Mediterranean Agronomic Institute of Montpellier

Montpellier University

Institut Agro

MASTER 2

ECONOMICS

"MEDITERRANEAN FARMING SYSTEM DESIGN FOR A SUSTAINABLE FOOD-SYSTEM"

Thesis submitted by: **KËRTOLLI Emirjona**

Multi-criteria analysis of on-farm climate change adaptation strategies in Egypt

Supervised by **Hatem, BELHOUCHETTE**

September 2022

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“The Mediterranean Agronomic Institute of Montpellier neither approves nor disapproves the opinions expressed in this thesis. The opinions herein are solely those of the author.

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Abstract

In this century, the hardest challenge that the world has started to experience is climate change, as a short term solution adaptation to climate change is becoming a more prominent topic of discussion everywhere around the world. The objective of this paper was to identify adaptation strategies that will have an impact on water scarcity and assess the most feasible strategy that can be implemented in the study area. The proposed adaptation strategies were evaluated through a transparent tool for selecting several interventions on-farm with the help of experts. We demonstrate how such an approach might enable comprehensive, transparent assessment that synthesizes the expanding body of knowledge in a policy-facing manner using several adaption alternatives. The majority of the adaptation options that the MCAs chose as the most feasible to be implemented in the region also involved significant levels of technical, social, or institutional complexity, so that does not mean that these interventions will not have any barriers. The findings in this paper indicate that the most feasible adaptation strategy for the study area is raised bed cultivation and the least feasible is giving loans to the women.

Author keywords

Climate change, adaptation, feasibility assessment, multi-criteria analysis.

Résumé

Au cours de ce siècle, le défi le plus difficile que le monde a commencé à rencontrer est le changement climatique. L'adaptation au changement climatique, en tant que solution à court terme, devient un sujet de discussion de plus en plus important partout dans le monde. L'objectif de ce document était d'identifier les stratégies d'adaptation qui auront un impact sur la pénurie d'eau et d'évaluer la stratégie la plus réalisable qui peut être mise en œuvre dans la zone d'étude. Les stratégies d'adaptation proposées ont été évaluées à l'aide d'un outil transparent permettant de sélectionner plusieurs interventions à la ferme avec l'aide d'experts. Nous démontrons comment une telle approche peut permettre une évaluation complète et transparente qui synthétise le corpus croissant de connaissances d'une manière orientée vers les politiques en utilisant plusieurs alternatives d'adaptation. La majorité des options d'adaptation que les AMC ont choisies comme les plus réalisables à mettre en œuvre dans la région impliquent également des niveaux significatifs de complexité technique, sociale ou institutionnelle, ce qui ne signifie pas que ces interventions ne rencontreront pas d'obstacles. Les résultats de ce document indiquent que la stratégie d'adaptation la plus réalisable pour la zone d'étude est la culture sur lits surélevés et la moins réalisable est l'octroi de prêts aux femmes.

Mots clés

Changement climatique, adaptation, étude de faisabilité, analyse multicritères.

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Emirjona Kërtolli

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Introduction

1. Background

Nowadays, climate change (CC) is one of the main issues that the world is dealing with, if we were talking about climate changes 40 or 50 years ago, it would not be considered a problem since the effects were not severe, so a small number of people would know what it is about, and why is important for the continuation of mankind. However, today the situation has changed, there are places around the world that face every day with the effects of climate change, such as rising temperatures, droughts, lack of water, rising sea levels has caused the disappearance of several islands, floods, etc. Climate change is, without a doubt, the greatest danger to world stability in this century and it will be more severe in the coming one (Adger et al., 2003).

The most affected sector is agriculture, where due to climate changes there has been a decrease in agricultural productivity and food availability, where changes in temperature through the period 1980 to 2008 caused a worldwide reduction in the productivity of maize, the reduction was 3,8% during this period, and yields of wheat were reduced by 5,5% (Ali and Erenstein, 2016), increased food insecurity, increased disease on crops, weeds, also changes on precipitation has a direct effect on agricultural production as it causes extreme events for instance droughts or floods, depletion of water resources, people having less access to food can cause humanitarian crises (Tubiello et al., 2008).

So climate change is an actual problem that will continue to change and the risks that will bring in the future are uncertain, so that is why it required a solution when one of the short-term solutions that can cope with the effects of climate change is adaptation. The core of adaptation is to deal with the negative effects that come from climate change while adapting to those changes (Adger et al., 2003). In recent years, adaptation is a term widely used as the situation is escalating, and quick solutions must be found that have no adverse environmental impacts and not only.

Adaptation in agriculture or any field has not started today or even 100 years ago, human society has adapted since it was created to the changes that may have been created during different periods of time, the best example is people in rural areas that have learned to live with climate changes through time even not by choice, they have learnt to adapt agricultural practices, proper use of natural resources, to create risk-management structures, etc.

In this paper, the case study will be developed in Egypt, where climate change has affected mainly agriculture, where the most important input for production which is water, is not available. We have to acknowledge that smallholders' farmers in Egypt have one main goal that is food security, after they produce the amount that is needed for their household they are not interested in any adaptation strategy as it might be costly for them, sometimes they do not have enough labour, land, or water (Dryzek et al., 2011). The worst scenarios that might happen if the farmer in Egypt is incapable to adapt with climate change could result in displacement, social interruption, illness and death (Masud et al., 2017). What are critical to increasing farmers' adaptive capabilities are access to water, farmer experience, financial support, agriculture not being the main source of income, technology, and better access to markets, capital, labour, and land (Gbetibouo et al., (2010).

2. Objectives

One of the research's goals is to identify adaptation strategies that are in accordance with the situation in Egypt while exploring the strategies that farmers have been using through the years and focusing on the constraints that a farmer in Egypt will face while adapting these strategies. Lastly, the main

objective is to make the feasibility assessment for choosing the most suitable interventions by using an MCAs.

The questions that this paper will answer are the following :

-Are these intervention choices similar among farmers in Luxor?

-Which of the interventions is more feasible to get implemented in the area?

3. The contribution of this paper

Going through different papers about climate change and adaptation strategies in agriculture, I encountered two main problems first these researches are done with no reference to traditional knowledge, so the findings of this study will enhance the knowledge about traditional practices which will contribute to research about climate change adaptation, policy formulation, or adaptation in the local level, secondly, there are not any studies about adaptation strategies implemented on-farm in Luxor, mostly these studies are done in regional or national scale, also to choose adaptation strategies in the study area the researches have not been using MCAs as a tool, but other analysis that sometimes were not relevant.

Also, what and how adaptation strategies in agriculture are implemented in Luxor is not extensively documented at the local level, so this can pave the way for many researchers that are aiming to work on adaptation strategies in the Luxor region. As a result, this paper will have several contributions such as 1) examination of the response to climate change that farmers have done in agriculture practices in Luxor 2) justification of the use of these adaptation strategies, 4) assess the impacts of these strategies in the farming system, 5) making feasibility assessment for the chosen interventions. As a result, this research will elaborate on the adaptation strategies on the farm while giving importance to the farmer's experience and knowledge.

This paper after the introduction will be organized into four parts, where :

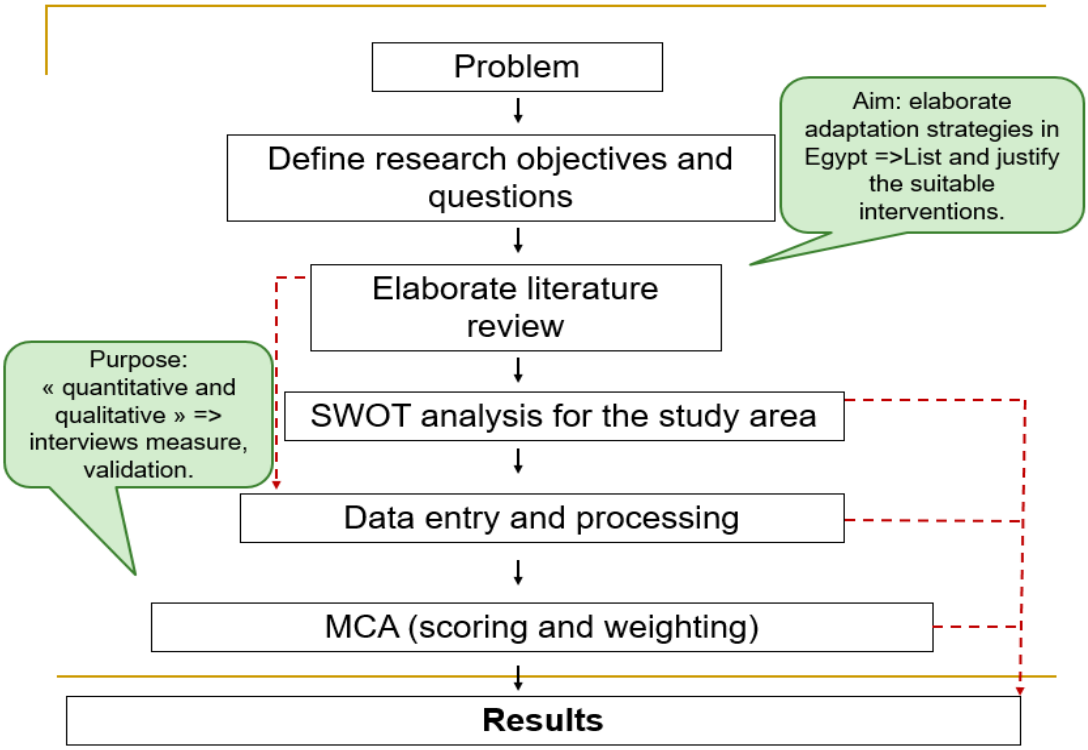
The **first part** of this paper consists of the literature review, where I have explored different papers about adaptation strategies, the process of it, and how can we track these strategies after we implement them.

The **second part** is about the methodology, which is based on using MCAs as a tool to analyse the adaptation strategies in Luxor.

The **third part** consists of the results obtained from the use of MCAs and the analysis of these results.

Lastly, the **fourth part** has to do with discussions, conclusions and recommendations.

Outline of the thesis:



Part I

Literature Review

I. Chapter I

1.1. The elaboration of the scientific literature

In this century, the hardest challenge that the world has started to experience is climate change. Before was considered as a far-away problem with impacts only on the environment but nowadays is impacting the whole system significantly (Purwanti et al., 2022). Climate change has become more widely acknowledged during the past ten years because people are getting more educated, also technology and media are playing a role in the spread of information.

According to many studies, the sector that is severely affected by climate change is agriculture and according to several studies, the effects will be more severe in the future. There are many factors that have made the situation vulnerable such as insufficient adaptability, the geographical position is a disadvantage for these countries as some of them already have high temperatures, so an increase by one degree through the years can cause problems for instance in production, consequently, food security will be the next issue to deal with. For instance, two elements are crucial for livelihood in Africa and in some parts of Asia and South America, water and food, where many people, particularly the poor, rely on local supply networks, so due to climate change in the near future, it will be hard to secure these two elements for them if the situation gets escalated (Nhemachena, 2009). So, climate change will have the greatest impact on people that are not stable financially and agriculture is their main source of income.

According to IPCC (2014), one of the ways that agriculture could be affected is directly through water availability, so there is a significant influence on the water supplies over all regions that already have issues with water scarcity, for instance, in some countries the consequences are already being felt, for example in Egypt, Lebanon, Jordan, Ethiopia, etc., and these countries are the first one that must take action as soon as possible, to prevent the effects before all this to turn into a catastrophe with more serious consequences.

1.2. Adaptation to climate change

Adaptation is mentioned by several international organizations and conferences regarding the importance to adapt with climate change and also specifying that the countries at risk are developing countries, so there is an urge for adaptation that already is having high costs, but how can we define adaptation?

In this paper, first I define the term adaptation as suggested in numerous articles, where some researchers see it as adjustment, change, policy option, long-term strategy, or progressive, some others as transformation, initiative, etc., it might seen as minor differences between one definition to the other but these changes may create various expectations from the stakeholders (Levina and Tirpak, 2006). In the report of IPCC (2001, p. 62), it is stated that « adaptation is an adjustment in natural or human systems in response to present or anticipated climatic stimuli or their consequences that mitigates harm or capitalizes on advantageous chances ». Meanwhile, UNDP's (2004, p.36) definition states that « Adaptation is a process by which strategies to moderate, cope with and take advantage of the consequences of climate events are enhanced, developed and implemented.». Also, UNDP (2004) suggested another definition of adaptation at the country level, so climate change adaptation strategies for a nation are a comprehensive program of actions with the main aim to reduce the effects of the negative effects of climate change. It is generally thought that adaptation at will repairs the consequences of climate change but in fact, adaptation is more than that it is a mechanism to lessen the effects of climate change and seize any new possibilities that may arise as a result of these changes, this depends on the objectives that stakeholders have for undertaking adaptation, in spite of

that in this paper adaptation will be considered only to repair and prevent the consequences that may come from climate change.

Adaptation strategies are not the same for each sector, so each sector adapts different strategies, according to the objectives that we want to archive, in this study the adaptation strategies will be focused on the agricultural sector, particularly on-farm and we will consider those interventions that have an impact on water and soil quality. So in this paper adaptation in agriculture will be defined as the intervention made in the farming system to improve the incomes and environment, the implementation of the chosen intervention will be mainly done by the farmer in cooperation with other institutions. In the adaptation process, many actors are needed to take parts of it, such as farmers, local communities, researchers, policymakers, agricultural extension services, and government and private organizations (Bryan et al., 2013).

Adaptation for water is not that easy to cope with it, but farmers, and institutions for the moment have found a way to deal with this problem by building dams, and reservoirs or better-improving water management, reducing the level of water waste through policies such as taxes, fees, etc. Also, Krysanova et al., did a study in 2010 on three continents Africa, Asia and Europe, and it concludes that European adaptation strategies regarding water due to climate change were more advanced compared with the other two continents, this is not a surprise due to the fact that Europe it is considered a rich continent compared with two others continent.

1.3. Types of adaptation strategies

There are different types of adaptation and IPCC categorizes them into different groups. The first type is called anticipatory adaptation or proactive adaptation, which occurs before the consequences of climate change are apparent. The second type is autonomous adaptation also called spontaneous adaptation occurs naturally without conscious reaction to climate, for instance, natural systems do not require human intervention to adapt to climate change because adaptation most of the time occurs through autonomous processes such as phonological or genetic changes, phenotypic acclimation, migration of animals to areas that are more suitable for living, etc., certainly humans can intervene in natural systems in cases where the purpose is to induce certain changes such as lowering non-climate pressures or managing migration (IPCC, 2014). Similar to autonomous adaptation is a private adaptation but in this type, it is needed the intervention of humans, so this adaptation happens when individuals, households, or private enterprises for their self-interest begin and carry out adaptation in response to climate hazards, which are frequently caused by specific severe occurrences. For instance, most of the time private adaptation is made at the local level, in the cases that the country is a developing country, it is hard for the government to be an active part of the process, due to many factors, so mostly local actors, sometimes even NGOs take actions for adaptations.

Meanwhile, planned adaptation is the opposite of spontaneous adaptation, this type of adaptation occurs due to a policy that was undertaken by responsible institutions at the national or local level, this intervention can be taken by other organizations besides the government, like the interventions that are taken by SupMed project with the support of the farmers in Egypt and Lebanon. So in the case of a planned adaptation, it is needed a close collaboration of farmers with the government or with the private sector, extension agencies, etc. If farmers use adaptation strategies to adapt to climate change indirectly will help the government to provide viable agricultural programs and policies. (IPCC, 2007) However, in our context, there is a need for a close relationship between the farmers and the researchers that are working on this project but less with the government for several reasons that are not the focus of this study.

Meanwhile, there is another type called public adaptation is when government take initiatives in the interest of society, similar to planned adaptation but this type of adaptation supports most of the time

the individual or private adaptation, nevertheless, even if an individual takes action on adaptation strategies there are many cases where public policies of a country are discouraging them (Stringer et al., 2009).

Further, adaptation can divide into two main levels that are national and international levels. The national level has four sub-groups, national, sub-national, regional, and local (Tripathi and Mishra, 2017) for instance, the national level where has to do with the output that comes from agriculture, national policies like subsidies or taxes, taking into consideration international policies regarding adaptation, promotion of alternatives for farmers, water management, etc. From all these levels local adaptation is very important, due to the fact that local actors are the first to recognize the seriousness and the effects of climate change.

1.4. Adaptation process

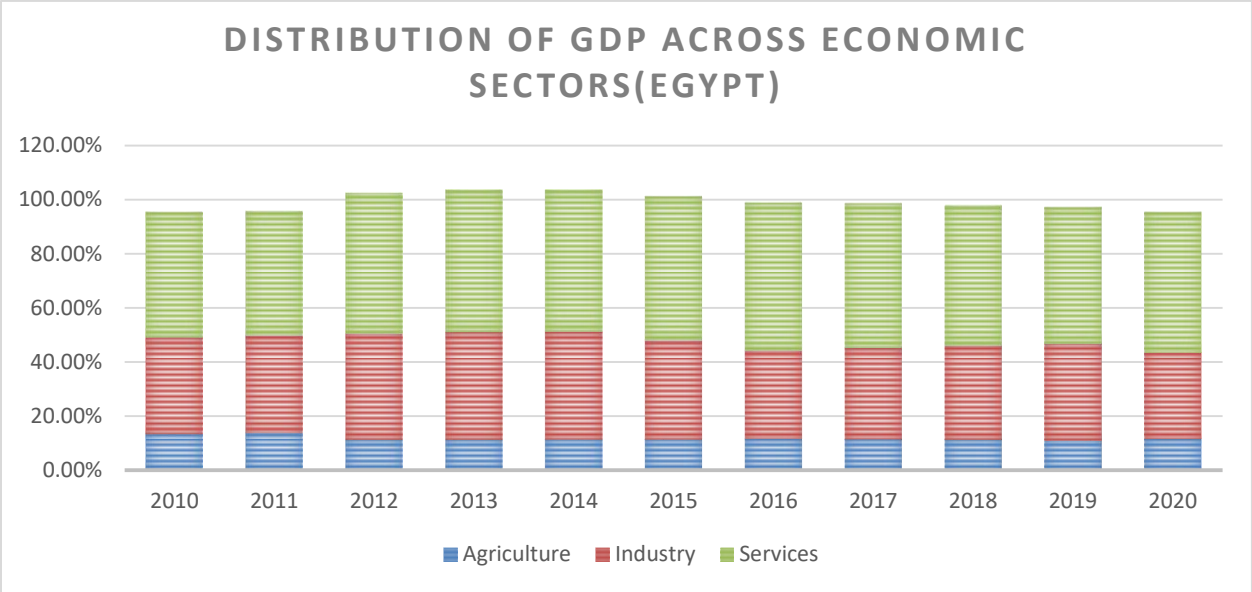
Agriculture adaptation is considered the intervention done in the farming system to archive multiple farming goals and at the same time cope with climate hazards. These interventions depend on the farming goals, which vary from farm to farm, one of these goals can be to increase production, profit, food security, or better management of water resources (Kandlinkar and Risbey, 2000).

IPCC in the report of 2001 suggested that is necessary to take measures as soon as possible, especially the countries that are not in favourable areas such as Egypt, however, years passed but the situation stayed the same, same issues, higher risks and hardly any taken measures, so in the report that was published in 2014, IPCC re-emphasized the importance of adaptation strategies in these countries and re-suggested to the governments to make adaptation strategies a priority. Furthermore, World Bank in the report done in 2006 about climate change states that the effects of these changes are quite visible and it is very urgent to adapt agricultural systems to climate change, even though in the near future there might be a decrease the GHGs emissions, that will not stop the trends, so adaptation it is important all the time may significantly lessen the negative economic impact (Shrestha et al., 2018).

Regarding adaptation strategies, in Egypt, has been seen as the responsibility of the government, but the government have been delayed in taking appropriate measures due to a lack of funds, professional staff, income to finance these projects, etc. All this has led to the escalation of the situation to the point that is today (Trærup and Stephan, 2015).

In the economic outlook done by the World Bank for Egypt, it was stated that agriculture's contribution to GDP between 2000 and 2020 has changed, wherein 2010 the contribution was 13,34% to the GDP, and in 2019 there is a decrease of it (table 1), but still, agriculture remains a crucial sector in the Egyptian economy (World Bank, 2017), despite that agricultural productivity is not so high due to the size of farms where the average size is 1.05 ha in Egypt and 0.4 ha in Luxor, although Nile river is the main water supply of the country as there are not many water resources (fig.1).

Table 1. Distribution of GDP across economic sectors from 2010-2020 in Egypt



Source: World Bank, 2020

Adapting agriculture to environmental changes is an immediate need in Egypt because the great majority of farmers are smallholder farmers and agriculture is their main source of income, they have a lower education level, dependent on natural resources, and issues on food security and availability of water, lack of support from local institutions, lack of access on information, technologies and infrastructure, etc., (Langyintuo and Mungoma, 2008). All these are barriers that make it hard for them to face the adjustment to these changes, therefore private or individual adaptability is unlikely to occur. Certainly, there are cases when these farmers managed to adapt but it was not enough to compensate for losses caused by climate change (Tripathi and Mishra, 2017). Anyhow the trend is that these effects will be even more severe in the coming years if appropriate measures are not taken today, therefore the adaptation according to IPCC (2014) is the most effective measure for the moment, till science finds another solution (Purwanti et al., 2022).

Figure 1. Water resources in Egypt from 2011-2019

Source : CAPMAS, 2019

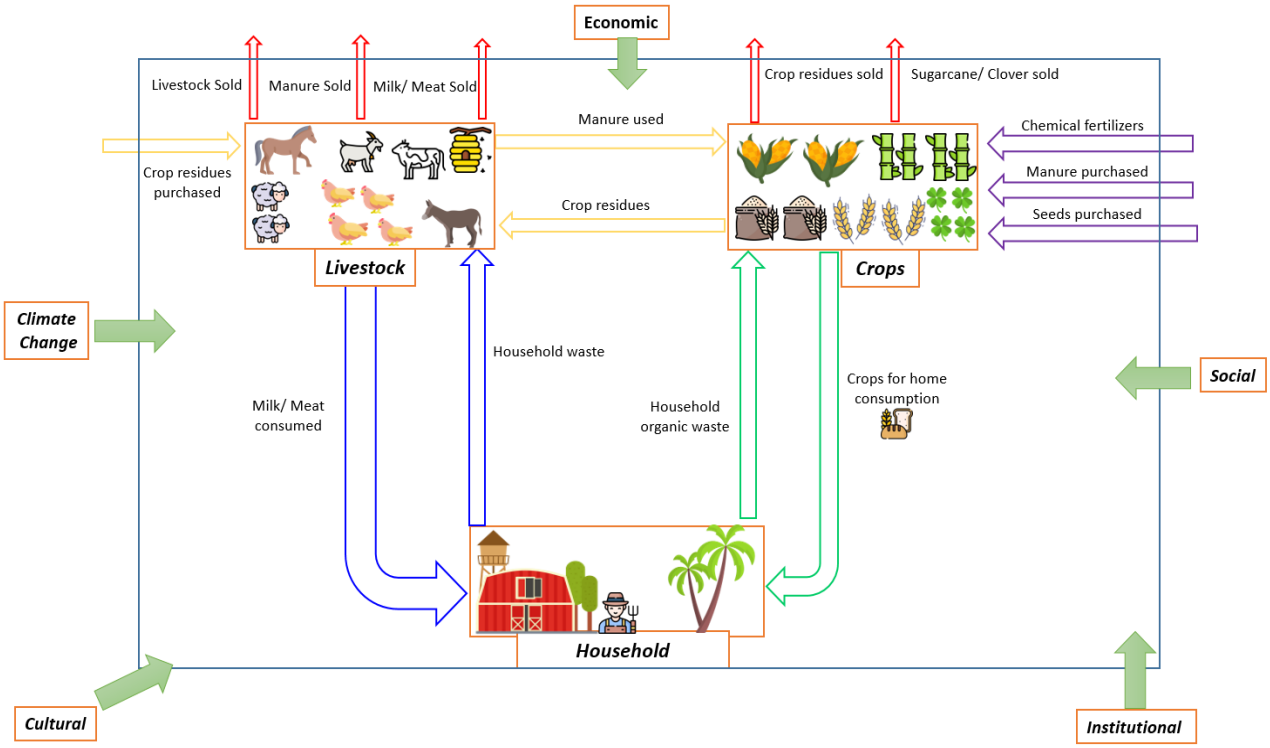
In order to identify appropriate adaptation strategies that farmer needs to adopt in order to decrease risks and enhance capacity, is required comprehensive information on risks and vulnerabilities (IPCC, 2014). It is critical to involve people with diverse expertise, experience, and backgrounds in formulating a strategy for adaptation in order to tackle and establish a shared approach to resolving the difficulties also this can help to implement successfully an adaptation strategy.

Farmers in Egypt have several reasons to adapt their farming practices to those changes, however, there can be mainly two reasons that a farmer will want to adopt, first of all, it can be to increase profit and secondly to avoid risks that come from climate change, one of the risks that might come due to these changes is food insecurity (Asayehegn et al., 2017).

There are different adaptations options suggested that might reduce vulnerability to climate change in agriculture, these options can be in crop, farm, local or national level, some examples are the interventions in sowing time, changing the crops or using heat-tolerant varieties in case of the region that is suffering from drought, or shifting from chemical fertilizers to organic fertilizers. Farm households that employ different strategies on their farms are therefore more likely to have greater food security, higher income and also less vulnerable than those that do not (Ali and Erenstein, 2017 ; Abid et al., 2015).

Because of the diversity and complexity of farming systems (fig.2) and farmers' livelihoods, the effects of climate change on smallholder farms will be specific for each farm and difficult to assess, but one of the solutions that can help with the challenge of comprehending climate change consequences at the farm level can be documenting local knowledge, attitudes, and practices (Shrestha et al., 2018).

Figure 2. An example of a smallholder farming system in Luxor, Egypt

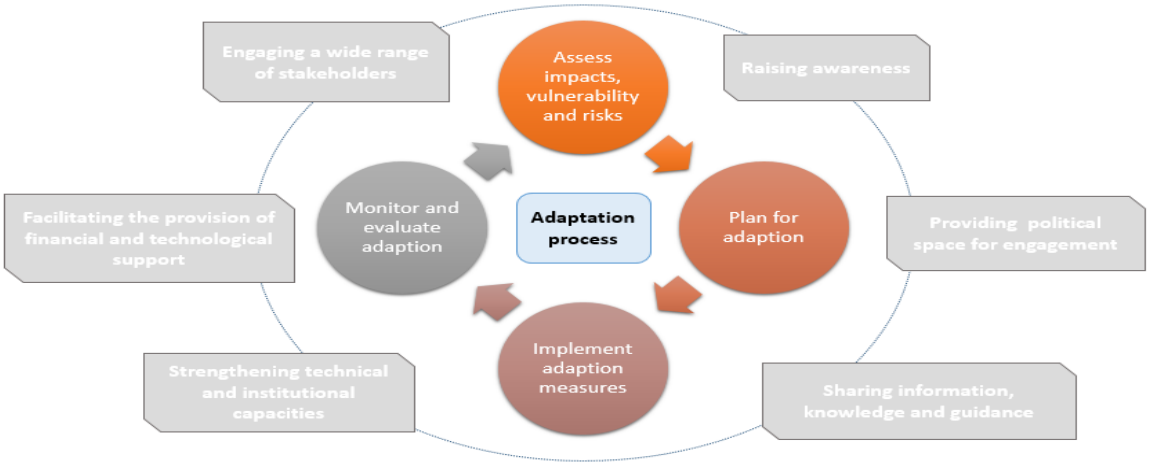


Source: Author, database of SupMed

Regardless of the level, an adaptation strategy should be well designed, it is needed a detailed analysis of the situation, where first we must analyze and identify the vulnerabilities that are caused by climatic hazards, secondly, it is important to identify the potential risks that might be due to climate change and also a review of adaptation options that can be implemented in the area where these

projects are taking place and then choosing the best option that is suitable with the problem that we want to solve after this the other steps have to do with reporting, monitoring, reviewing, etc., (fig 3).

Figure 3. Cycle of adaptation



Source: Adopted from UNFCC website

After going through different literature about Egypt, we can agree on one point that there are two main barriers to adaptation, first is the financial resources and second natural resources such as water, and soil quality, also there are other barriers but I see them less significant compare with those two. Other studies point out that the barriers to adaptation differ from one farmer to another farmer, this is because of some other factors like education, lack of information, access to land, farming experience, size of the farm, shortage of labour, perceptions of the need to change, etc., (Deressa et al., 2009). Another constrain is about beliefs, for instance, farmers in Luxor are aware that unlimited use of underwater will have negative effects, such as depletion of water, but they continue to use it without any limitation as they only have one goal which is to have higher yield and revenue (Tripathi and Mishra, 2017).

1.4.1. How can we assess their impact

After adopting a strategy, tracking is an important element for the effectiveness of this strategy so monitoring of an intervention is needed throughout the process till the outcome of it.

«Tracking refers to the monitoring of adaptation processes and outcomes along a continuum » (FAO, 2017, p. 47). While trying to monitor the adaptation in agriculture, we can face many challenges, for instance, several interventions, since several adaptations are taking place at the same time then the person responsible for monitoring the adaptation may bypass some parts and have under-reporting. The high cost of data collection can be one of the challenges that might cause problems to monitor an adaptation, in the case of this paper, it will be not as if the project is financed and everything is calculated in detail (Ford et al., 2013).

There are several frameworks suggested to monitor adaptation processes and also the outcomes from it, for instance, FAO has suggested a self-evaluation to assess the resilience of farmers and pastoralists (FAO, 2017), and the level of application can be for household and community, another framework it is suggested. After adopting the chosen strategy in agriculture, one way to check for its effectiveness of it might be by checking if food security is increased, also if there is a reduction in property damages, diversified livelihoods skills, etc. (IPCC, 2014; Ospina, 2016).

Farms have different sizes of lands, numbers of employees, sizes of families, resources and reasons for producing some of them for self-consumption, others for self-consumption and market, and another group of farmers only for the market, due to that farms vary even in terms of their level of vulnerability. So it will be hard to make a comparison between farms to see which one has the better adaptive capacity, but if we group the farms into farm typology then the comparison will be easier and more relevant but it will be not without bias (FAO, 2017).

1.5. The level of adaptation in Egypt

Over the years farmers in Egypt have adopted some strategies regarding climate change, where the most common are the strategies that are inexpensive for them, for instance, the use of different varieties, disease-resistant crops, new fertilizing practices for crops, protecting soils, mixed farming (crop-livestock), inter-planting, zero tillage, nowadays conservation agriculture (eg. agroforestry) is becoming a common adaptation strategy, but it is more expensive compare with the other strategies mentioned above and not a common option for small farmers in Egypt, etc. (Thornton and Herrero, 2014).

Some researchers emphasize that the farmers are the ones that do the adapting process with the support of government, agencies or international actors, but in the reality, who is doing the adaptation process in Egypt?

The study of Dryzek et al., (2011) analyzed who does the adapting process in general, without taking the consideration if the country is developed or developing, so based on this study to answer you need to take into consideration micro and macro scale, so in the micro-scale or farm-scale farmers are doing the adapting but not in the regional or national level, so in the macro level is the government with its agencies and other institutions in charge. This is the theory in an ideal country that every institution works in accordance with the duties, but in Egypt, the situation is a bit complex, there are cases where only the farmer does the adaptation of agriculture regarding climate change, without any support from government or other institutions, and there are other cases when the government tries to convinced the farmers to adapt with climate change, but due to the farmer's beliefs, perceptions regarding the issues, and other factors they do not accept to adapt their practices (UNFCCC, 2009).

Adaptation in agriculture, in general, entails two sorts of interventions to agricultural production systems, the first intervention is the improvement of diversification, which entails engaging in drought-tolerant and/or temperature-resistant producing activities, as well as activities that make optimal use of and take full advantage of current water and temperature circumstances.

1.6. Maladaptation

The benefits from adaptation strategies, unlikely from other solutions, can be seen practically immediately, so it does not take a long time to understand if a certain strategy is going well, however, the greatest impact will be later on (World Bank, 2008). Nevertheless, we have to acknowledge that adaptation can bring maladaptation which means that instead of fixing the situation that was intended, the opposite may happen that causes an increase in vulnerability rather than lowering it, but also because of it, there will be needed new adaptation strategies to fix the maladaptation (IPCC, 2001).

Maladaptation can reinforce vulnerabilities that already exist, disperse vulnerabilities, and generate new vulnerabilities. In case of dispersing vulnerabilities, for example, in Vietnam they implemented new policies to manage floods in lowlands such as creating hydroelectric dams and forest conservation, however, these policies helped the people in low lands but caused difficulty for mountain people by undermining access to land and access to resources that were used to have from the forest. This attempt for adaptation in low lands caused vulnerability for people in uplands to the effects of climate change.

Therefore, to avoid maladaptation several steps must be followed, first it is needed that adaptation projects be designed by professional and experienced people, also during the designing process, there should be an involvement of local actors. Adaptation strategies need to be new and not similar to other adaptation strategies that have been already implemented, by incorporating adaptation strategies into current projects will not bring the results that are expected (Eriksen et al., 2021). Although in many projects for adaptation strategies sometimes there is no clear information about the benefits that a certain adaptation strategy will bring, which are the costs, the limits as adaptation strategies have their limits because there is a diversity of vulnerabilities, that one adaptation strategy cannot solve, furthermore in developing countries there is the non-existence of governmental support on adaptation, this lack of support is on researches, awareness, funds, infrastructure, etc.

Part II

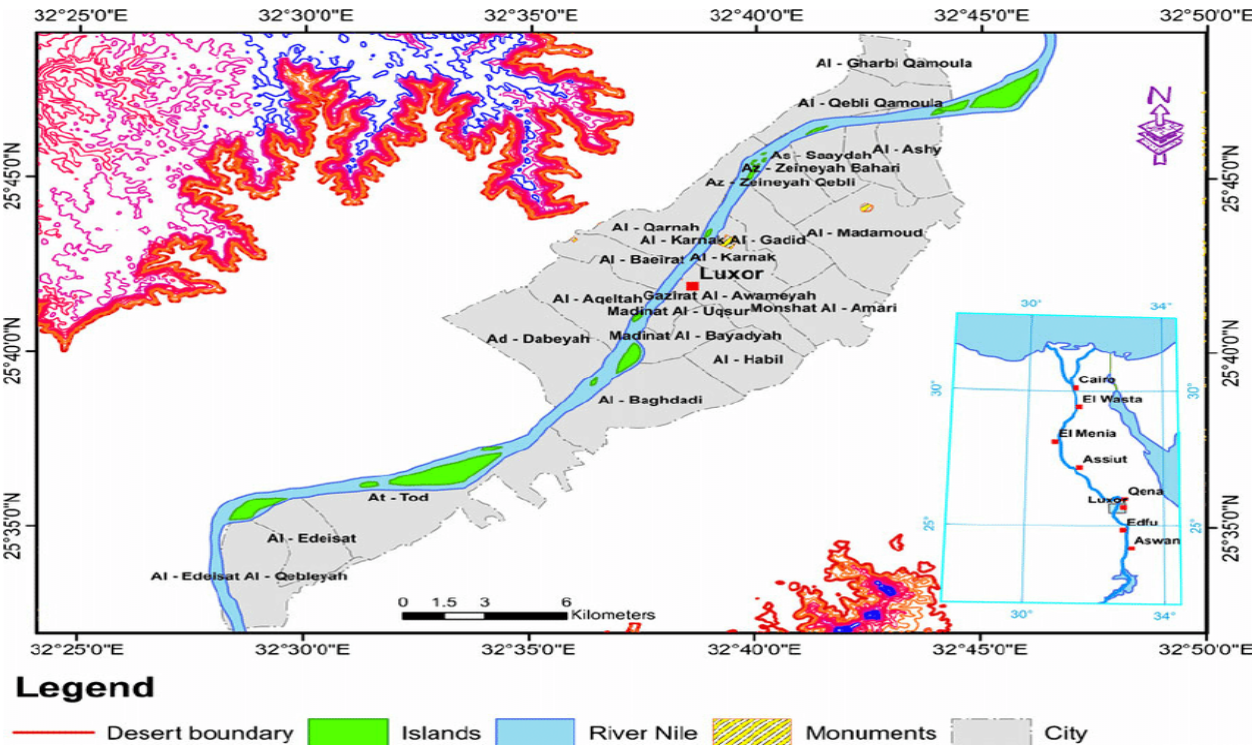
Methodology

2. Chapter II

2.1. Study area : Luxor, Egypt

My internship took place at the SupMed project, this project intends to help farmers in Egypt and Lebanon to adapt to climate change by using agroecological methods and better irrigation water management. The study area of this paper is Luxor in Egypt, concretely the sample is taken from two villages Elboghdadt and Elzanakta that are severely affected by climate change, where the most affected sector is agriculture causing problems with food security and water scarcity.

Figure 4. Map of Luxor Governorate



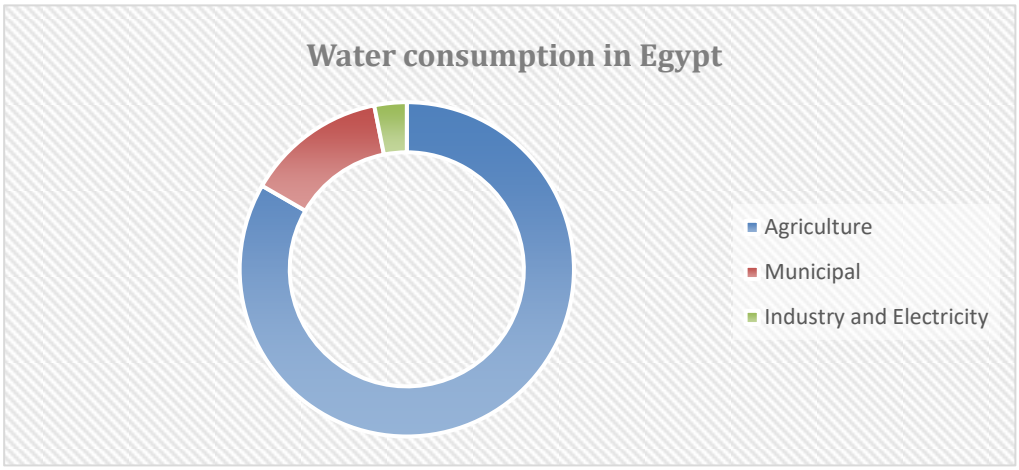
Source: Ayman, 2013

As is shown in the map (fig. 4), Luxor is located in Upper Egypt, with a total cultivated area of 460 km2, so on both sides of the Nile Valley, agricultural land makes up around 73.8 per cent of the total area, while urban areas make up about 19.4 per cent and barren ground makes up about 6.8%. Of all the sectors, agriculture is the largest consumer of water not only in Luxor but in the whole Egypt, however, the contribution to the GDP is not that high due to the low yields (Ayman, 2013).

Some of the factors that have caused low agricultural yields are the climatic ones, for instance in January, the highest air temperature is 22.9 degrees Celsius, while in July, it is 40.9 degrees Celsius, and rainstorms occur rarely and at different times throughout the year, also the Nile River and irrigation canals provide the majority of the area's surface water hydrology (Ayman, 2013) (fig. 5), therefore farming population is poor. The farming population in Luxor consists of small farming households with an average size of farm 0.4 ha, and lower yields, consequently, they are poor, main crops that these farms cultivate are sugar cane, winter wheat, grain and fodder corn, alfalfa, berseem, and tomatoes. Water consumption in Luxor has raised the last 50 years, because of various changes such as the expansion of agriculture, population and economic growth, and certainly, during the last decade, there are more tourists than before (Karajeh et al., 2013). According to AMCOW (2018),

Egypt uses more than 80% of the water that comes from the Nile River only for agriculture (fig. 5), and the rest goes for other sectors.

Figure 5. Water consumption in Egypt



Source: AMCOW, 2018

Moreover, Luxor has agriculture primarily for economic development as well as for food security, employment, etc., but in recent years it has been noticed that this dependence on agriculture has decreased as they started to give importance to other sectors as well. Some of the characteristics of Luxor that may be considered as threats to implementing the adaptation strategies are population growth, lack of sufficient water resources, dependence on imported food, and high unemployment.

2.2. SWOT analysis for adapting options in Luxor

By analyzing and going through different researches about Egypt, I came out with a SWOT analysis of the situation in Luxor in the context of agriculture, this analysis is needed later one to justify the chosen adaptation strategies. The SWOT analysis identifies the strengths, weaknesses, opportunities and threats that need to be considered and addressed in the Luxor region, regarding adaptation strategies for agriculture. The four elements of the SWOT analysis I divided into two groups the first group includes the strengths and opportunities that contribute to archive the adaptation strategies that we are going to select and the second group includes the threats and weakness that lists factors that will inhibit the implementation of these strategies. Greater knowledge of the strengths and weakness is essential for climate change adaptation, as these are the ones that on one hand can help the process of adaptation (strength, opportunities) and in another hand can delay it (weakness, threats). Understanding the barriers to adaptation, having a comprehensive awareness of climate change concerns and also knowing the region where these adaptation strategies will take place may help to build favourable attitudes toward addressing the risks and consequences of climate change and help to make the process of adaptation much smoother (Zsóka et al., 2013). Furthermore, because farmers in Luxor are crucial for applying appropriate adaptation techniques, this awareness and understanding may lead to adaptation approaches that lessen the negative implications of climate change (Bardsley and Rogers, 2011).

This SWOT analysis treats external and internal issues of the study area that can be assets or drawbacks for implementing certain adaptation strategies.

Table 2. SWOT analysis for Luxor

Strengths *To archive the adaptation objectives*	**Weaknesses** *Inhibit the implementation of these strategies.*	**Opportunities** *To archive the adaptation objectives*	**Threats** *Inhibit the implementation of these strategies.*
Availability of labor force	Climate arid with low level of rainfall	Attraction of the rural youth	Water scarcity (The depiliation of Nile river)
Several international and regional initiatives are taking place in the region	Lack of knowledge of farmers to implement the certain adaptation	Training for unskilled labor	Climate change
Improved export capabilities	Low incentive of information sharing by experienced farmers	Improving food exports	Conflicts for water use (Ethopia and Egypt conficts for nile river)
Food gap reduced in some crops	Water scarcity as a production constraint	Improvment of production	Urbanization
Diversified production activities	Agriculture production in Luxor is 100% irrigated	Improving water scarcity	Degradation of natural resources
Increased productivity in many crops	Low climate change awareness	Sustainable production methods	Population growth
Willigness of farmers to adapt	Weak institutional capacity		Low interest in soil preservation
Agriculture key pillar of the country's economy	High salinity		Low interest in the conservation of agricultural land
	Low adaptive capacity		
	Fragmented and lack of agricultural lands		
	Nile river main water resource for agriculture		
	Small farming households (average 0.4 ha)		
	Poverty of the farming population		
	Use of unsustainable methods for irrigation		
	Government gives less support to the environmental and ecological issues compare with the economic ones		
	Absence of extension services		
	Food insecurity		
	Desertification		

The education level of a farmer is crucial for adaptation to climate changes in agriculture while having a higher education level means that there will be greater access to knowledge and information so that is a high chance for adaptation and some of them are able to take advanced adaptive practices, the farmers with lower education level most of time are based on their experience (Maddison, 2007). But it is not only the farmer and his knowledge that hinders and can be a threat to the adaptation of strategies in Luxor, there are also other factors that affect, for example, economic, technological, social factors, and institutional where from this one we have the majority of the barriers as the institutions in Egypt do not make enough to help the farmers to adapt with those changes (Masud et al., 2017). Institutional barriers that farmers can encounter are several for instance lack of investment and support, and difficulty in accessing information and data on weather forecasting, this causes farmers to adopt only basic adaptation measures and a very small group manages to adopt advanced measures (Deressa et al., 2009). Furthermore, there are not enough policies regarding adaptation, so there are needed policies that introduce new crops that can withstand the climate

changes effects, soil conservation, water management also new adaptation strategies based on agroforestry, etc. Lack of access to information is not only because of institutions also social characteristics play a role, such as culture, the age that can be a determinant even for the experience of the farmer, or gender, for instance in developing countries women are not a priority to give access to information, or for owning land compare with men, for that reason is difficult for them to adopt the right strategies to cope with climate changes. There are many factors that have been drawbacks to the development of agriculture in Luxor such as water scarcity, urbanization, increase in population, a poor region, availability of agricultural land, salinity, limited access to the Nile river, fertilization, etc. In terms of quantity and quality, Egypt confronts considerable hurdles in addressing the country's water needs. Excessive water use, no effective management methods for water use, some of the water sources being polluted by agricultural waste, and the inability of the government to take appropriate action, are among the major challenges that this sector is facing.

2.3. Current and potential adaptation strategies for Luxor

In the study area, a form (annex 1) was sent to collect information about adaptation strategies that farmers practised in order to face climate change. In addition to this framework, several meetings were organized with the farmers for the purpose of better understanding the practices they used and what were their farming goals, so based on that informationthe experts can suggest new practices but taking in account the vulnerability. From these meetings and information gathering, it was possible to list some adaptation strategies that were currently being used in Luxor and some that were necessary to improve the current situation.

The introduction of improved agriculture techniques is an adaptation action that usually takes place in agriculture. In the Luxor area, this adaptation will consider some new techniques that may help the farmers to increase productivity and profitability and also reduce costs. The techniques that can be used are several for instance one of them is land holding consolidation, which unites several land parcels in one sizeable farm and is owned by one landlord. Various techniques can be used to fix this issue and one of them is land consolidation, as it can lessen the occurrence of land fragmentation. As a remedy for land fragmentation, this intervention is a crucial land management strategy that involves reorganizing the area, creating a new system of landowners and parcels, and building the necessary infrastructure (Beltramo, 2018). This intervention is useful for the study area since one of the main problems of agriculture there is land fragmentation, where a single holding is divided into several plots, and each plot is separated by another holder's property, an irrigation canal, or a drainage canal (Seyam and Bilassi, 1995). There are several factors that have caused land fragmentation in Egypt, such as overpopulation, inheritance, the consecutive Agrarian Reform laws, etc. According to evidence the phenomenon of land fragmentation mostly has been linked to inheritance. Due to the cultural rules in Egypt regarding inheritance, the land has been divided between the sons of the family for generations, this has resulted in reducing the size of agricultural land. If the farmers in Luxor will consider the consolidation of land then it can lessen the occurrence of land fragmentation, and also increase income as there will be more land to cultivate consequently increase of agricultural productivity. In this situation, land fragmentation hinders the growth of agriculture as well as the capacity of individual farms to achieve a sufficient economic dimension (Beltramo, 2018).

Another improved agriculture technique changing sowing dates was suggested by literature as a feasible option to deal with the changing temperatures. This one is not an innovative strategy as already exists among the farmers in Luxor and is a practice that they have used for centuries to adapt to climate change, but is useful and can help the farmer deal with climate changes in the short term when there is no other option. This technique will have the most impact on water, as the sowing

will take place in periods when temperatures are not that high so the crop will need less water as the evapotranspiration will be low.

However, an intervention that is not very common in the area is raised bed cultivation, this intervention can be very useful when land consolidation can not take place, this option uses a small amount of space so it is relevant for farms in Luxor. It is proven that are more productive compared with beds in the ground as in the raised beds soil is more compacted also has better drainage, it reduces the irrigation water as it uses all of it efficiently, prevent waterlogging also there is a reduced use of inputs such as seeds and fertilizers, provides better opportunity to lessen tillage (Kukal et al., 2005). So the farms that have adapted this type of intervention in both irrigated and dry lands there was an increase in production by a minimum of 20% (Akbar et al., 2007).

When it comes to intercropping, Brooker et al., (2015) and Rusinamhodzi et al., (2012) consider it as another improved agriculture technique that can reduce the risk of climate change especially for smallholder farmers as they are more vulnerable compared to others. From previous studies done on farms that do intercropping and farms that do monocultures is proven that with the same amount of inputs intercropping farms can produce more yield with fewer fertilizers and pesticides than the monocultures farm (Sustainability Community, 2021). The farmers in Luxor need to do intercropping for several reasons, first of all, it can help to fight against pests and diseases, also it can strengthen the soil's structure and contribute to better soil quality and maintains a balance in the fertility levels (Li et al., 2006), as the degradation level of soil in Luxor is increasing due to the overuse of land, unsustainable farming methods, and extreme weather events.

Introducing high-value crops such as medicinal and aromatic plants can be another intervention to be considered in the area. There are several reasons that the farmers in Luxor should consider these crops, besides the fact that they are profitable, also these crops adapt easily to climate change compared with other plants. Medicinal and aromatic plants are in high demand, but many farmers in Luxor do not have knowledge and experience on how to grow and harvest them, however even if they get trained to cultivate these kinds of crops it will be hard for them to find a market for selling. The benefits that farmers in Luxor will have by planting these crops will be an increase in domestic and export demand, the selling prices for these crops will be higher compared with traditional crops also the stored period is longer in this way the farmer can profit and sell these crops when the prices are higher, these crops are suitable for the climate of Luxor as they are heat resistant so they will survive in the dry region of Luxor and also increase of incomes from agriculture (Solidaridad, 2022).

Meanwhile, the cultivation of palms and willows is not an intervention that can easily be accepted as the farmers do not see any productivity of planting, however, there are some indirect impacts that windbreaks will have on the farm. Windbreaks such as palms and willows are trees that are planted in a straight line to improve crop productivity and conserve soil and water. By planting them the farm will be affected positively on irrigation efficiency and will lessen spray drift. Also, another impact will be the reduction of evaporation from the dams where farms get the irrigation water. As the main interest of the farmer is productivity is proven that windbreaks can boost crop yield and quality of production (Otway greening, 2012).

An intervention that takes place on a farm scale is the establishment of Water User Associations (WUSs). Water User Associations (WUAs) are groups from the local zone that have an interest in the efficiency of irrigation systems. The benefits that farms in Luxor will have by joining these associations are that there will be and better service to deliver water, there will be a system of maintenance and also it will decrease costs. However, these benefits do not come only by creating or joining these associations it should have active participation and interest of its members for better management of it (Pegram and Mazibuko, 2003). It is important to build trust within the association to

have democratic governing bodies with internal and external controls so there will be a smooth and efficient operation of it. If the association will work correctly with its purpose then the farmer will have several benefits from being a member of it such as there will be equal distribution of water among the farmers without taking into consideration the location that the farm or the size and type of it, this will also help in reducing the theft of water that happens regularly in this area. Also as the government in Egypt can not solve all the issues around the country due to other factors out of the scope of this paper, the WUAs can support them also by maintaining the canals. Overall there will be a protection of water resources from extensive use (World Bank, 2004).

Jat et al., (2006) conclude that the primary goal of laser land levelling is improved irrigation application consequently better distribution and efficiency of water in the field ultimately results in increased savings in irrigation water. So the main aim to implement this intervention in Luxor will be to increase crop yields, also improve the soil and the efficiency of water and fertilizer use. Farmer in Luxor to level the land have used primitive tools such as oxen-drawn that works with animal power mostly cow, but this method is not efficient, and time-consuming and also the animal gets tired so this should be replaced with machines. That is why laser levelling is introduced as an option that will have an impact on water conservation, so it will reduce the water waste as the irrigation will be more efficient and consequently that will eliminate the runoff. In order to provide a flat table-top-like surface, a laser land leveller is far more effective and faster than any tool that farmers in Egypt have been using. By using the machine, irrigation water reaches every portion of the field with minimal waste from run-off or waterlogging. By doing laser land levelling there will be fewer early plants that could not make it to grow due to over or under-watering. With laser levelling irrigation systems are able to evenly distribute water to all plants, resulting in healthier, more uniform growth so eventually crops will mature at the same time, which will have an increase in yield and the least amount of plant loss. Compared to traditional methods, laser land levelling uses less emission-producing agricultural equipment, uses less water-pumping equipment, and it eliminates fertilizer and chemical runoff, reducing water waste and protecting soil and rivers. It is proven by other studies that laser land levelling saves irrigation water by 20%-40% and also increases productivity So there is a reduction of time, an increase in productivity, less use of water and fertilizers, also indirectly it saves electricity, and a decrease of costs (Ats irrigation, 2022).

However, there are several other benefits that come from laser land levelling such as, an increase in cultivable land this happens by doing land laser levelling is proven by the study of Jat et al., 2006 that the plot size in the villages (Elboghdadt and Elzanakta) that were taken as study area was increased from 33 to 80%, this has happened due to the smoothness of land surface that has permitted larger plot sizes for irrigation. In the study by Rickman (2002), he suggested that added farming space will give the farmer the opportunity to restructure the land, which can cut operating time by 10% to 15%. When selecting an adaptation strategy is important also to check for the limitations, so later on to avoid maladaptation that will cause several negative impacts. Some of the limitations of this technique in the study area are the high cost of equipment, the minimum price of a laser land levelling machine is 1400 euros, so not all the farmers in Luxor can afford to buy this machine as most of them produce for self-consumption and feeding livestock and not for selling, but the other option is to rent it. Another limitation can be the need for a skilled operator to set and adjust laser settings and operate the machine if in the area will not be one person that is experienced in it then there will be other additional costs for training also if the person is not well trained than the land levelling will not be done properly so the results will not be as expected, and some studies have concluded that the laser land levelling is less efficient in irregular and small sized fields and in the case of our two villages, the farmer has in average 1 feddan (0,4 ha).

Women in Luxor have unequal access to resources and education, making them more vulnerable to hunger and food insecurity than men so ensuring female farmers in Luxor have equal access to the skills and resources they require to succeed could reduce the number of people living in poverty and hunger in the area, and make them less vulnerable to climate change. By establishing schemes for loans for women can be powerful agents in the fight against climate. For instance, Egypt's Principal Bank of Development and Agriculture which is the main financial institution for finance for agriculture in the country, most of the time many long-term loans to women are denied, as a result, there are fewer women landowners. Land, loans, necessary tools for farming and other resources are not equally accessible to women in Luxor as are to men, so the support that women receive is less if we compare it with the support that men receive. They are involved not only in agriculture activity but even in domestic activities which are hidden economically. In the end, they are more vulnerable to climatic hazards due to the same factors that limit productivity (OXFAM international, 2022; World Food Programme, 2021). Land and other resources are not equally accessible to women in Luxor.

Droughts have caused low productivity of fodder consequently the price of fodder has increased, that have increased the reliance on farmer fodder that comes from other areas or is imported making the farmers vulnerable to fluctuations in the price of fodder.

This has made herders in Luxor in desperate need of fodder that some farms instead of selling their products decide that a part of it to goes to self-consumption and a part of it for livestock feed as they can not afford it to buy in the market. So agriculture waste can be used as alternative fodder that can provide sustenance for animals, it can feed animals directly or it can be processed. After harvesting farmers can be recycled and transform the waste into various forms of food for animals. If the animal will eat 2 kg per day from this alternative fodder then the use of traditional fodder will be reduced by 30%, consequently, the profitability of the farm will increase and also will have more land to cultivate for other crops. Also, agriculture waste can be used not only for fodder but also as organic fertilizer, according to Eco-Business (2012) farmers' output could increase by 13.5% if they utilize organic fertilizer derived from plant waste instead of commercially supplied organic fertilizers. The use of this type as fertilizer will have several impacts not only on farmers' income but also will reduce pollution of the environment.

In the study area, not all the farms are specialized in livestock but some of them, so those farms recently are facing some problems due to the high heat coming from climatic changes where livestock has reduced the productivity as most of the time the animal is thirsty, less appetite, low fertility, high stress, etc., and these have caused a reduction of production consequently reducing the revenues that farmer had from livestock (Creoven, 2020). A solution for this is ventilation that offers air movement in the pens which makes the place less hot, fewer insects and flies, and improves the air quality. However, this intervention might cause a debate in Luxor as it increases power consumption, causes noise and is costly, so regarding the literature review, we might consider it one of the less adaptable interventions (Farm Energy, 2019).

For agriculture to be sustainable and to keep up with climate change, it is crucial to look for alternative crops with higher yields and that have fewer water requirements. One of the crops that meet these conditions mentioned above is sorghum, a crop that is adaptable to a wide range of agronomic and climatic circumstances, especially in regions with little rainfall or inaccessible irrigation water. Forage sorghum can provide a yield that is comparable to maize, indicating that there may be a chance for sorghum to take the place of corn in regions with insufficient water supplies (Getachew et al., 2016). Sorghum is a crop that grows in a variety of soil conditions, it is water-resistant and tolerant to drought, because of these features this crop is ideal for Luxor and can replace corn, as corn needs more irrigated water.

A useful intervention to deal with heat stress in dry areas is to choose crops that are heat resistant (National Science Foundation, 2009). During the reproductive stage, crop production can be greatly impacted by intense heat stress (Knox et al., 2012). This intense heat stress will cause several effects on agriculture production where the yields will be low and consequently it will affect global food production. The advantage of using heat-tolerant cultivars will be in lowering yield loss that occurs haphazardly in Luxor due to heat stress that varies with temperature levels because there are variances in the degree of heat stress among the growing seasons (Gourdji et al., 2013; Deryng et al., 2014).

Improved seeds can be not only for heat but also for salinity as also if the soil has a high level of salinity can reduce crop yields. The soil may naturally contain salt or salt can be even from the water for irrigation. The farmers in Luxor have used unsustainable irrigation practices due to pressure to put marginal land into production, this has caused the spreading of salinity more widely in the area. The main financial impact of salinity has brought to the farmers of Luxor is the lower income that farmers receive as a result of their lower output, so crops in this area are not only constrained by the heat but also salinity. Using this type of improved seeds is not that easy in practice as if the crop can contain a certain threshold of salt if not a high level of salinity might cause the death of the crop and also the reduction of yield so there is needed to the improved seeds will not decrease the quality of the food produced, also there is needed management of soil and water (Shannon and Qualset, 1984).

Due to the bad quality of soil in Luxor is needed an intervention that helps to increase the fertility of the soil. Soil moisture practices can be several such as no-tillage practices, precision conservation, harvest, crop rotations, etc (Delgado et al., 2013; FAO, 2018). The goal of soil moisture conservation is to lessen the amount of water evaporation from the soil. While preserving the water supply required for agricultural output, controlling soil moisture helps reduce the demand for crop irrigation (Sairam, 2021; Kumar et al., 2021). Meanwhile, organic fertilizers are sustainable and environmental friendly if we compare them with chemical fertilizers. Organic fertilizers can reduce the need for pesticides, phosphorus, nitrogen, and potassium so due to these reductions, we can assume that the organic fertilizers are costs saving. However, these type of fertilizers not have only an effect on costs but also improve the quality of soil by enhancing the soil texture as the water does not run off as easily, so it retains for longer periods of time, and boost microbial and fungi activity. On the other side, if we compare it with chemical fertilizers we can say that chemical fertilizers deplete the soil of its nutrients. (Holganix, 2021).

Lastly, worldwide some of the alternative water sources can be rainwater, greywater, recycled wastewater, groundwater, and stormwater. But in the case of Luxor, there is no possibility to have alternative rainwater due to the low amount of rain. According to Awadallah et al., (2017) Egypt is considered to be a hyperarid country with extremely little annual precipitation (Abdel-Maksoud, 2018). So the best possible it can be to reuse agricultural water, also, seawater desalination and the use of wastewater, however, their utilization is indicative of non-traditional water resources. (Ellah, 2020).

II. Chapter III

2.2. Research methodology

The research aims to identify the most feasible adaptation strategies that could be implemented in Luxor, the study's methodology and approach that this paper has followed will be covered in this section.

Data were also obtained from secondary and primary sources, as follows :

The secondary data were obtained through the secondary sources represented in journals, articles, books and previous studies related to the subject of the research, as well as using some websites of well-known Internationalorganizations such as FAO, World Bank, OECD, etc.

Also to collect the primary data, a structured questionnaire was designed by the researchers of SupMed to cover four axes: The first axis to measure the demographic situation where the sample was taken from 117 farms in the two villages, Elboghdadt and Elzanakta, the second axis is for the structure of the farm, the third axis is for the crops and the last one was for the irrigation, livestock and loan. This database in this paper was only used to analyse the situation in this area, meanwhile, the primary data used for MCAs analysis was obtained by experts.

2.3. Multi-criteria analysis

Considering the review of the literature and a deep study of the area I carried out an MCAs with the aim to rank all the adaptation options that are considered as potential options for the study area and to choose the most feasible ones.

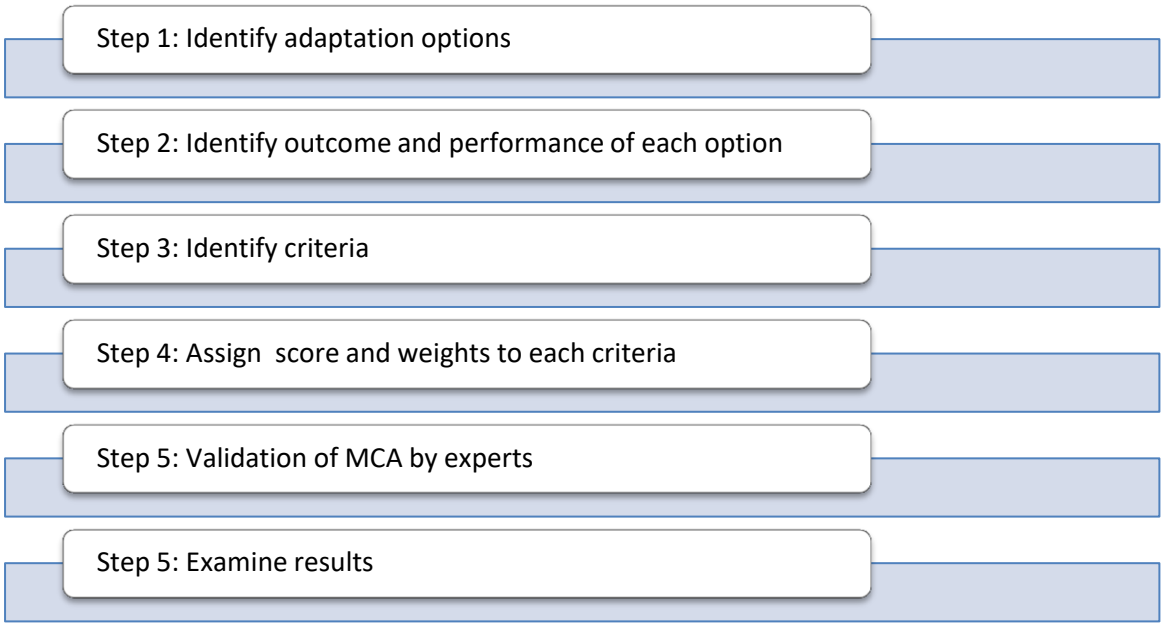
Brooks et al., (2009) define MCAs as ‘any structured approach used to determine overall preferences among alternative options, where the options accomplish several objectives’ (Brooks et al., 200, p. 46).

This method is used for analyzing the interventions that are provided by the local experts and literature review, by providing a decision-making framework to sift through layers of complex information and make consistent and transparent decisions.

The reason that MCAs is used as a suitable tool for this paper as it gives the possibility to use several criteria to evaluate the adaptation options, as well these criteria may be quantitative and qualitative, but in this case study we have partial data available for the chosen interventions, so with this tool, we can do the analysis despite the data availability. With this tool, we can eliminate the interventions that are not relevant to the study area and choose the relevant ones. In this chapter of empirical study the steps of doing the MCAs are shown at table 3,

In Luxor, there has been a lack of studies regarding feasibility assessments for adaptation options, due to several factors such as difficulties to assess adaptation outcomes and effectiveness, where often there has been an assumption that if an adaptation strategy is successful in a region will be successful even in Luxor or other regions, social or institutional barriers, and also lack of data has caused a problem in assessing the feasibility of interventions, and these barriers could have been overcome if the right method had been used to assess the feasibility.

Table 3. Steps of doing a MCAs analysis for the study area



2.4. Applied methodology

This part describes how the steps of doing an MCAs (fig. 1) were applied in the case study.

1- Identification and categorization of adaptation

The first step was to identify adaptation options, and this was mainly done in workshops organized in Luxor by the SupMed project. Stakeholders were involved in the identification of the adaptation options in the area, they identify several adaptation strategies, however, based on the literature review I identified some other options that could be an intervention for the area.

The outcomes and performance of each adaptation strategy are explained in chapter II, which it justifies the reasons that these strategies were chosen as a possible intervention

2.4.1. Criteria for scoring adaptation options

Assessing the feasibility of interventions is done based on three criteria (i) technical, (ii) economic and (iii) environmental. Feasibility means if the adaptation option can be easily or conveniently done. The technical feasibility has been scored based on three elements: technical capacity in the agriculture sector which refers to building and facilities, equipment, road network, labour etc., the other one is social complexity which refers to the acceptance of the farmers for the adaptation strategies suggested, also the consensus between concerned parties, their view, and cooperation; and the last one is institutional complexity, that refers to any barrier from institutions such as bureaucratic procedures to go through, not providing financial support for the farmers, etc, (table 2).

Secondly, the economic criteria include how much profit the farmer will have from this strategy, which is the costs of implementing it, such as the costs of buying the improved seeds or organic fertilizers, buying or renting a machine for land levelling, etc., also we should take into account transaction costs, the costs that might be incurred when we try to implement a certain intervention, these costs might be for training, transportation, extra charges, etc. In the case of Luxor, in some interventions there will be transaction costs due to the level of education of farmers, not all of them have experience in using a certain machine or planting a certain crop, so there will be a need for

training that consequently will cause a cost for them, and sometimes this cost can be higher than the initial ones, due to that the farmer might decide not to apply the intervention.

The environment is the last criterion for the analysis, which will consider the effect on water and soil as the most important issues in Egypt. From all the sectors, agriculture is the largest consumer of water not only in Luxor but in the whole of Egypt. More than 80% of the water in the country comes from the River Nile, which is its main water supply and agriculture is also the main user of it, soil salinization and excessive use of fertilizers in agriculture its causing degradation of the soil in the region (Darwish et al., 2013), that is why it is needed an intervention that will have a positive impact in those two elements, also there are interventions that can impact only one of these two elements, however, we will consider them as potential interventions.

Table 4. Description of sub-criteria

Sub-criteria	**Explanation**	**Comments**
Technical Capacity required	Technical capacity required for implementing the strategy	Higher score assigned indicate to low capacity required for the implementation of certain interventions.
Social complexity	Public support for certain adaptation strategy	Higher scores indicate a low level of social complexity.
Institutional complexity	Political acceptance for certain adaptation strategy	Higher score indicate that institutional complexity is low and lower score indicate that institutional complexity is high.
Profitability	The profit from implementing an intervention	Higher score indicate to high profitability for the implementation of certain interventions
Cost of action	Costs for the implementation of the strategy and also the costs for maintaince of it.	Higher score indicate that cost are low, and lower scores indicate that costs are high.
Transaction costs	Extra costs that may occur for training, transportation, etc.	Higher score indicate that transaction costs are low, and lower score indicate that transactions costs are high.
Effect on water	Reduction of using water and also the efficiency of it	Higher score indicate to high effect on water for the implementation of certain interventions.
Effect on soil	Improving the quality of soil	Higher score refers to high effect on soil for the implementation of certain interventions.

In the description for all criteria (table 4) for technical capacity, social and institutional complexity, cost of action and transaction costs higher scores mean lower, and the opposite, because when I will do the calculation having a high cost of action and high profitability means that the weighting will assume that having high cost is positive as same as having high profit, that is why it is needed this change.

2.4.2. Assigned scores and weight to criteria

The first step of this MCAs is to assign scores for each of the criteria related to the adaptation options (table 1). As we have to do with qualitative metrics, for each criterion, it is used a 5-point scale depending on the perceived importance of each criterion. So, 5 means very high, 4=high, 3=average, 2= low, and 1 means very low (Table 5).

The first scoring process was undertaken based on the subjective judgment of the author developed on the review of the literature, a deep study of the area and has been validated by the project manager of SupMed the second scoring process was done by the chosen experts.

Table 5. Scoring bands

1	2	3	4	5
Very low	Low	Average	High	Very high

After doing the scoring, the second step will be weighting, so this provides the relative importance of each of the individual criteria in the overall decision to choose which adaptation strategy should be implemented. To assign weights, there were two options, one is to give equal weighting to all the criteria and the second option is to give different weightings to different criteria, reflecting which criteria are more important in the objectives of this paper. These weights are set firstly by the author of this paper and then are validated by the chosen experts.

The method that was chosen for weights was the first option, by giving equal weights to the criteria, but for the sub-criteria, we chose the second option by assigning different weights to them.

- Technical criteria=0.333
- Economic criteria =0.333
- Envirnomental criteria=0.333 (table 3).

The total weight of 100% is divided between three criteria, where 33.3% is assigned to technical criteria, 33.3% to economic criteria and 33.3% to the environmental criteria. So there is an equal distribution of weight to the criteria due to the study area all the criteria are considered very important for the implementation of a certain strategy, if a strategy has high technical complexity but is profitable and sustainable does not mean that the farmer will implement it as the farm might not have the required technical capacity so it will be almost impossible for implementation or if they implement it by using the wrong tools might return to a maladaptation making the situation more vulnerable than it was before. In Luxor the goal of the farmers is not improving the environment but having high profit, they want a strategy that will be more profitable than the ones that they are currently using, so in this case, the chosen adaptation option needs to be chosen carefully based on each farm type goals, however, the impacts on environment should be taken into consideration.

To assign the weights for each sub-criteria it will be applied a general rule throughout this analysis. For each criterion we have a total weight of 33.3% or 0,333 and this one will be divided between the sub-criteria of each group, so if one of the sub-criteria is considered low importance (this judgment will come from the literature review, the conditions of the study area, and from experts) then we will range the weight between 0.01 to 0.09, if a sub-criteria for a specific adaptation option is considered that is moderately important than the range is between 0.1 to 0.14, and if the sub-criteria is crucial for that specific options to be implemented so the assigned weight will be 0.15 and up (table 4).

Table 6. Rule of assigning weights to sub-criteria

Percentage (Total 33.3%)	The level
0 %-9 %	Low importance
10 %-14 %	Moderately importance
15 % <	High importance

Technical criteria are divided into three sub-criteria (table 7), the sub-criteria that is assigned more weight in this group is the technical capacity because requires particular technical capabilities such as knowledge, tools, and skills that not all stakeholders of Luxor have, so the weight assigned is 0.15, however, even the institutional complexity is important as they can have major implications for the procedures, access of farmer to critical resources (as it is common in Egypt that government provides seeds and other inputs to the farmers). Social complexity in this group will be with less weight as we

take into account from the workshop done in Luxor by Othman Elshaikh and Emad Abdallah in 2022, that all farmers that participated in that workshop will accept the adaptation options suggested and they will be willing to participate in the climate adaptation agreement, nevertheless, there is still a chance that they will not accept certain strategy and we need to take into account.

Table 7. Weights assigned for each criterion

Technical (33.3%)			Economic (33.3%)			Environment (33.3%)	
Technical capacity required (15%)	Social complexity (5%)	Institutional complexity 3 (10.3%)	Profitability (15%)	Cost of action (13.3%)	Transaction costs (5 %)	Effect on water (20%)	Effect on soil (13.3%)
0,15	0,05	0,103	0,15	0,133	0,05	0,2	0,133

Regarding the economic criteria, profitability is important for the farmer but even the cost is a determinant of whether the farmer can afford or not a certain intervention, but there are not only the costs to implement the intervention but they are even transaction costs that can occur at the moment that this intervention is taking place, but these transactions costs will not occur in all the interventions, for that reason the weight is smaller compare with two others.

Lastly, the environment, soil, and water currently are the main issues in Egyptian agriculture as analysed in the literature review, however, we will give more importance to water as the soil quality can be fixed by finding other water resources in an area where temperatures are high and according to different scenarios probably the temperature will keep increasing.

The next step is the calculation of the final weight that is needed to rank the adaptation options and choose the ones that are feasible for the area. The final weight can be calculated by combining the relative weights of each criterion with the actual scores assigned to them. By combining these two steps, a final weight is reached that reflects the need for the adaptation strategy to be implemented in the study area. The following equation (i), was used to calculate the value of attribute score (x_i) to each criterion multiplied by the weights (w_i), giving the weighted sum (S) for each criterion of adaptation options.

$$\mathbf{S= \Sigma w_i * x_i; \ (i)}$$

To calculate the total of all the critera for each adaptation option we use the formula below (ii):

$$\mathbf{S_1=\Sigma w_1 * x_1 + w_2 * x_2 + w_3 * x_3 \ldots w_n * x_n \ (ii)}$$

As a result, if these adaptations will be suitable for farmers, then these farmers will be the basis for setting up demonstration plots for other farmers that did not agree or did not take part in the adaptation agreement.

3.3.3 Validation

In this MCAs, I approached the assessment systematically, starting with practices of literature review, scoring and weighting, followed by validation from experts.

For each adaptation strategy, all the criteria were assessed in two rounds, the first round was based on the literature review and the second round was with interviews with local experts, where each score and weight of the adaptation strategy's criteria were validated by at least two experts. In the end, the local expert's expertise and experience determine the relevance and strength of this MCAs study.

Once I have assigned scores and weights for each adaptation strategy, they will be analyzed by the chosen experts in order to validate the MCAs. Assessing the quality of the MCAs will depend

ultimately on the knowledge and experience of the chosen experts. The chosen expert needs to understand the study area, so the local experts will be a priority, and to have a broad knowledge of how an MCAs is implemented (if they do not have enough information then as a reference will be the methodology that I have used to implement the MCAs). Once the experts have checked the initial scores and weights, they will fill the table given to them, after filling their responses, I will analyse and compare them with each other and give reasons why they suggest different scoring, however, there will be cases that they might approve the initial scoring. If the scoring assessment differed, it will be reconciled based on their suggestion.

The goal of this validation is to assess the quality of MCAs so each adaptation strategy that will be chosen due to the results from MCAs needs to be a decision element based on a synthesis of the different responses provided.

Table 8. Team of experts

Team of experts	
Tahani Abdelhakim	Local Expert 1
Othman Elshaikh	Local Expert 2
Emad Aly	Local Expert 3

Since each of the selected experts has a distinct area of expertise and has worked in the subject area, it is anticipated that their points of view have addressed the key issues that should be taken into account when evaluating the various adaptation options in the context under study. The scoring will be completed independently by the experts in order to prevent any potential bias, and the final score it is calculated by averaging the total weight they provided for each choice based on each criterion.

2.5. Limitations

The chosen methodology does not mean that is not without caveats. First, there is an issue of scoring and weighting the criteria, because it looks relevant for the chosen group of experts it is not relevant for another group. Also, I have weighted the three main criteria equally, but future assessments can assign different weights to all criteria depending on the scope of their paper. The initial idea of making MCAs was by using the data from SupMed database, but we encountered some problems while analyzing the database such as unnecessary data for the study and a lack of sufficient evidence for interventions. In order to overcome this barrier I checked for data on some websites and Egyptian institutions but there was an absence of statistical data for Luxor through the years.

Whether or not these conclusions are reached directly or by the judgment of experts, there is a need to know how these decisions can be the right approach for implementing adaptation strategies.

Part III

Results

IV. Chapter IV

4.1. Results

This section describes the detailed application and results of each step described in Part II about the MCAs. One of the steps of MCAs was to define the term adaptation strategy that will be used in this paper, after doing the literature review and based on the knowledge of experts, agriculture adaptation in this paper will be considered the intervention done in the farming system to archive multiple farming goals and at the same time to cope with climate hazards.

4.1.1. Identification and categorization of adaptation options

The farming goals of farmers in Luxor vary from farm to farm, however, these goals can be the increase in production, an increase in profit, food security, etc.

Hence, there are several potential interventions that are or can take place in Luxor, but the ones identified were on-farm into three scales: crop scale, field scale and farm scale (table 9).

Table 9. Adaptation options for Luxor

No	Adaptation options	Who will make it?	Level of strategy
1	Land Holding consolidation	Private sector	Field-scale
2	Soil laser leveling	E.servicies	Field-scale
3	Raised bed cultivation	E.servicies	Field scale
4	The changing of the sowing dates	Farmer	Crop scale
5	Intercropping	Farmer	Crop scale
6	Cultivation of high-value crops such as medicinal and aromatic plants	E.servicies	Crop scale
7	Introduction of heat-tolerant varieties.	E.servicies	Crop scale
8	Production of alternative livestock fodder	Farmer	Crop scale
9	Using alternative water sources such as agricultural drainage or surface well	Farmer	Farm scale
10	Cultivation of palms and willows as windbreaks	Farmer	Farm scale
11	Establishment of Water User Associations (WUA)	Private sector	Farm scale
12	Establishing schemes for revolving loans with a focus on women.	Private sector	Farm scale
13	Use of fans in animal pens	Private sector	Farm scale
14	Cultivation of traditional crops such as sorghum instead of corn	Farmer	Crop scale
15	Soil moisture conservation practices	E.servicies	Field-scale
16	Water storage on farmland	E.services	Farm scale
17	Cultivation of salinity-resistant varieties	E.servicies	Crop scale
18	Using organic fertilizers	Farmer	Field-scale

Source: Farmers, local experts

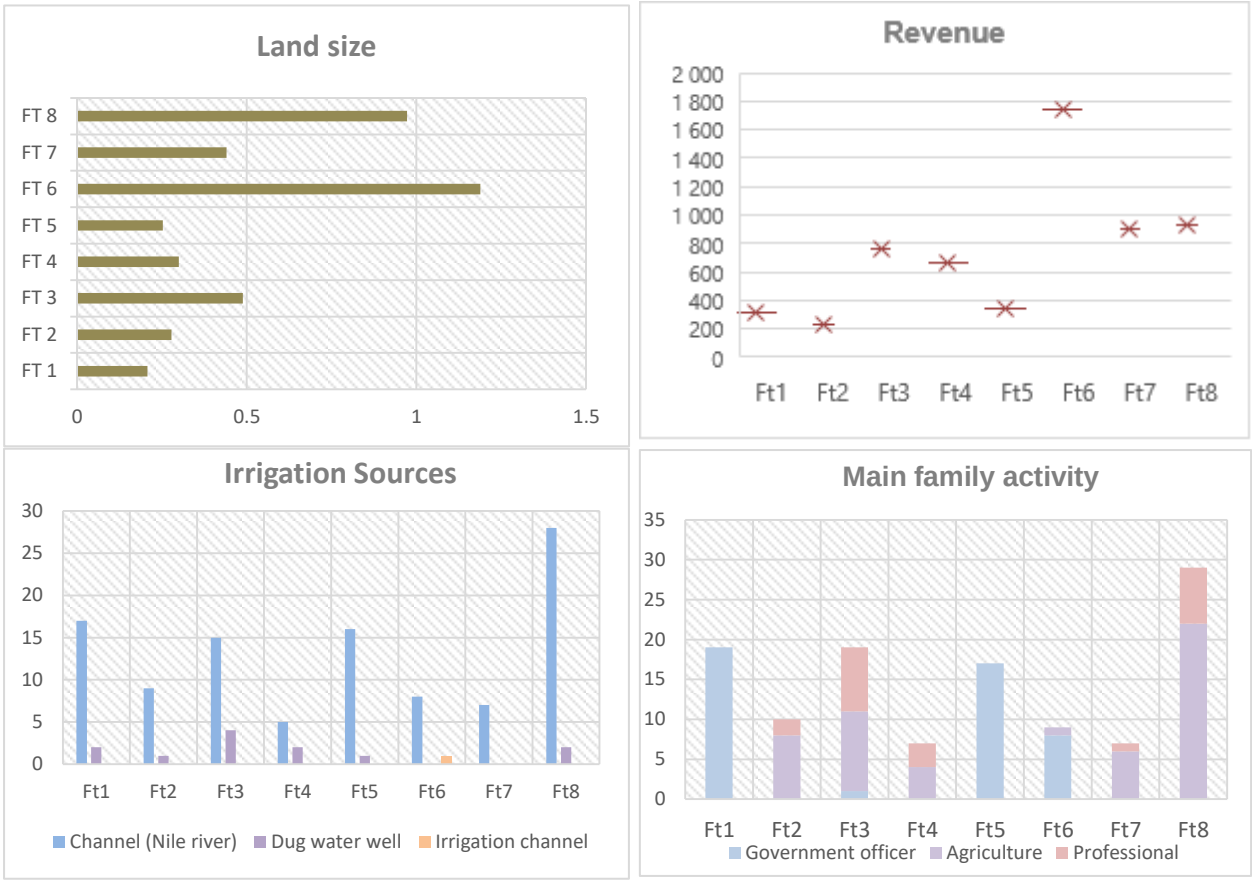
In spite of that, not all these interventions might have excepted an impact that's why these chosen interventions were explained in detail in the Study area (Chapter II), where was justified the reason that was chosen also the impacts that these interventions will have on the area.

4.1.2. Farm typology in Luxor

The farms that were taken into the sample were clustered into 8 farm types, where each farm type had its characteristics, due to similarities this cluster can be reduced it into 4 farm types.

For farm type 1 agriculture is not the main activity of the family, they do additional jobs in order to have extra income, this type plants several crops as the main reasons to produce is home consumption, also has low revenue but is not the poorest farm type (table 10) also mostly the water for irrigation comes from Nile river, this characteristic is not only in this farm type but in all farms in Luxor. Meanwhile, farm type 2 is the opposite of farm type 1 regarding family activity as in this farm type agriculture is the main activity and source of income where the reason to produce is mainly home consumption, unlike farm type 1, the head of the family is women so in this case, we will introduce a new intervention that is establishing schemes for revolving loans with a focus on women, same goes for farm type 3 where the head of the farm is women. In this type agriculture is the main activity of the family however not the main source of income as this farm type gets the income mostly from grants as it is food insecure. Contrary to previous farm types a part of the production goes for sales furthermore land size is bigger than average (0.48 ha), however, the yield is low.

Table 10. Main characteristics of the farm types



Source: Database of SupMed

Meanwhile, farm type 4 is heavily reliant on grants, also the land size is small and the production goes only for home consumption. Farm type 5 is entirely focused on livestock farming so the introduction of production of alternative livestock fodder will be suitable as this farm type buys mostly the fodder outside the farm as they produce fewer crops than they actually need. Farm type 6 is the farm that gets more revenue from agriculture compared with other farm types also the land size is the biggest of all farm types with an average of 1.18 ha, consequently produces on a larger scale so a large part of its

production goes for sale. Meantime farm type 7 the profit is high also the agriculture is the main activity of the family. Lastly is farm type 8 which recently has started livestock farming and government provides direct agricultural subsidies for mostly all the farms of this cluster.

4.2. Stakeholders

Identification of the key stakeholders that will implement the adaptations is crucial for the process because there are some adaptations that can not be implemented by the farmer due to the high level of complexity.

So the implementation of the chosen adaptation option will be done by:

- **Farmer**: influential group, they are the ones that will make the decision in the end to accept or not the interventions, and also they are the ones that get affected mostly from the interventions, their experience and knowledge are important.
- **Extension services**: Due to their experience with certain interventions, extension services are crucial because they can assist the farmer with implementation by educating them, providing them information about new techniques, supplying them with inputs, technical help, etc. (Wanigasundera and Atapattu, 2019).

One of the experts chosen for scoring and validation Othman Elshakih has suggested that stakeholders should be also the agriculture cooperatives, farmer associations and community development associations, depending on the type of intervention.

- **Agriculture cooperatives** will be chosen due to the importance that they have in the development of agriculture in the area as one of the oldest cooperation sectors that provides support and services to the farmers. However, these cooperatives do not function very well due to many factors such as lack of infrastructure, lack of cooperation between cooperatives, lack of financial resources, the intervention of the state, etc.
- **Farmer associations- i**n order to ensure that farmers are involved in the formation and implementation of policies and initiatives for agricultural development, farmer associations' main purpose is to represent farmers.
- **Community development associations** usually are a small type of cooperative or associations at the village level that have a defined geographic area, dealing mostly with inputs (Chamala and Shingi 1997).

4.3. Scoring by experts

After analyzing each adaptation options in Part I, their impacts and the reason that these options are relevant for the study area, the next step was scoring each adaptation option, the scoring is done according to the criteria and sub-criteria by three experts (annex 2). After the experts have done their individually scoring, then is done the average of their scores where we came up with this table.

From the literature, it was suggested that land consolidation is a very complex process and it requires high technical capacity, meanwhile at table 8, from chosen experts only expert 2 assigns the highest score, the other two experts see it as a complex process but not so high complexity, also the first expert argue that in Luxor area there is the very small size of holdings and land fragmentation is one of the main problems, there are many institutional difficulties due to ownership regulations, for that reason social and institutional complexity is high. So according to the experts, land holding consolidation will have positive impacts on the profitability as the farmer will have more area to produce consequently a big part of production will go for sale, as randomly happens in Luxor that mostly the production goes for self-consumption due to the small land size they can not produce for

the market. However, as a process is not that costly to be implemented, but might occur some transaction costs this depending on who will help with the implementation of this intervention

Table 11. Scoring adaptation strategies

Adaptation Strategies	Technical			Economic			Environment	
	Technical Capacity required	Social complexity	Insitutional complexity	Profitability	Cost of action	Transaction costs	Effect on water	Effect on soil
Land Holding	2	2	2	5	4	3	4	4
Soil laser leveling	3	3	3	4	4	3	5	4
Raised bed cultivation	3	4	3	4	4	3	5	4
The changing of the sowing dates	2	2	3	4	3	3	4	3
Intercropping	2	3	3	4	4	3	4	3
Cultivation of high-value crops such as medicinal and aromatic	3	3	3	5	3	4	3	3
Introduction of heat-tolerant varieties.	3	3	2	5	3	3	4	3
Production of alternative livestock	2	3	3	4	3	4	3	2
Using alternative water sources	3	3	2	3	3	3	5	3
Cultivation of palms and willows as	4	5	3	2	3	3	2	2
Establishment of Water User Associations	3	3	3	4	4	3	5	3
Establishing schemes for revolving loans with a focus on women.	3	3	2	4	3	3	2	2
Use of fans in animal pens	4	5	4	3	4	3	2	1
Cultivation of traditional crops such as sorghum instead of corn	2	3	3	3	3	3	4	2
Soil moisture conservation practices	3	4	3	3	3	3	4	4
Cultivation of salinity-resistant varieties	3	4	3	4	3	3	4	4
Using organic fertlizers	3	4	3	3	2	3	3	4

Note : Check table 2 for the description of scores

As claimed by two experts, soil laser levelling is another intervention that requires high technical capacity the support to implement this intervention will come from the ones that have the tools such as the owner of the tractor, as they have the technology, knowledge and experience on doing this intervention, also one of the experts suggests that there will not be any social barrier, as the farmer in Egypt are used to make the soil laser levelling in a primitive way that was called oxen farming, that needs so much time and work, so they are open to the tools that might make the agricultural production much easy. However, it is important and crucial that the person that does soil laser levelling be well trained. When it comes to raised bed cultivation there is a need for average technical capacity according to the scoring. However, this intervention will have an effect on water and soil, in view of the fact that soil will be more compacted. Furthermore will have better drainage, prevent waterlogging and will use the water efficiently. Additionally, there is a decrease in the utilization of inputs like seeds and fertilizers, which provides a better opportunity to lessen tillage, so the scoring by experts for the environmental criteria is high.

Another intervention scored by experts is improved seeds as the only way to cope with the challenges of the future regarding climate change. These modified seeds can cope with heat or high levels of salinity. The introduction of heat-tolerant and salinity-resistant varieties will not require high technical capacity as it will be like other seeds just with a better trait that the traditional ones. There will be low social complexity as the farmer is willing to have such seeds as the traditional seeds sometimes cannot make it till to harvesting due to the heat or salinity, nevertheless, there might be some institutional barriers, we have mentioned before that in Egypt the seeds are provided by the institutions this might cause extra costs for them to provide these improved seeds to the farmers (National Science foundation, 2009). Profitability in both cases will be higher than using traditional ones as there will be higher yields due to improved nutrition and climate resilience. However, the impacts on the environment will differ as the heat tolerant varieties will use less water than before so the most effective will be on the water, meanwhile, the salinity resistant varieties will have more impact on the soil as they will improve their quality (Tesfaye et al., 2017). Meanwhile, the establishment of Water User Associations (WUAs) will have an impact on the better management of water resources, however, it is considered a very complex intervention by literature and also from experts, because it needs very high technical capacity and it is a strategy that can not be implemented by the farmer but only by a group of farmers helped by the private sector. As a strategy, it might face institutional barriers to establishing it and also social as farmers might not accept to be part of it. Anyhow, it is excepted to have a high impact on water resources due to the better management of it, no thefts and also less waste, but it will be costly not only to get implemented but also to continue to function over time.

To carry on, establishing schemes for revolving loans with a focus on women needs a high capacity, it might face social complexity from male farmers as they will consider discrimination as only the women will get the loan but as we have mentioned in the literature review women in Luxor are not considered a priority to get loans from banks or other financial institution and this is supported even by the experts. From the financial analysis done by the expert Othman Elshakih for the SupMed project the profitability will be high as one of the conditions to get this loan will be to invest only in agriculture , so if one of the women with the given loan buys goats the total costs estimated will be 6980 EGP (349 eur) these costs include three goats, the fodder for one year, vet, administrative expenses and credit risk and the total revenue will be 10800 EGP (540 euro) so the percentage of profit will be 54,7% (annex 3), also there will be no transaction cost as this intervention will be implemented by the private sector.

As Egypt have soil degradation as a solution may be soil moisture conservation practices, these practices require high technical capacity so in the help to implement it will come to the extension services, besides that the farmer will need some extra training in order to master these techniques, so there will be costs for implementation and also transaction costs (table 11). Besides the costs, soil conservation practices have an impact on water and soil as well, where it reduces the quantity of water that gets lost and decreases crop irrigation needs, build organic matter and fixes soil structure.

Lastly, using organic fertilizers has divided the experts into two teams the first team is the one that scores very low on the technical capacity and the one that scores it very high, the first time justifies this scoring by suggesting that there is no technical capacity required as you can take for instance the manure from cow, and then apply to the crop but the other team suggest that are several steps that a farmer needs to follow as the organic fertilizer will not be used only one time but several times, so these steps start from collecting raw materials and then shedding and pileing the shredded raw materials, water the piles, till the last step that is to air-dry the organic fertilizer which helps to attain the moisture. The profit is considered to be average and mostly to have an impact on soil more than on water saving.

4.4. Feasibility assessment

The final weighted scores are used to prioritize the interventions as we can see in table 12, we have a long list of adaptation options that not all of them can be implemented in all farm types that we have in the sample. However, from the MCAs we could find out that not every adaptation suggested is feasible, so from this list of adaptations, only 6 of them had the highest weighted sum among the others.

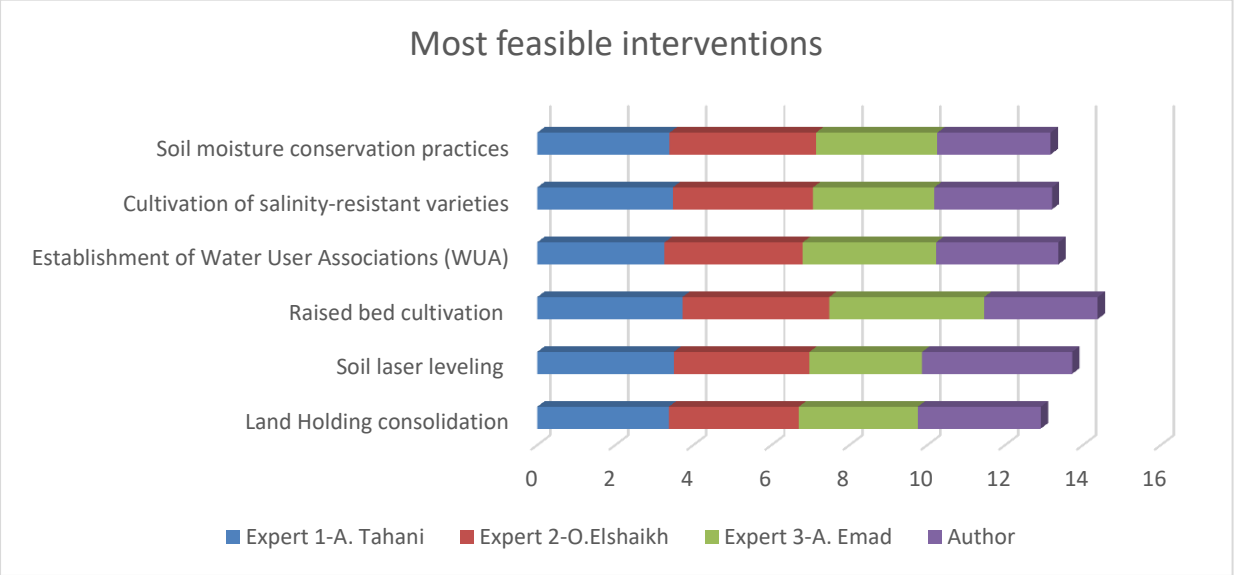
Table 12. Adaptation options for Luxor based on weighting feasibility, economic, and environmental criteria.

Adaptation options	Feasibility (33.3%)			Economic (33.3%)			Environment (33.3%)		Initial Weighted sum
	Technical Capacity required (15%)	Social complexity (8%)	Insitutional complexity (10%)	Profitability (11%)	Cost of action (11%)	Transaction costs (11%)	Effect on water (17%)	Effect on soil (17%)	
Land Holding consolidation	0,3375	0,16	0,18	0,71	0,53	0,14	0,75	0,50	3,31
Soil laser leveling	0,38	0,20	0,26	0,525	0,49875	0,15	0,90	0,53	3,43
Raised bed cultivation	0,45	0,23	0,28	0,60	0,47	0,16	0,90	0,50	3,59
The changing of the sowing dates	0,34	0,14	0,26	0,56	0,43	0,1375	0,70	0,33	2,89
Intercropping	0,3	0,18	0,28	0,56	0,47	0,1375	0,70	0,43	3,06
Cultivation of high-value crops such as medicinal and aromatic plants	0,45	0,18	0,33	0,68	0,399	0,18	0,60	0,37	3,18
Introduction of heat-tolerant varieties.	0,38	0,165	0,23	0,68	0,40	0,15	0,85	0,37	3,21
Production of alternative livestock fodder	0,3375	0,20	0,26	0,60	0,43	0,18	0,60	0,30	2,90
Using alternative water sources such as agricultural drainage or surface well	0,41	0,18	0,15	0,49	0,40	0,13	0,95	0,33	3,04
Cultivation of palms and willows as windbreaks	0,525	0,29	0,31	0,34	0,37	0,15	0,40	0,30	2,67
Establishment of Water User Associations (WUA)	0,49	0,18	0,26	0,60	0,4655	0,14	0,90	0,37	3,39
Establishing schemes for revolving loans with a focus on women	0,41	0,15	0,23	0,64	0,43	0,13	0,30	0,20	2,49
Use of fans in animal pens	0,53	0,27	0,44	0,4875	0,50	0,16	0,35	0,17	2,90
Cultivation of traditional crops such as sorghum instead of corn	0,34	0,15	0,28	0,4875	0,43	0,15	0,70	0,20	2,74
Soil moisture conservation practices	0,38	0,24	0,31	0,45	0,43225	0,15	0,80	0,50	3,26
Cultivation of salinity-resistant varieties	0,38	0,21	0,26	0,60	0,40	0,15	0,75	0,53	3,27
Using organic fertlizers	0,38	0,23	0,28	0,45	0,30	0,15	0,50	0,57	2,85

Note : High weight indicate that the adaptation option will be considered first to be implemented.

One of the features of this MCAs is the fact that we did not have much conflicting weight between the experts, As can be seen in table 13, the weights given by each expert are close to each other and also there are no big differences from the weight given based on the literature review. One of the experts who in many cases has set numbers that differ from his colleagues was Othman Elshaikh, that is due to the fact that he is an expert in the area and has a good acquaintance of the situation in Luxor.

Table 13. Top 5 adaptation strategies/Weighting by each expert



From the most feasible intervention, only at one point, we had contradictions of weights, this is between the experts and the literature review, where the experts give a lot of importance to raised bed cultivation, while the literature review gives a lot of importance to soil laser levelling, for the reasons that we have addressed in the previous chapters.

Table 14. Ranking of adaptation strategies

Adaptation Strategy	Farm type	Weighted sum	Ranking
Raised bed cultivation	ft1-ft8	3.59	1
Soil laser leveling	ft1-ft8	3,43	2
Establishment of Water User Associations (WUA)	ft1-ft8	3,39	3
Land holding consolidation	ft1-ft8	3,31	4
Cultivation of salinity-resistant varieties	ft1-ft8	3,27	5
Soil moisture conservation practices	ft1-ft8	3,26	6
Introduction of heat-tolerant varieties.	ft1-ft8	3,21	7
Cultivation of high-value crops such as medicinal and aromatic plants	ft1-ft8	3,18	8
Using alternative water sources such as agricultural drainage or surface well	ft1-ft8	3,04	9
Production of alternative livestock fodder	ft2&ft5&ft8	2,9	10
Use of fans in animal pens	ft2&ft5&ft8	2,9	11
The changing of the sowing dates	ft1-ft8	2,89	12
Using organic fertlizers	ft1-ft8	2,85	13
Cultivation of traditional crops such as sorghum instead of corn	ft1-ft8	2,74	14
Cultivation of palms and willows as windbreaks	ft1-ft8	2,67	15
Establishing schemes for revolving loans with a focus on women.	ft2&ft3	2,49	16

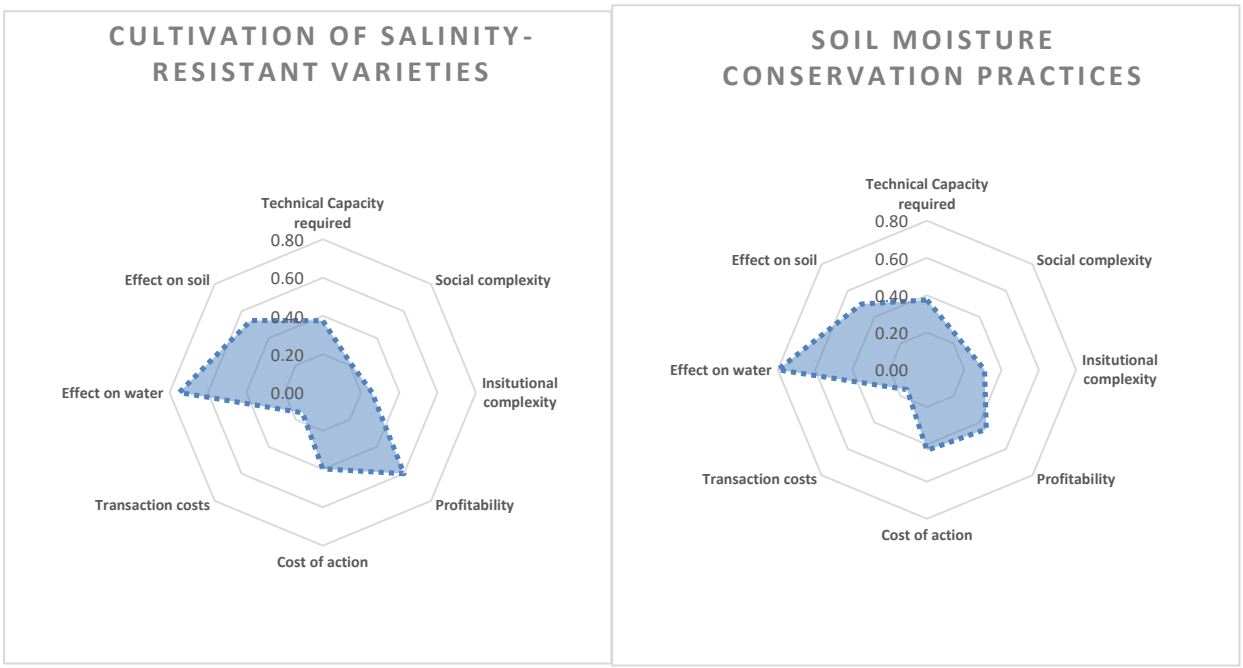
At table 14 we can see that all farm types can adopt the interventions that were chosen as the most feasible but this is not the case for the rest of the interventions due to the characteristics that have each farm type. From these characteristics we can understand which of the chosen adaptation options from the MCAs is more suitable for each type, for instance, one of the chosen interventions from the MCAs is the production of alternative livestock fodder that cannot be applied to farm type 1, 3, 4, 5, 6, 8 as they do not have livestock also establishing schemes for revolving loans with a focus on women is only suitable for farm type 2, 3 and 7 as the head of the farm is a woman.

Figure 6. Feasibility assessment of select adaptation options

The feasibility assessment identified adaptation strategies that are key to be implemented in Luxor (figures 6 and 7). As we can see from the ranking (table 14), this MCAs analysis shows that raised bed cultivation should be the top priority for implementation as a way to solve the land size problem in Luxor, also to be efficient in production (fig.6), so they can produce more by not using a lot of space, it can be done by the farmer as does not have high technical requirements. However, the establishment of Water Users Associations is a very complex intervention anyways is needed for

better management of water resources in the region, as it needs high technical capacity, it can not be implemented only by the farmer but with the help of farmer associations.

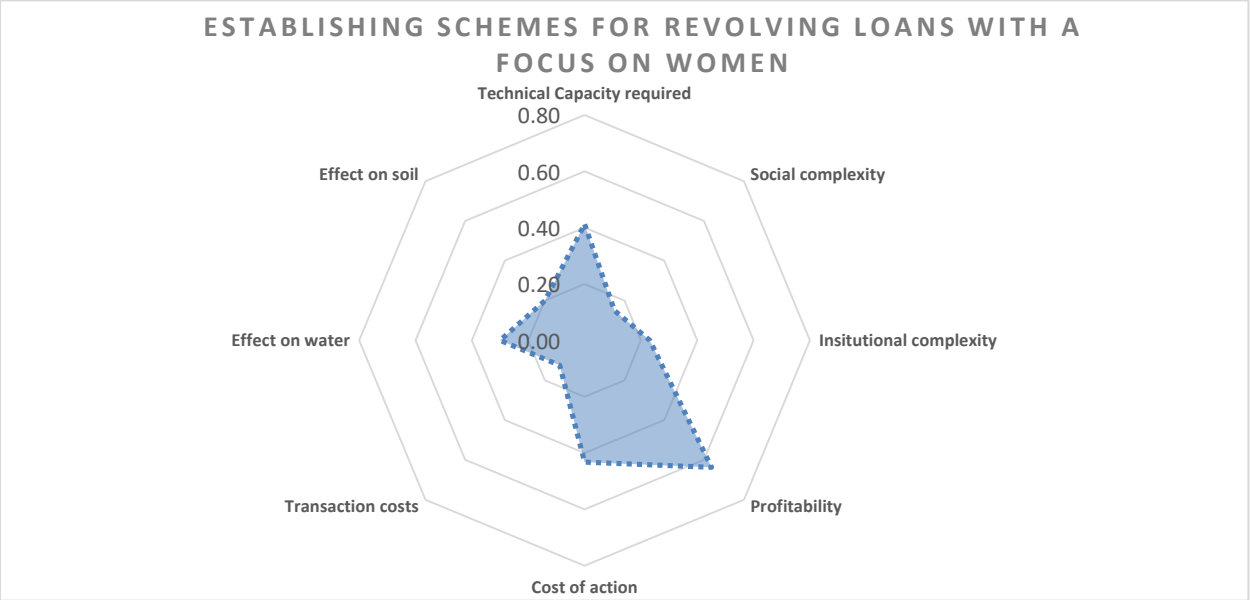
Figure 7. Feasibility assessment of select adaptation options



Soil moisturising conservation practices are an intervention much needed in the area due to the soil quality. Improved seeds (fig.7) as we have mentioned above are one of the best interventions that are not costly compared with the other ones, do not require high technical capacity from the farmer and do have a positive impact on the environment. From all the chosen interventions the most profitable one is considered the introduction of heat tolerant varieties where the profit is very high and the costs are average compared with other interventions in the ranking list.

This feasibility assessment has also identified the key gaps for each adaptation option, so for instance under soil laser levelling, there is not enormous progress on the effect on soil in terms of how it affects the quality of soil, there is little proof that this option is socially acceptable, and the level of profitability is not that high due to the costs that are in the same level. Certain feasibility indicators that are used for this assessment such as institutional acceptability, transaction costs, and profitability had limited evidence across most adaptation options.

Figure 8. The least feasible intervention



From the feasibility assessment, the literature and the experts agreed on one point that establishing schemes for revolving loans with a focus on women will not be a priority for the area (fig.8), because of the number of women that are head of the family is very low, also discrimination plays a role as to women are not offered as many opportunities as to men. This intervention will not have a direct impact on water and soil, but the profitability that women will have will be high.

Part IV

Discussions

V. Chapter V

5. Discussions

The study's primary goal was to determine the most feasible adaptation strategies that could be implemented in Luxor. To archive this objective, I opted to work by using MCAs to create data from the qualitative measures and after that to weight the data.

The initial idea of making MCAs was by using the data from SupMed database, but we encountered some problems while analyzing the database:

-Unnecessary data for the study;

-Lack of sufficient evidence for interventions;

-Absence of statistical data for Luxor through the years.

So due to the lack of data it was impossible to make a quantitative MCAs for adaptation strategies, because of that it was needed to change the path and get the needed data from experts by building a table for scoring, the experts scored each adaptation strategy based on three main criteria: technical, economic and environmental, moreover, the chosen criteria and scoring were straightforward and understandable, after that, we weighted them and did a final weight for all experts in order to get the most feasible interventions.

One of the advantages of using MCAs as a tool for assessment of feasibility in this paper as it is suitable for decision making even in our case where the data was missing and there were several criteria to be considered, this method allowed us to identify the most and least feasible interventions for the study area and rank these interventions. Also, the study area was a bit complex so by using this tool we could simplify the situation and create the needed data.

However, at the beginning of this paper was stated that the chosen methodology does not mean that is not without caveats, multi-criteria analyses are often based on slow and interactive processes, which may include negotiation with a large number of experts whose opinion differs from each other so this type of analysis needs more time as sometimes it can be slow when there is a large number of experts for scoring and validation, that is why in this paper we decided to have a small group of experts. Also, as there is a lack of reliable data over a period of time for adaptation strategies impacts there is difficult to validate the methodology, due to that it can be considered that is a subjective tool as the validation was done by experts based on their knowledge and expertise that they had in the study area. Additionally, scoring and weighting the criteria would be an issue, because while something may seem relevant to the selected group of experts, it may not be relevant to another group. Also, the three main criteria have been weighted equally, but future assessments can assign different weights to all criteria depending on the scope of their paper.

Based on the feasibility assessment, the most feasible intervention is raised bed cultivation, where experts support it as a form of production that somehow will end the problem of land fragmentation at least in a short time, as well water will be used efficiently and the plant will get all the necessary nutrients since they will be not lost in runoff and drainage water. While the intervention that is least feasible from all the list of adaptation strategies is giving loans to women, the reasons behind this are several such as unequal access to resources and education these have made the experts not give importance to this strategy as a possible scenario, also the number of female farmers is not high in the area where the sample was taken, also most of the time many long-term loans to women are denied, as a result, there are fewer women landowners, moreover cultural factors, besides all these reasons as an intervention does not directly affect the management of water or the quality of the soil, these have

caused the weighting to be low. If we compare the results obtained from the literature and those from the experts, we understand that we have a difference between them, for the literature the most feasible intervention is soil laser levelling, while for the experts based on weighting raised bed cultivation is more feasible. This has come as a result of the fact that the literature has given a imporantce to the costs so it suggests that is a need for wood, stone, timber, etc., and other materials to build the beds, also during the process there might be extra costs due to the location, so if the farm is in hilly terrain then the process of levelling will take place, while the experts have not given so much importance to this criterion as they are good connoisseurs of the terrain so they know that for this specific intervention in the study area will have low transaction costs and also technical complexity will not be high.

Based on this research, I think there are three ways that the results of this paper might change:

First, these obtained results may change if we change the weights that we have set for the criteria, if these weights change, then we will take another ranking, so the most feasible intervention will be different from the one chosen for this paper, since we have given the same importance to the criteria the, in another study they may give more importance to the effect on the environment and less importance to the economic benefits or technical complexity, due to that the most feasible interventions will be those interventions that have a high impact on the environment, however, the weighting is depending on the needs of farmers and their goals. Also, this order can change if we have quantitative data for all the adaptation strategies listed, these data can be on costs, profit, materials required, etc., in this way we can do a cost-benefit analysis. Thirdly, if the group of experts chosen to do the scoring was larger in number, then we would have a variety of results, more contradictions and different points of view regarding each intervention, so the possibility of returning to maladaptation would be lower. Whether or not these conclusions are reached directly or by the judgment of experts, there is a need to know how these taken decisions can be the right approach for implementing adaptation strategies

This feasibility assessment is interesting since it can create quantitative data that can cover different geographical areas so if I use the same methodology for the feasibility assessment in another area such as Lebanon as it is an arid area like Egypt, affected by climate change and have several problems beside environmental ones such as the siren and political crisis, social unrest, non-functioning institutions, unemployment, etc. From the initial method, I would not change the basics as these areas are similar but I would add some other elements because each area besides the common has their own characteristics. If we implement the same method in many regions that are arid, have water scarcity, maybe land degradation, then for many projects it would not be necessary to do preliminary studies and identify vulnerabilities before implementing different strategies, so they will directly apply the same method in different areas and save time. Anyhow this does not work in reality because there would be a high chance for maladaptation. Therefore we can take the basis of this methodology and add elements that are specific to the region under study. When determining the criteria for the new area the chosen decision-makers need to check if the chosen criteria fulfil some conditions such as efficiency, effectiveness, and urgency may be an adaptation strategy is not needed in a short time so there will be no need to include in the time being, also flexibility, legitimacy, equity, etc. In the concrete case for Lebanon, we would need to add some other criteria and assign different weights to them because the farmers there have different priorities from the farmers in Egypt, if a farmer in Egypt produces mostly to cover home consumption, the opposite happens in Lebanon, where the villages of SupMed sample produce mostly fruit trees and only one village produces vegetables, regardless of this, in all these villages the largest part of the production goes for sale, about 74.75%, which means that a farmer in Lebanon has a higher income, also it is more food secure than a farmer in Egypt, with just this information we can understand that the farmers in both study areas have

different priorities. When adding the new criteria, we also have to take into consideration the political aspect in Lebanon when we have an unstable government and corruption at high levels, so one of the criteria that should be added is political complexity, which can include institutional complexity, political support, legal complexity as sub-criteria.

Uncertainties arise from incomprehension of the integration of catastrophe risk reduction, poverty alleviation, and climate adaptation and mitigation. So, for future assessments more data on farms' agricultural practices in Luxor through the years are required, besides that there is a need for awareness of farmers, government and other stakeholders for the importance of adaptation in the Egyptian farming system. Also, the MCAs used in this paper can be suggestions for the government, agricultural institutions, experts, researchers and other stakeholders to follow for better decisions on adaptation strategies that they are going to implement. The researchers or decision makers who are going to use this tool to analyze the intervention in order to implement it when there is no data and there are no sure grounds that that specific intervention will be successful, however, the number of experts should be higher than the number that we used in this paper, this to have a larger range so that the error is smaller so the chosen intervention will be relevant for the area

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Appendices

Appendix 1: Sample form for interventions in the study area

A. Information for the Farm				
Farm type				
Name of the village				
Farmer name				
Total cultivated area (ha)				
Cultivated crops	1)	2)	3)	4)
The area planted with each crop (ha)	1)	2)	3)	4)
Crops to be contracted				
Name of the crop	*1)*	2)	3)	4)
Initial area(ha)	1)	2)	3)	4)
Area contracted(ha)	1)	2)	3)	4)

B. Interventions per crop						
Definition of the Intervention & Monitioring and Evaluation of Interventions						
	Crop 1-			**Crop 2-**		
Type of intervention	1)	2)	3)	1)	2)	3)
Description						
Why this intervention?						
Dates of Interventions						
Expected impact						
Dates for intervention control						
Means of control						
How the intervention was implemented ?						
The results of control						
The impact of the intervention						
To what extent the objectives are achieved?						
	Crop 3-			**Crop 4-**		
Type of intervention	1)	2)	3)	1)	2)	3)
Description						
Why this intervention?						
Dates of Interventions						
Expected impact						
Dates for intervention control						
Means of control						
How the intervention was implemented ?						
The results of control						
The impact of the intervention						
To what extent the objectives are achieved?						

C. Interventions at farm scale			
Type of intervention			
Description			
Why this intervention ?			
Dates of Interventions			

Expected impact			
Dates for intervention control			
Is there a need for new agricultural operation?			
Is there a need for traning?			
Means of control			
How the intervention was implemented ?			
The results of control			
The impact of the intervention			
To what extent the objectives are achieved?			

Appendix 2: Sample form to be filled by experts for scorings in order to estimate the average weights

Adaptation options	Technical			Economic			Envirnoment	
	Technical Capacity required	Social complexity	Insitutional complexity	Profitability	Cost of action	Transaction costs	Effect on water	Effect on soil
Land Holding consolidation								
Soil laser leveling								
Raised bed cultivation								
The changing of the sowing dates								
Intercropping								
Cultivation of high-value crops such as medicinal and aromatic plants								
Introduction of heat- tolerant varieties.								
Production of alternative livestock fodder								
Using alternative water sources such as agricultural drainage or surface well								
Cultivation of palms and willows as windbreaks								
Establishment of Water User Associations (WUA)								
Establishing schemes for revolving loans with a focus on women.								
Use of fans in animal pens								
Cultivation of traditional crops such as sorghum instead of corn								
Soil moisture conservation practices								
Cultivation of salinity-resistant varieties								
Using organic fertilizers								

a. Table filled by Expert 1: Abdelhakim tahani

Adaptation options	**Technical**			**Economic**			**Envirnoment**	
	Technical Capacity required	Social complexity	Insitutional complexity	Profitability	Cost of action	Transaction costs	Effect on water	Effect on soil
Land Holding consolidation	3	1	1	5	4	2	5	4
Soil laser leveling	4	4	4	3	3	3	4	3
Raised bed cultivation	4	4	4	4	3	4	4	3
The changing of the sowing dates	3	2	1	3	4	3	4	2
Intercropping	2	4	3	3	4	3	4	3
Cultivation of high-value crops such as medicinal and aromatic plants	3	4	4	4	3	4	2	2
Introduction of heat- tolerant varieties.	3	4	2	4	3	3	4	2
Production of alternative livestock fodder	3	4	3	3	4	4	3	2

Using alternative water sources such as agricultural drainage or surface well	4	2	1	3	3	2	4	2
Cultivation of palms and willows as windbreaks	4	4	4	2	3	4	3	2
Establishment of Water User Associations (WUA)	4	3	3	4	4	2	4	2
Establishing schemes for revolving loans with a focus on women.	4	3	2	3	4	2	2	2
Use of fans in animal pens	4	4	4	4	4	4	3	2
Cultivation of traditional crops such as sorghum instead of corn	4	4	4	3	4	4	3	2
Soil moisture conservation practices	3	4	4	3	4	4	3	3
Cultivation of salinity-resistant varieties	4	4	2	4	3	4	3	4
Using organic fertilizers	4	4	4	4	3	4	2	4

b. Table filled by Expert 2 : Othman Elshaikh

Adaptation options	**Technical**			**Economic**			**Envirnoment**	
	Technical Capacity required	Social complexity	Insitutional complexity	Profitability	Cost of action	Transaction costs	Effect on water	Effect on soil
Land Holding consolidation	1	1	1	5	4	3	5	5
Soil laser leveling	1	4	1	5	4	3	5	5
Raised bed cultivation	2	4	2	5	4	3	5	5
The changing of the sowing dates	3	3	2	5	5	3	5	5
Intercropping	1	3	2	5	4	3	5	5
Cultivation of high-value crops such as medicinal and aromatic plants	3	3	2	5	4	3	5	5
Introduction of heat- tolerant varieties.	3	3	2	5	4	3	5	5
Production of alternative livestock fodder	1	2	2	5	4	3	4	1
Using alternative water sources such as agricultural drainage or surface well	2	4	1	5	4	3	5	2
Cultivation of palms and willows as windbreaks	4	5	2	2	3	3	1	1
Establishment of Water User Associations (WUA)	2	2	1	5	4	3	5	5
Establishing schemes for revolving loans with a focus on women.	2	2	1	5	3	3	1	1
Use of fans in animal pens	5	5	5	2	5	3	1	1
Cultivation of traditional crops such as sorghum instead of corn	2	3	2	3	5	3	5	1
Soil moisture conservation practices	3	5	2	3	4	3	5	5
Cultivation of salinity-resistant varieties	2	5	2	3	4	3	5	5
Using organic fertilizers	1	5	1	1	1	3	1	5

c. Table filled by Expert 3 : Emad Aly

Adaptation options	**Technical**	**Economic**	**Envirnoment**

	Technical Capacity required	Social complexity	Insitutional complexity	Profitability	Cost of action	Transaction costs	Effect on water	Effect on soil
Land Holding consolidation	2	2	2	5	3	3	3	4
Soil laser leveling	2	3	3	2	3	3	4	3
Raised bed cultivation	4	5	3	3	4	4	5	4
The changing of the sowing dates	2	2	4	4	3	4	2	2
Intercropping	3	4	4	4	4	4	3	1
Cultivation of high-value crops such as medicinal and aromatic plants	3	2	4	4	3	4	2	2
Introduction of heat- tolerant varieties.	2	2	2	5	2	4	3	2
Production of alternative livestock fodder	2	4	3	4	3	4	1	3
Using alternative water sources such as agricultural drainage or surface well	2	4	2	3	2	3	5	4
Cultivation of palms and willows as windbreaks	4	5	4	3	3	4	1	2
Establishment of Water User Associations (WUA)	4	5	3	4	2	3	4	3
Establishing schemes for revolving loans with a focus on women.	2	1	3	5	2	2	1	1
Use of fans in animal pens	2	4	5	4	2	4	1	1
Cultivation of traditional crops such as sorghum instead of corn	1	2	4	4	3	4	2	1
Soil moisture conservation practices	2	5	4	3	2	3	4	3
Cultivation of salinity-resistant varieties	2	3	3	5	2	3	3	4
Using organic fertilizers	3	4	4	4	3	4	4	4

Appendix 3: Financial viability of estabilishing schemes for revolving loans to the women

Establishing schemes for revolving loans Goats				
Costs	Unit	Amount	Unit price (egp)	Totals (EGP)
Heads of goats	Head	3	1200	3600
Fodder for one year	Ton	1	5000	3000
Vet				200
Administrative expenses and credit risk				180

Total costs				6980
Revenue				
Revenue of selling 3 new kids born(3 out of 6 are be delivered to NGO to be revolved to another beneficiary)	Head	6	1200	7200
The Mothers	Head	3	1200	3600
Total revenues				10800
Net profit				3820
%profit				54.7%