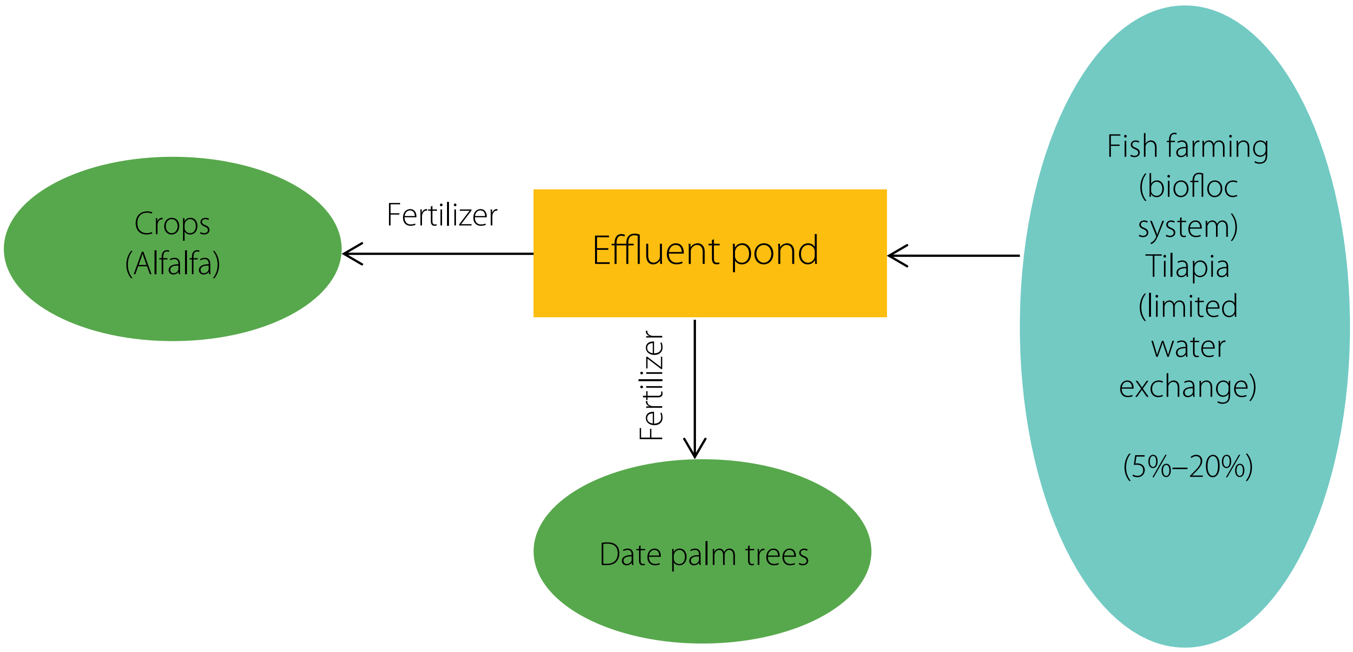
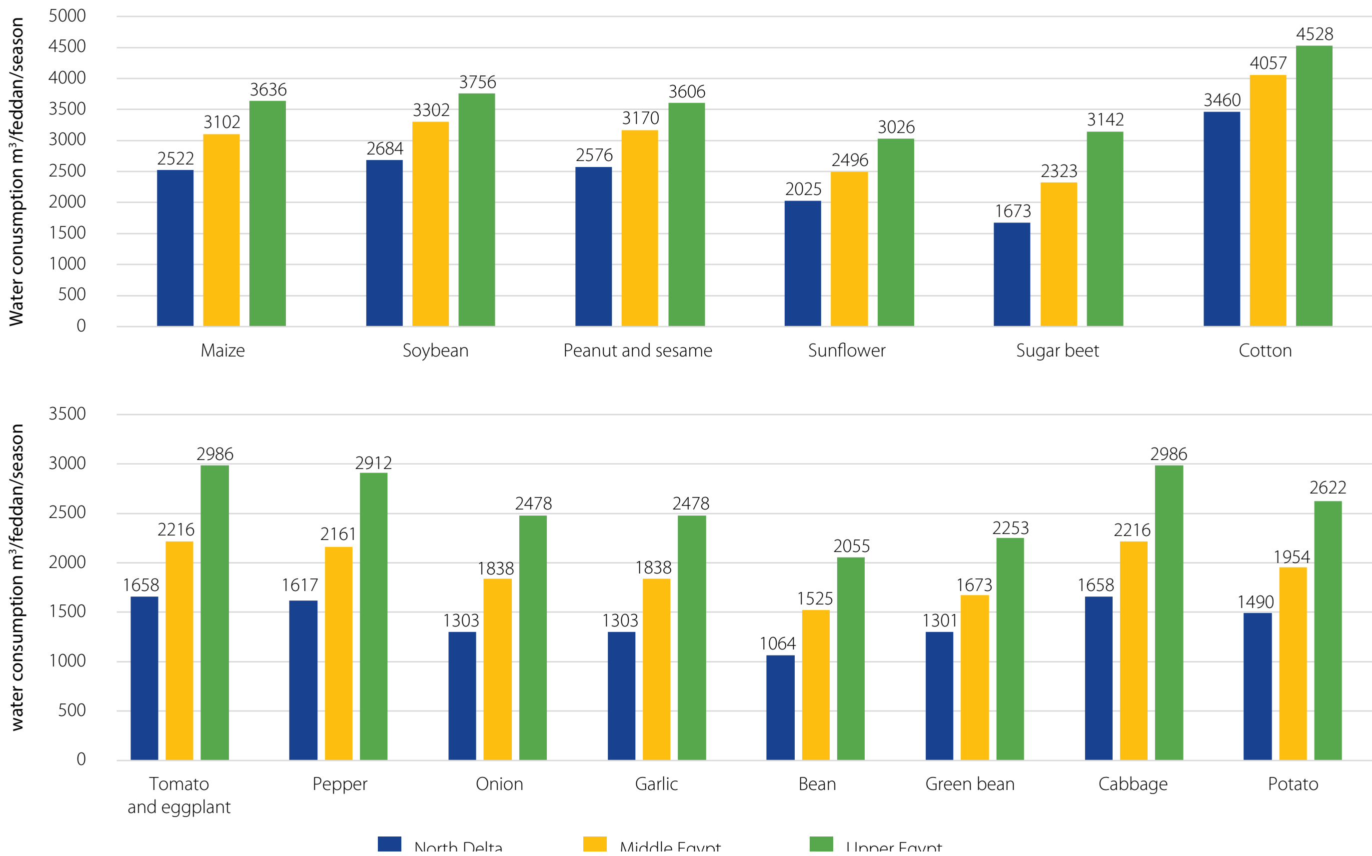
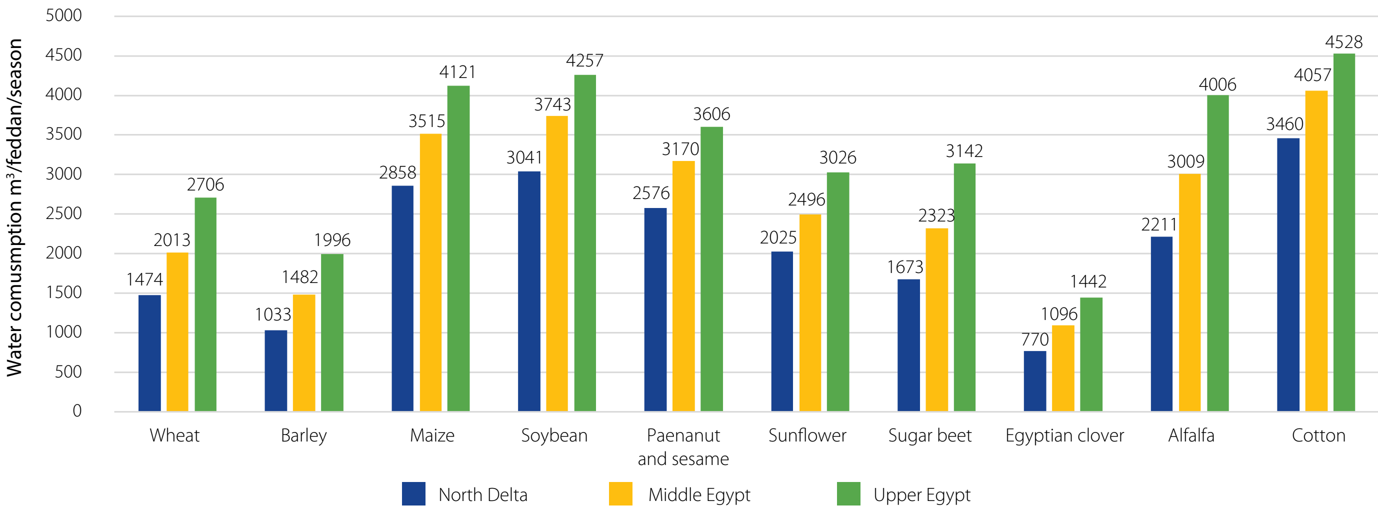


Figure 13. Sustainable water farming in El-Wahat El-Bahariya for JK for Agriculture Investment.



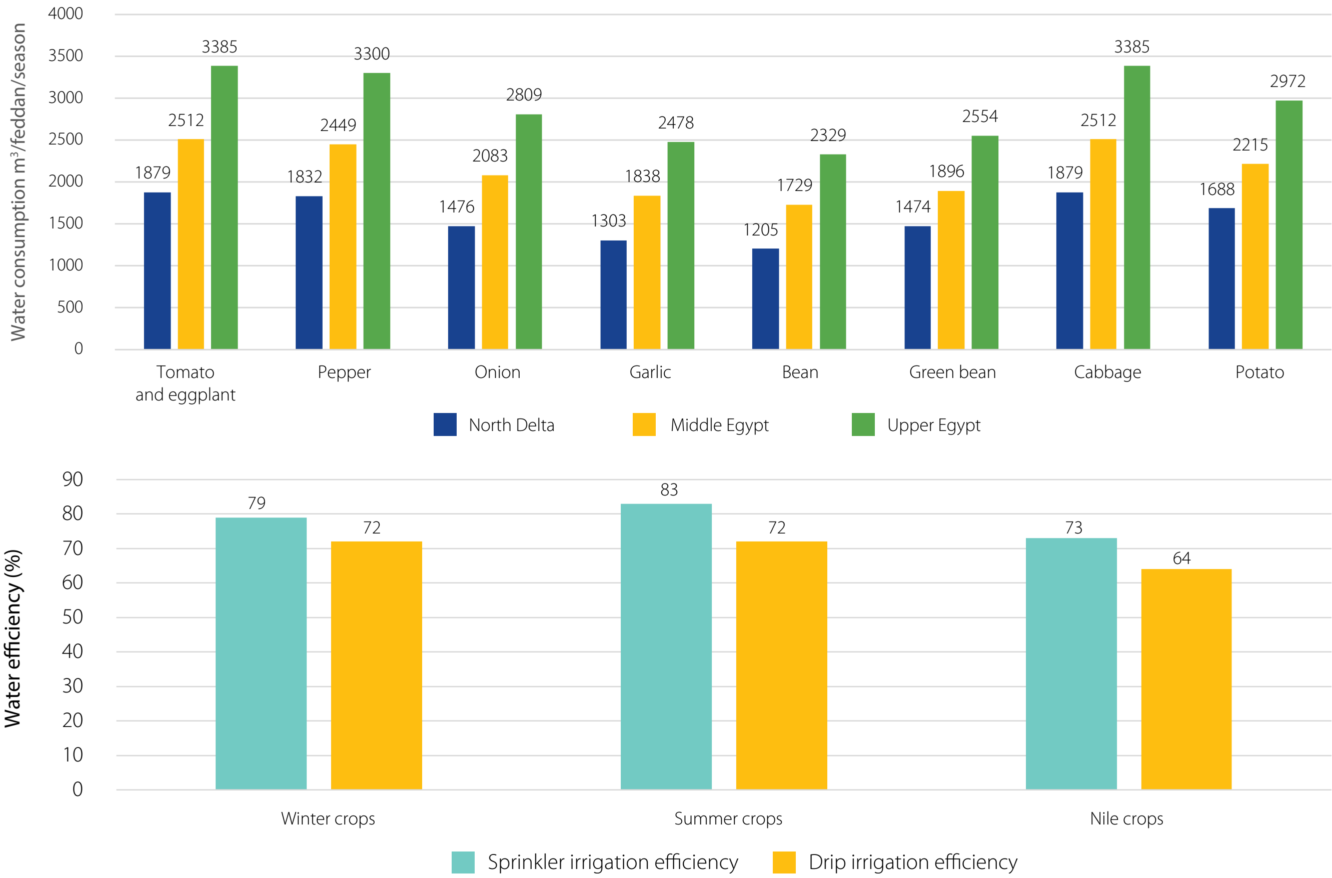
Source: CAPMAS 2022b.

Figure 14. Total freshwater consumption of drip irrigation for field and vegetable crops in Egypt.



Source: CAPMAS 2022b.

Figure 15. Total freshwater consumption of sprinkler irrigation for field and vegetable crops in Egypt.



Source: CAPMAS 2022b.

Figure 16. Efficiency of drip and sprinkler irrigation systems.

The El-Keram farm established IAA in Egypt in 2000. It integrated tilapia and catfish culture ponds with clover crops on 55 ha in the desert zone between Cairo and Alexandria. Since then, the farm has increased water conservation 72% without the use of chemical fertilizers.

10.3. Best management practices

Using best management practices (BMPs) can achieve sustainability by improving IAA production of both fish and crops. BMPs involve legal compliance, social responsibility, proper site selection, farm construction and good practices in farm management—from pond preparations to harvest and post-harvest activities. BMPs lead to better production, productivity and returns as well as environmental and social benefits.

10.3.1. Inputs

BMPS include such elements as a sustainable and acceptable water source, high quality fry, good quality feed, clean energy, highly skilled labor and approved aquatic drugs.

10.3.2. Operations

Farm operations include producing fish or shrimp and providing services such as storing feed and aquatic drugs, proper feeding and cleaning tanks, as well as sampling, handling, grading and packaging fish.

10.3.3. Marketing

Marketing includes assessing consumer wants and needs, and selling and promoting the fish farm's products and services.

10.4. Marketing fish and other aquatic products

Marketing fish includes all the activities and value-added products involved in fish farming that flow from farmer to consumer. It includes various operations required to move the fish or fish products from the producer to the consumer. Marketing value-added fish products often entails buying and selling fish by an individual who may not be a fish farmer. In fish marketing, which includes both fish products and live fish, the price of fish is determined by the parties involved, such as farmers and intermediaries like wholesale and retail traders.

Item	Non-integrated agriculture production system	El-Keram integrated system in 2000	El-Keram integrated system in 2016
Water units (number)	3	1	0.85
Nile tilapia (t)	100	100	100
African catfish (t)	100	100	100
Clover (t)	4500	7800	7800
Sheep (number)	1000	1300	1500
Warm water	No	Yes	Yes
Organic fertilizer	No	Yes	Yes
Chemical fertilizer	Yes	No	No
Waste	Variable	No	No
Irrigated land (ha)	42	55	55
Water conservation (%)	0	67	72

Source: Sadek 2011; Corner et al. 2020.

Table 2. Comparison of water use in El-Keram.

10.4.1. Elements of marketing fish and other aquatic products

During our field visits to the IAA farms, stakeholders complained about poor marketing links to sell their products, as their farms are located far from the main fish zones. For example, from Moghra it is 140 km to Alexandria and 230 km to Cairo. Several articles and papers, including Asogwa and Asogwa (2019) and Collins (2022) have reported that marketing channels could be sustained with different tools or platforms to reach the target audience.

We recommend supporting the IFMA in Moghra and the MFFA in Menia to lead marketing activities. The Moghra zone is the desert extension of New Alamein, a new city in northwest Egypt that lies on the Mediterranean Sea. There, IAA farmers could have good marketing opportunities for selling both plant and fish crops, especially during the summer holiday season.

10.5. Innovation opportunities for sustainability development of IAA

Nengas (2020) reported seven digital farming innovations for aquaculture worldwide. Of these seven, we found that five could have an impact on the Egyptian aquaculture market.

10.5.1. Digital feeding

Cage Eye is a decision-making tool that uses advanced hydro acoustic technology to monitor fish movement and environmental data with advanced machine learning algorithms. It measures fish density, speed and acceleration during feeding. Correlated with feeding patterns, these parameters offer unique insights into the appetites of fish so that farmers can use feed according to the nutritional needs of their fish. Efficient feeding can save up to 20% of feed costs.

10.5.2. Artificial intelligence

Using artificial intelligence technologies can identify behavioral changes in fish during feeding. The system learns by using cameras to observe how the fish move and to measure speed, acceleration and dispersion in the cage, tank or pond. It decides when to stop feeding or change the feeding rate according to the fish's appetite, ensuring optimal growth and feed use. The system can also detect early disease symptoms, which can reduce mortalities and antibiotic use and provide environmental protection and an overall improvement in farm management.

10.5.3. Smart sensing

Data from sensing technologies and underwater cameras can be uploaded to an online software tool, which the farm operator can review from their operation room, personal computer, tablet or smartphone. It allows operators to have a full overview of the nutrition, health and environment of the species in the farm, enabling them to be proactive before a situation becomes critical. Aqua Manager is an example of the kind of commercial analytics software used in aquaculture to centralize multiple sources of data on a single cloud-based platform. This mobile data application synchronizes with a live farm operations dashboard to provide real-time insights and predictive analytics.

10.5.4. The internet of things

The internet of things (IOT) is an interconnected network of devices, sensors, computers, tanks, grading equipment, fish counters and pumps within a state-of-the-art fish farm. Every part of the network communicates with each other, sending and uploading critical data to a central command station, providing the operator a complete view of the entire facility. The IOT generates a huge amount of data that can be (i) analyzed and manipulated using big data tools, (ii) used in combination with science tools to detect and predict production parameters and (iii) referred to when making important decisions.

There are four main functions of an IOT system.

First, an IOT system initiates product network marketing against the background of e-commerce (e-marketing) by using the internet to implement product sales. E-commerce network marketing has low costs and strong interaction, attracts customers, and reduces sales and maintenance costs. Mobile e-commerce is mainly used on mobile phones and electronic equipment. It has a high degree of integration for implementing a mobile office and providing people with more diverse services. Mobile terminals can also serve for personal banking, trading and entertainment.

Second, the IOT strengthens the capacities and functions of IAA farmers by providing them with support and advisory services to adopt new techniques, participate in applied research, take part in training, exchange knowledge, express their needs and adapt inventions. Aquaculture associations and NGOs can help create strategic partnerships to scale and disseminate innovations through replication or promotion at the political level by creating relationships with key actors of change.

Third, it provides training on how to use the network marketing talents of IAA products. Local governments at all levels should increase investment in rural vocational education and build a variety of IAA vocational education and training institutions to provide farmers with knowledge and guidance. Doing so will allow farmers to enhance their network, business and marketing management technology and effectively improve their awareness and use of information.

Finally, an IOT system establishes pilot aquaculture projects to better understand the systemic constraints that inhibit growth in the IAA sector. These include different government projects that use freshwater, brackish water, solar energy, RAS and desalination stations (Plate 8).

Plate 8. A desalination station for underground water (4500 ppm) (left), and grape trees irrigated with desalinated water (right) in the governorate of Giza.

11. Feedback

On December 19, 2022, we held a workshop at the Safir Hotel in Cairo to review our findings and receive expert feedback for the study (Annex 11).

11.1. Discussion

Despite the social, economic and environmental benefits of IAA, the system is not widely practiced in Egypt because of water management issues and the increased labor and capital required for water management. Although many Egyptian farmers are aware of its benefits, they do not understand how to use effluent fish farm water for growing crops.

But there is still an opportunity to increase the adoption and improve the performance of IAA in Egypt, taking into consideration the experiences of other countries. Abdul-Rahman et al. (2011) reported that IAA systems are able to save water because fish culture is a non-consumptive productive part that does not compete with irrigation. The unique feature of IAA is that it increases production without increasing the amount of water used (Verdegem et al. 2009). According to Abdul-Rahman et al. (2011), using effluent fish farm water in IAA can increase productivity 2.13 kg for fish and maize production, and as high as 8.46 kg for fish and vegetable production for each 1 m^3 of water. In addition, water productivity can be further increased by integrating and diversifying crops (Dugan et al. 2006; Ali and Talukder 2008; Verdegem et al. 2009). Fish waste increases the amount of organic fertilizer and replenishes nitrogen and phosphorus, which improves fertility (Giap et al. 2005). The sediment dredged from the bottom of ponds is an effective fertilizer that can boost crop production (Ahmed et al. 2007; Nagoli et al. 2009). Furthermore, vegetables and grasses grown on pond sediment protect dikes against erosion. Using quality water in fishponds and reusing water for dike cropping can increase water efficiency. In regions where water is scarce, IAA could represent an optimal solution for improving water production and food security.

11.2. Recommendations

We have made several recommendations to strengthen IAA activities to support food security and economic development. They were generated based on interviews conducted with farmers (Annex 12), the SWOT analyses from our field visits (Section 9) and the feedback from the workshop (Annex 11). An advocacy campaign needs to be developed to inform policymakers and all stakeholders about the importance of IAA for security, economic development and environmental consideration. IAA producers need to consult governmental authorities, mainly the LFRPDA, MOALR and MWRI, to support IAA producers in the country.

Our recommendations fall under five objectives:

1. Increase knowledge and innovation.
2. Build resilience and competitiveness.
3. Optimize and protect the environment
4. Increase social awareness and consumer information.
5. Establish policy dialogue and coordination between government authorities and the private sector.

Sustainable development of IAA can only be achieved through cooperation between government, business, NGOs and international research institutions to promote the development of sustainable IAA production. Stakeholders requested that a union of IAA actors be established for internal dialogue and to develop a planning team and choose a team leader.

Objective 1: Increase knowledge and innovation.

Innovation	Sustainable development of IAA is underpinned by internationally competitive research and innovation that is responsive to emerging opportunities and threats, specifically for farmed aquatic products.
Capacity building and training	Aquaculture provides a diverse range of secure and rewarding job opportunities across the supply chain, supported by necessary skills development processes. BMPs constitute some of the guidelines established to guide fish farmers to practice better aquaculture. BMPs are the most effective method to reduce environmental impacts. They are compatible with resource management goals and limit costs at aquaculture facilities.
Experimental IAA station	An experimental IAA station is a part of the collaborative partnership between NGOs and research bodies, such as the Desert Research Center, CLAR, and Egyptian universities (Matrouh, Damanhour, Sinai and El Wadi El-Gadid).

Objective 2: Build resilience and competitiveness.

Optimize water use efficiency	Provide training and capacity building opportunities that are tailored to the specific needs of both genders and marginalized groups, including skills related to fish and crop production, marketing and business management.
Animal aquatic health and public health	Optimize production and the reputation of Egyptian IAA products through a combination of natural growing conditions, careful husbandry and vigilant monitoring.
Climate change adaptation and mitigation	Enhance adaptation to extreme weather events and other negative effects of climate change.
Diversification and adding value	Consolidate high quality and value-added aquatic food products.

Objective 3: Optimize and protect the environment.

Environmental performance	Minimize negative impacts and maximize positive impacts on people and the planet.
Animal welfare	Optimize production of Egyptian IAA products through better conditions for rearing fish and shrimp.

Objective 4: Increase social awareness and consumer information.

Communication on Egyptian aquaculture	Provide accurate information that is essential to make consumers more aware of the contribution of the sector to aquaculture production.
Integration in local communities	Integrate IAA among all members of local communities, particularly those who are traditionally marginalized or excluded, to provide positive environmental, economic and social contributions.
Data and monitoring	Collect sufficient and timely information from the IAA sector to help make evidence-based decisions for planning, licensing, control and sustainable development of aquaculture.

Objective 5: Establish policy dialogue and coordination between government authorities and the private sector.

Stakeholder coordination and support for administrative issues	It is important to ensure coordination between government and the private sector. Stakeholder coordination should involve vulnerable members of the community in the planning and decision-making processes for IAA systems to support the lack of technical, administrative and logistical expertise (in quality and quantity) in the sector with adequate regulations.
Investment map for IAA	The investment map aims to help IAA members of the community, including marginalized and vulnerable groups. IAA investors should make decisions supported by a clear vision of the available competitive factors. An investment map contributes to transparency and promotes equal opportunities for investors in all sectors, including the industrial sector.
Social impact assessment	Conduct a potential social impact assessment to locate investment in the local IAA community, identify any groups that could be affected and ensure that steps are taken to mitigate those impacts. In addition, stakeholders must be involved in the investment process. Engage local stakeholders, including community members, civil society organizations and marginalized groups, to ensure that their voices are heard and their perspectives are taken into account in the investment process.

11.3. Conclusion

IAA is an important farming practice that improves water use efficiency, increases farm income, improves the soil and reduces the use of chemical fertilizers in crop fertilization. Stakeholders consulted during the field visits and the workshop made several recommendations to achieve economic trade balance, food security and sustainability. Scaling IAA sustainably in Egypt requires creating innovative solutions for implementing IAA systems.

During the next 10 years, IAA will become an important approach for sustainable development. This study highlighted the importance of using ICT, smart sensing and IOT for optimal use of resources. It is recommended that hybrid water management be adopted for the fish farm component of IAA systems by using both an FTS and RAS based on the irrigation requirements for crops.

Key recommendations of the study are as follows:

- Examine the experiences of successful IAA countries.
- Adopt innovating modern technologies such as biofloc.
- Use fertigation and sandponics.
- Determine the cultured fish and shrimp candidates.
- Enable gender participation.
- Study the environmental impact of IAA.
- Facilitate the procedures for licensing aquaculture projects.
- Follow up on the value production chain.
- Build the capacity of stakeholders.
- Use water more efficiently.
- Explore innovative water desalination systems.
- Use renewable energy, mainly solar energy.
- Orient e-marketing.
- Support the private sector financially.
- Support product network marketing.
- Establish pilot IAA farms as demonstration farms for private farmers so that they can better understand how to manage them.
- Provide extension services to IAA farms and advocate for the importance of IAA systems to improve the use of water resources and for better food security.

The following are the most important recommendations to improve the performance of IAA systems in Egypt:

- Establish or develop an integrated and specialized program to raise the efficiency and build the capacity of stakeholders in the aquaculture sector.
- Encourage IAA projects to use water more efficiently.
- Develop a BMP manual for the IAA sector.
- Establish a special database for statistical information on IAA systems.
- Examine the experiences of successful countries to display marketing models. Facilitate the procedures for licensing aquaculture projects with all concerned authorities.
- Review the legislation governing the aquaculture sector.
- Study the environmental impact of IAA systems and classify environmental activities according to project scale and production technologies.
- Facilitate the access of IAA farms to soft loans to support private sector initiatives.
- Develop a promotional campaign to raise awareness of the importance of IAA systems.

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Annex 1. Field visits

Location	Date	Description
Moghra, Marssa Matrouh governorate	December 5–7, 2022	Go Green, El-Radwan - Pangasius for Aquaculture (SOFEC) and El-Janna Misr (four IAA farms did not reply to our calls)
Beni-Sweif governorate	December 8, 2022	Arzak
Menia governorate	December 9–11, 2022	Alam El-Awel for Investment, Monastery of Anba Anthony, Samir and Korlos Samir farm, Abdel-Monem Omran farm, (four IAA farms were out of the aquaculture business)
Wadi-El-Natroun, Beheira governorate	December 13, 2022	El-Keram El-Alamiaa
Alexandria governorate	December 14, 2022	Agromar for Agriculture Investment
Giza governorate	December 15–16, 2022	Kiwa Grow, El-Zeini Group, El Zeini for Agriculture Development, Nature Works
Workshop	December 19, 2022	22 participants

Table 3. Field visits made during the study.

Annex 2. Lists of farms

Company	Host	Farm description	Issues
Go Green	Eng. Aly Mokhtar, general director of agriculture sector (01507771299)	• A total of 21,000 feddans were dedicated as agricultural land for the company, but only 14,000 feddans were cultivated with jojoba trees. • The salinity of different wells ranged from 750 to 7300 ppm. • The salinity of water reservoirs used as fishponds and pumped for irrigation ranged from 2100 to 7000 ppm. It was clear that the water quality of these reservoirs was not managed correctly. • Nile tilapia, mullet and seabass were the cultured species.	• High salinity levels of the well-water made it unusable for crop irrigation. • Maintaining transportation and supply was difficult. • It is difficult to transport good quality fry from hatcheries in the Nile Delta. • Fish marketing is a problem.
SOFEC (El-Radwan - Pangasius)	Mr. Osama Salama, part owner (01270546454)	• The cultivated area is 80 feddans. • Well-water salinity is 750 ppm. • The salinity of the fishponds is 6100 ppm. • Nile tilapia, pangasius and mullet are the fish species cultured.	• Fish feed prices were higher. • High water salinity of fishponds can affect crop irrigation. • Transporting fry, maintaining the supply of fish feed supply and conducting proper marketing are all problematic.
Capital	Labor. Abdullah El-Arby (01283444690)	• The cultivated area is 150 feddans. • The water salinity of fishponds is 510 ppm. • Nile tilapia and mullet are the fish species cultured.	• Transporting fry, maintaining the supply of fish feed and conducting proper marketing are all problematic. • Some suppliers provide poor quality fry.
El-Janna Masr	Mrs. Samira Aid (01279984173, 01027799178)	• The cultivated area is 30 feddans. • The salinity of the fishponds is 5500 ppm. • Nile tilapia and mullet are the fish species cultured.	• Transporting fry, maintaining the supply of fish feed and conducting proper marketing are all problematic. • High water salinity of fishponds can affect crop irrigation.

Table 4. List of IAA sites visited in Moghra, Marssa-Matrouh.

Farm/company	Host	IAA description
Arzaaq	Waleed Hashem, owner (01003632719)	• It is located along the Western Asyut desert road, about 65 km from Giza. • The cultivated area is 5 feddans integrated with 400 m^3 and 1200 m^3 fishponds. • Water sources are the Nile via a canal, with a salinity level of 150 ppm, and underground water, at 1500 ppm. • Olive trees, guava, pomegranate, citrus trees and vegetables are the crops cultivated. • Nile tilapia is the only fish species cultured. • Chickens, ducks, turkeys, pigeons and goats are integrated into the farm, which uses their feces as organic fertilizer for the crops. Ducks are also integrated into the fishpond.

Table 5. List of IAA farms visited in the governorate of Beni-Sweif.

Farm/company	Host	Description
Alam El-Awel for Investment (Figure 10)	Abdelsalam El-Shiekh, manager of project (01006089107)	• It is located on the Western Asyut desert road, 280 km from Cairo and 40 km from Menia. • The cultivated area is 5 feddans. • Agricultural land dedicated for the company is 1030 feddans. • The water salinity of various wells is 600–650 ppm. • Nile tilapia is the only fish species cultured.
Abdelmonem Omran farm	Abdelmonem Omran, owner (01066584827)	• It is located on the Western Asyut desert road, 262 km from Cairo. • The cultivated area is 75 feddans. • The water salinity of the well is 850 ppm. • Nile tilapia is the only fish species cultured.
Monastery of Anba Anthony	Father Anthony Nabil (01287227123) Amir Makram, agronomist and fish farming engineer (01201281186)	• It is located on the West Asyut desert road, 8 km from the Menia road. • Of the monastery's 120 feddans, 90 are cultivated. • The water salinity of the well is 8000 ppm. • Nile tilapia is the only fish species cultured.
Korlos farm	Korlos Samir, owner (01157188177)	• It is located on the Western Asyut desert road, 235 km from Cairo. • The cultivated area is 7.5 feddans. • The water salinity of the well is 1400 ppm. • Nile tilapia is the only fish species cultured. • Fish farm water is used to irrigate the 7.5 feddans, all alfalfa, which is used to feed cattle.
Reda Ahmed Mohamed farm	Reda Ahmed Mohamed, owner, (01127363747)	• It is located on the Western Asyut desert road, 205 km from Cairo. • The farm is no longer in the fish production business because of clogged waterpipes.
Moulazem Helal Ibrahim farm	Moulazem Helal Ibrahim, owner, (01127415731) (01127415731)	• It is located on the Western Asyut desert road, 220 km from Cairo. • The farm is no longer in the fish production business because it had too many fish stolen in 2021 and 2022.
Saoudi Aly Mohamed farm	Saoudi Aly Mohamed, owner, (01100944801) (01100944801)	• It is located on the Western Asyut desert road, 200 km from Cairo. • The farm is no longer in the fish production business because it violated government laws for agricultural land.
Abou Zaeid El-Sayed farm	Abou-Zaeid El-Sayed, owner (01061168041)	• It is located on the Western Asyut desert road, 230 km from Cairo. • The farm is no longer in the fish production business because of the high cost of tilapia feed and poor fry quality.

Table 6. List of IAA farms visited in the governorate of Menia.

Farm/company	Host	Description
El-Keram El-Alamiaa	Eng. Tamer Galal, executive manager	• The company has 55 ha of irrigated land. • It produces 100 t of tilapia and 100 t of African catfish. • It grows 7800 t of alfalfa per year • It has 1300 head of sheep. • Through IAA, it uses only 72% of the water needed in traditional irrigation for crops. • It produces its own organic fertilizer from biogas, which is a mixture of clean energy and organic fertilizer.

Table 7. List of IAA farms visited in the governorate of Beheira.

Farm/company	Host	IAA description
Agromar for Agriculture Investment	Eng. Eslam Osman, fish farm manager	• The project is composed of 20 feddans of agricultural land and 2 feddans that use an RAS for eel production, 200 t per year. • The farm uses well-water with a salinity level of 5 ppt. • The daily effluent from the eel farm ranges from 5% to 10% of the total water volume (620 m^3). • The daily effluent from the eel farm is 31–62 m^3, which is used to irrigate the 20 feddans of land to cultivate wheat during winter (3.2 t/feddan) and maize (20 t/feddan) during summer. In addition, water is used from the canal to compensate for the water needed for the crops.

Table 8. List of IAA farms visited in the governorate of Alexandria.

Farm/company	Host	IAA description
Kiwa Grow (sandponic project)	Eng. Khaled El-Sherif, partner and executive manager	• It is located at km 58 of the Cairo-Alexandria desert road. • Green vegetables are grown in 1500 m^2 of greenhouse space. • The water salinity of the well is 900–1100 ppm. • Nile tilapia is the only fish species cultured.
El Zeini for Agriculture Development	Dr. Sami El-Zeini, chairperson	• The company is located at km 65 of the Cairo-Alexandria desert road. • Green vegetables are grown in 4000 m^2 of greenhouse space. • The water salinity of the well is 1750 ppm. • Two desalination stations have a daily pumping capacity of 700 and 1100 m^3 to produce desalinated water with a salinity level of 100–120 ppm. • Mangoes, grapes and oranges are grown on 150 feddans of cultivated land. • Nile tilapia is the only fish species cultured.
Nature Works	Eng. Abdel-Rahman Nassef, partner and executive manager	• The farm is located in the 6th of October city in Giza governorate. • It has 1200 m^2 of greenhouse space. • The water salinity is 200 ppm. • Nile tilapia is the only fish species cultured.

Table 9. List of IAA farms visited in the governorate of Giza.

Annex 3. Feedback from the workshop

Group No.	**Group (1)** Improve water use efficiency and water management for IAA systems for better water productivity.	**Group (2)** Improve management of the fish/shrimp culture component and BMPs (input, operation and marketing).	**Group (3)** Identify existing IAA technologies and innovations in Egypt.
Questions/Issues	• Sandy soil requires irrigation. Water consumption is higher than clay soil, because there is no clay layer that sequesters and preserves water. • Jojoba seeds are rich in crude protein (25%–30%), but it is not well used in animal feed.	• Divide the production factors into the structural system, type of production and its components, preferably intensive for economic feasibility. • Determine the cultivated IAA land area, quantities and type of water available, the culture system and the types of cultured fish. • Use variable high quality aquatic feeding schedules according to temperature, density, age of fish and oxygen; develop the use of traditional aquatic feeds such as Azolla. • Promote non-traditional aquaculture systems like biofloc. • Increase the employability of IAA through education, work experience and personal improvement. • Elevate new energy sources, mainly solar energy. • Practice BMPs under extension programs.	• Some of the problems facing farmers in Al-Moghra are high energy costs, not enough applied research, poor water quality, high salinity and a lack of quantity, lack of trained fish workers, poor communications stations to monitor water quality, inadequate marketing, personal dependence on projects, and a lack of a clear strategy.

Group No.	Group (1) Improve water use efficiency and water management for IAA systems for better water productivity.	Group (2) Improve management of the fish/shrimp culture component and BMPs (input, operation and marketing).	Group (3) Identify existing IAA technologies and innovations in Egypt.
Recommendations	• Achieve IAA through economic trade, food security and sustainability. • Promote jojoba cultivation in Moghra for export to the US and Spain. • Determine the appropriate fish/shrimp species to culture with jojoba. • Treat the salinity and iron levels in the water in order to reuse it. • Maximize the use of underground water with different salinity levels. • Use solar energy. • Ensure the services are in place for moving an agricultural product from the farm to the consumer. • Develop a sustainable IAA road map for projects in desert/arid zones and create a marketing plan for local and export needs.	• Follow the example of the newly established IAA project for Alam El-Awel for Investment with a yearly production target of 1200 t of tilapia by 2025. It is important to design a PRAS fish farm following certain low-cost IAA farm construction techniques that use locally available materials along with improved skills and technology.	• Establish an applied research center. • Inquire about modern technologies. • Facilitate the presence of a police station to secure different activities. • Explore innovative water desalination systems. • Use solar energy. • Promote the benefits of the highly saline water generated from the desalination plants in the cultivation of marine fish such as seabream, seabass, or shrimp farming. • Conduct e-marketing and establish shopping centers. • Provide communication stations with sufficient range to cover the farms. • Establish research centers and extension stations to serve as integrated farms exporting products to world markets. • Organize other workshops to discuss the point of views of stakeholders.

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