المحاصيل والوسائل الحديثة للزراعات المقاوِمة للجفاف في إقليم شمال وشرق سوريا

(دراسة في التحدّيات والحلول الزراعية لمواجهة التغيّر المناخي)

The crops and modern methods for drought-resistant agriculture in North and East Syria

(A study of agricultural challenges and solutions to confront climate change)

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introduction

Agriculture is the cornerstone of the economic and social life of North and East Syria, with the majority of the population relying on this sector as their primary source of livelihood.

With successive droughts and the intensifying effects of climate change, the agricultural sector faces increasing challenges that threaten food security and societal stability. This necessitates a reconsideration of traditional agricultural patterns and a shift towards more flexible and sustainable solutions.

This research is based on the basic premise that ensuring a secure agricultural future in the region requires the development of comprehensive agricultural policies based on scientific knowledge, modern technology, and financial support as key pillars. Hence, the research seeks to review the current agricultural reality in the region and analyze the most important drought-resistant crops that could constitute a strategic alternative in light of declining water resources. In addition to highlighting the most prominent modern agricultural methods applicable in the region's environment.

The study also examines successful international experiences in the field of dry and sustainable agriculture in Jordan, Morocco, and Spain, and analyzes the extent to which these models can be adapted to the specificities of the local reality in the region of North and East Syria.

concludes with a set of practical recommendations based on a comparative analysis between local reality and international models, with the proposal of realistic agricultural policies based on the concepts of sustainable agriculture. Food security and effective resource management.

Chapter One: Theoretical and Conceptual Framework

1.1 About the North and East Syria region and the prevailing climate there:

North and East Syria is one of the most important agricultural regions in Syria; It is characterised by its relatively fertile soil and the vastness of its agricultural area. It constitutes the country's food basket and contributes a large proportion of grain production, especially wheat and barley.

The climate in the northeastern region of Syria is classified as semi-arid to arid, characterized by scarce and irregular rainfall, in addition to high temperatures in the summer and low temperatures in the winter. Annual rainfall rates range between 150 and 400 mm, and these rates decrease towards the southeast of the region. Climate changes in recent years have led to an exacerbation of drought and the recurrence of years of rain shortages; This has particularly harmed rainfed agriculture.

1.2Definition of basic concepts

1.2.1Drought

Drought is defined as a state of severe and persistent decrease in rainfall rates below the normal annual average, which leads to a shortage of water resources and also negatively impacts agricultural production and related economic activities.

Several types of droughts can be distinguished: climatic drought, agricultural drought, and hydrological drought. In this research, we are concerned with the agricultural type,

which is manifested in the inability of the soil to retain sufficient moisture for crop growth.

1.2.2Drought-resistant agriculture

Drought-resistant agriculture is a set of agricultural activities and practices that aim to adapt to water scarcity and increase production capacity in difficult climatic conditions.

This includes the use of adapted crops, the application of efficient water management techniques, the improvement of soil properties, and the development of resilient agricultural systems based on local climate knowledge.

1.2.3Agricultural Sustainability

Agricultural sustainability refers to the ability to produce food, feed, and fiber over the long term, without harming natural resources or disrupting ecosystems.

involves maintaining soil fertility, rational use of water, and adopting agricultural practices that reduce dependence on harmful external inputs.

In the Syrian context, agricultural sustainability takes on a vital dimension in light of accelerating climate change and resource scarcity.

1.3The relationship between the three concepts

These concepts are closely related within the theoretical framework of this research. Drought represents the main environmental challenge, resilient agriculture constitutes the technical response to this challenge, and sustainability represents the ultimate goal sought by agricultural policies and practices.

Therefore, promoting drought-resistant agriculture is an essential step towards achieving sustainable agricultural development in the North and East Syria region.

Chapter Two: Drought- Resistant Crops

2.1 Review of the most important crops suitable for dry farming

Drought - resistant crops are an essential part of the climate change adaptation strategy in arid and semi-arid areas (north and east Syria region), where drought rates are increasing significantly. Selecting crops that can withstand water scarcity is crucial to ensure the continuity of agricultural production.

The most prominent crops that can be grown in this region and that can withstand drought conditions are:

1- Durum wheat (Triticum durum): Durum wheat is a major crop in northeastern Syria and one of the most drought- tolerant crops. It is well adapted to sandy, dry soils and is the most popular choice in rain -fed, arid areas.
2- Barley (Hordeum vulgare): Barley is the second most widely grown crop in the region after wheat.

Barley grows well in dry areas with limited rainfall. Farmers rely on barley as a supplementary crop in dry years, where it is used as food for humans and animals.

3- Corn (Zea mays): Although corn requires large amounts of water, there are drought -resistant varieties of corn that can grow in areas of northeastern Syria, especially during periods of partial drought. These varieties are distinguished by their ability to adapt to moderate droughts.
4- Lentils and beans (Lens culinaris, Vicia faba): Legumes are drought - tolerant, with roots adapted to dry soil and benefiting from surface water and fog. These crops also play a role in improving soil fertility due to their ability to fix nitrogen.
5- Chickpeas (Cicer arietinum): Chickpeas are a crop that has a high tolerance to drought.

It is grown in areas with scarce water, and this crop contributes to improving the soil through its nitrogen compounds.

2.2 Analysis of the characteristics of each crop and its tolerance to drought

1- Durum wheat: Durum wheat has a high ability to adapt to drought conditions, as it can benefit from a small amount of water، and it is distinguished by deep roots that help it reach groundwater.

Durum wheat requires moderate temperatures, but it can tolerate some high temperatures during dry periods. It can be grown in areas with limited rainfall.

2- Barley: Barley is considered one of the crops that can be grown in dry soils because it has the ability to improve water utilization. It is characterized by its rapid growth compared to wheat, which makes it an ideal choice during short periods of drought. Barley is also able to adapt to nutrient- poor soils.

3- Corn: It is known that corn needs a large amount of water during the growth period, but it has the ability to resist drought for a short period.

Some modern corn varieties are better adapted to dry conditions thanks to agricultural research focused on improving their genetic characteristics.

4- Lentils and beans: Legumes such as lentils and beans are the most drought-resistant winter crops. These crops have the ability to grow in nutrient - poor soil, and their low water requirement makes them ideal for dry conditions.

5- Chickpeas: Chickpeas require short periods of drought, but at the same time they are able to grow in poor soil. Chickpea seeds can withstand drought for long periods, allowing them to maintain productivity in dry environments.

2.3 Drought- resistant crop cultivation techniques

Cultivation techniques vary from crop to crop, but there are some general practices that can be adopted to improve crops' ability to whithstand drought:

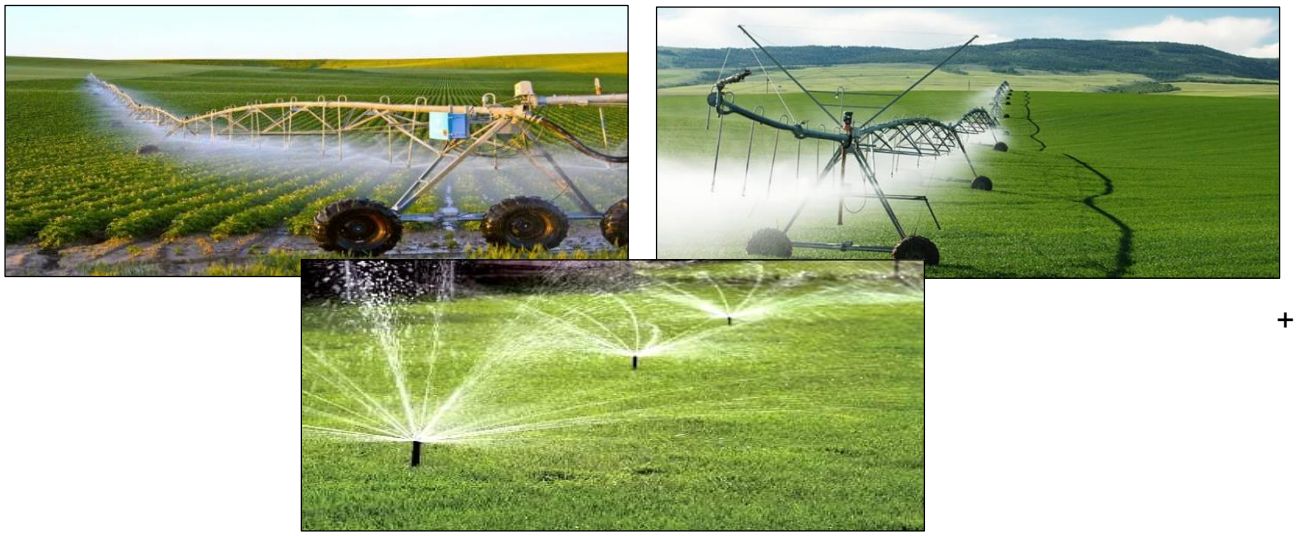
1- Improving irrigation methods: Using drip or sprinkler irrigation techniques can contribute to greater water conservation, especially in rainfed lands. These methods help direct water directly to crop roots, reducing water loss.
2- Use of improved seeds: Developing drought-resistant seeds can enhance crops ' ability to adapt to climate change. Agricultural research is developing crop varieties that are more tolerant to dry conditions by modifying their genetic characteristics.
3- Conservation agriculture: This type of agriculture aims to reduce water loss through techniques such as no-till farming, which conserves soil moisture and reduces evaporation. Conservation agriculture also supports the soil by stimulating biological activity within it.

2.4 Water-saving irrigation techniques:

The use of modern irrigation technologies is considered one of the essential factors that contribute to enhancing the ability of agriculture to adapt to dry conditions in the North and East Syria region. Given the scarcity of water in the region, the importance of modern technologies in improving the efficient and economical use of water and reducing the burden on water resources

1- Drip irrigation: Drip irrigation is one of the most important techniques used to conserve water in agriculture. This technique relies on directing water directly to the roots of plants, reducing losses resulting from evaporation or water seepage into the soil. This method also helps reduce irrigation costs and improve crop production efficiency. Drip irrigation is distinguished by its ability to provide plants with precise amounts of water, making it ideal for cultivation in arid environments.

2- Sprinkler irrigation: This method relies on spraying water evenly over the soil surface using pipes and sprinkler equipment. This method is considered effective in covering large agricultural areas, especially in lands where deep water sources are not available. Sprinkler irrigation may be less efficient than drip irrigation in some cases, but it can be used to distribute water evenly in lands with a soil structure that allows for sprinkling.



3- Closed pipe irrigation (submerged irrigation): This method is considered a water-saving irrigation method, as water is directed directly to the roots through a network of closed pipes, which improves water distribution and reduces loss. This method contributes to reducing evaporation in hot and dry regions.

4- Irrigation using reused water: In some arid regions, irrigation techniques using reused water are used through wastewater treatment plants. This method helps

reduce pressure on traditional water resources, especially in areas experiencing a scarcity of fresh water.

2.5 Improved seeds and smart fertilizers

1- Improved Seeds: Improved seeds are considered one of the most significant developments in modern agriculture. Improved seeds aim to enhance plants' ability to withstand harsh environmental conditions such as drought. Many seed varieties have been developed with greater capacity to absorb and store water, enhancing plants ability to survive longer periods under drought conditions. These varieties include crops such as wheat, barley, and corn, whose drought resistance has been enhanced through genetic selection or genetic modification.

2- Smart fertilizers: Smart fertilizers are a type of fertilizer that promotes plant growth using minimal water. Smart fertilizers include fertilizers that release nutrients gradually according to plant needs, helping to reduce nutrient loss due to evaporation or leaching.

These fertilizers help improve water use efficiency and increase crop productivity.

2.6 No-till farming

No - till farming is a modern technique that contributes to conserving water in the soil. This technique relies on reducing the use of agricultural machinery in the soil preparation process, which helps conserve moisture. Additionally, no-till farming helps reduce erosion and improve soil structure by preserving organic matter. This method contributes to reducing water loss and increasing the soil's moisture-retaining capacity, making it ideal for arid regions.

2.7 digital agriculture

Digital agriculture involves the use of modern technology to collect and analyze data related to agricultural production. Digital agriculture uses sensors and data analysis tools to monitor soil and plant conditions, helping farmers make accurate decisions regarding irrigation and fertilization. Digital agriculture also provides solutions for predicting weather patterns and determining the best planting times, which helps optimize resource use and reduce water waste.

Some of the tools involved in digital agriculture include:

1- **Ground sensors**: These devices help measure soil moisture levels, temperature, and other environmental variables that affect plant growth.
2- **Drones**: Drones are used to monitor crops and agricultural areas from the air, and to provide accurate images to analyze plant health and water needs.

3- **Computational models**: Computational models are used to predict future climate conditions and to guide agricultural practices in line with expected drought conditions.

2.8 Challenges facing the application of modern methods in agriculture

Despite the many benefits offered by modern agricultural technologies, there are many challenges that may prevent the widespread adoption of these technologies in the North and East Syria region. Among these challenges:

1- Financing and cost: The cost of installing and maintaining some modern technologies, such as drip irrigation and improved seeds, may be high for farmers in the region, especially in areas with weak economic capacity.
2- Training and knowledge transfer: Farmers need training to use modern technologies effectively. Sometimes, farmers face difficulties in acquiring the knowledge and skills necessary to implement these technologies.
3- Infrastructure: Some areas lack the appropriate infrastructure to apply these technologies sustainably; For example, it may be difficult to provide sufficient irrigation water or establish wastewater treatment plants in some districts.

Chapter Three: Field Study and Data Analysis

3.1 introduction

The field study is based on data collection from the agricultural landscape in North and East Syria, with the aim of understanding how modern agricultural technologies are being implemented, including drought-resistant crops and the use of advanced agricultural techniques such as water-saving irrigation and improved seeds. This chapter relies on an analysis of data collected through questionnaires and qualitative interviews with farmers and agricultural experts in the region.

3.2 Data collection methodology

Data were collected through three main tools:

1- **Questionnaires**: A special questionnaire was designed to suit the study of agricultural conditions in the North and East Syria region. The questionnaires were directed to a sample of farmers in various provinces of Raqqa and Al-Jazeera. The questions covered several aspects, such as the types of crops grown, the irrigation methods used, and the extent of adoption of modern technologies.

2- **Qualitative interviews**: Interviews were conducted with a group of agricultural experts, such as agricultural engineers and supervisors of agricultural extension programs. These interviews aimed to collect information about the effectiveness of modern agricultural technologies and the challenges farmers face in applying them.
3- **Field review:** Field visits were conducted to some agricultural areas in the North and East Syria region, where the use of modern irrigation techniques was monitored, the quality of the cultivated crops was evaluated, and the extent of the impact of modern techniques on agricultural productivity under drought conditions was examined.

3.3 Data analysis

The data were analyzed based on the results obtained from questionnaires, interviews, and field review. The data were categorized into several main themes, including irrigation techniques, drought-resistant crops, and the adoption of modern agricultural methods.

3.3.1 Irrigation techniques used

Through a farmer survey, it was found that approximately 60 % of farmers in the Syrian Al-Jazeera region use traditional irrigation techniques such as flood irrigation, while only 30% rely on drip irrigation. Many farmers indicated that traditional irrigation is not suitable for the region's arid conditions, as it causes significant water loss and negatively impacts productivity. In contrast, farmers using modern irrigation techniques expressed great satisfaction due to their ability to save water and improve agricultural efficiency.

Interviews with agricultural experts showed that drip irrigation techniques, in addition to irrigation using reused water, were the most effective in reducing the effects of drought and achieving agricultural sustainability.

Experts also pointed out that most farmers still need practical training on how to use these technologies correctly and effectively.

3.3.2 Drought- resistant crops

Survey results showed that the most widely cultivated crops in the region include wheat, barley, corn, and vegetables such as potatoes and tomatoes. Although most of these crops are traditional crops that require large amounts of water, many farmers indicated that some improved varieties of wheat and barley have shown greater drought

tolerance. Some alternative crops, such as millet and peanuts, have also shown resilience to drought conditions.

Agricultural experts added that some improved wheat and barley varieties developed using genetic improvement techniques have demonstrated good drought resistance, making them a good option for farmers in the region. They also noted the importance of using local seeds adapted to the local climate.

The following (Table No.1) is a comparison between the most important drought-resistant crops in the North and East Syria region in terms of tolerance, productivity, and growth period:

comments	Growth period (in days)	Relative (kg/h)	Drought resistance degree	The crop
It requires early planting to achieve the best production.	120-100	2500-1500	Medium to high	Durum wheat (durum)
Tolerates poor and saline soil	110-90	2200-100	High	barley
Enriches the soil with organic nitrogen	100-90	800-500	Medium	Lentils
Sensitive to excess moisture after flowering	110-95	1800-1000	relatively high	chickpeas
Suitable for dry and semi-dry environments	95-75	1600-800	very high	millet
Relatively resistant to drought and water scarcity	100-85	1200-500	Medium to high	Sesame

It needs supplemental watering in the first season.	perennial	6000-8000 (green fodder)	High	(local clover)

Based on studies by the Food and Agriculture Organization (FAO), the International Center for Agricultural Research and Development (ICARDA), and reports from the Syrian Ministry of Agriculture.

3.3.3 Adopting modern technologies in agriculture

Data from the field study indicate that the adoption of modern agricultural technologies in North and East Syria still faces a number of structural and cognitive challenges. These findings were based on questionnaires and interviews conducted with a sample of 80 male and female farmers selected from various areas, including the northern countryside of Raqqa province, the countryside of Al-Jazeera and the eastern countryside of Deir ez-Zor province. The sample was distributed based on gender, including 50 male farmers and 30 female farmers, reflecting the study's interest in monitoring differences in the adoption of agricultural technologies between the two genders.

Survey result showed that only about 40% of participants had actually started using some modern agricultural technologies, such as improved seeds, smart fertilizers, and drip irrigation techniques. The largest percentage, representing 60% of respondents, expressed reservations or reluctance to use these methods, which is due to several main factors. The most prominent of these are: the high costs associated with acquiring these technologies, And the weakness of governmental and institutional support, The scarcity of agricultural extension programmes, and the low general awareness among farmers of the benefits of these technologies in the medium and long term.

In contrast, in -depth interviews conducted with a number of agricultural engineers working in local institutions and non-governmental organizations indicated positive indicators of a gradual increase in adoption of these technologies, particularly in areas that had previously witnessed awareness-raising or training interventions. Some experts reported that the use of improved seeds has become relatively popular among a group of young farmers, and that there is growing interest in experimenting with smart fertilizers as a means of enhancing productivity under unstable climatic conditions.

Based on the above, the study emphasizes the importance of strengthening agricultural awareness programs and expanding the scope of practical training courses targeting farmers of both genders, while providing financial incentives or technical support that contribute to reducing the cost of adopting these technologies. The study also

recommends restructuring agricultural extension mechanisms in the region to make them more efficient in transferring modern knowledge and more sensitive to the needs and circumstances of local farmers.

3.4 Challenges facing the adoption of modern technologies

The field study showed that there are several major challenges that prevent the adoption of modern agricultural technologies in the North and East Syria region:

1- High cost: The high cost of modern irrigation technologies, such as drip irrigation, purchasing improved seeds, and smart fertilizers, is one of the biggest obstacles facing farmers.

   While farmers indicate that they do not have the financial capacity to cover these costs.

2- Lack of training and technical support: Many farmers suffer from a lack of technical support and training in the use of modern technologies. The study showed that more than 50% of farmers do not receive adequate training on how to use modern irrigation technologies or how to implement advanced agricultural methods.
3- Concerns about the ineffectiveness of technologies in local conditions: Some farmers feel uncertain about the effectiveness of modern technologies in local conditions, as they believe that the technologies may not be fully suitable for the harsh climate of the region.

3.5 Field study results

Results of direct interviews and questionnaires directed to 80 male and female farmers from various districts of the North Region And eastern Syria (50 males and 30 females) showed a set of important indicators about the level of adoption of modern agricultural technologies, and the benefits resulting from them. and the obstacles that prevent its widespread dissemination. These results were analyzed according to three main axes :

1- Adopting modern irrigation techniques

A large number of farmers who adopted modern irrigation techniques, such as drip or sprinkler irrigation, reported that these methods contributed significantly to increasing water efficiency and reducing waste, especially in light of declining rainfall and increasing droughts. They also noted a clear improvement in productivity and crop quality, particularly in vegetable and grain crops. However, the percentage of adopters remains below the desired level due to the cost of installing these systems and the scarcity of technical and financial support.

2- Use of improved seeds

The results showed that the use of improved seeds – especially drought -resistant varieties – helped improve the adaptive capacity of agricultural crops to climate change. This had a positive impact on the quantity and quality of production. It was observed that farmers who received prior training or participated in pilot projects were more willing to adopt these technologies.

3- Main challenges

Data show that the high cost of acquiring modern agricultural technologies represents the biggest obstacle facing farmers, in addition to the absence or weakness of government support and agricultural extension programs. Interviews also revealed a knowledge gap among some farmers regarding the benefits and methods of using these technologies, highlighting the need for broader awareness-raising and training interventions.

The following table (No. 2) shows the percentage of adoption of these technologies within the targeted sample:

The most prominent challenges	The most important benefits	percentage	Number of adoptees	Axis
High cost - lack of technical support	Reducing water consumption - increasing productivity	%42.5	34out of 80	Modern irrigation techniques
Poor awareness - difficulty accessing improved varieties	Drought resistance - Improved crop quality	%41.25	33out of 80	Use of improved seeds
High cost and poor availability in local markets	Promote plant growth and reduce the amount used	%35	28out of 80	Smart fertilizer application

These results indicate that a significant percentage of farmers are relatively willing to adopt modern technologies; however, this remains conditional on the existence of long-term systematic support, combining awareness, training, and material and technical support.

Chapter Four: Results and Recommendations

4.1 Main results

The results of the field study and graphic analysis collected from farmers and agricultural experts in the provinces of North and East Syria reveal a set of key findings that confirm the importance of introducing modern agricultural technologies to enhance the ability to resist drought and achieve agricultural sustainability under the harsh climatic conditions experienced by the region.

1- Success of modern irrigation techniques: The results showed that farmers who used modern irrigation techniques، such as drip irrigation، they have witnessed increased water-use efficiency, which has helped reduce irrigation costs and significantly increase productivity compared to traditional irrigation techniques. Farmers who have used these techniques have also expressed great satisfaction with their ability to improve agricultural productivity during drought.
2- Utilizing drought-resistant crops: The study results showed that some crops, such as wheat and barley, as well as some alternative crops, such as millet, demonstrated good resistance to drought when grown using modern irrigation techniques. These crops have proven effective in confronting climate change, which is a positive step toward agricultural sustainability in the region.
3- Economic and technical challenges: One of the biggest challenges facing farmers is the high cost of modern agricultural technologies, including drip irrigation and improved seeds. Furthermore, many farmers face difficulty obtaining the appropriate training and technical resources that enable them to fully benefit from these technologies.
4- Lack of government and technical support: The study revealed a significant lack of government and technical support to encourage farmers to adopt modern agricultural technologies. The results indicate that the provision of training programs and greater financial support could significantly contribute to improving adoption rates of these technologies.

4.2 Recommendations

Based on the results obtained in this research, several recommendations can be presented aimed at enhancing the capacity of agriculture to drought resistance and achieving agricultural sustainability in the North and East Syria region:

1- Increasing financial and technical support for farmers: It is essential for relevant authorities, represented by the Autonomous Administration, to provide financial support to farmers to cover the costs of modern agricultural technologies, through the provision of soft loans or direct support for the purchase of modern irrigation technologies, such as drip irrigation systems and improved seeds.
2- Expand training and awareness programs: Training programs should be created to enhance farmers' knowledge of how to properly use modern technologies.

These programs should include practical and field training on modern irrigation systems and the use of smart fertilizers.

3- Encouraging local agricultural research: Local research on developing drought-resistant crops that are suited to the local environment in the Syrian Al -Jazeera region should be encouraged. This research can help find practical and effective solutions to increase crop productivity under dry conditions.
4- Enhancing Public-Private Cooperation: It is important for the Autonomous Administration of North and East Syria to cooperate with non-governmental organizations and the private sector to implement joint projects aimed at improving agricultural productivity and enhancing agriculture's resilience to drought. The private sector can offer innovative solutions that represent real opportunities for expanding the scope of modern agricultural technologies.
5- Promoting sustainable agriculture: It is important to adopt sustainable agriculture methods, such as no-till farming. (Zero Tillage) and Water Conservation Agriculture. These methods not only help reduce the impact of drought, but also contribute to maintaining soil health and increasing its fertility in the long term.
6- Raising environmental awareness: Awareness campaigns should be implemented on climate change and its impact on agriculture in the region, as well as the importance of drought-resistant agricultural techniques; Increasing environmental awareness may help farmers adopt sustainable agricultural techniques and improve the sustainability of agricultural production in the future.

Chapter Five: Recruitment and Adapting International Experiences in Dry and Sustainable Agriculture

In light of the environmental and climatic challenges facing the agricultural sector in the North and East Syria region, especially the increasing frequency of drought, the need has emerged to study successful international experiences in dry and sustainable agriculture, and to transfer their locally applicable elements.

This chapter reviews models from three countries with pioneering experiences in this field: Jordan, Morocco, and Spain, with an analysis of the similarities and differences and the opportunities available to adapt these experiences to local reality.

First: Jordan's experience - water conservation agriculture and supplementary irrigation

Climate context and challenges

Jordan suffers from severe water scarcity, ranking among the ten poorest countries in the world in terms of water availability. It also faces a short agricultural season with extensive reliance on rainfed agriculture in the highlands.

Pioneering responses and experiences

Water harvesting techniques: building small earth dams and collection tanks and exploiting valleys to store rainwater.

- supplementary irrigation: providing limited amounts of water at critical stages of crop growth.

- Climate Early Warning System: To guide farmers on the ideal timing for planting or harvesting.

- Developing drought-resistant varieties: such as wheat and barley grown in the central highlands.

Local applicability

These models can be used in rainfed areas in the countryside of Raqqa, Tabqa and Al-Jazeera provinces; This is achieved by rehabilitating flood channels, building water tanks, and directing farmers towards using low-cost irrigation techniques.

Second: Morocco's experience - conservation agriculture and crop rotation

Natural conditions and challenges

Morocco relies heavily on rainfed agriculture and is subject to recurring droughts, which has necessitated the development of long-term national policies, most notably the “Green Morocco Plan”.

Axes of the Moroccan experience

No -till farming to conserve soil moisture and prevent erosion.

Adopting drought- resistant crops, such as lentils and chickpeas.

-Diversifying agricultural rotations and reviving legumes in the soil to enhance its fertility.

-Motivating farmers through direct financial and technical support for small farmers.

Transferable lessons

This experience serves as a model for transitioning from unregulated seasonal agriculture to a sustainable development model, and the Autonomous Administration can adopt similar plans to provide incentives to farmers to adopt conservative agricultural techniques, especially in the provinces of Al- Jazeera and Deir ez-Zor.

Third: Spain ’s experience – precision agriculture and advanced irrigation systems

Environmental and economic situation

Southern Spain, especially Andalusia, faces harsh climatic conditions and limited water supplies, which has led to the adoption of an advanced model of smart and sustainable agriculture.

The most prominent components of the Spanish model:

Precision agriculture: Using satellites and remote sensing to determine the actual need for irrigation or fertilizer.

Drip irrigation: a system that saves up to 50% of water compared to flood irrigation.

Reuse of treated water in agriculture, especially in olive cultivation.

Encouraging mixed farming (drought- resistant fruit trees such as olives and almonds).

Local air conditioning capability

If technical support is provided, modern irrigation techniques and the use of treated greywater in gardening and home agriculture projects in cities can be disseminated. Olive and pistachio cultivation can also be generalized in the irrigated areas around the Euphrates River.

Fourth: Comparative analysis and local adaptation capabilities (North and East Syria region):

Regional applicability	Spain	Morocco	Jordan	element
Partially in rainfed and irrigated areas	Groundwater and treatment	Limited seasonal rains	rainwater harvesting	Water source
Highly compatible	Olives - Vegetables - Legumes	Legumes - grains	Wheat - Barley - Lentils	Type of crops
Need technical and financial support	Precision Agriculture - Drip Irrigation	No-till crop rotations	Supplementary irrigation - climate forecasting	Technology used
Need sustainable support programs	Governmental - European Union support	Wide (Green Morocco Plan)	Limited projects International organizations	Incentives and support

Adopting international experiences in dry farming does not mean completely replicating it; rather, it requires careful analysis and thoughtful adaptation to the specific

environmental, economic, and social conditions of North and East Syria. The comparison indicates that water - conserving agriculture, adopting drought-resistant crops, and developing smart irrigation infrastructure are priorities for future agricultural response. This also requires an effective role for the autonomous administration in formulating integrated agricultural financing and extension policies .

Chapter Six: Scientific and Practical Proposals and Solutions for Modernizing Agriculture in North and East Syria

The agricultural sector in North and East Syria constitutes the cornerstone of food and economic security. However, this sector suffers from accumulated challenges due to drought, weak infrastructure, and the reliance on traditional methods. Therefore, this chapter proposes a set of scientific and practical solutions within three main axes: knowledge, technology, and financial and organizational support, based on successful global experiences and the specificities of the local reality.

First: Knowledge Axis - Building Capacities and Expanding the Knowledge Base

6.1 Development of digital guidance platforms

Create applications or electronic platforms in local languages (Arabic and Kurdish) that provide updated information to farmers about planting dates, seed quality, pest control methods, and modern irrigation methods.

6.2 Practical training for farmers

Launching awareness programs and agricultural training centers that provide practical workshops in villages and agricultural areas, in cooperation with local agricultural engineers and international organizations.

6.3 Bringing international experiences

Transfer and adapt successful experiences in sustainable dry farming from countries such as Jordan, Morocco and southern Spain, and apply it on a local scale with appropriate modifications.

6.4 Disseminating sustainable agriculture concepts

Integrating smart and sustainable agriculture concepts into vocational education curricula or through community initiatives to encourage new generations to engage in agricultural production using modern methods.

Second: Technology Axis - Updating the Technical and Production Infrastructure

6.1 Closed-circuit agriculture (CEA) systems:

Introducing greenhouse and soil-less cultivation systems (Hydroponics and Aeroponics) to reduce water consumption and achieve intensive production in small spaces.

2.6 Solar-powered smart irrigation systems:

Deploying drip irrigation systems based on solar-powered pumps, especially in areas with poor electricity supply, to reduce water waste and improve irrigation efficiency.

3.6 Using soil moisture sensors:

Installing low-cost sensors to accurately measure soil moisture, allowing for precise determination of irrigation timing and quantities, thus rationalizing consumption.

4.6 Drones:

Using drones to spray pesticides, monitor plant diseases, and accurately assess crop growth, especially in large areas.

5.6 Distinction between rainfed and irrigated agriculture:

Identify different solutions for each type:

-Rainfed agriculture: Supporting drought-resistant crops such as wheat Barley and lentils .

-Irrigated agriculture: developing irrigation networks and using high-yield varieties of vegetables and fruits.

Third: The axis of financial and regulatory support - towards economic sustainability

3.1 Dedicated agricultural support funds

Establishing small financing funds to support modern agricultural projects with joint funding from the Autonomous Administration and international organizations.

3.2 contract farming

Encouraging farmers to enter into advance contracts with buyers (such as factories, markets, and organizations) to stabilize prices and ensure marketing.

3.3 agricultural value chains

Developing the production chain from cultivation to storage and manufacturing (e.g. converting tomatoes into paste - herbs into oils - grains into flour); which increases the economic value of the crop.

3.4 Activating agricultural cooperatives

Restructuring agricultural cooperatives and expanding their tasks to include: purchasing seeds and equipment at group prices, and organizing training courses, And collective marketing of crops.

3.5 Stimulating green agricultural investment

(Green agricultural investment is the directing of financial resources towards agricultural projects that use environmentally friendly technologies, reduce pollution, and protect soil and water. Achieving environmental and economic sustainability together).

Encourage sustainable agricultural projects that use clean energy and renewable resources, and provide them with tax exemptions or incentives.

The solutions proposed in this chapter represent an integrated scientific and practical response to the agricultural crisis in North and East Syria.

The gradual implementation of these proposals, with the participation of official bodies, civil society, and international organizations, will contribute to building an agricultural sector that is more resilient and sustainable in the face of increasing environmental and economic challenges.

In light of the findings and analyses of this study, it becomes clear that the future of agriculture in North and East Syria depends not only on the size of available natural resources, but also primarily on how to employ modern knowledge and technologies in a manner that is compatible with the environmental and social specificity of the region. The data revealed that farmers have a latent desire for change; however, this desire is hindered by economic and cognitive obstacles that can only be overcome through well - thought-out interventions that take into account the needs of different agricultural groups and offer realistic, implementable solutions.

Achieving true agricultural sustainability in North and East Syria cannot be achieved without building solid bridges between scientific research and daily agricultural practice. Hence, the need for an effective partnership between academic institutions (research and study centers) and executive bodies (the Executive Council of North and East Syria) emerges. This partnership ensures the transfer of modern agricultural knowledge to the field and enhances farmers' capabilities through education and technical support. And economic stimulus.

This study does not claim to provide ready-made solutions; rather, it opens the door to a broader scientific and societal dialogue that rethinks the form and feasibility of agriculture in light of accelerating climate change.

When agriculture is nurtured with knowledge and managed with wisdom, it is not merely a means of survival; rather, it becomes a lever for development and stability, and a pillar

for preserving identity and dignity in societies where the land has long been the center of life and meaning.

Recommendations and future prospects:

Based on the findings of this study, a number of recommendations can be made to support agricultural trends and enhance the capacity of agricultural communities in North and East Syria to confront the challenges of drought and climate change:

1- Developing governmental and non-governmental support programs that target financing the introduction of modern agricultural technologies, such as smart irrigation systems and improved drought-resistant seeds, with a focus on vulnerable groups of small farmers.
2- Strengthening the agricultural extension infrastructure by training local cadres and activating specialized agricultural centers, ensuring the delivery of modern knowledge to various villages and agricultural regions.
3- Integrating agricultural education into school and community curricula, while establishing youth initiatives for practical agricultural learning, with the aim of building a generation more aware of the opportunities and challenges of agriculture in the context of climate change.
4- Launching applied research projects in cooperation with universities and scientific centers to test the effectiveness of drought -resistant crops in the local environment and evaluate the adaptability of modern technologies to the specificities of the region's soil and climate.
5- Encouraging cooperation among farmers by establishing local cooperatives associations that work to exchange expertise and facilitate access to shared resources.

From a research perspective, the study proposes future expansion into comparative studies covering different regions of Syria, to comprehensively analyze the impact of agricultural and environmental policies, while examining gender and societal disparities in the adoption of modern technologies. It also recommends focusing on the economic and social aspects related to food security, linking them to concepts of climate justice, rural development, and sustainability.

-The End–

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