AWESOME

WATER-ECOSYSTEM-FOOD

CASE STUDY REPORT

June, 2021

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LIST OF ACRONYMS

CS:	Case Study
EC:	European Commission
ES:	Ecosystem Services
GA:	Grant Agreement
GAs:	General Assembly
GERD:	Grand Ethiopian Renaissance Dam
MAWGs:	Multi Actor Working Groups
MB:	Management Board
Mx:	Month number
NBI:	Nile Basin Initiative
PC:	Project Coordinator
RP:	Reporting Period
SOC:	Soil Organic Carbon
WP:	Work Package

EXECUTIVE SUMMARY

This report provides a description of the case study in terms of its socio-economic profile, its key Ecosystem Services (ES) and Water Ecosystem Food and Energy (WEFE) Nexus issues. It follows the three-level nature of AWESOME methodology, representing the regional level of analysis in the Mediterranean at the macro-level, the river basin at the meso level and the case study at the micro (local) level. The report is based on primary data from weather stations, results from chemical analysis, regular measurement of parameters and measurement of parameters of the plants at harvesting time and secondary data from scientific journals, literature review and online databases (EUROSTAT, World Development Bank, Michigan State University Global Edge portal, Worldometer). In addition, stakeholder identification and mapping are conducted, which result in a long list of 76 stakeholders and a short list of 22 stakeholders. These stakeholders are mapped with the use of Miro online tool through a collaborative research process involving AUEB, Zon Gardens, Aachen University (RWTH) and the assistance of Politecnico di Milano (POLIMI). Finally, the key ecosystem services of the Nile Basin also addressed in this work are: i) provisioning, particularly crop production, livestock maintenance, fish catch, drinking water supply, wild food production, ii) regulating particularly water flow, carbon sequestration and sediment retention, iii) supporting services particularly forests, vegetation and habitat provision, iv) cultural such as commercial navigation, religious and spiritual services.

1. INTRODUCTION

The research adopts a three-level approach, namely macro-, meso- and micro- level. The macro level is the regional one (Mediterranean and North-East Africa), the meso level refers to the Nile river basin scale and the micro level is represented by the demo sites in Egypt. At the macro level, water resources are limited and the WEFE nexus exhibits high vulnerability to pollution and weather extremes. On the meso level the current water demands from Nile are the 80% of all water demands and are projected to reach the 150 – 160% of the current demand by 2050, which in combination with the demographic projections of 1 billion people and the GERD management in Ethiopia can cause hydro-political conflict among the riparian countries.

The River Nile is the longest in the world, being about 6,650 km long with a river basin of nearly 3,500,000 km^2. It flows from Central Africa to the Mediterranean Sea passing from 11 countries: Burundi, Democratic Republic of Congo, Egypt, Eritrea, Ethiopia, Kenya, Rwanda, South Sudan, Sudan, Tanzania, and Uganda. Taking into account the increased interlinkages between rivers' upstream and downstream users, the stakeholders from the three out of the four countries of the Eastern Nile basin are involved, particularly from Egypt, Ethiopia and Sudan, which cover the main countries comprised in the AWESOME meso level analyses.

The research conducted in this work draws attention on the main literature review findings regarding the WEFE Nexus issues, the key ecosystems at the meso level as well as the potential change in the ecosystems from the two AWESOME case studies based on hydroponic and aquaponic systems.

Section 1 contains a description of the report's content and its link with particular tasks of the other WPs in AWESOME project. Section 2 describes the methodology to approach the case study, how it links with the wider multi-scale nature of AWESOME project and the method for data collection. The steps are presented towards the convening of the Multi-Actors Working Groups (MAWGs) as a state-of-the-art participatory method in order to manage WEFE Nexus. Section 3 contains description of the case study area, as it is defined by the demo site and information on the socio-economic profile of Egypt, Ethiopia and Sudan accompanied by justification for their choice and link with the scope of the multi-scale nature of AWESOME research. Maps and figures enrich the picture of the presented areas. A baseline of the key WEFE Nexus issues is given following the same three-scale nature of AWESOME, with particular focus on Egypt. Following the baseline of the case study level the steps for identifying, listing, analysing and mapping stakeholders are presented along with a detailed justification on their positioning on the mapping tool. Section 4 proceeds in the micro level analysis with a presentation of the experiments on soilless agriculture in the demo site. Aquaponics, hydroponics along with their advantages and disadvantages are explained as well as their subsystems such as Deep Water Culture, Nutrient Film Technique, Media Bed/ Media Based, Sandponic. The implication of the soilless technological experiments on WEFE Nexus are presented. Section 5 contains descriptions of Lab-scale and Pilot-scale experiments. Finally, Section 6 provides some final remarks and present the next steps in relation to the case study.

2. METHODOLOGY

2.1 CASE STUDY APPROACH

In the AWESOME project, the WEFE Nexus applies as it can improve water, energy, food security and ecosystem conservation by increasing efficiency and productivity of each water drop used in agriculture, by reducing the trade-offs and by addressing soilless agricultural solutions that enhance the synergies, as these will be underlined with the assistance of stakeholders and finally by enhancing projections that will spread across diverse sectors (such as agricultural, industrial etc). AWESOME will assess the social, technical, and economic benefits of cross-sectoral governance of the WEFE Nexus, zooming in from the Mediterranean region down to the Nile River Basin and then to the farm scale, where soilless agriculture techniques are being tested.

In order to support the transition to sustainable agriculture, the AWESOME's platform has a multi-scale nature that will allow for the translation of solutions tested at the micro-level into models running at the meso level, in order to finally inform the upscaling of local solutions to the macro level.

The project adopts a three-scales of research, namely:

- Macro Level
- Meso Level
- Micro Level

The macro level is the regional one and is represented by the macro scale processes and policies and influence dynamics in terms of water, energy, food supply and demand as well as ecosystem services within the Mediterranean region. To be more realistic, the representations at the macro level in order to be more realistic are seen under the current and future socio-techno-economic and climate scenarios related to the macro level, as these are modelled in WP2. The macro level enlarges the scope of the project to a wider, extra-basin spatial scale and increases the impact of the work done in the basin level.

The meso level refers to the river basin scale, where the strategic planning needs to take place based on realistic projection in order to be useful for decision making. That meso level is informed by the experiment and innovations developed on the micro level. In order to define a more focused scope for the meso level interactions that maps onto the modelling exercise conducted within WP2, WP6 focuses on three main countries crossed by the Nile River: Egypt, Ethiopia and Sudan. Adopting a systems approach, the bottom-up participatory nature of the stakeholders engagement framework will serve towards a detailed intra-basin analysis driven by stakeholders from the river basin level.

The micro level is represented by the demo site where innovative technological solutions are first trailed via experiments and then piloted, with the aim of increasing the productivity of a unit of water in terms of valuable products such as crops and fish. A description of these solutions is presented in section 4 of this report, within details on soilless agriculture (hydroponics and aquaponics, potentially supported by solar energy in greenhouses as well as desalinated water). At the micro level, innovative WEFE solutions will be examined for successful uptake at meso and macro levels.

2.2 Data collection methods

For the description of the case study, secondary data were gathered (such as GDP, aspects of hydroponics and acuaponics industry, environmental conditions on the micro-, meso- and macro-level), which are already published in journals, literature, in EUROSTAT[1] online portal, World Development Bank[2], Michigan State University Global Edge portal[3] and Worldometer[4]. The identification and listing of the stakeholders were based as first step on review of relevant literature and documentation with the assistance of Zon Gardens and contacts of AUEB, POLIMI and RWTH, same occurred to develop the mapping of the stakeholders with the online tool Miro (https://miro.com/). Also, a collaborative process of research and discussion with field experts has started, with the aim to ensure feedback on the identified stakeholders, but also their positioning in terms of their interactions within the WEFE Nexus. The soilless agriculture description was developed based on literature review, data from weather stations, results from chemical analysis, regular measurement of parameters (pH, temperature, etc.) and measurement of parameters of the plants at harvesting time.

2.3 Stakeholder identification and mapping

The steps followed for the creation of the stakeholder database are explained in the following.
It was crucial to ensure the representativity from all WEFE sectors with their relevant subsectors. For this reason, several organizations were identified from the: i) Water sector, broken down in water supply, water quality, water affairs, ii) Energy sector broken down in subsectors that affect more water use, such as hydropower, solar energy, wind energy, desalination iii) Food sector broken down in traditional agriculture, food security, hydroponics, and aquaculture, iv) Ecosystem sector broken down in ecosystems. Two extra sectors were chosen in the framework of the pandemic crisis: v) the Public health sector broken down in clinical medicine and other human health and finally the vi) Social sector and vii) others. The above categories were cross-referenced in a matrix in order to produce an initial database.
There was the need to ensure consistency with the three-level nature of AWESOME model for the the micro-, meso- and macro- level of analysis, described in section 2.1. Therefore, it was decided that the MAWGs will feed the analysis of the meso-/macro- and micro- level. Specifically in AWESOME:

1. On the meso/macro level, for ensuring a more focused scope for the meso/macro level interactions that maps onto the AWESOME modelling exercises, the MAWGs focus on three main countries crossed by the Nile River: Egypt, Ethiopia and Sudan.
2. On the micro level, local stakeholders involved are the ones affected directly by the innovative technological solutions related with the area around the demo city. Innovative

WEFE solutions will be examined with them for ensuring subsequent successful uptake at meso and macro levels.

For the MAWGs To promote holistic solutions that serve all the diverse groups of stakeholder, rather than focus on a few, it was decided to follow the Quadraple Helix model of stakeholders engagement to shape the MAWGs[5]. The broad categories included were public institutions (at demo site, local and regional level), private organizations (start-ups, SMEs, corporations), academia (universities, research centers and organizations), non-governmental organizations.

3. CASE STUDY AT THE MESO-LEVEL

In order to be able to work on the key drivers of change in terms of WEFE Nexus and the subsequent building of scenarios and actions that need to be taken by the countries comprising the meso level, there is the need to focus first on the case study at that scale.

The River Nile is the longest in the world, being about 6,650 km long with a river basin of nearly 3,500,000 km^2. It flows from Central Africa to the Mediterranean Sea passing from 11 countries: Burundi, Democratic Republic of Congo, Egypt, Eritrea, Ethiopia, Kenya, Rwanda, South Sudan, Sudan, Tanzania, and Uganda. The Nile River Basin is very important as a shared water basin in Africa with a variability from aridity in its northern areas to tropical rainforests towards eastern and central areas. This is why the precipitation distribution differs significantly in the wet and dry period in the tropical areas. Despite the disagreement among climate models on the impact of climate change on the precipitation in the Nile Basin, the projections on the increase of temperature suggest a trend towards the warming of the surface temperature over the region, that can cause extreme weather events like floods and droughts as well as disasters that can lead to destruction of infrastructure including water ones. Nile Basin water resources are quite sensitive to climate variability and change, with projections until 2049 showing a reduction on flow and projections from 2070 to 2099 showing both increasing and decreasing trends [6].

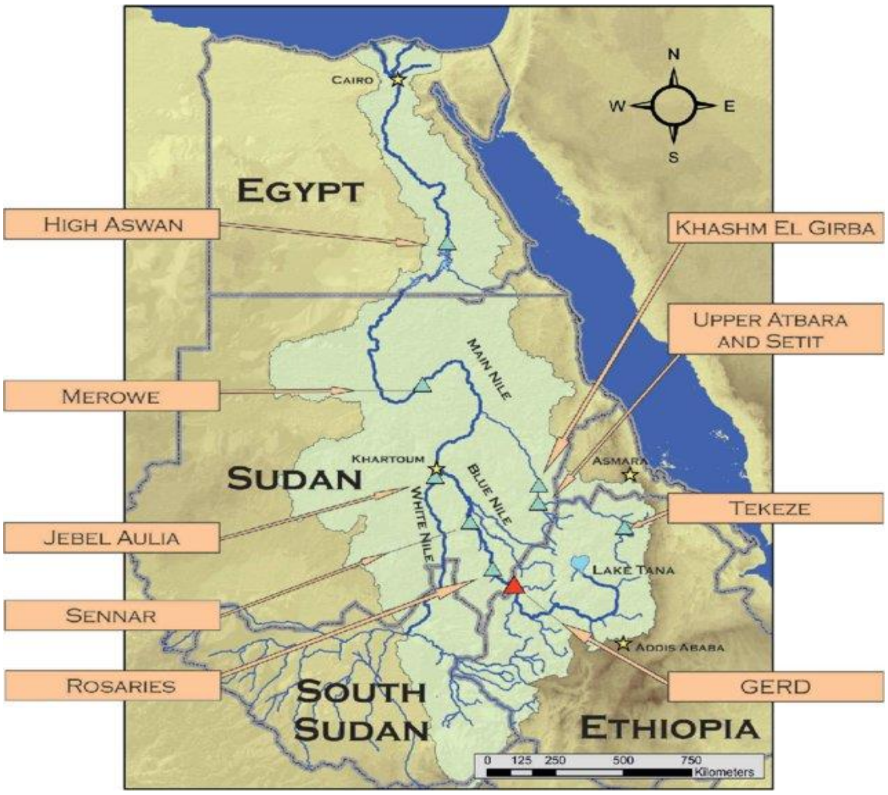

Figure 1 - Map of Nile River Basin Eastern Nile Basin with reservoirs [7]

Table 1 - Statistical facts on Nile River Basin: characteristics of basin, location and riparian countries [8]

Basin Area	3173 × 103 km^2
Location	−4°S to 31°N and 24°E to 40°E
Riparian States	Burundi, DR Congo, Egypt, Eritrea, Ethiopia, Kenya, Rwanda, Tanzania, South Sudan, Sudan and Uganda
Main Tributaries	Victoria Nile/Albert Nile, Bahr El Jabel, White Nile, Baro Pibor-Sobat, Blue Nile, Atbara, Bahr El Ghazal
River Length	6850 km
Estimated Navigable Length	4149 km
Major Lakes with in the Basin	Lake Victoria, Lake Tana, Lake Kyoga, Lake Albert
Population (Total in all the Nile Countries)*	437 Million
% Population within the Nile Basin*	54% (238 Million)
Temperature	Night Minimum −10 °C and daily Maximum in June 47 °C
Precipitation	Max Annual 2060 mm/year in Uganda
Min Annual 0 mm/year in Egypt	
Mean Annual flow (Discharge) (km^3/year) at Aswan	84 × 109 m^3
Discharge/Unit area	28 × 10^3 m^3/km^2
Main Consumptive Water use	Agriculture

The Eastern Nile basin includes one third of Ethiopia, a portion of Sudan (including South Sudan), the biggest part of cultivated and inhabited area of Egypt and a small section of Atbara that touches Eritrea. The included rivers are the Blue Nile, the Baro-Akobo-Sobat, the Atbara and the main Nile. Approximately the 86% of the Nile flow originates in the Ethiopian highlands. While Baro-Akobo (Sobat) river has a regular course, the two other Ethiopian rivers, Abbay River (Blue Nile) and Tekeze River (Atbara) have particularly characteristic of hydrological regimes. They have a flow that varies dramatically due to high seasonal variability in rainfall. That variability causes partly the problem of the big amounts of annual loss of topsoil. Specifically, more than 400 million m^3 of topsoil is lost from the Abbay basin, while for the whole country the loss is translated to 106 million $ annually, and the problem is increasing [9, 10]. Additionally, with that high variability Egypt would be exposed to high hydrological risk without the High Aswan Dam to ensure storage capacity. On the other side, the dominant uses of the Nile waters up to now are irrigated agriculture and hydropower generation, taking place in Egypt and Sudan[9] with Ethiopia being able to utilize only the 5% of its surface water which translates to the 0.6% of the Nile basin water resources, although the three Ethiopian sub-basins of the Eastern Nile constitute the 68% of its available water resources[11] (Arsano 2005). This situation might change soon with the construction of the Grand Ethiopian Renaissance Dam (GERD), which is under construction in the Benishangul-Gumuz region of Ethiopia, on the Blue Nile River, located 40km east of Sudan.

Taking into account the increased interconnectedness between rivers' upstream and downstream users, AWESOME research focuses on inviting stakeholders from the three out of the four countries of the Eastern Nile basin, particularly Egypt, Ethiopia and Sudan.

3.1 SOCIO-ECONOMIC AND ENVIRONMENTAL PROFILE OF EGYPT

Egypt is the most populated Arab country, and the third most populous in the African continent, with 104 million inhabitants as of 2021. Egypt is witnessing a decline in the annual population growth rate, as of 2020, the current annual population growth rate is 1.94%. The population is equivalent to 1.31% of the total world's population in 2021. The urban population is 43% of total in 2020 (44,041,052 people) and is mostly populated along the Nile, the Delta and near the Suez Canal. The total land area is around 100 thousand km2 (995,450 km2)[12].

Egypt is classified by the World Bank in 2019 as a Lower Middle-Income Country, and as a Developing country by the United Nations. The main sectors influencing Egypt's economy are Manufacturing Industries (17.1% of total GDP), Wholesale & Retail Trade (14.5% of total GDP), and Agriculture, Forestry & Fishing (12.1% of total GDP) in 2020[4].

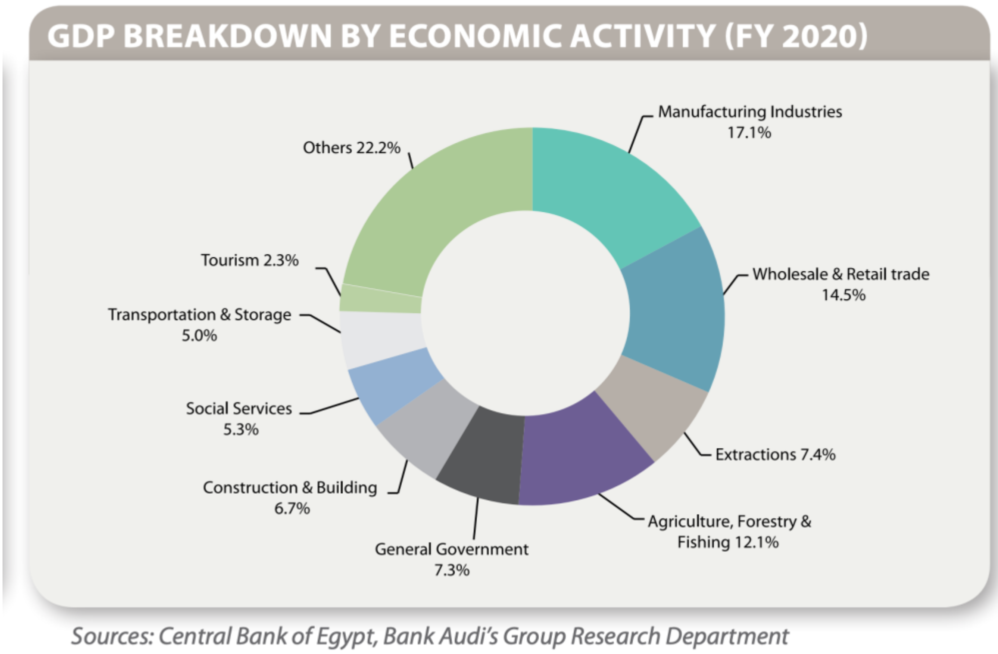

Figure 2 - GDP Breakdown by economic activity, Egypt Central Bank of Egypt[12]

Egypt's primary sectors demonstrated positive growth of 3.3% in FY 2020, as a result of the Egyptian government forward movement of investment in land reclamation projects, increasing the agricultural output area available. Agriculture, Forestry & Fishing is the third largest contributor to the Egyptian Economy as it witnessed an increase from 11.4% in 2019. On the other hand, Egypt's

rice production is under pressure, due to the water scarcity concerns caused by the ongoing construction of the Grand Ethiopian Renaissance Dam[12].
Manufacturing and extractive industries, and Construction & building sectors have contributed immensely to GDP's growth, but show negative performance in comparison of performance in the previous fiscal year 2019. The total labour force in FY 2020, is around 31 million inhabitants (31,441,059) from which 23% of the total labour force are employees of the Agriculture sector[3], [12].
Air pollution is an alarming issue facing the Egyptian government. Also, energy is exponentially needed to meet development needs, however, Egypt plans to reduce its reliance on oil and natural gases (95%) and shift to induce and produce clean energy [13].

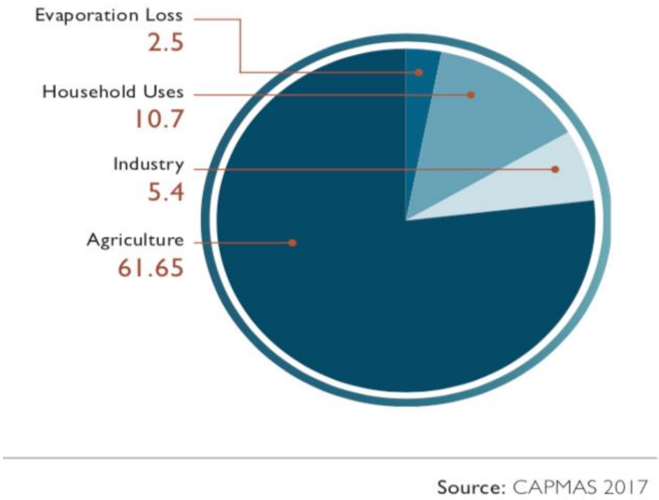

Figure 3 - Classification of Egypt's water needs, 2017 (80,25 million cubic meters/year) meter based on the Annual report on environment and statistics[14].

Water's annual use in Egypt in 2017 was estimated at 80.25 billion cubic meters, where 61.65% were consumed by the Agriculture sector. However, overexploitation of the aquifer is alarming and water security is targeted by creating renewable water resources. The status of Egypt's canals and drainage networks is deteriorating, posing a serious threat to the country's water resources. Canal and drain networks need to be renewed, and the increase of infringements on them necessitates immediate care. Direct drainage of water into the Nile is a great environmental problem. Thermal effluent, industrial drainage, agricultural drainage and sanitary drainage, contaminates the River Nile, reducing its usage efficiency, and pollution's impact are difficult to keep maintained[13].

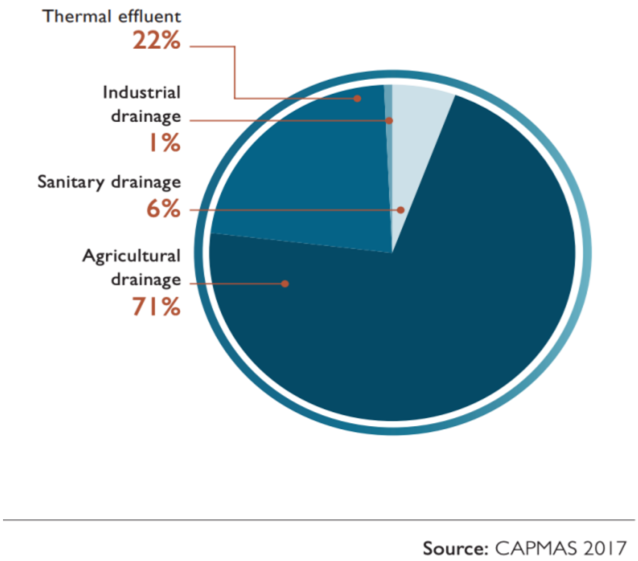

Figure 4 - Total direct drainage to the Nile, 2017 meter based on the Annual report on environment and statistics[14].

The environmental state of Egypt is negatively impacted by inhabitants' lifestyle. Global environmental programmes and environmental agencies have contributed by improving the environmental performance and developing the sustainable development frameworks. In 2017, the Ministry of Environment faced numerous issues including air quality and water security. Waste management is a major challenge (and opportunity) facing Egyptians, and climate change's impact. One of the most important steps is developing environmental monitoring systems and networks, creating indicators and calculators for air or waterways, and developing law enforcement systems to handle chemicals and hazardous substances types, and wastes[13].

3.2 Socio-economic and environmental profile of Ethiopia

Ethiopia is the second most populated country in Africa after Nigeria and based on the 2019 official statistics, its population exceeds 112 million people and is one of the poorest countries based on its per capita income of 850$. However, due to the sustained economic growth of the last 10 years the percentage of the population living below the poverty line has decreased by 6%.
The figure below contains visualizations on the profile of comparable socio-economic indicators[1] at the national level, based on household surveys of 2011 and 2016[2].

1 Gini coefficient is an inequality measure to capture the deviation of the distribution of per capita consumption from a perfectly equal one. The value of the index is expressed from 0 (perfectly equality) to 100 (complete inequality).
*Poverty rate is the ratio of the number of people whose income falls below the poverty line
Food shortage is the percentage of households reporting a inability to cover food needs in the last twelve months

Figure 5 - Inequality, poverty, and food security indicator, Ethiopia, 2011-2016 based on data from the Ehtiopia Socioeconomic Dashboard of the World Bank Group[15]

In terms of the access to services, based on the same survey in 2016 the 61,4% of population has access to improved water, 23,1% has access to electricity, and 6,1% access to improved sanitation. From 2010/11 to 2019/20 the country's growth average rate increased 9.4%, while its GDP growth slowed down to 6.1% due to the COVID-19 pandemic. However, its agricultural production has slightly improved during the same period. The main industrial sector is construction, while the biggest part of the growth is based on services. The main economic impact from COVID-19 is focused on the increase in unemployment, a very recent increase in poverty and increased price of basic foods.
In terms of the sectors adding value to the GDP, agriculture, fishing and forestry has the first position, followed by industry including construction. The figure below contains a visualization of the percentage diverse sectors account for in GDP, from 1990 to 2018, based on the World Bank's latest country profiles.

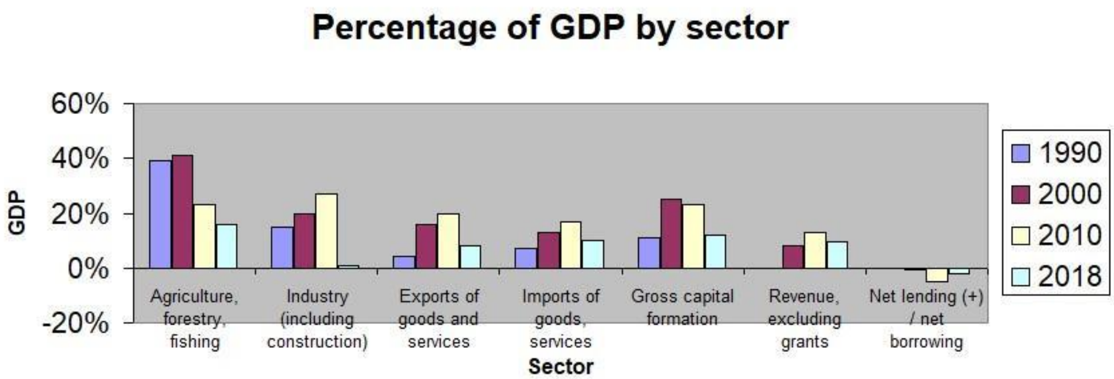

Figure 6 - Percentage of GDP per sector (1990-2018), Ethiopia based on World Development Indicators[2]

Ethiopia possesses a strategic location in the Horn of Africa, close to the Middle East, bordering Somalia, Kenya, South Sudan and Eritrea. Dry lowland plains, high plateaus and mountains are its characteristic terrains, while there is a high diversity in climate and biodiversity. According to the Climate Change Adaptation programme of UNDP, the main environmental problems in the country include land degradation, soil erosion, deforestation, loss of biodiversity, desertification, recurrent drought, flood and water and air pollution.

Ethiopia has large regional differences in its topography and although it is an arid country, its rainfall patterns exhibit high variability (which accounts for the problem of serious food insecurity). Its climate ranges from hot and arid to cold and humid. Drought is the most serious natural hazard related to climate, which makes the country one of the most drought-prone ones with socio-economic challenges exacerbating its vulnerability to climate change in terms of the agricultural production, livestock, water resources and human health.

Specifically, the agriculture is mainly rainfed and the livelihoods dependence on crop cultivation, pastoralism and agro-pastoralism increase the sensitivity to climate. The biggest percentage of subsistence farmers are small-scale who use low-intensive technologies and are heavily dependent on rain and climate. Due to the small size of the plots most households depending on crop agriculture cannot secure food adequately, and have limited capacity to invest in farming techniques that can increase their resilience to climate.

In terms of the country's livestock sector, this is the largest in Africa dependent on climate patterns. The majority of pastoralists are dependent on limited water and forage availability. Higher temperatures impact health and productivity with impacting livelihood and income[16].

In terms of Ethiopia's water resources these include twelve river basins (including Nile) unevenly distributed. Projected increases in droughts, evaporation, evapotranspiration and runoff might impact further the availability in water-scarce areas[17]. Although there is still a high degree of uncertainty on water availability under GHG emissions scenarios in combination with the different scenarios of population level, following SSP2 projections on population growth the per capita water availability for the country will decline by 65% by 2080 in comparison with 200[18].

3.3 SOCIO-ECONOMIC AND ENVIRONMENTAL PROFILE OF SUDAN

According to the World Bank country profiles, Sudan has a population of 41.80 millions (as of 2018 data) with an annual population growth of 2.4%. 46% of the population was living below the poverty lines according to the last data of 2010 (World Bank Group, 2021). The country's GDP in 2018 was 33 billions US$ with a negative growth rate of -2.3%.

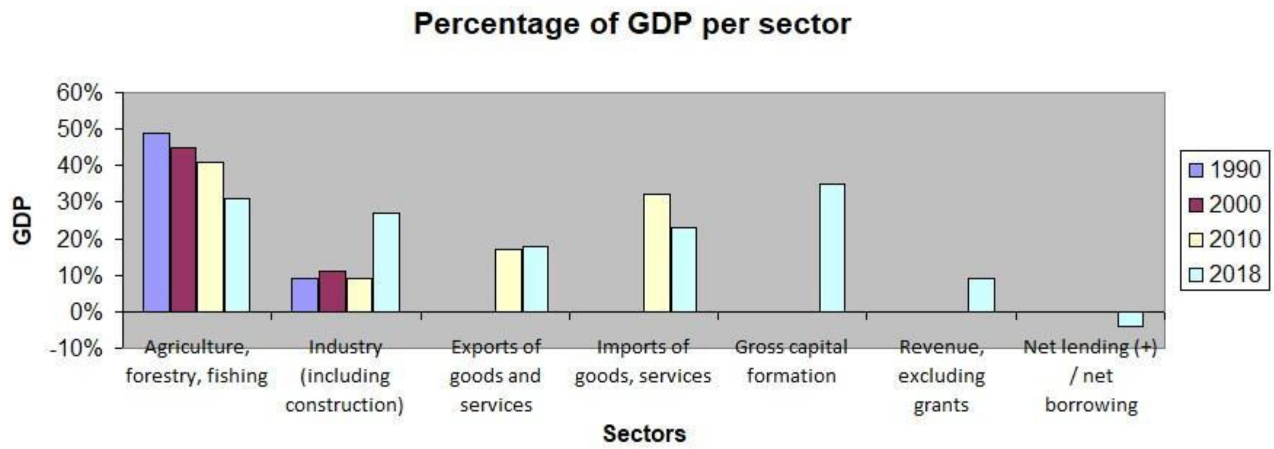

Figure 7 - Percentage of GDP per sector (1990 – 2018), Sudan based on World Development Indicators[2]

COVID-19 has impacted the price of basic foods, the exports and has risen the unemployment levels[15].

Sudan is located at the intersection of Sub-Saharan Africa and the Middle-East and extends across the Red Sea. It borders Libya, Egypt, Chad, the Central African Republic, South Sudan, Ethiopia and Eritrea. Is the third biggest African country covering 1.88 million km^2, but after the secession of South Sudan, during 2011, its size was reduced by 24.7%[19]. In terms of its atmosphere, data for the period 1981-2016 reflect a rainfall season starting later and drought conditions that are more frequent the last few years. Due to the high temperatures that can reach 47°C as well as the low rainfall, the country is generally arid and dry[20]. Climate change has caused droughts and floods, sea level rise, temperature rise and rainfall variability. Climate change adaptation efforts consist of a swift cultivation of drought-resistant crops and animal breeds, as well as a shift to renewable forms of energy.

In terms of land resources, more than 72% of the country is desert, while less than 1/3 of the arable land is under cultivation[21]. A serious issue is that the reduction of the country's forest coverage from 40% of total land area in 1950 is reduced to 27% in 2015[21]. Due to the declining yields in cereal, farmers expand the cultivated land at a high rate every year. According to UNEP and the Higher Council for Environment and Natural Resources in Sudan[22], in 2020 most of the problems related to land is urban encroachment (such as the expansion of Khartoum since 1984, land degradation and land conflicts among farmers and pastoralists.

In terms of water resources the annual per capita water availability is significantly below the water scarcity margin, while Nile River Basin accounts for 73% of the country's freshwater sources[21]. The river, before it becomes Nile, has the White and the Blue Nile that meet in Khartoum and then flow as the Nile River via Egypt. A very small amount of water is produced from non-conventional sources including desalination of sea water and treatment of wastewater. The country faces the threat of

siltation and water pollution, and the challenge of using mainly transboundary water resources which make the availability susceptible to upstream countries' water demand.
In terms of energy resources, the 56% comes from biomass such as charcoal, animal waste, wood and agricultural residues, 39% from petroleum (diesel, gasoline, heavy oil) and 5% from hydropower[23].
According to UNEP and the Higher Council for Environment and Natural Resources in Sudan[22], in 2020 the most persistent environmental problems of Sudan is the desertification, the use of banned pesticides, and solid waste problems. Particularly, desertification, which is mainly caused by the poor cultivation methods, has serious impacts on food security.

3.4 KEY WEFE NEXUS CHALLENGES ACROSS THE THREE AWESOME LEVELS

The Water-Energy-Food-Ecosystems Nexus (WEFE) represents the interlinkages of the water, energy, and food sectors including their dependency on impact ecosystems (e.g. freshwater, forests, grasslands and wetlands). These four aspects are directly linked to human well-being and poverty reduction[24]. The approach focuses on assessing and quantifying interactions in a complex system between multiple goals, and the influence of achieving one goal on the fulfilment of others[25]. The method uses an integrated approach in order to analyze the synergies and trade-offs between sectors aiming to maximize the efficiency of using the resources, while adapting policies and institutional interventions[26].
The WEFE nexus has entered the governance discourse aiming to present the complexity of systems such as agriculture through demonstrating physical and institutional connections. In terms of policy, the WEFE Nexus aids us to work towards achieving security for water, food, and energy simultaneously[27], while it is also used in order to identify potential trade-offs at the policy design stage, and developing solutions benefiting multiple SDGs[21]. The Water-Energy-Food Nexus concept has a crucial role in achieving the goals of the Paris Agreement and the SDGs[21].
In the AWESOME project the WEFE Nexus applies as it can improve water, energy, food security and ecosystem conservation by increasing efficiency and productivity of each water drop used in agriculture, by reducing the trade-offs and by addressing soilless agricultural solutions that enhance the synergies, as these will be underlined with the assistance of stakeholders and finally by enhancing projections that will spread across diverse sectors (such as agricultural, industrial etc). AWESOME will assess the social, technical, and economic benefits of cross-sectoral governance of the WEFE Nexus, zooming in from the Mediterranean region down to the Nile River Basin and then to the farm scale, where soilless agriculture techniques are being tested. A description of the Nexus from the three macro-, meso-, and micro levels perspectives, is presented in the following.
Historically, the Mediterranean region is a geographical area with diversity of socio-political, economic and environmental conditions, where the policies and interventions affecting water, energy and food have been managed separately[26]. Attempts to incorporate integrated water management concepts have not reached at the practice level. There is a variety of problems related

to water, energy, food and ecosystems that render the area as one of the most vulnerable worldwide, especially within the context of climate variability and change, population growth, and developmental pressures. Water pollution issues and water scarcity[28], imbalanced water allocation among sectoral users, food waste and loss and high demand for food and energy[26] are the most prevailing among these problems. The Mediterranean region is characterized by increasing food insecurity. Food loss and waste and changing dietary habits have impacted the Nexus. There is a shift in people's preferences from legumes, fruits and vegetables towards animal protein and sugar consumptions that has impacted the use of energy and water resources[29]. Despite the problem of water scarcity and land degradation, the agricultural practices are not sound, and a significant proportion of food is lost or wasted in the food value chain[26]. According to FAO's fact sheet in 2009, 30% of food was wasted along the production and consumption chain and a considerable amount of water was used for the production of one Kcal of food energy. However, the practice of wastewater reuse has brought successful solutions for agricultural production in water scarce areas. Besides the water resources reduction and the increase of agricultural yields in these cases water quality has improved by nutrient retention in irrigation[30].

Water resources are limited in the Mediterranean region and especially vulnerable to pollution and weather extremes across its countries. Water is supplied mainly for industrial, energy, agricultural and domestic use, while it can directly affect public health in cases of point or diffuse pollution. Due to subsidized water services in most of the Mediterranean countries, necessary practice for sustaining farming and domestic use, the water prices do not reflect the environmental cost of water use and that leads to overirrigation/overuse[31]. Groundwater resources are ery often overexploited, sometimes even through illegal pumping, in arid and drought-prone regions with profitable agriculture, such as Egypt. The depletion of groundwater sources increases the risks of drought and contributes to unbalanced aquifer dynamics even causing environmental trade-offs in wetlands[32].

The food and especially the water element of Nexus need to be analyzed taking into consideration the energy and carbon footprint of the whole supply chain of the products, from production processes, manufacturing operations to transportation. Water security needs to expand beyond the production sites and extend to the entire supply chain, especially in cases of agricultural products that are energy intensive[26].

The water, energy, food and ecosystems interlinkages need to be addressed at the river basin level (meso), in order to be able to proceed to trade-offs identification and synergies among stakeholders. The Nexus approach is relevant for any transboundary river basin in order to manage the interlinked resources and socio-economic issues that appear. This is particularly true for the Nile Basin, that faces rapid population and economic growth and, as already presented, where international cooperation is further challenged by the discussions about the GERD management. To face the hydro-political conflicts among the riparian countries, the Nexus approach has the potential to address trade-offs among the stakeholders for the water, energy and food resources and promote understanding for shared benefits[33].

The current water demands for irrigation along the Nile arrives at 83 BCM, meaning the 80% of the entire water demands and are projected to reach the 150 – 160% of the current demand by 2050. These numbers in combination with the demographic projections of 1 billion people (UN medium variant) explain how the demand for water supply as well as food and energy will escalate rapidly. The total current evaporation from the rivers' dams is 17.2 BCM and it keeps increasing. The planned growth in installed capacities is 21,000 MW, while the storage capacities of the planned dams will arrive 200 BCM. The water demand might exceed the available resources soon without measures and there is the need to apply the WEFE Nexus in order to balance the use of resources between the water – energy – food – ecosystems as well as between upstream and downstream.

The Nile River Basin, under the Nexus approach, is a resource basin where all water values, whether direct or indirect, are analysed, and natural resources, such as land and energy connected to the basin are considered for the cooperation of all water users and the basin development[34]. Egypt has relatively well-performing irrigation systems with one of the highest water-use efficiencies internationally for crops like cotton and wheat[35]. On the other hand, Sudan's poor irrigation systems are causing poor yields due to water inefficiency, poor canal maintenance, and lack of water. Sudan's irrigated agriculture is stagnating while it irrigates only 1% of its arable land[36].

Water use for food production is a priority of WEFE Nexus in Egypt, considering the Agricultural sector that is the largest user of water resources from total water needs. Egypt faces water security problems due to inefficient irrigation techniques and over-exploitation of groundwater and with the GERD being 73% complete as of May 2020 adding pressure on the availability of water[37]. Also, food self-sufficiency in Egypt is limited by scarce water resources thus, 50-60% of food is imported, however 20% of overall crop production has increased since 2010. In 2017 winter crops production reached up to 89.8 million tonnes (Mt) while summer crops reached 48.1 Mt tonnes, as a result of reclaimed land, and sustainable water usage to a certain extent[14]. Although 33% of international trade volumes dropped due to Covid-19 pandemic, exports rose up to 8.4 Mt in 2020, keeping in mind only 5.4 Mt of agricultural products were exported in 2019. Another priority tackled by WEFE in Egypt is the Energy use for water treatment and conveyance, fuel-powered and energy-intensive water lifting plants. These aspects are addressed by projects shedding light on the importance of directing efforts to increase water supply through desalination units and wastewater reuse, although it will even need more energy, but with the current surplus in energy and the expansion in renewables, it would be a viable trade-off. Promoting biogas and bio-solids in wastewater treatment plants is covered in the context of Egypt by WEFE Nexus. Desalination is promoted to increase national water supply, reusing treated wastewater recycles nutrients and reduces energy intensive fertilizers, renewable energy promoted for irrigation systems e.g.: solar pumping, and considering the energy potential of agricultural residues. WEFE Nexus aims to increase water efficiency in Egypt in the agricultural sector by 60% to save energy[37, 38].

In the Egyptian context, the Nexus approach provides excellent opportunities for the sharing of technical, economic and institutional innovations, providing opportunities for regional cooperation and economic integration. Nexus mainstreaming can only be achieved in Egypt through participatory approaches and vertical integration across levels and scales.

3.5 KEY ECOSYSTEM SERVICES AT MESO LEVEL

This part of the report is based on commonly accepted frameworks for the classification of the Ecosystem Services (ES) that assist the definition and classification of the ES and render them operational among natural scientists and economists as well as bring the ES in the policy agenda and decision making. The classification and description of ES in that section is based on the Common International Classification of Ecosystem Services (CICES) developed by the European Environment Agency (EEA)[39].

The concept of Ecosystem Services is used in AWESOME in order to understand the multiplicity of benefits at the meso level, obtained from the river basin ecosystems and to research the lost or gained services as an indicator of the ecosystems vulnerability. It was noticed that although studies on ES exist for the whole area, especially on the country level, very few exist for Sudan. Here follows a description of the key ES categories at the meso level which result from the river and its tributaries that flow through several wetlands that are crucial for the regions biodiversity. Most of the meso level ES (as well as local ones) described here such as water quality and species habitats (including endangered) results from wetlands that rely on a minimum inflow of water. The key ecosystem services of the Nile Basin are provisioning, regulating, cultural and supporting services (including habitat).

3.5.1 Provisioning Services

The provisioning services include all the outputs of materials, energy and nutrients from ecosystems. These are mainly extractive services necessary for activities such as hunting, fishing and gathering. In some cases, these are relative to industrial agricultural systems.

The basic services under this category are the crop production from irrigated agriculture and mainly production of cereals, vegetables, fruits and crops which are essential for sustaining livelihoods. Comparing the economic value of different crops, the molasses production is the highest (even though it is a by-product), followed by sugar and bio-ethanol production. The values for cereals and vegetables are lower[40].

Livestock maintenance is essential for millions of pastoralists and farming families that use the areas wetlands as watering points and pasture and are directly vulnerable to the livestock water productivity (LWP). The production is spatially distributed across the basin and depend on the variability of livestock meat and milk production on one hand and in feed water productivity on the other hand. Despite the variability, total water need for feed production is estimated to be roughly

94 BCM, which amounts to approximately 5% of the total annual rainfall (68 BCM of total annual rainfall when excluding water for residues)[41].

One of the most important provisioning services is the fish catch. Fishing and the associated businesses provide a supplement to daily diet and income[42]. The consumption of fish depends on the proximity to fish production centres. In 2013 the inland fish production in the countries around river basin represented the 70% - 100% of total fisheries production[43]. This should be seen in correlation with the fact the aquaculture is still in infancy in Sudan and Ethiopia and in 2013 over 89% of this production came from Egypt[43] .

In most studies the drinking water supply is excluded from the research as more than 2/3 of the drinking water comes from the groundwater wells, which supply 2.6 to 6.5 BCM per year[44].

Many households rely on the wild food of Nile basin's wetlands with most common the balanities aegyptica (Lalop) fruits and nuts, Tamarindus indica fruits (Koat) and wild vegetables such as neet and leaves, while also local communities rely on the hunting around wetlands for their livelihoods.

In terms of fuelwood production, there are basin-wide data that indicate 75 MCM of fuelwood to be exported informally out of Nile basin. Sudan exports 26 MCM and it is believed that 88% of actual production is produced sustainably[45]. Further activities such as beekeeping in Nile's forests is reported in a few studies, however there are no official data on numbers.

The loss of provisioning services that are provided by freshwater ecosystems is linked with particular stressors except of climate change, such as land use change and species invasion. These although might interact in some cases to mitigate each other such as increased fish catch due to fish invasion, which might appear as increased ES delivery, in other cases one can promote the proliferation of the other such as synergistically fish kill by aquatic fish invasion and land use changes[46].

3.5.2 Regulating Services

The regulating and maintaining services are the services provided by the freshwater system through processes that move water, energy, organisms, sediment and nutrients across the river basin and link atmospheric, terrestrial, marine and groundwater systems. The regulating and maintaining services support the functioning and the productivity of the surrounding ecosystem.

The main regulating service is the water flow which is necessary for hydropower generation. In Ethiopia the hydropower plants, distributed across the major river basin generate 650 TWh per year, according to the Ministry of Water and Energy[44]. Water flow is also used for storing surplus water during the wet periods and releasing it for use during the arid periods[40].

Carbon sequestration is one of the most important ecosystems services of river basins due to its impact on global climate change as the surrounding soil represents an important terrestrial stock of carbon (C) and the organic carbon dynamic SOC of agricultural lands comprises the main pool of terrestrial C[47]. In many studies seems that there is still not a complete understanding of the long-term impacts of land use and management on soil in the Nile basin, especially regarding the organic carbon dynamic (SOC) and there are no localized data[48]. However, there is an agreement that the

greater losses of SOC stock come from the current management of cropland and grassland, due to increased erosion, persistent removal of organic materials, grazing pressures and high rates of decompositions and smaller losses comes from management of shrubland and forestland[48].
Sediment retention is a service highly impacted in the Eastern Nile and the in Ethiopia, Sudan and Egypt the water resources development is threatened by soil erosion /sedimentation[49]. Water purification function extent throughout Nile's corridors, but it tends to be accentuated in riparian zones, floodplains and wetlands which are most important as they regulate the quality and quantity of water coming from uplands and function as buffers against flooding as well as excess sediment loads related to runoff[50].

3.5.3 Supporting Services

Supporting services are necessary for the production or the maintenance of all other ecosystem services underpinning them by nutrient and water cycling, soil formation, production of atmospheric oxygen and biomass, as well as the provision of natural habitats which support biodiversity. They differ from provisioning, regulating, and cultural services in that their impacts on people are either indirect or occur over extended periods of time.
The rivers are fringed by gallery forests and herbaceous littoral vegetation. The latter is dominated by papyrus, common reed (Phragmites australis), water lily, Nile cabbage (Pistia stratiotes), and occasionally water hyacinth. The rivers are inhabited by numerous species of vertebrates, including the hippopotamus, Nile crocodile, Nile monitor, rock python, spotted-necked otter, and numerous cobras. They also support many species of birds, amphibians, and fish. The habitats of Nile basin are critical for selected migratory birds for a stop-over or over-wintering. There are more than 15 national parks in the Nile basin, providing protection to many animals that are endemic, vulnerable or endangered as well as other types of protected areas (Ramsar sites and World Heritage sites). Dinder National Park and biosphere reserve in Sudan, the Omo National Park in Ethiopia and the Gabal Elba National Park in Egypt.

3.5.4 Cultural Services

The cultural services, according to the Millennium Ecosystem Assessment are the "non material benefits people obtain from the ecosystems" and particularly "cultural diversity, spiritual and religious values, knowledge systems, education, inspiration, aesthetic values, sense of place, cultural heritage values, recreation and ecotourism"[51].
In cases that the water bodies are navigable the water flows serve also for commercial navigation purposes. For example in Lake Tana, Ethiopia, an enterprise provides transport of goods and people to seven ports, as well as touring services for tourists who use inland water transportation to visit historic places and monasteries.
Although there are no official studies for the values of spiritual and religious services in the Nile

basin, the values local people put on natural medicines production could be linked with those local spiritual values[52]. The Nile Basin Initiative (NBI), in its 6th Webinar series on ES[53] mentions that 16% of households obtain their herbal medicines from Nile's wetlands and 2000 patients visit traditional healers of the Nile basin every year.

3.6 WEFE NEXUS STAKEHOLDERS AT MESO LEVEL

3.6.1 Identification of stakeholders

76 Seventy-six (76) stakeholders were identified in the initial matrix with equal representativity of each sector and they were split in a short list and long list of stakeholders depending on their usefulness for engagement.

Table 2 - Long listed Stakeholders

	SECTORS	SUBSECTORS	ORGANIZATIONS	BROAD CATEGORIES	SCALE
1	**WATER**	WATER SUPPLY	River Basin authorities	governmental	basin /national
			Ministry of Water Resources, & Irrigation	governmental	national /regional
2					
3			Water resources management authority	governmental	basin
4			National irrigation institutes/directorates	governmental	national /regional
5			National Water Research Center		national
6			Egyptian Global Water Partnership		
7			Hydrology institutes	research center	National
8			Nile Research Institute	research center	International
9			Groundwater research institutes	research center	National
10			Global Water Partnership Africa	inter-governmental	International
11		WATER QUALITY	ReNile	Business	National
12			21 Farmers	Business	National
13		WATER AFFAIRS	Water Affairs	governmental	national /regional
14			Ministry of Foreign Affairs	governmental	national /regional
15			Ministry of Housing	governmental	National
16			Nile Basin Initiative		Regional

17	**ENERGY**	HYDROPOWER	High Aswan Dam Authority	non-governmental	National
18			Electricity Supply Corporations	non-governmental	National
19			Electricity Supply Authority	governmental	national /regional
20			Ministry of Energy	governmental	national /regional
21			New and Renewable Energy Authority	Governmental	National
22		SOLAR ENERGY	Solar energy power stations	governmental	National
23			Solar energy power stations	Business	National
24			SolarizEgypt	Business	National
25		WIND ENERGY	Wind energy power stations	governmental	National
26		DESALINATION	Desalination stations	governmental	National
27			International Desalination and Water Treatment Group (IDWT)	Business	National
28			National directorates of energy	governmental	national /regional
29	**FOOD**	TRADITIONAL AGRICULTURE	Ministry of Agriculture & land reclamation (MALR)	governmental	national /regional
30			Food reserve agencies	governmental	National
31			Agriculture research center		
32			Egyptian Center of Organic Agriculture (ECOA)		
33			Central Laboratory for Agriculture Climate (CLAC)	Governmental/academic	national
34			Desert Research Center	Governmental/academic	
35			Land Reclamation & Development Authority	Governmental	
36			Crops agencies	governmental	National
37			Farmers union	interest groups	Basin
38			Water consumers union	interest groups	Basin
39			Export Development Fund	Governmental	National
40			Egyptian Countryside Development Company	Governmental	National
41			Ministry of International Cooperation	Governmental	
42			El Salhiya for Agricultural Investments	public-private	National
43			Daltex/Pico	Private	

46			Sekem	Private	
47			Sara's Organic Farm	Private	
48		FOOD SECURITY	Food and Agriculture Organization of the UN	inter-governmental	International
49			International Center for Agricultural Research in Dry Areas (ICARDA)	non-governmental	International
50			Global Alliance for Improved Nutrition	inter-governmental	International
51			Community Initiative Facilitation and Assistance (CIFA)	inter-governmental	International
52			Agency for Cooperation in Development (CAFOD)	inter-governmental	International
53			Food Security Cluster (FSC)	inter-governmental	International
54		HYDROPONICS	Center for Applied Research on the Environment and Sustainability (CARES)	Academic	National
55			Agrimatic	Private	National
56			Akrat	Private	National
57		AQUACULTURE	US Soybean Export Council (USSEC)	non-for-profit	International
58			Worldfish	non-for-profit	International
59	**ECOSYSTEMS**	ECOSYSTEMS	Environmental Management Agencies	governmental / non-governmental	National
60			Ministry of Environment	governmental	
61			National parks conservation agencies	non-governmental	basin/national
62			Department of fisheries (Ministry)	governmental	National/regional
63			Institute Meteorological services	research centers	National/regional
64			Heliopolis University of Sustainable Development	research centers	National/regional
65		CONSERVATION	National heritage conservation commission	research centers	basin/ national
66			WWF	non-for-profit	Basin
67			Ministry of Environment/ environmental affairs	governmental	National/regional
68			Desert research institues	research centers	National /regional
69			IUCN (International Union	non-governmental	Regional

			for Conservation of Nature)		
70			GIZ - Transboundary water cooperation in the Nile Basin	non-governmental	Regional
71	**PUBLIC HEALTH**	CLINICAL MEDICINE	Red Cross Society	non-governmental	National
72		OTHER HUMAN HEALTH	Ministry of Health	governmental	national /regional
73			Ministry of Social Services /Welfare	governmental	national /regional
74	**SOCIAL**	SUSTAINABLE LIVELIHOOD	Sawiris Foundation	non-for-profit	National
75			Ministry of Development and Economic Planning	governmental	National
76	**OTHER**		World Food Program	non-for-profit	International

3.6.2 Analysis and mapping

Once the basic list of stakeholders was finalized, further analysis was conducted in order to understand their relevance, their potential perspectives and interests, their relationships to each other. The criteria used in order to analyse each stakeholder were the following:

i) Influence: how much influence they have. (here it is important to understand what actors fall within this sphere of influence (e.g. the research community, the locals, the SMEs etc)

ii) Interest: how likely they are to engage in activities or initiatives relevant to the WEFE Nexus

Using Miro as a visual tool, the stakeholders listed in Table 2 were plotted on a graph where *Influence* was represented in x-axes and *Interest* in y-axes. The mapping allowed the research team to see where each actor stands when evaluated against the same two key criteria, and to compare them to one another.

The complexity of the matrix/database of stakeholders was visualized on the Miro canvas along with the interplay of relationships among them. Figure 1 below presents a sample from the stakeholder mapping illustrating influence on the vertical axis and interest on the horizontal. The resultant mapping produced a grouping of stakeholders under four quadrants:

- Quadrant 1 - Low Interest/Low Influence: 13 stakeholders
- Quadrant 2 - Low Interest/High Influence: 12 stakeholders
- Quadrant 3 - High Interest/Low Influence: 30 stakeholders
- Quadrant 4 - High Interest/High Influence: 16 stakeholders

Figure 8 - Mapping of stakeholders in progress on Miro

The mapping was undertaken via an iterative process whereby the initial plotting based on input from project scientists and local partners, was further revised by field experts. The stakeholders within quadrant 4, constitute the core group of stakeholders within the context of the WEFE Nexus in the case of the AWESOME project and will serve as the basis of the Multi-Actor Working Group (MAWG) formation. In addition to these core stakeholders, consideration was also given to the inclusion of stakeholders at the upper limits of quadrants 2 and 3 in order to develop the shortlist of stakeholders from which the MAWG participants are selected and invited (see table 3). The relevant WEFE stakeholders will be further examined during the workshop discussions about key WEFE drivers.

Table 3 - Short listed Stakeholders

Sector	SubSector	Organizations/ companies	Broad categories	Scale
WATER	Supply	Ministry of Water Resources & Irrigation	governmental	national /regional
	Quality	ReNile	business	national

		River Basin Initiative		regional
ENERGY	Solar	Solar energy developer/ Integrator (Solarize)	business	national
	Wind			
FOOD	Traditional Agriculture	Ministry of Agriculture & land reclamation (MALR)	governmental	national /regional
		Egyptian Center of Organic Agriculture (ECOA)		
		Central Laboratory for Agriculture Climate (CLAC)	governmental/ academic	national
		Desert Research Center		
		Export Development Fund	governmental	national
		El Salheva for agricultural investments	public-private	national
		Daltex/Pico	private	
		Sara's Organic Farm	private	
	FOOD SECURITY	Food and Agriculture Organization of the UN	inter-governmental	international
	HYDROPONICS	Center for Applied Research on the Environment and Sustainability (CARES)	academic	national
		Agrimatic	Business	national
	AQUACULTURE	Worldfish	non-for-profit	international
ECOSYSTEMS	CONSERVATION	GIZ – Transboundary water cooperation in the Nile Basin	non-governmental	regional
SOCIAL	Sustainable Livelihoods	Ministry of Development and Economic Planning	governmental	national
		World Food Program	non-for-profit	international

High Interest, High influence

The stakeholders belonging to the category "high interest, high influence" are listed hereafter:

Water Management Service Providers, Water resources management Authority, Water Affairs – the development and control of water quality and pollution is their primary concern of the Nile River.

Implementation takes place by establishing a monitoring and evaluation system for reporting and dissemination.

Wastewater treatment, reuse of treated wastewater, drainage, groundwater, and irrigation of/from the Nile River is also their focus. Planning waterways, policies and affairs is their collective area of high influences.
River Basin authorities – controls and plan the Nile Rivers' environmental, water quality state, the delta's standard, water distribution in the context of socioeconomic benefits, promoting regional peace and security.

Ministry of Water resources and irrigation - is the most influential public entity in water supply and management as the entity is the main decision maker in water related matters. The government's statement launched the priorities of President Abdel Fattah al-Sisi at the parliament to move from the stage of stabilizing the pillars of the state to reaping the fruits, having the improvement of the individual's living standard as a focus of concern. The strategic objective of the ministry is water security: preserving Egypt's historical water resources, the Nile river, hence, relevant to WEFE challenges and goals.
Ministry of Agriculture & land reclamation - agriculture accounts for a large portion of the countries' GDP. It is the most influential agricultural entity as it is public and the decision makers, moreover, it is very active with daily updates in agriculture strategies and decisions. There are highly active institutes within the ministry, including Desert Research. Land distribution and utilization is currently a hot-topic within the Egyptian Government.

Central Laboratory for Agriculture Climate (CLAC) - focuses on providing solutions to the unstable climate conditions, directly linked to WEFE Nexus goals of food security and Ecosystem's condition. Currently implementing the following activities:

1- Completing and updating the agricultural meteorological database.
2- Assessing plant growth, yield and expected risks.
3- Conducting agricultural meteorological-related research.
4- Producing cut flowers, medicinal and aromatic plants and vegetable crops under soilless agriculture conditions.
5- Follow-up with research on organic agriculture and promoting its concepts among farmers.
6- Modifying the greenhouse atmosphere by using novel greenhouse structures for better ventilation.
7- Evaluating cucumber hybrids developed under different climatic conditions.

Desert Research Center - is the most active and influential academic and research institute within the Ministry of Agriculture and land reclamation. DRC's objective is to utilize dry lands for agriculture by genetic engineering, greenhouses installation, water desalination, and land reclamation; focusing on researching and using high technology, witnessed within large public projects within the North Coast, the Southern Sector of Egypt and Sinai. Agriculture is the focal point of DRC, thus, relevant to WEFE Nexus's goals.

Export Development Fund - is an initiative by the Ministry of Trade and Industry, acting as regulators to control the movement of export. It is relevant to AWESOME, as it helps push forward technologies to be used.

Center for Applied Research on the Environment and Sustainability (CARES) - is a very active academic center through programs and applied interdisciplinary research, and community services guiding sustainable development efforts in Egypt through. CARES focuses on research activities related to water, energy, and food while considering their interconnectedness, to develop urban agriculture solutions. The three main research streams: Water desalination – addressing water scarcity, Advanced agriculture techniques (such as Aquaponics, Hydroponics and Recirculating Aquaculture Systems) – addressing food security and, Renewable Energy – addressing high energy consumption.

Ministry of Environment - is the decision maker and implementer of environmental policies, it is a governmental entity that has recently become active and influential. Interest in AWESOME is expected to be great, as the ministry's current focus is moving forward to the succession of Egypt's 2030 vision and the sub-goals of 2022, water sustainability and management, and green technologies including renewable energy is the Ministry's current concern.

High interest, Low influence

The stakeholders belonging to the category "high interest, low influence" are listed hereafter:

ReNile - ReNile is a leading Egyptian company in the field of online environmental services, providing effective solutions and modern systems in the field of tool customers, like: fish farming smart services, hydroponics and aquaponics monitoring systems, to manage fish farms and consultation.

Ministry of Development and Economic Planning - is the decision maker and implementer in regards to many economic strategies and policies, it is a governmental entity that has recently become active and influential. The Ministry of Planning and Economic Development launched the "Environmental Sustainability Standards Guide: The Strategic Framework for Green Recovery", in cooperation with the Ministry of Environment, and all relevant governmental entities. It is the first of its kind to raise awareness of sectors and interventions that have a direct positive impact on the environment and guide government and private sectors towards investing in them, as well as performance indicators that measure progress towards that goal, allowing for serious and ambitious steps towards sustainable development, of which the "green economy" is one of the main pillars.

World Food Programme (WFP) - non-for-profit, international organization, The country strategic plan contributes to Egypt's United Nations partnership development framework and WFP's Strategic Results 1, 2, 4 and 5, with a focus on Sustainable Development Goals 2, and 17, while also contributing to Sustainable Development Goals 4 and 13. Egypt's country strategic plan addresses four WFP Strategic Results: number 1 – everyone has access to food; number 2 – no one suffers from malnutrition; number 4 – food systems are sustainable; and number 5 – developing countries have strengthened capacities to implement the SDGs. hence, relevant and influential to AWESOME.

GIZ - GIZ works in Egypt on behalf of the German Federal Ministry for Economic Cooperation and Development (BMZ). It also implements projects on behalf of other German ministries, the European Union and international organisations. GIZ's activities support the Egyptian Government's Sustainable Development Strategy (SDS): Egypt Vision 2030 in the following priority areas: GIZ advises the Egyptian Ministry of Electricity on renewable energy and energy efficiency in order to reduce the climate impact of the country's electricity production. It helps partner institutions working in the field of urban development. GIZ runs a project designed to promote the more efficient use of water in agriculture in order to prevent future water shortages. It advises on general water supply improvements and on the management of wastewater and solid waste.

International Desalination and Water Treatment Group (IDWT) - are experts and active in the water industry providing solutions for water related issues. Their technologies are comprehensive including Ultra Filtration Technology as Pretreatment for Reverse Osmosis, Co2 Removal Towers, and ZLD (Zero Liquid Discharge). Their inclusion is important because of their high technology to solve water related problems and their expertise. Hence it is relevant to the soilless agriculture technology and WEFE's goal of water security.
Nile River Basin Initiative (NBI) - is the leading and only all inclusive platform for the Basin States, it is a regional, intergovernmental partnership of 10 Nile Basin countries. The goals and objectives of NBI, go along with WEFE goals and challenges of water security, 3 main goals including Facilitating Basin cooperation, water resources management, and water resources development. NBI follows a sustainable framework to develop guiding principles for water resource management and development across the Nile Basin countries, although not a legal framework however, builds guidance to planning and process development for water policies and strategies. Hence it is an important entity to be included in the conversation to share the perspective of the region, and economic impacts of soilless agriculture along the Basin.

International center for Agricultural Research in Dry Areas (ICARDA) - is a non-governmental, international organization with a strong partnership with the government. Egypt forms the hub of ICARDA's Nile Valley and Red Sea Regional Program, which strategically aligns activities with Sudan, Eritrea, and Yemen. The country is also a key player in ICARDA's new decentralization strategy as a thematic research location for sustainable intensification in irrigated systems. Egypt-ICARDA has successfully delivered solutions to improve livelihoods and enhance food security.

Agrimatic farms - is a representative of national, private hydroponics/ aquaponics producers. Optimizing soil-less technology and limited fertile land, water scarcity and slow agricultural development, there is a dire need for alternative sources for food security.

Worldfish Egypt - is a non-profit, international organization that is the only representative of the fishery and aquaculture sector. A key research focus has been on improving fish genetics to transform Egypt into a role model for African aquaculture development. WorldFish works closely with aquaculture stakeholders, the private sector and government organizations to deliver research on increasing aquaculture productivity, increasing the flow-on benefits of fish farming to women and youth, and enhancing fish value chains, hence highly influential to AWESOME.

Heliopolis University of Sustainable Development - provides academic programs and research towards Sustainable Development. The University has a Faculty of Organic Agriculture strives to be among the leading institutions in teaching, learning, research in the field of organic agriculture to serve the Egyptian community. On the international level, Faculty of Organic Agriculture established university industry partnership with various national and international institutions including: Padova University in Italy, Hohenheim University, RWTH Aachen University in Germany, Mediterranean Agronomic Institute of Bari in Italy, Demeter International, and IFOAMi n Germany.

Al Salhiya for Agricultural Investments - is a government controlled agriculture cooperation. Representing large lands and large agricultural operations, it also exports, and advances in agriculture inside and outside of Egypt.

Daltex Corp - is a private agricultural cooperation. Representing large lands and large agricultural operations, it also exports agricultural products and advances in agriculture inside and outside of Egypt.

Sekem - represents large scale organic farming. Moreover, promotes only sustainable methods of production including, natural pest control through Predators, graving plants through cattle management, land reclamation of deserted lands. The perspective of Organic agriculture is interesting in relation to soilless agriculture technologies, as well as, relevant to food, water and ecosystem security.

Sara’s Organic Farm - represents smallholder organic farming, has an entrepreneurial perspective, certified organic by the European Council for Organic Agriculture as well as Lara’s Premium Produce (sister company) which is Global G.A.P. and G.R.A.S.P. certified, grown using low input, regenerative farming methods. As mentioned before, the perspective of Organic agriculture is interesting in relation to soilless agriculture technologies, as well as, relevant to food, water and ecosystem security.

Food and Agriculture Organization of the UN (FAO) - represents the perspective of intergovernmental and international organization. The FAO's efforts are directed towards Improving agricultural productivity, raising the degree of food security in strategic food commodities, water efficiency and productivity, and Sustainable use of natural agricultural resources. It is highly influential, as partners with the government of Egypt for the implementation and succession of programmes and projects.

Agriculture Research Center – conducts its research work on agricultural economics, mechanization, animal health, animal production and reproduction, horticulture, soils, water and field crops. Although demonstrated high interest, implementation of the research is rare, or on small-scale.

U.S. Soybean Export Council, Farmers Union, Food security cluster, Crops agencies – works towards the goal of food security and sufficient production, despite large population demands, and environment and climate change footprint. Implemented projects are few and researches are great in number, hence placed as low influence.

Fisheries and aquaculture institute, ministry of Agriculture – is divided into marine, and aquaculture sub-sectors, providing statistical information on fish utilization, role of fisheries in the national economy, supply and demands, food security, employment, and trade. Constraints and opportunities of the government and non-government reports direct farmers or prospect farmers. It has low influence, as information is not always available and accurately provided, does not induce independent projects.

Al Alfi Foundation for Human and Social Development – the work focuses on education, particularly Science and Technology as the core development of social and economic advancement, leadership, innovation and social responsibility. Focusing on providing grants to Egyptian undergraduates and postgraduates, providing society with well-educated graduates is the foundation's output, showing high-interest, with low influence to AWESOME.

Technology Innovation and transfer centres – focusing on technology transfer and marketing, research project follow-up, funding opportunities and international cooperation, and intellectual property and patent culture of new technologies – Green technologies. Encouraging commercial investment and licensing of ideas and discoveries is a focus. Although it shows great interests, its influence is limited.

Groundwater Research Institute and Groundwater Partnership in Africa– being pioneer institutes for groundwater research activities and research plans for national project development in Egypt. Demonstrating low influence as limited projects are implemented, and not related to hydroponics.

Ministry of Social Solidarity – it is related as advocates for food security to cover population's demands and domestic water availability.

National Protection entity- is an entity under the Ministry of Environment's board, works towards biodiversity protection and ensuring healthy livelihood including water, nutrients and climate conditions are available to maintain and promote a suitable environment.

High Influence, Low interest

The stakeholders belonging to the category "high influence, low interest" are listed hereafter:

Ministry of Electricity and Renewable Energy – the ministries' influence would be high from promoting green technologies, however, as a ministry the agriculture sector is of low interest.
Food reserve agencies – interested in food security, data and information of food amounts and population demands are highly influential to production methods and needs.

Electricity supply authority and national doctorates of energy – highly influential to record data about electricity supply and demand and influential to the project as energy consuming technologies to be implemented.

Desalination stations – government invested $2.8 billion for 47 desalination plants in 2020, hence highly influential to AWESOME project.

IUCN – Highly influences water research, projects, and policies with reliable and credible information produced and projects.

Hydropower corporations and wind energy power stations –act as renewable energy sources for information and implementation projects and are highly influential to AWESOME projects.

Low influence, Low interest

The stakeholders belonging to the category "low influence, low interest" are listed hereafter:

WWF – aims to promote good water governance, protect freshwater ecosystems, manage water resources in changing climate, increase supply of more sustainably sourced food, raise awareness and enforce policies of efficient food production, however has low influence and interest in AWESOME projects as has minimal project output to Egypt.

Ministry of International cooperation – mapping the extent of sustainable development goals impact by cooperation of foreign investment. However, it has limited direct influence on the AWESOME Project.

Community Initiative Facilitation and Assistance (CIFA) – works to provide livelihoods and deal with disasters, support local initiatives to enhance sustainable development through the adoption of the latest technology and approaches and focus on Kenya. However, it has limited direct influence on the AWESOME Project.

Sawiris Foundation for Social Development – creates applied programs to achieve economic empowerment and Social empowerment including: micro-enterprise development program, agricultural development program, training and employment program, health, women empowerment program and provides basic services. Has limited direct linkage to AWESOME projects.

The Ministry of Health – High quality and food security is the concern of the ministry, cross-linking with goals of WEF Nexus, however technologies and approaches carried out by AWESOME do not match, and has limited influence on the project.

Agency for Cooperation in Development (ACORD) – provides research and analysis of economics, energy & environment, human rights, foreign policy, and ICT, needed to make decisions and build solutions for a better world based on evidence of research.

Institute Meteorological services - monitors changes in the atmosphere and provides meteorological services to all sectors of the country, as well as the interchange of data and information regionally and internationally, in accordance with international standards and duties. Providing information needed to assess food and water security, however has limited influence to AWESOME project’s prospect goals.

4. MICRO LEVEL: SOILLESS AGRICULTURE AS A WEFE NEXUS INNOVATION

AWESOME's research at the micro level aims to explore and demonstrate the potential of innovative technological solutions for increasing agricultural production, while reducing water and energy consumption, as well as negative impacts on ecosystem services, applied on the micro-scale pilots of the project. The aim of the proposed solutions is to add a sustainable source of water resources and maximize the productivity of a unit of water in terms of valuable products such as crops and fish.

Technology has permeated every sector, including agriculture. This poses advantages to farmers' ability to gain greater control over production. In addition, yields are increased because work can be carried out largely independently of the weather. Soilless agriculture comes in multiple forms, from which hydroponics is the most popular. Hydroponic and aquaponic systems are concepts for agriculture outside of soil[54]. The main difference between hydroponics and aquaponics is that aquaponics use fish to provide nutrients, and hydroponics use formulated solutions[55]. A description of both methods follows along with their advantages and disadvantages, as well as subsystems of hydroponics and subsystems that originate from hydroponics but are mainly integrated in aquaponics. Moreover, traditional agriculture is compared with these soilless systems.

4.1 Hydroponic Systems

Hydroponics is a technology-based solution for sustainable agriculture, which focuses on replacing the soil with a nutrition-rich aquatic medium to the plants in a fully controlled and closed environment, this guarantees quality consistency all year round and even out of season. The technology adopted conserves 85% of the water used in traditional agriculture, which makes it a suitable solution for areas with water shortages.

In general, the application of hydroponic systems is not limited to certain regions. The cultivation method is particularly advantageous where land and water are only available for agricultural use to a limited extent. The cultivation of hydroponics is mainly limited to small-growing and annual plants. Within this scope, various plant species are cultivated (flowers, corps, medicinal plants)[56]. Some examples are listed in Table 4.

Table 4 - List of crops suitable for cultivation in hydroponic systems based on [56]

Types of Crops	Examples
Cereal grains	Rice, Maize
Fruits	Strawberries

Vegetables	Tomatoes, Onions, Cabbage, Lettuce
Herbs	Parsley, Mint
Flowers	Roses, Chrysanthemum
Medicinal crops	Aloe vera
Fodder crops	Alfalfa, Barley

Within the field of hydroponics, there is differentiation based on the different operation methods used. In other cases, plants can be grown with the roots immersed in the solution or in a medium, which supports the roots (e. g. peat moss, perlite, rockwool, gravel). There is further differentiation of hydroponics based on whether the surplus nutrient is reused after it has been delivered to the roots in open and closed systems[57]. To ensure an adequate supply of nutrients and therefore a natural growing process, the water is enriched with natural, nutritive salts and minerals according to the needs of the plant species. Typically, the systems are used inside greenhouses, to assure ideal environmental conditions.

4.1.1 Advantages and disadvantages of Hydroponic Systems

Compared to conventional agriculture, soilless agricultural production can scale up to 10 times, which results in a competitive production cost especially out of season, and requires less land and water for plant cultivation[58]. Another advantage is the reduced consumption of land and water. Because of this, and the fact that the systems are closed and thus not directly connected to the environment, the discharge/ output water can be controlled. Therefore, the environmental impact is potentially lower, if managed properly.

In combination with cultivation in greenhouses, all aspects of the plant environment can be adjusted. Due to the possibility to provide for the plants‘ needs in a very precise and careful way in hydroponics systems, the plants can reach their full genetic potential. If the nutrient solution is in a closed system, evaporation and discharge into the environment are limited, allowing hydroponic systems to be used worldwide, even in drought-stricken areas[58].

Furthermore, soil-borne pests, fungi and diseases can be eliminated, as can weeds and litter. This in turn reduces the need for pesticides and additional labour, and thus labour costs. In hydroponics, the maturity cycle of crops is shorter compared to traditional agriculture, which results in significantly higher yields. In addition, the time between cultivation cycles is shortened, as no soil preparation is required[58]. Due to the high level of technologization, only basic agricultural skills are required[57].

However, it is necessary to underline that as a method of cultivation, especially in combination with greenhouses, hydroponics involve a high technological and capital-intensive effort, especially when the systems are combined with greenhouses[57]. This makes it difficult to get started with this method of cultivation. Unlike traditional cultivation, the roots of the plants might be exposed to light, which promotes the growth of algae. These compete with crops for water, nutrients and oxygen. [58]

4.2 Aquaponic Systems

Aquaponics is the combination of hydroponics with aquaculture; plants are using fish’s waste as organic fertilization for the seedlings after undergoing mechanical and biological filtration. The fishes to be used are Tilapia or Bada Fish, as they are one of the most commonly used types of fish for aquaculture, in addition to being a familiar and affordable type of fish in the Mediterranean countries. Moreover, both fish' kinds are Omnivores, thus can be fed with plants and animals, eliminating the expensive feed. Also, they are adaptable to extreme environments of high temperatures and high pH.

The combination of two cultivation systems enables synergies by using the waste material of the fish for plant nutrition. Some of these nutrients are immediately available to plants after excretion by the fish, while other components must first be degraded by microorganisms. Especially, with low daily water exchange, nutrient concentrations are generated that are comparable to the solutions used in hydroponic systems.[59]

In recirculating aquaculture systems (RAS) fish are bred using relatively small water volumes, as the water can be reused after removing toxic components. At the same time, nontoxic nutrients, and organic waste increase. In aquaculture systems, this nutrient-rich material is waste material and may lead to additional costs if treated by municipal sewage treatment plants[59].

As with hydroponics systems, the application of aquaponics systems is not limited to certain regions. Since the demand for water and land is lower than with traditional methods, the cultivation method is particularly advantageous where land and water are only available to a limited extent. Therefore, these systems are also suitable for semi-arid and arid regions[60].

Since plants and fish influence each other, the facilities must be planned and organized carefully. Plant and fish species must be considered, as well as stocking density and resulting waste discharge, to generate a balanced overall system. Crops like lettuce, herbs, spinach, and watercress have a low to medium nutrition demand, tomatoes, bell peppers, and cucumber, on the other hand, require a significantly higher amount of nutrients[60].

Generally, a variety of warm-water as well as cold-water fish species can be used for aquaponics. The prerequisite is that the species tolerate a high stocking density and are not sensitive to nutrients such as potassium[59]. Examples are tilapia, trout, perch, arctic char, catfish, largemouth bass, crappies, pacu, and bass. While tilapia is most commonly used in North America, different species of cod are grown in Australian aquaponic systems[59,60] .

4.2.1 Advantages and disadvantages of Aquaponic Systems

When properly designed, aquaponics leads to high food production rates regarding water consumption, (artificial) fertilizer input and waste generation. Mainly, this originates from harnessing symbiotic effects. The nutrient uptake of the plants results in their growth and in the purification of the water. Therefore, less artificial fertilizer is necessary, while the water can be recirculated much longer[59, 61]. As the implementation of the systems is not limited by site-dependent specifications (e. g. soil composition, precipitation amount), aquaponic systems are suitable to promote the local food production and thereby, support the local economy. The fact that not only one product can be offered also increases product diversity[60].

In addition to these benefits, there are some requirements for the successful operation of aquaponic systems. Recirculating systems in general are expensive as well in construction as in operation. In aquaponics, the subsystems (plant cultivation and fish farming) must be organized in a way the requirements of each system are met[59]. Therefore, success depends to a large extent on careful management, taking into account all influencing factors[60]. This causes the area requirement for plant cultivation to be significantly higher compared to the space needed for fish keeping and requests adapted harvesting cycles for both crops and fish. Most of the labour must be dedicated to the care of the crops (seeding, transplantation, maintenance, harvesting) and requires corresponding skills. Hence, to operate a commercial aquaponics facility, it is favourable to employ both an aquaculturist and a horticulturist. Also, means of control of plant pests and diseases are limited to those that are compatible with fish farming, which could be considered both, benefit, and constraint[59].

4.3 Subsystems of hydro- and aquaponics

In the following, a brief description of subsystems of hydro- and aquaponic-systems will be given. These subsystems are:

- Deep Water Culture (DWC)
- Nutrient Film Technique (NFT)
- Media-Bed/Media-Based
- Sandponic

All of these subsystems are used directly in hydroponic systems and/or are integrated into aquaponic systems. Below, the description of the subsystems goes into detail on the setup, areas of applications and advantages of each subsystem.

A summary of all facts is given in Table 5 .

4.3.1 Deep Water Culture (DWC)

Deep Water Culture (DWC) is the straightforward form of hydroponic systems[54]. It has a simple structure, as can be seen in Figure 9. It is the most commercially adopted technique of hydroponic systems[62].

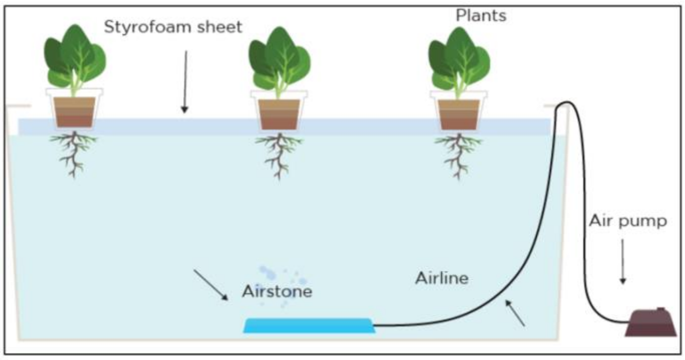

Figure 9 - Deep Water Culture (DWC) [63]

In a Deep Water Culture, plants are supported by a platform which floats on a bath of hydrodynamic nutrient solution[54]. The platform has holes for the plants, which allows the roots to be submerged in the water and have constant contact with the nutrient solution[54, 62]. Aeration and therefore oxygen are supplied via diffuser air-stone, to prevent stagnation and oxygen deprivation in the root zone[62].

The air-stone is placed under the rafts and is connected to an air pump, which constantly runs to secure oxygen supply. A DWC system can be set up in glass basins, plastic boxes, concrete basins, and others with water depths ranging from 10 cm to 1 m. Advantages of the simple and reliable system are e.g., the ease of use, simple cleaning and the notably lower risk of plant mortality during power outages. Since the plants are floating and are in continuous contact with the nutrient solution. Even in the event of a power outage or stopping of the air pump, there is no risk of damage to the plants[54, 62].

In case of a pump malfunction, there are many hours left for repairs as plants can live up to 2 weeks without water flow or aeration before problems occur[63], [54] and this system needs larger volume of water than other subsystems. In this sub-system, there is a constant water flow, it takes up more space but a large sump tank is not needed[64]. The system is well suited to warmer tropical climates and is insensitive to large temperature and nutrient fluctuations.

Most conveniently used plants in DWC are according to El-Kazzaz and El-Kazzaz[54] lettuce, strawberries, and herbs, with herbs growing particularly well.

4.3.2 Nutrient Film Technique (NFT)

The Nutrient Film Technique (NFT) as seen in Figure 10, is designed as a recirculating system. Highly oxygenated dissolved nutrients run continuously over the plants through a set of channels. The fluid runs-off into a tank and is pumped back to the plants. The reservoir contains a submersible pump and air stones for optimal dissolved oxygen levels, for optimal nutrient uptake, and stagnation prevention. The solution is held at the lowest point of the reservoir. Typically, baskets hanging in a PVC pipe contain the plants and are set up in a slight angle for drainage purposes. In this way the shallow stream of water can run from the top to the roots and off to the tank. Thus, the nutrient solution is continuously recycled. NFT can be done on a timer or with continuous flow[54, 63] .

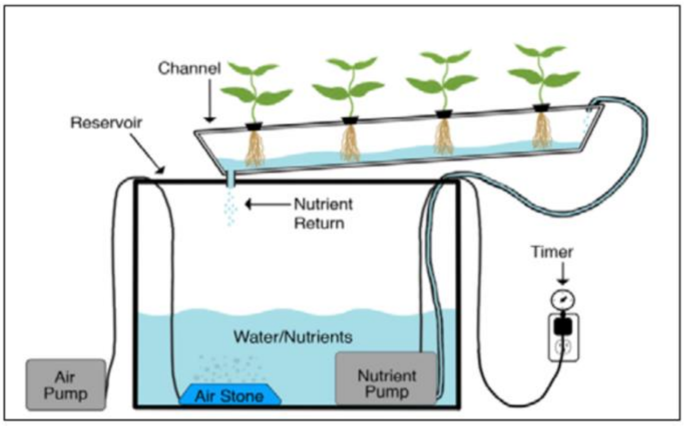

Figure 10 - Nutrient Film Technique (NFT) based on [63]

Main advantage of NFT is the systems handling. Using mobile channels makes it easy to change row spacing, add or remove channels from the system. The set-up is light weight which also allows stackable, vertical installation of channels over one another or also above DWC systems. It is easy to clean and customizable. Harvest methods are flexible [63, 62]. A smaller sump tank and smaller volume of water is needed in this sub-system of hydro-and aquaponic systems. Roof and vertical farming can be done by supplemental light. However, separate biofilters needed and material of these subsystems are costly. There is a smaller volume of water in the system and decreases more quickly than in other subsystems so fluctuation water is unstable due to evaporation and should be added more often. Water - root contact is lower in this system, which causes the nutrient uptake from water to be lower compared to other subsystems.
For NFT, plants with small root systems are well suited such as lettuce, strawberries, and herbs[54]. Patillo (2017) [62] also names basil, lettuce, tomatoes, cucumber and pepper as suitable plants. Commercially most widely used in NFT systems is lettuce[64].

4.3.3 Media-Bed/ Media-Based

For the previously described systems roots are either directly in contact with the water or sur-rounded by growth medium (Flood and Drain/ Ebb and Flow). For these soilless cultures (systems above), growth medium is the substitute for soil. Thus, a solid medium provides support for the plants.
The growth medium provides the roots a supportive medium so they do not fall over during irrigation processes and hold oxygen and nutrient solution for time periods where there is no water flow. Nutrients and oxygen can be stored in the medium for a period of time, and provide a steady supply until the recirculating water reaches the plants again. As substrates, several inorganic or

organic materials, such as coco coir, rice husk, vermiculite, perlite, gravel, and others are used, see Figure 11 [54] and /or mixtures of several substrates. In aquaponic systems, media beds also support the colonization of nitrifying bacteria[66] .

Figure 11 - Examples of substrates in soilless culture based on mixtures of substrates[54]

4.3.4 Sandponics

In the following, the system of Sandponics is explained. Sandponics is a system that uses sand as primary medium. The system consists of an air-permeable bed filled with sand compliant, a dripping water supplier and a liquid fertilizer diluter[67] .

To improve efficiency, Sandponics have undergone adaptations which mainly show in a shift from drip irrigation to floor irrigation. The New Sandponics (NSP) system is displayed in Figures 12-14. NSP is a liquid fertilizer cultivator that consists of a small amount of sand media with a liquid fertilizer tank at the bottom. It is based on floor irrigation, which supplies fertilizer from the tank using capillary action of an irrigation cloth. Besides changing the irrigation method to enable a control of water fertilizer supply, the change to a new, lighter medium makes NSP easier to install and maintain[68].

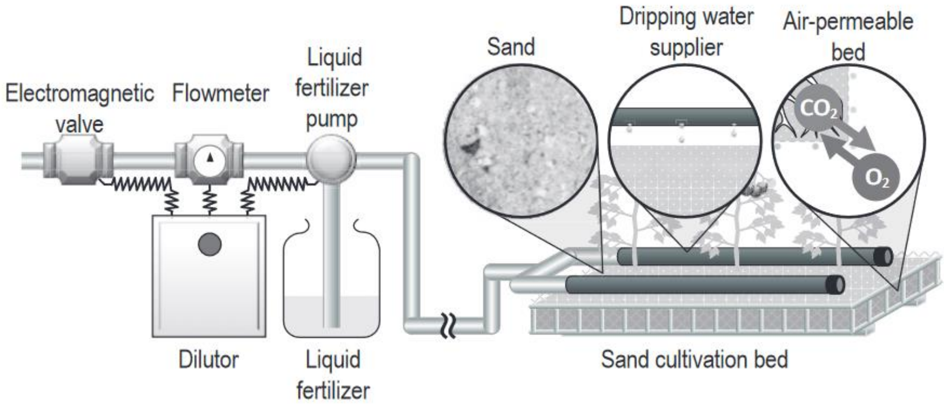

Figure 12 - Configuration of the Sandponics System from [67]

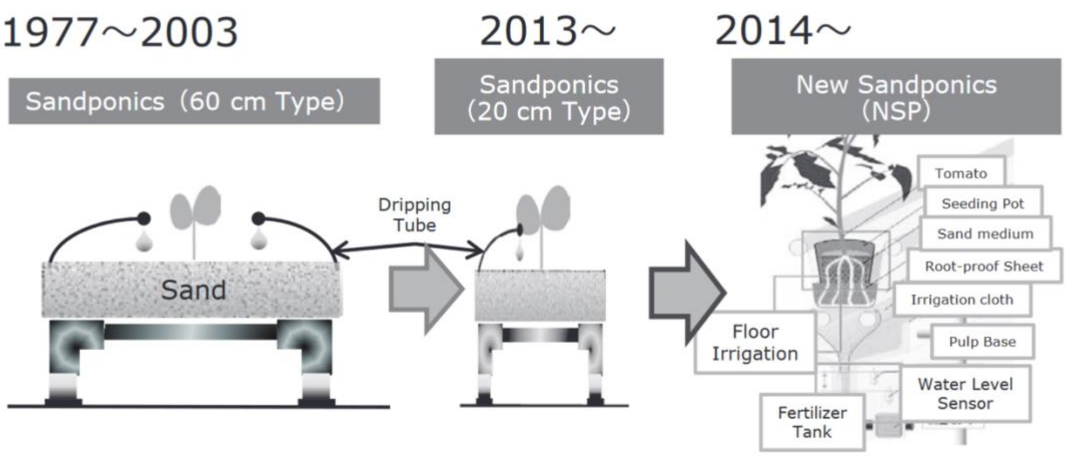

Figure 13 - Development of Sandponic system components from [68]

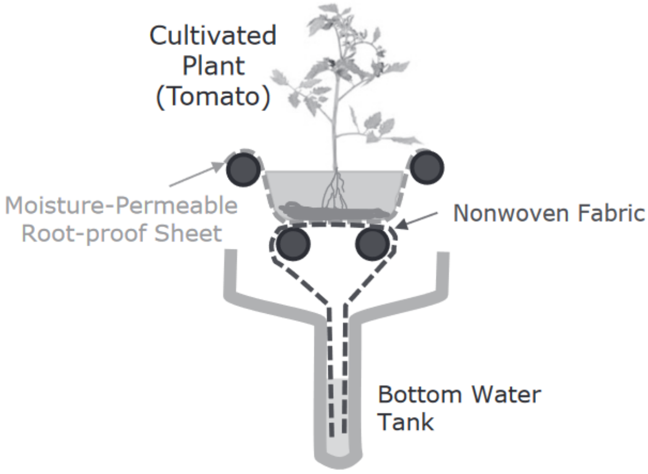

Figure 14 - Schematic Structure of NSP from [68]

Sandponics are used for industrial cultivation[67] . NSP systems have several advantages. They have a simple water supply management[67] and roots can be easily removed after production which generates little waste[68] . There is a stable moisture stress, the fast water supply keeps pace with the water absorption speed of the plant and oxygen is sufficiently supplied by the liquid fertilizer and media[68]. Overall, it enables cultivation with less medium than other cultivation methods and high-quality, large-quantity harvests[68].

4.4 SOIL CULTIVATION/TRADITIONAL AGRICULTURE IN GREENHOUSE, INTEGRATED INTO AQUA-/HYDROPONIC SYSTEMS

The treatment of soil cultivation under greenhouse conditions is used to compare with soilless farming, i.e. hydro- and aquaponic systems. Irrigation of soil is provided by integrating components of hydroponic systems in our hydroponic experiments and components of aquaponics in aquaponic experiments.

Fertilization programs are traditionally planned with chemical fertilizers after soil analysis from an external laboratory. Plants grow in a natural root environment and are colonized by multiflora and fungi[69] and it is also possible to do organic farming. Unfortunately, Egypt has very poor soil in terms of soil minerals. The result of soil analysis is also evidence of unfertile soil with organic matter deficiencies. Lettuce grows in cool weather and high light intensity[70]. It is known that Egypt has a Mediterranean climate and mostly hot temperatures. The mean temperature can be even 18°C in wintertime[71]. High salinity in water and soil is also a major issue in agricultural settings in Egypt. Soilless agriculture provides plant growth with desalination of water. In hydro-and aquaponic systems, seeds of weeds and/or spores of plant diseases are not found, or the pests do not winter as in the soil. Plant rotation is necessary in conventional agriculture, but farmers often produce similar crops from the same family. The used fertilizers in traditional agriculture may cause the soil to become salted or calcified by changing the pH value over time. Thus, nutrient uptake from the soil may not be sufficient for plant growth and consequently, other processes are necessary to make the soil healthy again. In addition, the cost of synthetic fertilizers is high. Table 5 summarizes 4 sub-systems of hydro-and-aquaponics and soil cultivations and their features, advantages, and disadvantages.

Table 5 - Summary of hydro- and aquaponic subsystems

Sub-system	Components	Areas of application	Advantages	Disadvantages
DWC	Airstone, Air pump, floating platform for plants	Commercial use: lettuce, strawberries, herbs	Simple, reliable, simple cleaning, no risk for plants in case of power outage, inexpensive, good for warmer tropical climates, not sensitive to large temperature and nutrient fluctuations. - Constant water flow - Small sump tank needed Endut et al., 2010)	Levelling of oxygen content on the water -> solution via airstone, device for roots aeration needed (Patillo, 2017) -Separate biofilter demand (Lennard and Leonard, 2006, require large volume water, takes up much space, labour demand,
NFT	Recirculating system; air stone; air pump; nutrient pump; timer	Flexible setup; flexible harvest methods	Flexible setup: mobile channels; light weight; stackable; vertical installation of channels over one another - Require smaller volume of water - Light hydroponic infrastructure, suits well for roof farming -Nutrient uptake is not high	Clogging of tubes if diameters is small (Patillo, 2017) Separate biofilter needed (Lennard and Leonard, 2006) high costly, water is less stable, can need to add more water because of evaporation and there is less water in the system
Media-Bed	Growth medium is substitute for plants	Soilless cultures like: Flood and Drain/Ebb and Flow systems	Nutrients and oxygen are saved in the media maintaining a steady supply. – provides Biofiltration in the system media serves as substrate for nitrifying bacteria in aquaponics (Rakocy, 2007) -Good biofiltration also in hydroponics	large sump tank needed, if flood and drain method to be used - High hydroponic infrastructure - Maintenance and cleaning difficult - Clogging leading to water channeling, inefficient biofiltration and inefficient nutrient delivery to plants (Endut et al., 2010)
Sandponic	Sand medium; liquid fertilizer; irrigation cloth	Industrial cultivation	Simple water supply management; easy removal of roots; little waste; large-quantity harvest	It is quite new system, more knowledge needed about it
Soil	Soil	Can be produced all	- Less infrastructure - Natural roots environment	- it is difficult to control nutrients in soil cultivation

		kind of crops, annuall, perennial and biennial plants for hobby, industrial or for nature	- Colonized by broad microflora and fungi (Lennard and Leonard, 2006) - Accepted as"organic way of cultivation"	-It is not easy to find good soil everywhere - with fertilisation can lead to environmental pollination or salinity in soil - more vulnerable for diseases and host for pests -long time needed for production

4.5 WEFE IMPLICATIONS OF SOILLESS TECHNOLOGY

The findings and factors summarized in the previous sections demonstrate the need for sustainable principles to be added to secure Water and Food security, here comes the WEFE Nexus analysis and description of the interlinkages between the three sectors (water, food, and energy) to associate potential synergies and limit trade-offs between the three sectors[72]. The expanding population and accelerating demand call for the consistent need for socio-economic development through sector interactions in a systematic way.

The AWESOME objective at the micro level is to demonstrate the differences of systems/techniques of soilless agriculture for efficiency and productivity both using hydroponics and aquaponics separately for a comprehensive comparison to form reliable conclusions. Starting by carrying out two case studies, the first case study is the lab scale and the second, the pilot-scale will potentially be 5 to 10 times larger. On a lab scale, the various subsystems DWC, NFT, Mediabed and Sandponics systems are tested as hydroponics and compared with soil cultivation. In addition, these systems will be tested in an aquaponics and compared with Integrated Vega Culture (IVA). Subsequently, the most promising test setup for hydro and aquaponics will be further tested in the pilot plant.

When carefully managed, soilless farming methods are superior to traditional agriculture in several aspects and lead to both economic and sustainability-related benefits. While global arable lands are decreasing due to concretion and natural disaster, global warming causes an increase in the rate of dry land dry land according to reports of Food and Agriculture Organization of the United Nations[73].The amount of food produced per unit area is about 12 times higher in hydroponic systems compared to traditional agriculture.

The methods used in traditional agriculture can lead to ecosystem degradation or loss. Synthetic pesticides are still used to control weeds, plant diseases and pests to a large extent in developing countries and to a small extent in developed countries. The use of natural pesticides has ever increased in the last decades, but its overall proportional share among pest management techniques is still quite low in developing countries. Even if pesticides are not used now, pesticides that have been used in the past may contaminate the soil in these agricultural areas, and the soil must be disinfected for agricultural use again. The half-life of some synthetic pesticides in nature can take many years. The misuse (including overuse) of pesticides in traditional agriculture may damage groundwater, air and soil and eventually endanger human health.

Some pesticides show toxic or lethal effects on non-target organisms such as predators, competitors, herbivores, symbionts, parasites, and pathogens. Not only these non-target organisms around the pest, use of synthetic pesticides can be detrimental on marine ecosystems, freshwater ecosystems, mammals, birds, reptiles etc. They can also cause damage to small-sized nematodes living in the terrestrial ecosystem, which add vitality to the soil and contribute drainage of the soil. In hydro-and aquaponic systems, seeds of weeds and/or spores of plant diseases are not found, or the pests do not winter as in the soil. Moreover, in these agritech systems, culture plants do not compete with weeds for nutrient intake, light or space and do not need mechanical workforce to control weeds.

The synthetic fertilizers used in traditional agriculture may cause the soil to become salted or calcified by changing the pH value over time. Thus, nutrient uptake from soil can be not sufficient for plant growth, and consequently it needs other processes to make the soil healthy again. In addition, the cost of synthetic fertilizers is high. Aquaponic systems consist of hydroponics and aquaculture elements (fish, prawn, snails), which create self-sustaining living in recirculating water and provide multi-tropic food. For the system to work, nitrifying bacteria should be added to the fish's water. These bacteria allow the plants to turn ammonia from the fish waste into nitrates, which is used as nutrients by the plants. Through this process, the plants can absorb waste from fish tanks and recirculate clean water back in without needing any fertilizer.

Crop rotation is necessary in conventional agriculture, but farmers often produce similar crops from the same family. For instance, a farmer produces on rotation a variety of cereal in the same field every year which causes an uptake of the same proportion of nutrition elements from the soil. If a legume plant is planted after a cereal, nitrogen will be supplied to the soil and the fertilization regime of the soil will be positively changed. In traditional agriculture carried out in greenhouses, culture plants such as tomatoes (Lycopersicum esculentum), peppers (Capsicum annuum), eggplant (Solanum melongena), which generally belong to the solanaceae family (nightshades), are produced twice a year in the Mediterranean region. In hydro- and aquaponic systems, however, it is possible to produce the same crop in the same grow area by providing suitable environmental conditions for the plant throughout the year. In addition, the plants grow in a much shorter time compared to traditional agriculture. E.g, while lettuce (Lactuva sativa) grows in the soil in 70 days, it can be harvested a short time such as 30 days in these soilless agriculture systems. In addition, the areas that can be considered are not only, but also those where only water and electricity supply can be ensured.

Economic benefits of soilless agriculture are not limited to land reclamation, irrigation, and electricity consumption. The possibility of increasing work opportunities, from engineers, scientists, project managers, financial personnel, quality control personnel, and other kinds of roles, leads to being a social benefit, and an economic benefit. Moreover, improving the working capacity and efficiency of incumbent laborers on a macro-scale, increases opportunities. This aids with the work

– poverty balance cycle, accessible income, aiding with UN's SDG 2 of Zero Hunger. Moreover, due to the high productivity of crops by the various soilless agriculture techniques, the prices of crops in the market fall in response to its availability, allowing access to high-quality, clean products to all societal levels.

4.5.1 Impact of Soilless Agriculture on Water Savings

While facing challenges of mitigating and adapting to climate change and other stress, the Mediterranean countries who are large contributors to the world's food production, demand for irrigating water is expected to increase a range between 4% and 18%, by 2100. Reports show that irrigation accounts for 50% to 90% of the total water demand within the Mediterranean region.[74] Hydroponics, aeroponics, and aquaponics systems can save more than 80% of irrigation water used in comparison to conventional agriculture. The percentage of irrigation water saved in the context of the Hydroponics system depends on its solution system used, and whether it is a closed or an opened system. Nutrient Solution Hydroponics closed system is the most efficient and can save up to 90% of the irrigation water used in comparison with conventional agricultural irrigation water usage. The least but yet very efficient system is the Media Soilless Hydroponics Open system and can save up to 80% of irrigation water in comparison to conventional agricultural consumption. Moreover, aeroponics and aquaponics can save up to 95% and 80%, respectively of irrigation water in comparison to conventional agriculture water consumption (Table 6).

Table 6 - Comparison of parameters for different new farming systems with conventional farming systems

Parameters	Hydroponic system				Aeroponics	Aquaponics
	Media Soilless system		Nutrient solution system			
	Open	Closed	Open	Closed		
% Irrigation water saving	80	85	85	90	95	%85-80
% Fertilizer saving	55	80	68	85	85	%99-85
% Productivity increase	100	150	200	250	300	%150-100
% Water productivity	1000	1600	2000	3500	8000	1000-1600

4.5.2 Impact of Soilless Agriculture on Food Production

The water productivity increase percentage found to be highest in the aeroponics System (300%). Also, the aquaponics system's water productivity percentage can reach 150% followed by the lowest water productive system, that is Media Soil-less Open hydroponic system, accounting for a 100% water productivity increase, which is still large. Water Productivity percentage is found to be the maximum of 8000% increase in aeroponics, followed by Nutrient Solution Hydroponics closed system that reaches up to 3500% compared to conventional agricultural water productivity.

Moreover, aquaponics' water productivity percentage ranges from 1000% to 16000% increase. In contrast to the various Hydroponics system types, the least water productive system is the Media Soil-less Open Hydroponic system accounting for a 1000% increase in water productivity in regard to conventional water productivity percentage [2].

4.5.3 Financial Considerations

A comparison of the capital expenditures (CAPEX) and operational expenditures (OPEX) of soilless agriculture with those of conventional agriculture is necessary. In conventional agriculture these indexes depend on irrigation methods, availability of water, land location, and soil salinity.

Particularly the OPEX increases with chemical fertilizers usage increase, soil conditioners and with distance from a water source. While in the case of using irrigation pumps or water wells, the fuel and maintenance fees are to be added to the CAPEX and OPEX. The CAPEX for digging a water well exceeds USD 5500 [75] .

However, soilless agriculture techniques do not require land specifications. Electrical consumption is the most expensive factor in comparison to other factors of soil-less agriculture and varies with the design. Electricity installation costs could reach up to USD 6700 per acre and Electrical consumption varies from 50 kW and could reach up to 8000 kWh per month.

2 All these percentages (of soilless agriculture) were found to be in comparison with conventional agriculture's productivity percentage increase

5. LAB-SCALE EXPERIMENTS

5.1 Pre-experimental procedure and system set up

Since germination affects subsequent seedling growth, first a seedling experiment was conducted to determine if the medium influenced seedling development and the performance of the media bed subsystem.

Before beginning the experiments, at least 450 lettuce seeds are sown with 1-2 cm depth into trays (209 seedlings can be grown in a tray, (the size of trays 70 X 40 cm) with the media type selected according to the results of seedling experiment. At the time of media preparation, 8.5 g of (N-P-K, 19.19.19 + T.E) fertilizer is added to the growing media for 1 complete seedling tray (209 cells) and will be irrigated. After sowing, the seeds are planted, they remain in a warm environment for 2 days, covered in incubation. 2 days later, they are taken to the place for seedlings in the greenhouse. During the experiment, 0.25 g of (N-P-K, 19.19.19 + TE) mixed in 1 l of water are daily sprayed to the media of the seedlings.
23-day-old seedlings are transferred into the growing areas of the hydroponic systems. The system components are collaborated before starting the experiments. The table above shows key players in experiments and their roles in all pre-experimental steps.
The Nile tilapia fishes (*Oreochromis niloticus*) are reared until experiments begin to use in aquaculture and aquaponics. The production cycle for tilapia requires 24 weeks. Tilapias are reared 52 weeks without harvesting, the rearing tanks consist of 5 fish tanks and each one has a volume of 2 m^3. During the growth of the fish, they are fed daily using feeder from 6.0 % body weight (initial) to 1.2 % (final) [76] .
The system components are collaborated before starting experiments. The quality and components of the water to be used in experiments are tested in order to determine the plant nutrition programme for the lettuce. Also, the soil is analysed before the experiments begin in soil in an air-conditioned greenhouse. Plant nutrition formulations are applied according to these analyses. Table 6 shows pre-experimental steps of seedling.

Table 7 - Pre-experimental procedure steps for the systems

Key players	Hydroponic systems	Aquaponic systems
Seedlings	The seeds of the lettuce are sown into trays with a growing media. After developing 2-3 leaves, the plants are fertilized. 23-day-old seedlings are transferred to the system grow area.	The seeds of the lettuce are sown into trays with a growing media. After developing 2-3 leaves, the plants are fertilized. 23-day-old seedlings are transferred to the system grow area.
Tilapias	-	The Tilapias are fed 24 hours intervals at the same time every day. Fishes are reared without harvesting.

Plant nutrient solutions	After testing the system water, hydroponic nutrient solutions are added to the system. The nutrient solutions are prepared based on the full strength modified Hoagland solution.	After testing the system water, aquaponic nutrient solutions are added to the systems and microelements into RAS water.

Table 8 - Pre-experimental procedure steps for of seedlings

Steps	Description
Sowing the seeds	The seeds of the lettuce are sown into trays in 1- 2 cm depth with chosen growing media from seedling experiment.
Media preparation and irrigation	8.5 g of (N-P-K, 19.19.19 + T.E) fertilizer is added into growing media for 1 complete seedling tray (209 cells) and will be irrigated.
Incubation	After sowing seeds, seedling trays stay covered in a warm environment for 2 days. Afterwards, they are taken to their place in the greenhouse.
Fertilization and irrigation of seedlings	0.25 g of (N-P-K, 19.19.19 + TE) fertilizer is daily sprayed to the media from emergence of the seedling until transplanting time of seedlings with 1 L water. Seeds are irrigated until the emergence of seedling, then they will be daily irrigated by spraying with fertilizer.
Transplanting of seedlings	23-day old seedlings are transplanted into growing area in subsystems
Integration on soil cultivation	Hydroponic system or aquaponic system components are integrated to soil cultivation area in greenhouse without nutrients

5.2 Lab-Scale Experiment

The lab-scale experiments are conducted in a highly controlled greenhouse. The half-moon greenhouse is fitted with an automated environmental control unit, managing the facility's environmental parameters, including temperature, humidity and water, and monitoring pH, dissolved oxygen in the water, light intensity, and nutritional uptake.

The greenhouse holds a seedling area, where seeds are cultivated in preparation to be transferred to complete their growth cycle within the system. It also holds a traditional agriculture section acting as the experiment's control for traditional in-soil greenhouse agriculture.

The main growing area consists of 3 DWC units, 3 NFT units, 3 Media-Beds, and 3 Sandponics units, making a total of 12 independent and interlinkable randomly distributed units for experimentation (Figure 15)

Figure 15 - AWESOME Lab-scale Greenhouse – Cairo, Egypt

Figure 16 - Independent and interlinkable circulation for each Grow-Bed – Sandponics

In the lab scale setup, several subsystems of hydroponic and aquaponic systems are tested and compared with traditional greenhouse agriculture. Seeds are sown into seedling trays with substrates. After 23 days, 31-40 seedlings are transplanted into the growing area of the hydro-and -aquaponic systems. Each system consists of 3 units. The growing units are 1.322 m^2. Five experiment cycles are planned. Each single experiment takes 30 days. Table 5 shows all experimental flow and treatments.

Growth and general health of experimental plants are observed by capturing images with 3-day-intervals and processing these images. Environmental parameters are daily checked. These environmental parameters in the greenhouse and the systems are air temperature, water temperature, relative humidity, DO (Dissolved Oxygen), pH, EC, photoperiod, lighting, used water, discharged water etc. Growth and harvest parameters of lettuce are measured in all hydroponic and aquaponic systems. These parameters are plant height, number of leaves, diameter of stem, fresh mass of shoot and root, dry mass of shoot and root.

In the first test cycle, lettuces are planted with different spatial distributions in hydroponic experiments. This experiment aims to characterize lettuce production and suitability to the growing system also in relation to plant spatial arrangements and densities. The objective of the study is to increase the economical use of resources and a higher yield per unit of area in hydroponics. This hydroponic experiment cycle with different subsystems of the hydroponic system is planned with 2 different planting distances. These treatments are listed in Table 9 the time scheduling.

Figure 17 - Nutrient Film Technique (NFT)

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Figure 18 - Deep-Water-Culture (DWC) Grow Bed

A separate greenhouse includes 5 fish cultivation tanks, in addition to a mechanical filter for the aquaponic experiment. The aquaculture system is fitted to be linked as the main source of nutrition for the lab-scale facility during the aquaponic experiment. On the lab-scale, the aquaponics productivity and efficiency will be compared to the Hydroponics before merging both, through crop analysis of quality and quantity.

In aquaponic systems, plants are hydroponically cultivated using fish wastewater from the system, which contains nutrients derived from fish feed. Sometimes, micro element deficiency may occur in aquaponic systems. In this test cycle, by adding different proportions of micronutrient elements and comparing it with the control group that is not treated, with 0 % supplement of microelement.

Lettuces are optimally cultivated in long day conditions. In the third test cycle, we will test the efficiency of supplementary lights by analysing the extending of the photoperiod on lettuce growth. To reduce power consumption in the last treatment, LED lamps are used.

In the fourth and fifth experiment cycles, repeats of microelement experiments and spatial distribution experiments are carried out in aquaponic and hydroponic systems, respectively.

Table 9 - Experimental cycles

Test cycle	systems	Experiments	Aims	Project month	Treatments
1. Test cycle	Hydroponic Experiments	Plant spacing	To characterize lettuce production and suitability to the growing system also in relation to plant spatial arrangements and densities. To get more yield per unit area in hydroponics	M13 May 2021	20 X25 cm
				M14 Jun 2021	15 X20 cm
2. Test cycle	Aquaponic experiments	Micro elements	In aquaponic systems, plants are hydroponically cultivated using fish waste water from the system, which contains nutrients derived from fish feed. Sometimes, micro element deficiency may occur in aquaponic systems. In this test cycle, by adding different proportions of micronutrient elements and comparing it with the control group that was not treated at all.	M17 Sept 2021	Without treatment
				M18 Oct 2021	app. 25 % adding micro elements into RAS water
				M19 Nov 2021	app.50 % adding micro elements into RAS water
3. Test cycle	Hydroponic experiments	Supplementary light	Lettuces are optimally cultivated in long day conditions. In this test cycle, we will test the	M21 Jan 2022	Metal halide lamps
				M22 Feb 2022	Blue and red lamps

			efficiency of supplementary lights by extending/photo period.		
4. Test cycle	Aquaponic experiments/ repeats	Micro elements	Repeat of aquaponic experiments in different season	M24 Apr 2022	Without treatment
				M25 May 2022	App. 25 % adding micro elements into RAS water
				M26 Jun 2022	App. 50% adding micro elements into RAS water
5. Test cycle	Hydroponic Experiments/ repeats	Plant spacing	Repeat of hydroponic plant spacing experiments	M27 Jul 2022	20 X25 cm
				M 28 Aug	15 X20 cm

Table 10 - First hydroponic experiment cycles with different subsystems of hydroponic system on the schedule

Sub-systems	First Experiment (Treatment of plant spacing 20 X 25 cm	Second Experiment (Treatment of plant spacing 15 X 20 cm
DWC	M13 (May 2021)	M14 (Jun 2021)
NFT	M13 (May 2021)	M14 (Jun 2021)
Media-bed	M13 (May 2021)	M14 (Jun 2021)
Sandponics	M13 (May 2021)	M14 (Jun 2021)
Soil cultivation	M13-M15 (May – Jul 2021)	M20-M22 (Dec 2021- Feb 2022)

Besides, measurements of growth and harvest parameters, leaf nutrient and chlorophyll content are measured by an external laboratory, see table 11. In supplementary light experiments, the taste of lettuces grown in different subsystems is tested on-site.

Table 11 - Analyses to be made in experiment cycles

Experiment cycle	Analysis	Aim
1. Spatial distribution	Leaf content	To determine whether lettuces sufficiently uptake nutrients from sub-systems and soils with different planting distances.
	Chlorophyll	To find the presence of biotic stress factors and also of abiotic issues such as light, drought and pigment inhibiting. With narrow

		planting, leaves of lettuce can shade each other and lead to reduced plant growth.
2. Micro elements in aquaponics	Leaf content	To measure nutrient uptake and determine nutritive value and to identify if it is suffering from a nutrient deficiency.
	Chlorophyll	In the first experiment, this analysis will be made to compare chlorophyll content with hydroponic experiment.
3. Supplementary light in hydroponic	Leaf content	To measure nutrient uptake and determine nutritive value and to identify if it is suffering from a nutrient deficiency.
	Chlorophyll	To find the presence of biotic stress factors and also of abiotic issues such as light, drought and pigment inhibiting.

After conducting experiments in the different subsystems, the best performing subsystem for each, hydroponics and aquaponics, will be used for the pilot scale experiments.

5.3 Pilot-Scale Experiment

The pilot-scale experiment will be conducted based on the recommendations resulting from the experiment. It aims at applying the recommended technique on a larger and more commercial setup to further test the viability and impact of the technology at the Nile River Basin and further in the Mediterranean on both technical and socio-economic levels. The production area is expected to increase; however, the most notable change is expected to be in the productivity increase from the same greenhouse area, potentially reaching up to 5 -10 times. Water consumption per unit of food (crops and fish), as well as electricity demand for circulating the water, will be measured and compared. This is to ensure resource optimization.

6. CONCLUSIONS AND NEXT STEPS

Global challenges such as population growth, demands for increased food production, and the pressures on resource (in addition to issues such as climate change, soil degradation, water scarcity, environmental pollution) are on the rise. There is an urgent need to find alternative, sustainable, and reliable ways to secure food supply. Innovative agriculture techniques such as hydroponics could provide part of the solution to these problems.

That report provides a description of the case study in terms of its socio-economic profile, its key Ecosystem Services (ES) and Water Ecosystem Food and Energy (WEFE) Nexus issues, positioning that case study in the three-level nature of AWESOME methodology. The research of the environmental and socio-economic condition of the Mediterranean and river basin level forms a prerequisite for the selection of the stakeholders that will be engaged to collaborate with the research team throughout the project. The state of the art methodology of convening the MAWGs is presented showing its linkage with the research towards smart agriculture and food security policy. On the local level are presented the experiments with hydroponics, aquaponics and their subsystems that have been rarely studied (e.g., sandponics). The lab- and pilot scale studies of the AWESOME project aim at filling this knowledge gap and providing a basis for future works. These case studies can contribute to the improvement of the use of hydroponics and aquaponics in agricultural settings.

There is a strong linkage between the work of WP6 and the other WPs, mainly lying on the analysis at the micro level (WP5), the meso level (WP2-WP4), the macro level (WP2-WP3) and the increase in dissemination (WP7). The WEFE assessments and Ecosystem Services identification at the case study level included in this report will be cross-referenced in Task 2.5 of WP2 in order to arrive the at economic valuation of the Total Economic Value of key ES on the meso level. Additionally, based on the stakeholders' feedback from WP6, the outputs from the experiments on the demo site will be evaluated in order to ensure economic profitability as well as social and environmental sustainability. The work in the MAWGs will ground the impact of the experiments on the micro level in real world situations and increase their practical application. The outputs of WP6 will be also used in order to validate the candidate WEFE portfolios of WP4 based on the policy makers and diverse stakeholders feedback. Finally, in accordance to the Table 2.3 of the Grant Agreement, the main target groups of AWESOME are already invited to participate in the first MAWG: policy makers at case study level, farmers and stakeholders at case study level, policy makers at national level, scientific community, NGOs, industry, business associations, practitioners and farmers (with direct link with WP7 and particularly within their tasks of stakeholders outreach).

The next steps of WP6 will focus on the realization of workshops in six diverse frameworks. The first one will be conducted in two parts. One with stakeholders of the micro level in Arabic language (with physical presence) and one with stakeholders from the meso level in English (virtually) aiming to extract the key drivers, to validate the existing initial stakeholders map and produce a series of mental maps. The first one will take place on July 5th 2021 and the second in Summer 2021. The resulting and validated mental maps will be combined in order to create an holistic WEFE Nexus systems map. The focus of the second round of workshops will be on the AWESOME modelling scenarios and the Ecosystem Services that are examined in WP2 and WP3. It will take place in October 2021, with the aim to present the initial scenarios and identify, prioritize and evaluate the Ecosystem Services. The third MAWG workshop will take place on March 2022 continuing with the theme of Ecosystem Services aiming to validate the initial findings and evaluate the inputs.

The fourth, fifth and sixth MAWG workshops will take place in the third year of the AWESOME project focusing respectively on capacity development (skills gap assessment), validation of model and local workers training.

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