DOCTORAL (PhD) DISSERTATION

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István Széchenyi Economics and Management Doctoral School

The role of sustainability transition in strengthening agricultural development resilience to water scarcity in Morocco

Doctoral (PhD) dissertation

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The role of sustainability transition in strengthening agricultural development resilience to water scarcity in Morocco

Dissertation to obtain a PhD degree

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i.e.	id est
e.g.	exempli gratia
etc.	et cetera

Abstract

In Morocco, the fifth-largest African economy by GDP, agriculture is still considered the backbone of the country's economy. Socially, agriculture is still a prominent employer nationally, especially in rural areas where the rural population depends on this activity for their livelihood, which demonstrates the sector's relevance to rural development. As the increase in drought frequency affects the sector's viability, its adaptability and sustainability are becoming paramount. The thesis examines the relevance of the transition to sustainability to enhance agricultural development resiliency regarding water shortages, with the focus on the available strategies, methods, and practices, which could further enrich and inform the current governmental and scientific discourse. To achieve the research objectives, a multi-method approach was applied. Based on the literature review analysis and the in-depth interviews conducted, hypotheses were developed. Using quantitative methods, the dataset generated from the questionnaire results was analyzed, and the hypotheses were tested. Based on all research results, an attempt was made to present suggestions and a concept suitable for the sector's current state. The results indicate that drought and, specifically, water shortages constitute a major challenge and threat to agricultural development for this decade and the following. Similarly, the drought, as a key issue, is substantiated not only by the reviewed literature and the in-depth interviews conducted, but also by farmers directly confronted with the situation, as indicated by the survey findings. The analysis of the responses also demonstrates that the farmers are inclined to cooperate in adopting and transitioning to sustainable agriculture practices if it is intended to help tackle the prevalence of drought challenges and adapt to climate change. In the same vein, the prevailing adaptive strategy among farmers facing drought and general water shortages is the increase in water abstraction. At the same time, this trend is unfortunately coupled with less efficient irrigation practices. Additionally, the results indicate the need to improve farmers' education and technology adoption and the alignment of food security and the agricultural export policy with the sustainability and adaptation objectives of the agriculture sector. Furthermore, costs constitute the common denominator challenge to implementing sustainable practices in the sub-regions where the survey was conducted, even though the availability of support, including financial support, from the government or other proposed institutions does not necessarily influence the decision on adopting sustainable practices. It is concluded that sustainability in the sector can only be achieved if there is an effective commitment to this transition and the existing social, structural, and export policy hurdles are overcome.

Keywords:

Agriculture, climate change, water shortages, sustainable development, socio-economic, rural areas, Morocco

1. INTRODUCTION

Climate change has significant global implications and is a decisive issue in this century. Several phenomena are involved in its effects, such as increased temperatures, extreme weather events like droughts and floods, rising sea levels, and erratic rainfall events (Bolan et al., 2024; Yan, 2021). One of the major global concerns is the availability of water resources. While the impacts on water security vary based on geographical contexts, according to the projections, the escalation will persist and add more pressure to water accessibility, availability, supply, and demand, particularly in Africa (Amparo-Salcedo et al., 2025; Bates et al., 2008). As global water demand will increase due to climate change, exacerbating the challenges of sustainable water management, agriculture's water demand will be the most affected compared to other sectors (UNESCO, 2020; X. Wang et al., 2016).

Agriculture is the cornerstone of many global economies and is considered the most water-intensive sector. Nearly 70% of water withdrawal depletion is attributed to agricultural activities. Given its implications worldwide, it is suggested that large-scale policy interventions are necessary to lessen the risk of water resource depletion through adaptation policies for water irrigation use (Haile et al., 2024; Ingrao et al., 2023). Water shortage is a significant threat not only to agricultural development but also to food quality, quantity, and society's food security. Therefore, improving water resource management in agriculture is necessary to ensure water and food security (Aryal et al., 2024; Morison et al., 2008; Oyeagu & Lewu, 2025). The integration of these considerations in water management policy efforts can only be assured by a transition to sustainable agriculture (Biswas et al., 2025; Markland et al., 2017).

As sustainability serves as an approach embodied by a balance of environmental, social, and economic considerations, facing the imminent threats posed by climate change. In agriculture, sustainability efforts aim to address various challenges such as soil erosion, degradation, and biodiversity loss, which are often caused by the monocropping farming system (Belete & Yadete, 2023; Hashakimana et al., 2023; Velten et al., 2015). The challenge of water scarcity is also a pressing one in many regions across the globe. Since the growing demand for both domestic and industrial use will likely lead to water supplies being diverted further from agriculture. And an increase in irrigation areas is forecasted in the future. Sustainable agricultural development views water as the most crucial resource worldwide (Biswas et al., 2025; Chartzoulakis & Bertaki, 2015; Hardelin & Lankoski, 2015). The

farmers are struggling to deal with the challenge of managing water scarcity to attain sustainability. This entails improving farmers' resilience and adaptive capacity as a precondition for sustainability, especially by examining real-life farming experiences and drawing insights for policy and practice (Hansen & Heinse, 2022; Maleksaeidi & Karami, 2013; L. J. Pearson & Dare, 2021). Improving agricultural resilience will enable the maintenance and increase of productivity in a changing climate through developing policies and practical measures based on sustainable adaptation strategies (Benďáková et al., 2024; Urruty et al., 2016).

The dissertation is structured into four main chapters. The literature analysis chapter consists of the relevant existing literature that provided the basis for the research's aims and hypotheses. The methodology chapter provides details regarding the in-depth interviews and the survey questionnaire conducted, as well as the data collection and analysis approaches relied on by the study. In the results of the empirical research chapter, the focus is on examining the qualitative and quantitative research results and proposing alternatives and suggestions for discussion based on the relevant literature reviewed. The final chapters present the new scientific results and future research opportunities, along with a summary and conclusions of the study.

1.1. PROBLEM STATEMENT

Although agriculture has been one of the most relevant economic activities throughout history, in Morocco, one could say that it did not start to receive significant systematic adjustment attempts through the modernization lens until the mid-90s to early 2000s. As a result, the sector's modernization became more central to the governmental discussions in developing previous agricultural plans and investments. Furthermore, climate change's potential impact on the sector has prompted the country to further incorporate adaptation in its plans, particularly with the introduction of the Green Morocco Plan (2008-2020) (Akesbi, 2012; Elalaoui et al., 2021; MAFM, 2021).

However, the increase in drought frequency in the region has a detrimental effect on agriculture, especially in Morocco, where rain-fed agriculture is prevalent, and the sector still requires modernization (Essa et al., 2023; Tramblay et al., 2020). With water resources in jeopardy, drought not only affects the yield on average but also poses a serious threat to national food security and to ensuring sustainability in food systems (Benayad et al., 2024; Toumi, 2016). Besides the breakdown of food systems, the implications of water shortages

on agriculture could seriously affect economic growth, as the sector is still considered the backbone of the economy. Socially, water shortages in agriculture will affect a large percentage of the population that still relies on this activity as their primary source of income, especially in rural areas, where it is central to their livelihood (IRES, 2024; Meliho et al., 2019).

To deal with the current situation, urgent measures are necessary to address the exacerbated circumstances. And sustainability becomes an essential element in adaptation discourses (Baraj et al., 2024; Sivakumar, 2021). As the approach presents an opportunity for its innovative solutions to cope with climate change challenges, which in turn promote adaptation and mitigation efforts. One of the alternatives consists of the available sustainable practices, which are efficient tools for adapting to the dwindling of water resources. In addition, as irrigation efficiency is often low, with less than 65% of the water applied being used by the crops. Irrigation based on sustainable practices has become a priority for agriculture, especially in arid areas (Chartzoulakis & Bertaki, 2015; Hardelin & Lankoski, 2015; OECD, 2014).

The government recognized the increased severity of drought impacts on agricultural productivity as one of the main challenges posed by climate change. Subsequently, Moroccan agriculture is actively included in the country's policy to combat the effects of climate change (MAFM, 2019, 2021). The research aims to analyze the sector's resiliency, specifically regarding water scarcity, and propose alternatives based on the principle of sustainability, highlighting available strategies, methods, and practices. In summary, the research focuses on the relevance of the transition to sustainability to enhance agricultural development resiliency regarding the escalating water shortages, the current state of the sector, and how well the relevant stakeholders are prepared to contribute to it.

1.2. RESEARCH GAPS AND RESEARCH QUESTIONS

As water shortages are considered one of the main drivers for examining the relevance of the transition to sustainability to enhance agricultural development resiliency in Morocco. The research topic, along with its research gaps, was validated in the wake of the comprehensive exam (complex exam) organized by the doctoral school.

Research novelty

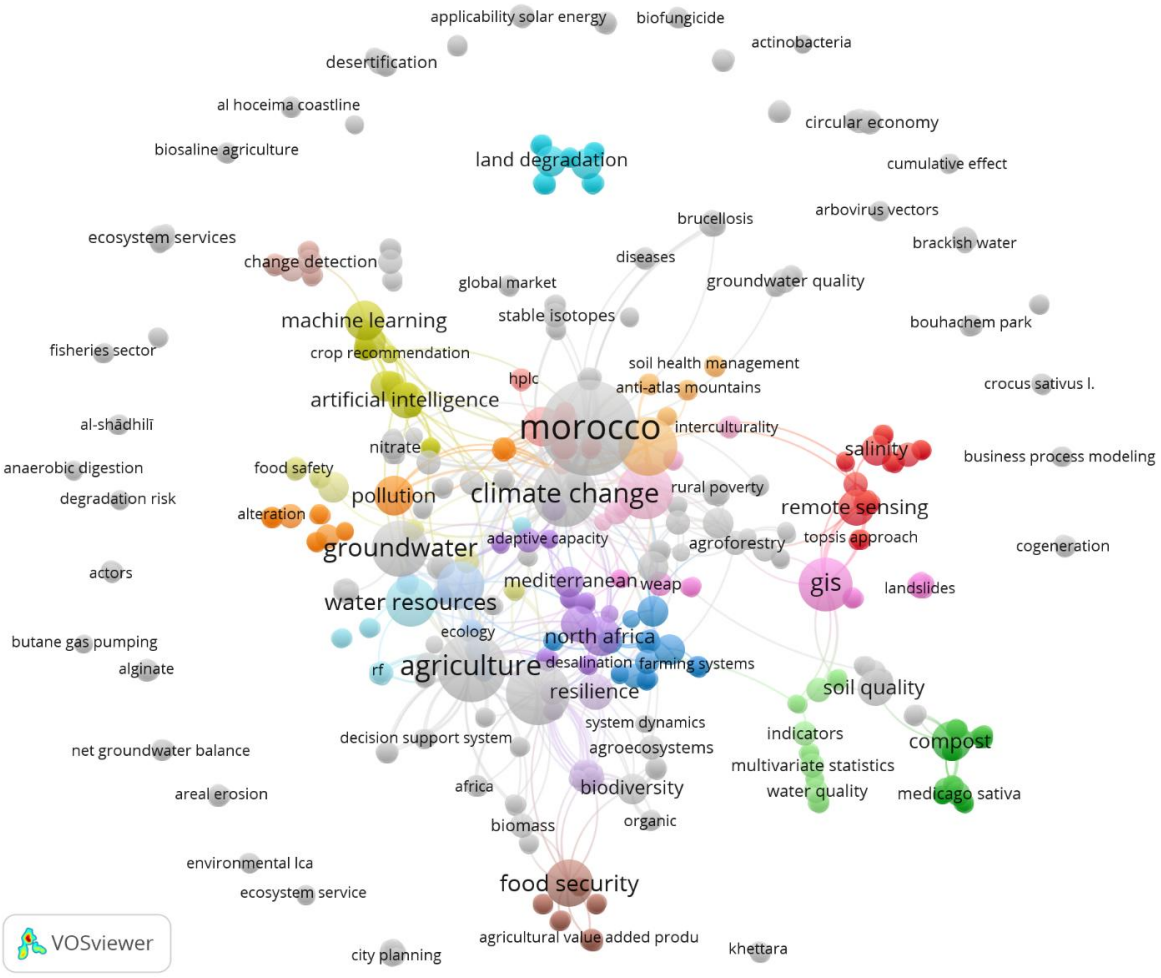

Figure 1: Representation of the results based on the Scopus database using VOSviewer software (date of the database consultation 26/04/2023)

Source: Author's own research (VOSviewer, 2023)

An examination was conducted in the Scopus database using sustainable, agriculture, and Morocco search terms, the search included all types of documents (Articles, Conference papers, Book chapters, Reviews, Books, Conference reviews) from all available languages, presented in Figure 1. The result was the following: 199 documents were found. 191 documents are in English language, seven documents in French language, one document in Spanish language, and one in English/Turkish.

Based on the author's keywords co-occurrence from the bibliographic data created from Scopus. Three occurrences of the keyword vulnerability were found (n = 4), Four occurrences of the keyword resilience were found (n = 4), seven occurrences of the keyword

water were found (n = 7), and one occurrence of the keyword water shortage from different documents was found (n = 1). However, after manually screening the documents: nine documents were found relating to the vulnerability term, twelve documents were found related to the word resilience, 106 documents were found related to the word water, and four document was found related to water shortage. In addition, the same search was conducted using sustainable agriculture, Morocco, resilience, and vulnerability search terms in Web of Science, ScienceDirect, and ProQuest databases. In ScienceDirect, the search was narrowed via the advanced search tool (Title, abstract or author-specified keywords) using the same terms. Also, in ProQuest, which provides three available databases, the search was narrowed to only dissertations and theses and included water for the search terms. The results were the following: ScienceDirect (n= 4), Web of Science (n= 7), ProQuest (n= 170) (date of the databases consultation 26/04/2023).

After carefully analyzing all the documents from the mentioned databases, no documents tackled the main agricultural region of Morocco from a socio-economic perspective and sustainability regarding water shortages (Marrakesh-Safi region), which constitutes the main focus of the quantitative part of the dissertation. As a result, two research gaps can be identified from the socio-economic research field relating to agricultural development. Population gap since we can conclude that the main agricultural region is understudied (Miles, 2017; Robinson et al., 2011). This subsequently leads us to the second research gap which is the empirical gap from the same region (Miles, 2017; Müller-Bloch & Kranz, 2015).

Beyond the mentioned gaps, it is essential to emphasize the strategic relevance of the agricultural sector in the country, as it constitutes 13% of the Gross Domestic Product (GDP), representing more than one-third of the national workforce, with the agri-food sector accounting for nearly 21% of total exports, and the sector's vital role in underpinning national food security (El Fartassi et al., 2023; ETF, 2021; MAFM, 2021).

This thesis contributes to sustainability transition theory literature by demonstrating climate adaptation mechanisms in the context of enhancing agricultural development resilience amidst water shortages. The main research question that the dissertation aims to address is the following: *How can the transition to sustainable agriculture be effectively fostered to enhance agricultural development resilience in Morocco amidst persistent water shortages?* It is translated into four sub-questions:

Sub-question 1: What is Morocco's past and current agricultural development status concerning the sustainability aspects of this sector and water resources?

Based on the literature review, the results of the sub-question helped and provided the basis for the subsequent research sub-questions and contextualized the findings.

Sub-question 2: How do farmers view sustainable agriculture solutions, and what are the perceived challenges associated with this transition? How do farmers cope with and adapt to water shortages?

The second sub-question was predominantly examined through a survey conducted with farmers from the leading agricultural region by size of agricultural area (Marrakesh-Safi region), which covers 38,445 km² and comprises 2,055,977 ha of agricultural land (HCPM, 2025c; MAFRD, 2023).

Sub-question 3: How do institutions view and contribute to Morocco's transition to sustainable agriculture? What are the perceived hindrances to this transition?

The third sub-question was mainly addressed through in-depth interviews with specialists from different organizations, including governmental and state institutions, from the same region where the survey was conducted.

Sub-question 4: Are there any appropriate sustainable strategies, methods, and practices to enhance the resilience of agricultural development facing water shortages in Morocco?

The last sub-question was tackled by combining insights from the previous results of the dissertation's sub-questions. In addition, an extensive literature review analysis was conducted to find, suggest, or build any appropriate sustainable concept, methods, and practices to enhance the resilience of agriculture development facing water shortages in Morocco.

The following are the hypotheses presented for the study, which are primarily related to sub-question 2, while also providing secondary insights into sub-questions 3 and 4:

> *H1: The extent to which farmers' inclination for sustainable practices adoption is influenced by the degree of the perceived climate change's impact on the farms.*
>
> *H2: The extent to which farmers' inclination for sustainable practices adoption is influenced by the number of practices already applied to conserve water on the farms.*

H3: The extent to which farmers' inclination for sustainable practices adoption is influenced by the support opportunities offered by the government for the farms.

H4: The number of practices already applied to conserve water on the farms is influenced by the level of education attained by the farmers.

1.3. METHODOLOGICAL APPROACH

A multi-stage empirical procedure has been employed to fully address both the main research question and the sub-questions.

The primary focus of the research process is five research objectives (*A1-A5*), which are divided into six phases (*P1-P6*) and generate eight different results (*R1-R8*).

As Table 1 shows, the dissertation relied on a comprehensive literature review (*P1/A1/R1*). To address the main research question, a division into sub-questions was required. Also, taking into account the qualitative survey insights, from in-depth interviews conducted (*P2/A2/R2*), hypotheses are developed ($H1_1$/$H2_1$/$H3_1$/$H4_1$).

To test hypotheses, quantitative survey methods are employed to generate data. For data collection, a quantitative questionnaire was distributed using a snowball system. Based on the data obtained, hypotheses $H1_1$, $H2_1$, $H3_1$, and $H4_1$ were tested (*P3/A3/R3*). The analysis of the gathered data was expressed through graphs, and the relations were examined (*P4/A3/R4*). The quantitative methods were the main tool to address sub-question 2 (*A3*).

To address sub-question 4 (*A4*), a concept along with suggestions was provided based on the previous research results (*R1-R4*), which strived to combine the relevant outcomes (*P5/A4/R5*). Despite their simplicity, the concept and suggestions are significant enough to enable various interest groups to work on and refine them further.

The main research question (*A5*) was addressed with the use of all research findings. Throughout the process, all findings were compared and discussed. Following that, the scientific results were deduced (*P6/A5/R6*). Afterward, the results were analyzed for practical feasibility, contribution, and professional implications were elaborated (*P6/A5/R7*). Lastly, open research questions are explored (*P6/A5/R8*).

The following Table 1 provides a methodological overview and a presentation of the dissertation’s structure for better clarity.

Table 1: Research process

Aims	Research Hypotheses	Phase	Process	Results
A1: Status quo of the literature (Answering the Sub-question 1)		P1	Literature analysis	R1: Current status of the literature.
A2: Answering the Sub-question 3		P2	Qualitative interviews	R2: The institutions' views, their contribution to Morocco's transition to sustainable agriculture, and the perceived hindrances to this transition.
A3: Answering the Sub-question 2	$H1_1$ $H2_1$ $H3_1$ $H4_1$	P3	Quantitative survey	R3: The farmers' views on the challenges associated with sustainable agriculture solutions and the adaptation to water shortages.
		P4	Analysis of the gathered data	R4: Express the data through tables and graphs, and explain the relations.
A4: Answering the Sub-question 4		P5	Possibility of appropriate sustainable strategies, methods, and practices	R5: A proposed sustainable agricultural development concept and suggestions adapted to the current situation in Morocco.
A5: Answering the main research question		P6	Results and final conclusions	R6: Scientific results R7: Contribution, Professional implications R8: Further research opportunities

Source: Author's own research work, 2024

2. LITERATURE REVIEW

In order to address the dissertation's first aim, *A1: Status quo of the literature*, the main research question, along with the sub-questions, offers the frame for the literature study. The chapter presents the theoretical framework of the dissertation and provides the necessary knowledge to address the main research question and the sub-questions. The basic related theoretical concepts are discussed with consideration of the current perspectives. The chapter is structured around three subchapters: Rural and agricultural development, climate change and water resources, and sustainable agricultural development. The subchapters begin with an introduction, delve into the country's situation, and end with a short summary of the main findings. In order to address *R1: Current status of the literature*, the theoretical background presents an overview of the existing research state. The theoretical framework is based mainly on the available sources online, as well as accessible scientific databases (e.g., ScienceDirect, SpringerLink). The theoretical background insights are also implicitly incorporated into the subsequent research process results. The following Figure 2 provides a general presentation of the organization of the literature review chapter.

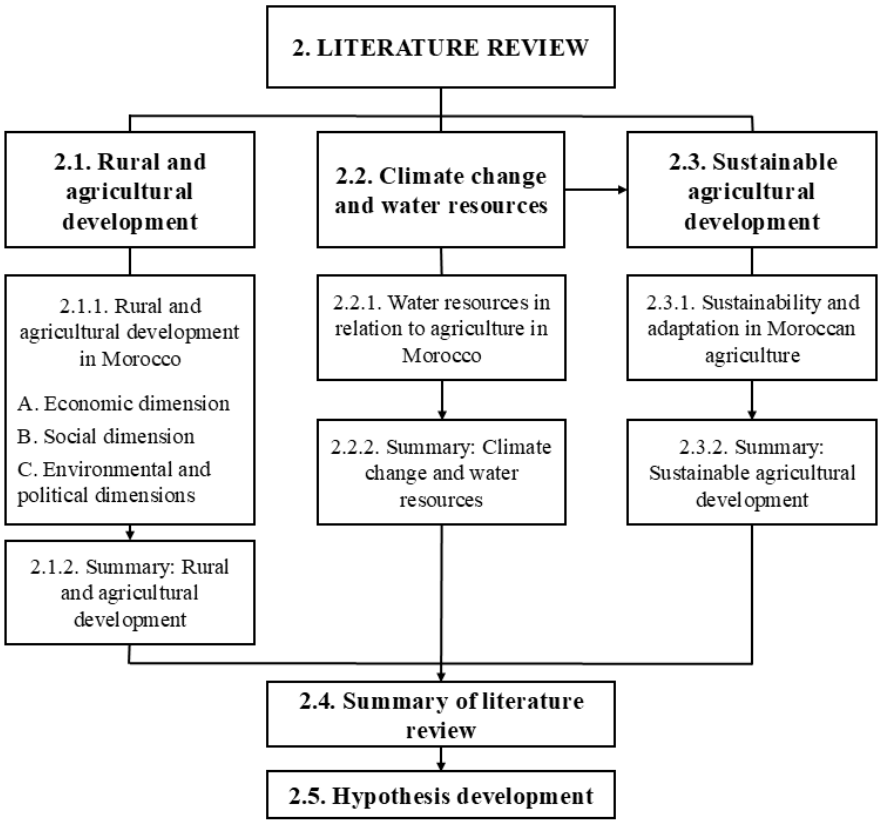

Figure 2: Organizational structure and the flow of the literature review

Source: Author's own research work, 2026

The literature examined provided the theoretical framework for the qualitative research part of the research *(R2)*. The quantitative part of the study *(R3, R4)* is based on both qualitative exploration *(R2)* and, to a considerable extent, on the literature discussed. As a further result of the literature chapter, a set of suggestions along with a proposed concept was developed and presented in *4.3. Discussion of the research results* subchapter contributing to *R5: A proposed sustainable agricultural development concept and suggestions adapted to the current situation in Morocco*.

2.1. RURAL AND AGRICULTURAL DEVELOPMENT

In Africa, the population of its developing countries remains largely rural. Agriculture also constitutes one of the most prominent economic activities providing employment to a large population in rural areas. As rural areas are commonly defined either as areas that are not urban areas that usually vary in socioeconomic, institutional, sociocultural, and environment, or as areas with low population density and depend for the most part on the primary sector (C. Atkinson, 2017; Chromý et al., 2011; Straka & Tuzová, 2016). At a more general level, the World Bank defined rural development as a strategy aimed at improving the economic and social life of a particular group of people, especially the rural poor (Chambers, 2013; Straka & Tuzová, 2016). Many factors can characterize rural development. For instance, rural development by Moseley (2003: 4) is described as a sustained and sustainable economic, social, cultural, and environmental change aimed at improving the long-term well-being of the entire community (Moseley, 2003). Since rural areas are significantly impacted by climate change, the transition to sustainable solutions is a must to cope with current and future scenarios. As sustainable development is considered the key to climate change adaptation and mitigation. To achieve sustainable development under the current circumstances, rural development perspectives must consider several aspects, such as quality-of-life improvement, reduced inequalities, rural resilience, sustainable agriculture, and circular economy (C. L. Atkinson & Atkinson, 2023; El Chami et al., 2020; Visseren-Hamakers, 2020). In terms of the sustainable rural development concept, as it is underpinned and can be evaluated through the analysis of the four basic pillars, which are social, economic, political, and environmental. it is defined as a holistic approach where the day-to-day basic needs of rural populations are met through reliable public utilities in combination with technical, socio-economic, and environmental conditions to sustain regional economies, the links between urban and rural regions, and to improve resilience to

economic shocks and environmental disruptions as a result of climate change (Lele, 1975; Mihai & Iatu, 2020; OECD, 2016; Samir, 2023b; Singh, 2009).

As agriculture is considered a vital component of rural development and an engine for economic transformation, particularly for developing countries, agricultural development can be defined as the process of enhancing agricultural output and rural incomes, thereby alleviating poverty, contributing to economic growth, ensuring food security, and expanding export capacity. Agricultural development can be evaluated through examining the evolution of the GDP in terms of agriculture's average annual rate of growth and the sector's contribution to poverty reduction in rural areas (OECD, 2016; R.D. Norton, 2014; Singh, 2009; Udemezue & Osegbue, 2018).

Since Morocco's agriculture is characterized by traditional patterns, a particularly important question is: which development path should be pursued in the future? Can Morocco avoid resource-intensive industrial agricultural development and create a long-term sustainable agricultural structure rooted in rural development? To achieve long-term sustainability, it is crucial to establish stable economic and social frameworks that align with environmental conservation. This requires cultivating a supportive political environment, which is essential to enact policies and regulations that promote sustainability. A stable and flexible society can successfully face the impact of climate change. A well-organized society can receive and share information in time, has collective knowledge and memory, has appropriate adaptation capacity, and will be able to reorganize itself from time to time. The study attempts to examine the extent to which the Moroccan rural socioeconomic position meets these requirements (Samir & Pappné Vancsó, 2023).

2.1.1. Rural and agricultural development in Morocco

Morocco is generally considered a country undergoing demographic, economic, and political transformation. The economic situation of Morocco as a developing country still depends to an inordinate degree on agriculture (Amiri et al., 2021). Since it has made important efforts to promote its agricultural development; the sector has become essential to the economic and social development of the country. In addition, agriculture is crucial for the rural population who depend on it, its strategic dimension in terms of food security, and its contribution to regulating the trade balance (HCPM, 2011). To examine rural development, the challenges associated with it, and the sustainability aspects. It was necessary to investigate it from the lens of the fundamental pillars underpinning sustainable rural development. The explored

sustainable rural development aspects are deemed to bring clarity to the current situation in rural areas of Morocco, rural development, agriculture, and its sustainability. The economic dimension focused on the main economic activity in rural areas and the physical infrastructure to foster potential sustainable rural development plans (the sustainability efforts in agriculture will be further elaborated in the third subchapter). The social dimension was interested mainly in the social infrastructure, essentially education, poverty, and health coverage challenges, including essential equipment availability, and discussing the specificities of the nomadic population in Morocco. Additionally, the study also explored the environmental and political dimensions. The following subsection provides an overview of rural and agricultural development and was organized under four pillars: economic, social, environmental and political dimensions (Samir, 2023b, 2023c).

A. Economic dimension

Agriculture has always been associated with rural areas, and the exploitation of land-intensive natural resources for agriculture and forestry has traditionally been the center of rural development (Manimozhi & Vidhya, 2021; Samir, 2023b). To examine the economic dimension of rural development, its sustainability, and the current state and the relevance of agriculture for Morocco's rural areas, the following part presents the state and the aspects of agricultural development and its relevance to the rural population, and then the study explores the physical infrastructure in rural areas of the country.

Agriculture

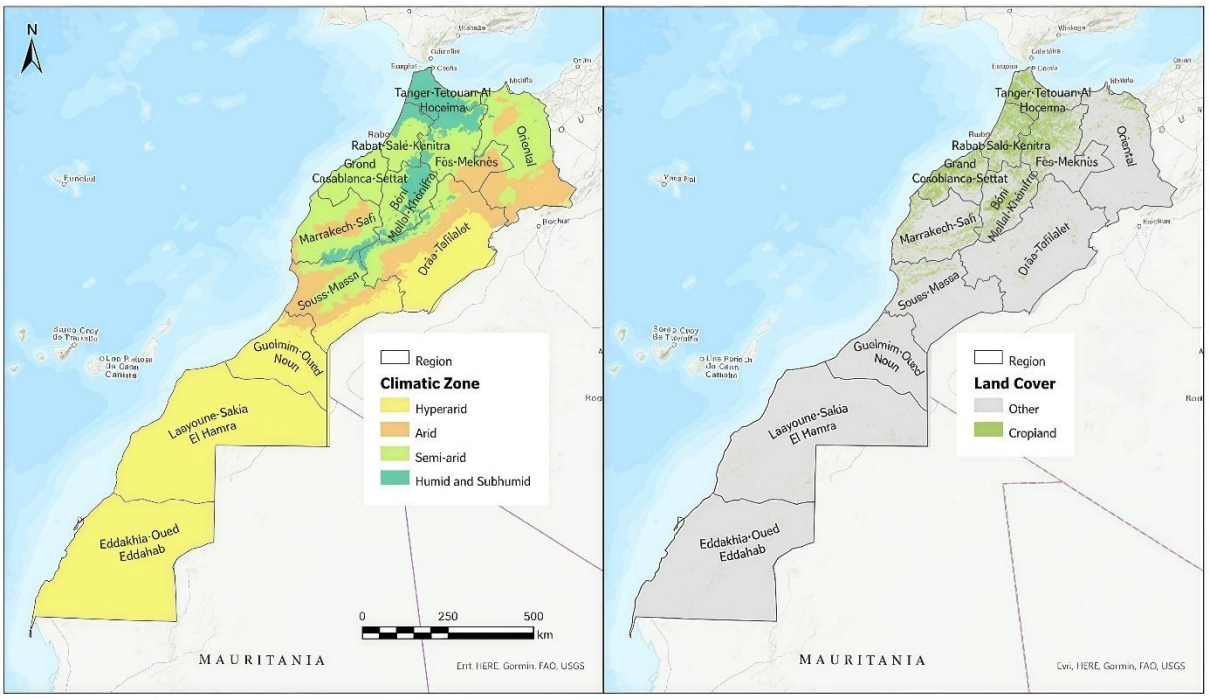

Figure 3: Morocco's map according to administrative regions, presenting the climatic zones based on the De Martonne aridity index and the distribution of cropland

Source: (El Fartassi et al., 2023)

Taking into consideration Figure 3, the agriculture sector is of strategic importance, with agricultural land occupying approximately 9 million hectares of the country's total land surface area. In the last decade, the Moroccan government was more interested in fostering rural development through agricultural development in order to increase employment opportunities for job seekers in rural areas and decrease the rural-to-urban migration trend. Agricultural development was mainly promoted via the Green Morocco Plan (2008–2020), followed by the Green Generation Strategy (2020–2030) (Akesbi, 2012; Elalaoui et al., 2021; MAFM, 2021; MAFRD, 2023; Samir, 2023b).

Table 2: Agriculture in Morocco by regions based on the available data in 2023

	Agricultural land (Ha)	Irrigated surface area (Ha)	Surface area equipped with drip irrigation (Ha)	Beef cattle	Sheep livestock	Goat livestock
Marrakesh-Safi	2,055,977	345,032	105,600	471,000	3,800,000	793,000
Casablanca-Settat	1,263,042	168,238	56,990	2,560,344	768,490	88,100
Fès-Meknès	1,235,521	193,542	82,759	426,370	2,990,000	423,900
Béni Mellal-Khénifra	994,463	226,293	40,975	2,770,000	378,000	967,000
Rabat-Salé-Kénitra	942,980	208,000	83,000	603,649	1,936,253	158,925
Oriental	889,450	181,388	40,236	3,200,000	960,000	123,400
Tanger-Tétouan-Al Hoceïma	729,149	66,174	32,337	356,180	800,000	470,000
Souss Massa	453,445	174,862	108,192	149,800	1,356,000	1,128,000
Drâa-Tafilalet	270,910	201,922	36,868	84,518	1,451,000	650,800
Guelmim-Oued Noun	164,099	36,602	3,000	214,833	242,784	33,080
Laâyoune-Sakia El Hamra	136,000	5,543	1,051	302,000	206,000	105,000
Oued Ed-Dahab-Lagouira	100,000	1,152	1,083	40,000	40,000	30,000
Morocco (Total)	9,235,036	1,808,748	592,091	11,178,694	14,928,527	4,971,205

Sources: (HCPM, 2025c; MAFRD, 2023)

According to the available data presented by the government in Table 2. Among the twelve main regions of Morocco, the Marrakesh-Safi region constitutes the main region in terms of the agricultural land surface (22.26% of the total agricultural surface of the country) and the irrigated surface area. In addition, the agriculture sector has the highest employment rate in this region compared to the other sectors, with 39.7% (2021) of the total active population, and represents 61.3% of the total active population in rural areas (2021) from the same region

(HCPM, 2021a). The following Figure 4 presents the structure of rural employment by sector of activity.

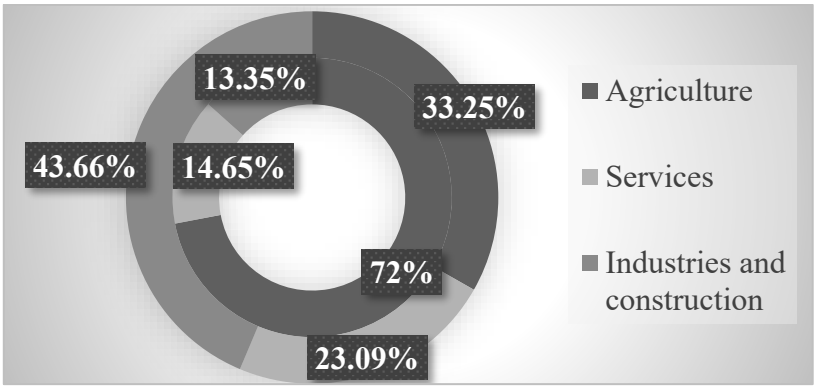

Figure 4: Structure of rural employment by sector of activity (%) (2019-2021) (national on the outside, rural on the inside)

Sources: (MAFM, 2021; MEFM, 2019)

Morocco, often considered the third-largest agri-food exporter in Africa, still depends to a disproportionate degree on agriculture (Amiri et al., 2021; Odjo et al., 2023; World Bank, 2023). The sector accounts for 13% of the total GDP and represents about 35% of all employment with 72% of rural employment (El Fartassi et al., 2023; MAFM, 2021), where the majority of the rural population still depends on agriculture for their livelihood. In addition, smallholders represent 70% of farms in Morocco, and close to 10 million people are involved, to varying degrees, in agricultural activities (MEFM, 2019). As agriculture is considered the primary economic activity in rural areas by figures in Morocco. The economic dimension of sustainable rural development cannot be achieved without the sustainability of agriculture in Morocco. In addition, the sustainability of this sector will boost the case to include sustainability in future rural development plans (Samir, 2023b).

Morocco's agriculture development strategy has been successful as the GDP from agriculture's average annual rate of growth has doubled reaching +5.25% (2008-2018) compared to the previous decade's +2.5% (1997-2007) (MAFM, 2021). And was achieved primarily through promoting the development of modern agriculture with high added value and productivity in the irrigated and relatively prosperous unirrigated areas, that meet the market requirements, via private investment (Akesbi, 2012). And secondly, by providing support to small-scale agriculture and boosting the incomes of the most disadvantaged farmers, especially in landlocked areas (HCPM, 2020a; Mengoub et al., 2021; Vitry et al.,

2015). The following Figure 5 presents the structure of Agricultural Value Added over the period 2008-2018.

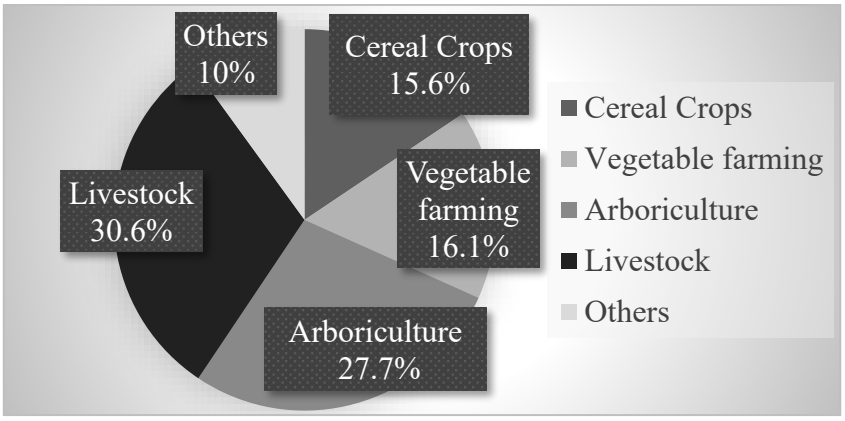

Figure 5: Structure of Agricultural Value Added over the period 2008-2018 (in %)

Source: (MEFM, 2019)

Since 2000, the new agricultural strategies towards better agricultural production's adaptation to the agroclimatic context have changed the structure of the Agricultural Value Added and were placed under great emphasis within the framework of the Green Morocco Plan (2008-2020), to support high value-added agricultural production, such as vegetable farming (16.1%), arboriculture (27.7%), and livestock (30.6%). In addition, promoting crops that are more resilient to climatic hazards has reduced the volatility of Agricultural Value Added, measured by the standard deviation of agricultural growth, with a notable attenuation of 61.8% between 1990-1999 and 2000-2018. Furthermore, encouraging the conversion of cereal crops in regions with unfavorable conditions to other high value-added agriculture, intensifying production, and diversifying agricultural activities for greater resilience (MAFM, 2021; MEFM, 2019). The following Figure 6 presents the sectoral distribution of cooperatives by sector in 2020.

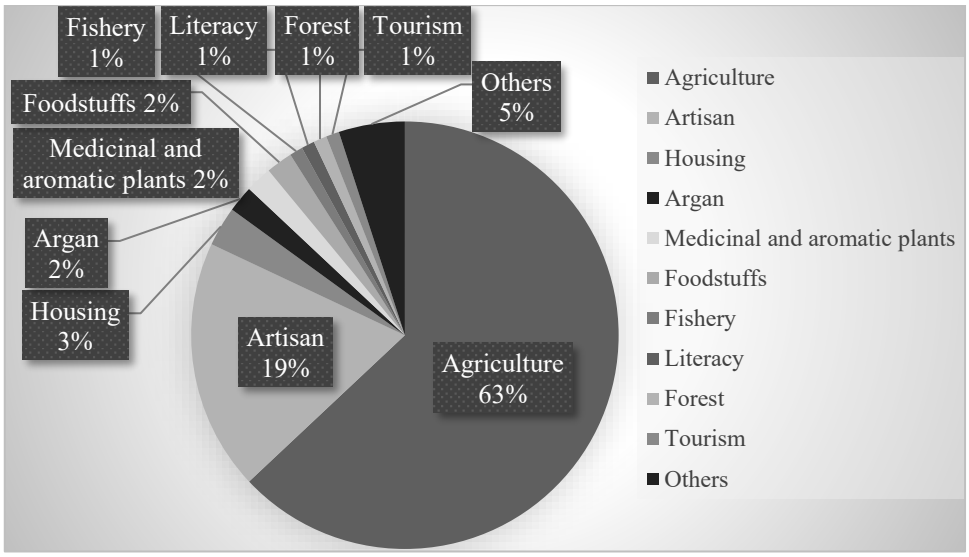

Figure 6: Sectoral distribution of cooperatives by sector in 2020

Source: (Y. M. Alaoui & Zouiten, 2022)

Based on the presented figure, it is clear that agricultural cooperatives are the dominant cooperatives in terms of numbers in the country. This is due to the Green Morocco Plan's strategy (2008–2020), which fostered the creation of agricultural cooperatives in order to support small-scale, traditional farming, to promote the organization of farmers, and to ensure that even smallholder and disadvantaged farmers benefit from development efforts. These efforts were also coupled with the launch of supporting programs such as the MOURAFAKA program (2011), presenting a set of tools for agricultural cooperatives, mainly in terms of organizational support and management training. The Green Morocco Plan (2008–2020) fostered the creation of nearly 10,000 agricultural cooperatives for the benefit of 90,000 beneficiaries, 79% of whom are women, subsequently promoting the integration of farmers into value chains. This is partly also due to the launching of the national program for creating agricultural cooperatives (2015-2020) that aimed to support and strengthen the professional organization of the active and newly created cooperatives. The agricultural cooperatives are also considered one of the cornerstones of the Green Generation Strategy (2020–2030). It should be mentioned that the increase in agricultural cooperatives was also due to the implementation of Law 112.12 on cooperatives in 2014 (Y. M. Alaoui & Zouiten, 2022; Ibourk & El Aynaoui, 2023; Lebdaoui, 2022; MAFM, 2021). The following Figure 7 presents the structure of agricultural lands in Morocco

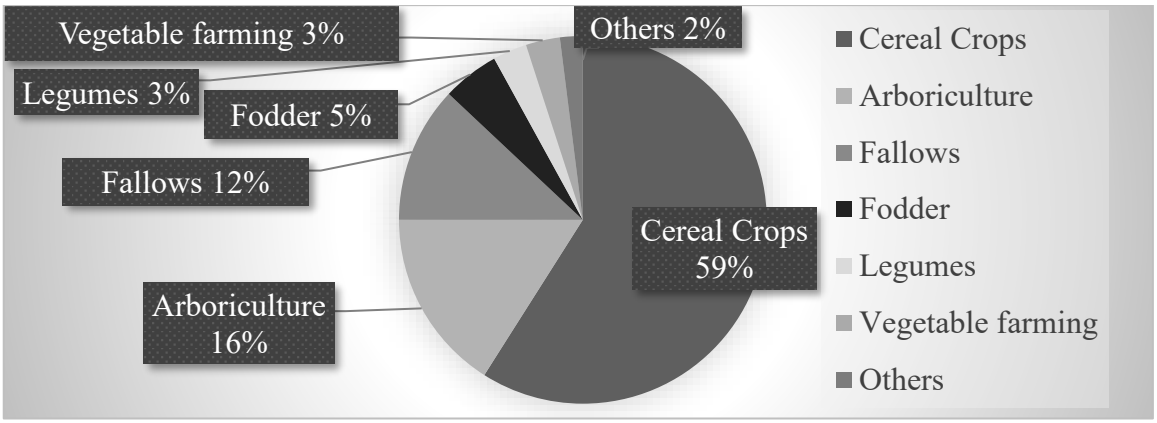

Figure 7: Structure of agricultural lands in Morocco

Sources: (MAFM, 2019; MEFM, 2019)

During the period 2008-2018, the production of cereal varied between 33.5 million quintals recorded in 2016 and 114.7 million quintals recorded in 2015. A significant change in cereal share in agricultural value-added was caused by these variations, which fluctuated between 7.4% in 2016 and 21.4% in 2009. Cereal crops, which occupy almost 60% of the total agricultural lands, are 90% practiced in rainfed areas. This concentration in the rainfed areas, particularly at the level of the unfavorable rainfed areas, renders them more vulnerable to climatic hazards, especially to drought in the Moroccan case (MAFM, 2019; MEFM, 2019).

Moreover, given the high illiteracy rate of 38% (2024) in rural areas and low adoption of technologies, smallholders, who represent 70% of farms, are often unable to implement new practices and technologies, resulting in the management of water resources that is insufficiently rationalized, low irrigation efficiency, and low adaptive and productive capacity. The heavy reliance on agriculture explains this sector's relevance to Morocco's rural population and rural development (El Fartassi et al., 2023; Gailhard & Bavorova, 2014; Harvey et al., 2014; HCPM, 2025b; He et al., 2016; MAFM, 2021; Maini et al., 2021; MEFM, 2019; Samir, 2023b).

It is important to mention that the agriculture sector also faces challenges with regard to agricultural land management and land fragmentation, which hinder agricultural development efforts. Agricultural land management in Morocco is generally presented in three phases: the first phase, which is after the country gained independence, is characterized by the government's intervention to implement measures in order to control the real estate and limit the acquisition of agricultural land by foreigners and joint-stock companies. The second phase consists of a reduction in government intervention, which started in the 80s

and was highlighted by the process of liberalization and privatization of the sector. Lastly, the agricultural land liberalization and privatization phase, which consisted of a period of consolidation of the liberal-leaning reforms and was supported by ambitious agricultural support programs in the early 2000s. Despite significant progress in agricultural policies and the positive initiatives that have been implemented, notably via the Green Morocco Plan (2008–2020) and the Green Generation Strategy (2020–2030), due to the historical context, the persistent disputes and the many land tenure statuses still limit the optimal exploitation of the agricultural lands. Complex administrative rules, collective land conflicts, and the fragmentation of the lands are still major obstacles to agricultural development in the country (Akesbi, 2012; Azaguagh & El-Ayachi, 2021b; CESE, 2017; Mohamed, 2014, 2020; Oulkhir, 2023).

Regarding gender equality and women's empowerment, based on the figures provided by the OECD, women's employment stands at 52.2% in the agriculture sector, mostly in low-wage job positions, which is the highest compared to the rest of the Mediterranean countries. The participation of women in the Moroccan labor market stands at 21.3% and is concentrated in the agricultural and industrial sectors. One of the explanations for the current situation is the fact that women's illiteracy rate is the highest in the country by gender. Additionally, about 17% of women in non-agricultural employment work informally. Gender equality in terms of access to education will help shift the current situation and boost economic development, including in the agriculture sector (OECD, 2020, 2021). The mentioned facts constitute the main achievements and challenges for agricultural development and the economic dimension of sustainable rural development that depends largely on the sustainability of the agricultural sector in Morocco (Samir, 2023c).

Physical infrastructure

A robust infrastructure is required to support rural development. Roads, irrigation facilities, electrification, drinking water supply, drainage lines, and adequate houses are some key elements demonstrating rural development. This part of the study covered most of the mentioned aspects. Additionally, it is important to mention that most of these aspects in Morocco were quantified from the available data of the previous national census of 2014.

In terms of the development of rural roads in Morocco, it started with the 1st National Programme of Rural Roads in 1995, and throughout the following decade, which led to an increase in the rural roads accessibility rate from 34% to 54%. Given the success of the first

rural roads national program. The Moroccan government launched the 2nd National Programme of Rural Roads in 2005 for the next 6 years. By the year 2011, rural roads accessibility reached 80%, subsequently encouraging the launch of the Territorial Upgrading Programme and increasing the accessibility to rural roads to 85% by the end of 2017. The government aimed to reach 90% of the accessibility to rural roads by the end of 2023 via the Program to Reduce Territorial and Social Disparities launched in 2017 (HCPM, 2018c, 2025c; Samir, 2023b).

Concerning the electrification rate in rural areas, it was about 84.6%, close to the accessibility rate in urban areas of 95.2% in 2014. The country achieved an electrification rate of 91.6% (2014). Regarding the accessibility rate to the public water supply system, it was approximately 73% nationally (2014). However, it was tremendously low in rural areas (37.8%) compared to urban areas, which reached 91.3% (2014). The drainage lines accessibility rate in Morocco was 58.9% nationwide and 88.2% in urban areas (2014). However, it was significantly low in rural areas, with only a 2.9% accessibility rate (2014) (HCPM, 2018c, 2025c; Samir, 2023b).

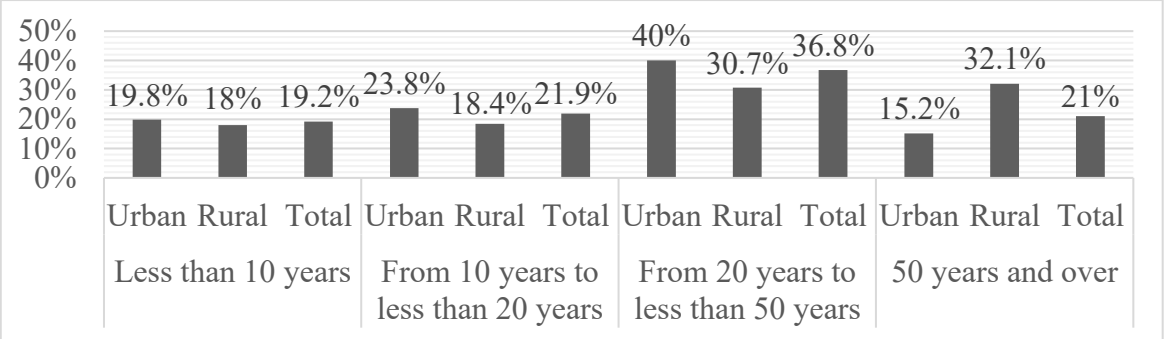

Figure 8: Household distribution by the age of housing in percentage (2014)

Sources: (MNTP, 2019)

In terms of housing, Figure 8 demonstrates that the rural population has the highest rate regarding the age of housing. In rural areas, 32% of housing is aged 50 years or over, making it less suitable for living if it is not maintained correctly. As for the ownership in rural regions, it is much higher than in urban regions (89.6% compared to 62.7% in 2014). The rural population in Morocco tends to live in villages close to their extended family, sometimes in a large household located on the farmland where they collectively work and maintain the same agricultural land. In rural areas, houses are mostly traditionally built. However, the newly built houses in rural areas tend to rely on more modern methods. The

current physical infrastructure is not robust enough to facilitate the transition to sustainable rural development, as it was further demonstrated in the recent earthquake that hit the country on the eighth of September 2023, where a catastrophic number of the rural population died in the collapse of their traditionally built houses and the lack of emergency facilities located and provided for these areas (HCPM, 2018a, 2018b, 2018c, 2025c; MNTP, 2019; Samir, 2023b).

B. Social dimension

Rural development is significant in Morocco since over one-third of the population lives in rural areas (37.25% of the total population resides in rural areas in 2024), which prompted the government and the institutions to invest in development projects and plans in these areas. Since the independence of Morocco, seven population censuses have been conducted in 1960, 1971, 1982, 1994, 2004, and 2014, and the last census was in 2024. Based on the available data, the population of Morocco in 2014 is distributed into 1538 communes, which constitute the unit of local governments for administrative purposes. Moroccan communes comprise 256 urban and 1282 rural. In addition, the size of a commune varies between 55 and 520,428 people. The five main economic regions comprise about three-quarters of Morocco's total households. At the national level, the average household size decreased from 5.2 in 2004 to 4.6 in 2014, with an average annual growth rate of 2.59% in the number of households. The average household size was much higher in rural areas, with 5.3 in 2014 (6 in 2004), compared to urban areas, with just 4.2 in 2014 (4.8 in 2004). However, the average annual growth rate in the number of households in urban areas stood at 3.4% compared to rural areas, with only 1.2%. (HCPM, 2018a, 2018b, 2018c, 2021b, 2025c, 2025b, 2025a). The following part of the study tackled the following aspects: Illiteracy, poverty, healthcare, essential equipment availability, and the nomadic population in Morocco (Samir, 2023b; Samir & Pappné Vancsó, 2023).

Illiteracy

Table 3: Illiteracy rates based on sex and place of residence (Population aged 10+) (%)

	Urban			Rural			Total		
	Women	Men	Total	Women	Men	Total	Women	Men	Total
1960			73%			91%	96%	78%	87%
1971	68%	43%	56%	98%	78%	88%	87%	66%	76%
1982			44%			82%	78%	51%	65%
1994	48.6%	24.7%	37%	89.1%	60.6%	75%	67.4%	41.4%	54.7%
2004	39.5%	18.8%	29.4%	74.5%	46%	60.5%	54.7%	30.8%	43%
2014	31%	14%	22.6%	60.1%	34.9%	47.5%	42.1%	22.2%	32.2%
2024			17.3%			38%	32.4	17.2%	24.8%

Sources: (Courbage, 1996; Fosset, 1973; HCPM, 2018a, 2018b, 2018c, 2024, 2025c, 2025a, 2025b)

Table 3, which was developed from the figures available from the government censuses results, shows that the illiteracy rate is much higher in rural areas than in urban regions for both genders, as the result of the 2024 census indicates that the illiteracy rate in rural areas stands at 38% compared to urban areas with 17.3%. For instance, the men illiteracy rate in rural areas was 34.9% in the census of 2014, almost double and a half compared to 14% in urban regions for the same year. The same observation can be made for rural women (60.1% in 2014) compared to their urban counterparts (31% in 2014). The limited access to the institutions such as schools in rural areas could explain this disparity. Furthermore, the women's illiteracy rate is the highest, regardless of the place of residence. However, based on the previous censuses, the illiteracy rate is substantially decreasing, from 91% recorded sixty years ago to 38% in 2024 for rural areas. In addition, thanks to the various school social support programs and initiatives the enrolment rate in the rural areas reached before the pandemic in 2020, 47,4% for Preschool (between the age 4 to 7 years old), for primary school enrolment rate reached over 90 % (between 7 to 13 years old), in middle school enrolment rate is 44,3% (between 13 to 16 years old) and 12,2% in High school (HCPM, 2022). Given the mentioned figures, illiteracy in rural areas is expected to decrease further in the current decade (HCPM, 2018a, 2018b, 2018c, 2022, 2024).

Nevertheless, it is worth mentioning the municipal population results since the official results also included the population counted separately (French term: population comptée à part), which is all people forced to live in a community in specific establishments for

professional, social, or health reasons, and given that the study is interested in the currently active rural population (specifically farmers). Furthermore, the municipal population results also provide more detail regarding the rural population's level of education (HCPM, 2025c, 2025b).

Based on the available data, the country's illiteracy rate is 36.9% for 2014 and 31.8% (2024) nationally. In rural areas, the figure stood at 50.9% (2014) and 43.3% in 2024, with 25.2% attended middle school or higher education in 2024. It is noteworthy to underline that, under law No. 1-63-071 (1963), education is compulsory for all Moroccans of both sexes (since 1963), from the age of seven until they reach the age of thirteen. Additionally, there is currently a government discussion regarding a major reform to update the compulsory education age from age four to sixteen (HCPM, 2018a, 2018b, 2018c, 2025c, 2025a, 2025b).

Poverty

Table 4: The absolute poverty rate and vulnerability to poverty rate in Morocco (%)

		2013	2019
Absolute poverty	Urban	1.6%	0.5%
	Rural	9.5%	3.9%
	Total	4.8%	1.7%
Vulnerability to poverty	Urban	7.9%	4.6%
	Rural	17.4%	11.9%
	Total	12.5%	7.3%

Sources: (HCPM, 2021b; Samir, 2023c)

Poverty in Morocco, based on Table 4, has also substantially decreased in the last decade, thanks to the significant part of the development achieved via agriculture for rural farmers through the Green Morocco Plan (2008-2020), followed by the Green Generation Strategy (2020-2030). The government's agricultural strategies included the promotion of various sustainable practices and technologies, and the introduction of plans to support the newly emerging middle class of farmers in rural communities, including access to domestic and international markets (HCPM, 2021b, 2025c; Samir, 2023c). In rural areas, absolute poverty has reduced by over 5% between 2013 and 2019. However, absolute poverty has risen during the pandemic from 1.7% to 11.7% nationwide, from 0.5% to 7.1% in urban areas, and from 3.9% to 19.8% in rural areas. In terms of relative poverty, it constitutes 12.7% nationally, 6.8% in urban areas, and 22.9% in rural areas, reaching 4.5 million people, with two-thirds (66.4%) living in rural areas (2019) (HCPM, 2022). In 2019, rural populations' vulnerability

to poverty declined to 11.9%. During the lockdown, vulnerability to poverty has also increased from 7.3% to 16.7% nationally. Depending on the residence, these proportions range from 4.6% before the lockdown to 14.6% in urban areas and 11.9% to 20.2% in rural areas. Social inequalities also deteriorated and exceeded the socially intolerable threshold (42%). The Gini index reached 44.4%, corresponding with a high-income disparity, compared to 38.5% before the health crisis (HCPM, 2021b, 2022). However, government support has mitigated the impacts of the COVID-19 pandemic. Public support for households has significantly reduced the effects of the lockdown on household living standards. At the national level, absolute poverty has decreased from 11.7% to 2.5% after government support. In urban areas, 7.1% to 1.4%, and 19.8% to 4.5% in rural areas. The Gini index, the most widely used measure of income inequality in a society, dropped from 44.4% before government support to 38.4%, about the same level as before the pandemic (HCPM, 2022; Samir, 2023c, 2023b).

Healthcare

Table 5: The rate of health coverage of the population (%)

	1991	1998	2001	2007	2014
Urban	23,7%	21,8%	21,1%	25%	44,5%
Rural	3,1%	3,8%	3,8%	3,8%	23,7%
Total	12,8%	13,5%	13,5%	15,8%	36,2%

Sources: (HCPM, 2018a, 2021b; Samir, 2023b)

Table 5 shows that health coverage in rural areas tremendously improved in 2014 compared to the previous years. This improvement resulted from the RAMED program's implementation in 2011, which targets economically deprived people not covered by any health insurance scheme (HCPM, 2018a, 2021b, 2022; Samir, 2023b). The following Figure 9 presents the coverage rate of the population aged 15 and over by health insurance.

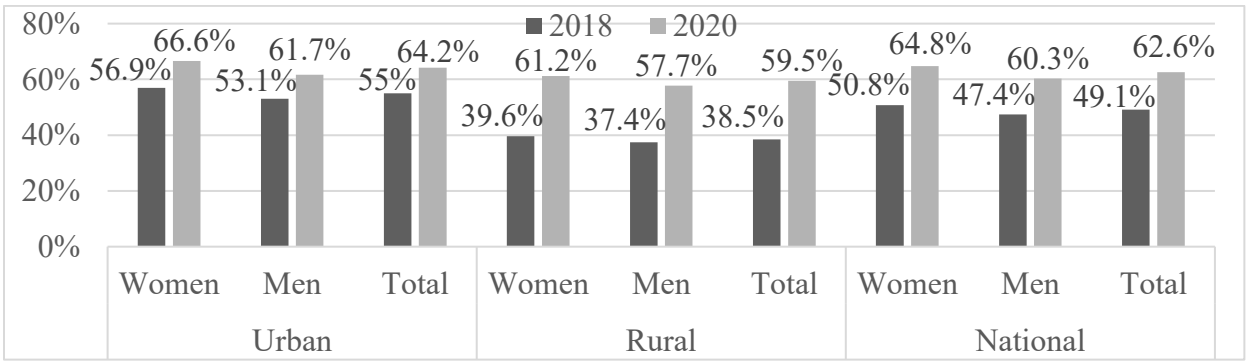

Figure 9: The coverage rate of the population aged 15 and over by health insurance (AMO and RAMED) (%)

Sources: (HCPM, 2021b, 2022; Samir, 2023b)

AMO is compulsory health insurance for Moroccan employees, paid by both employers and employees as a percentage of salary. The graph shows that health insurance coverage in rural areas reached about 60% of the total population aged 15 and over in 2020. In addition, women's health coverage in 2020 was 61.2% compared with 57.7% for men in rural areas (HCPM, 2021b, 2022). In terms of maternal mortality in Morocco, it is perceived as 2.5 times higher in rural areas than in urban areas. As maternal mortality ratio stood at 72.6 per 100,000 live births for the period 2015-2016 nationwide. In rural areas, it constitutes 111.1/100,000 live births compared to 44.6/100,000 live births in urban areas. Nevertheless, maternal mortality decreased by 35% during the 2010 to 2016 period, with an average annual reduction rate of 7% (MHM, 2018; Samir, 2023b).

Essential equipment availability

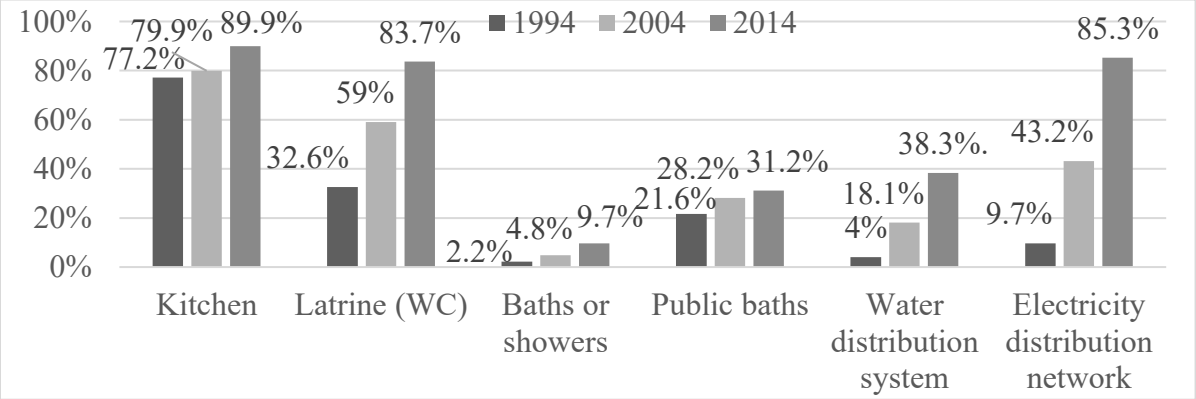

Figure 10: Structure of households according to essential equipment availability in rural areas (%)

Sources: (MNTP, 2019)

Figure 10 shows that the electricity availability for households in rural areas has significantly increased in the last decades, from 9.7% in 1994 to 85.3% in the previous census of 2014. In terms of latrine (WC) availability, it has improved considerably from 32.6% in 1994 to 83.7% in 2014. In addition, households in rural areas had always possessed available kitchens as essential equipment for their daily life. However, the availability of baths, showers, and public baths in rural areas is rather limited. Additionally, water availability for

households in rural areas is still low, reaching 38.3% in the previous census (MNTP, 2019; Samir & Pappné Vancsó, 2023).

The Moroccan nomads

The nomadic population constitutes a small minority in Morocco. It is characterized by the practice of animal husbandry and frequent movements motivated by the search for grazing areas and water points. The number of nomads on 1 September 2014 was 25,274 compared to 68,540 in 2004, representing a 63% decrease. 95% of the nomadic population is concentrated in four regions, all in the east and south of the country. Some of these regions are considered the least developed part of the nation. In terms of households, the number of nomadic households stood at 4044. The family structure of this population is still dominated by large households, which corresponds to an average size of 6.2 compared to 4.6 at the national level (2014). Approximately 68.2% of nomadic households are composed of five or more persons (32.8% are consist of at least eight people), 10.6% are composed of four individuals, 8.1% consist of three persons, 7.1% of two persons, and only 6.1% was made up of one individual. However, the average fertility rate per nomadic woman decreased from 4.3 in 2004 to 4 in 2014. Despite this slight decline, this index was almost double the observed nationwide (2.2 children per woman) in 2014. The nomadic population is predominantly young. 36.0% of the population is under the age of 15 compared to 28% of the total population in Morocco. About 47.5% are under 20, and 65.5% are under 30. Nomads are more active than the entire population. Their employment rate reached 56.8% as opposed to 47.6% at the national level. In terms of unemployment, nomads are less exposed than the general population. Their unemployment rate stood at 10.1% (16.2% at the national level), 8.6% for men (12.4% nationwide), and 16.7% for women (29.6% nationally) in 2014. This difference could be explained by the fact that most nomads work and inherit the traditional jobs of their families. Illiteracy among the nomadic population is relatively high. Its illiteracy rate stood at 81.9% compared to 32.2% nationally (2014). 89.5% of nomadic women are illiterate compared to 74.9% of nomadic men in 2014. Similarly, the educational level of the nomadic population remains very low. 84% of nomads have no level of education, 2.2% have attended preschool at most, 9.3% elementary school, 2.7% junior high schools, high school and higher education were only 1.2% and 0.6% respectively in 2014. Access to education among nomadic children is still minimal. The enrolment rate for children aged 7 to 12 is 31.3% (94.5% nationally), 39.8% among nomads boys, but only 23.5% among nomads girls in 2014 (HCPM, 2016; Samir & Pappné Vancsó, 2023).

C. Environmental and political dimensions

Rural development faces many challenges in Morocco. The political and environmental aspects related to development and sustainability in rural areas are presented, mainly via exploring the methods of wastewater disposal and investigating the practices of household waste disposal in Morocco. The study relied on the available data from the conducted censuses from 2004 and 2014. Lastly, the incentives and factors that could foster the transition to sustainable rural development were also discussed (Samir, 2023b).

Table 6: Distribution of households according to wastewater disposal methods in Morocco (%)

Methods of wastewater disposal	2004			2014		
	Urban	Rural	Total	Urban	Rural	Total
Public sewage system	79%	1.8%	48.6%	88.2%	2.8%	59%
Septic Tank	11%	36.5%	21%	9.6%	49.2%	23.2%
Drywell	3.1%	18.9%	9.3%	1.3%	21.3%	8.2%
In nature	6.9%	42.8%	21.1%	0.6%	25.7%	9.2%
Others				0.3%	1%	0.4%

Sources: (MNTP, 2019)

Table 6 demonstrates the disparity between rural and urban areas regarding the different wastewater disposal methods. Urban areas mostly use public sewage systems for wastewater disposal (from 79% in 2004 to 88.2% in the last census) compared to rural areas, which could be explained by the limited access to this method. In terms of the adoption of the septic tank method, it is increasingly popular in rural areas (from 36.5% in 2004 to 49.2% in 2014). The use of dry wells is slightly increasing in rural areas (from 18.9% to 21.3%). Concerning wastewater disposal in nature, it was decreasing rapidly in urban areas from 6.9% in 2004 to 0.6% in 2014. However, although wastewater disposal in rural areas has also dropped from 42.8% to 25.7% in 2014, more is needed to protect and sustain the environmental aspect in rural areas (Samir, 2023b).

The wise use of water in the Moroccan context is quite relevant. As agriculture relies heavily on natural resources and is increasingly subject to water risks. This requires urgent action to address this issue, not only in the main relatively industrial cities but also in rural areas by raising the awareness of the rural population regarding this finite resource and fostering the adoption of sustainable practices to adapt to the current water shortages facing the country during the last and current decade. However, since 70% of farms are smallholders and are

usually unable to implement new sustainable practices and technologies as a result of the high illiteracy rate, this further increases the vulnerability and marginalization of rural communities. Subsequently, affects the progress of rural development plans and the sustainability of the rural communities (MEFM, 2019; Samir, 2023b).

Table 7: Distribution of households according to waste disposal methods in Morocco (2014) (%)

Disposal of household waste methods	Urban	Rural	Total
Common waste bins	67.7%	2.7%	45.5%
Common or private garbage truck	26.9%	5.9%	19.7%
In nature	4.8%	89.3%	33.6%
Others	0.6%	2.1%	1.2%

Sources: (MNTP, 2019)

In terms of waste disposal methods used in the rural areas of the country, it is mainly disposed of in nature (about 89.3%) based on the available data from the government census in Table 7, and only about 10 percent are disposed of through appropriate methods via common waste bins and common or private garbage truck facilities, which constitutes from a sustainability perspective one of the issues facing its environmental dimension. Based on the mentioned figures, we can also deduce that rural infrastructure is still a work in progress in order to support and foster sustainable rural development in future plans and increase the resiliency of rural communities (Samir, 2023b; Samir & Pappné Vancsó, 2023).

Politically, the government focuses more on the economic dimension of rural development, specifically on agricultural development, than on the other dimensions of equal importance from the sustainability aspect. However, it reduced poverty in rural areas for a better standard of living, created job opportunities, supported rural youth entrepreneurship, and even slowly reduced the severity of the rural exodus that Morocco experienced in the last fifty years after its independence (Samir, 2023b).

Despite the country's progress, there is still no clear integrative sustainable rural development model that applies to its specificities. Although the second component of the National Strategy for Development of Rural Space and Mountain Zones (NSDRSMZ) via the government's declaration of January 2012 concerns integrated and territorialized projects of an economic and environmental nature. The national strategy was essentially focused on the physical and social infrastructure of rural development, boosting agricultural

development for economic purposes and reducing disparities via the Programme for the Reduction of Territorial and Social Disparities (PRTSD), which was launched in 2015 for the period 2017 – 2023, ignoring to a certain degree the environmental dimension that constitutes one of the basic pillars of sustainability in rural development (HCPM, 2025c; Samir, 2023b).

Certainly, at the national level, the government has made significant efforts to protect the environment, such as through the framework law on the National Charter of the Environment and Sustainable Development, which was based on the royal guidelines of July 30, 2011, and the implementation of the Environment Upgrade Strategy (EUS). The country also held the 7th rank in the Climate Change Performance Index (2023) and was ranked 70th with a score of 70.9, better compared to the previous year in the 2023 Sustainable Development Goals (SDGs) index assessing the progress towards achieving all 17 SDGs. Additionally, the country is engaged and presented the voluntary national review on the implementation of the Sustainable Development Goals (SDG) in 2016 and 2020, provided to the United Nations Economic and Social Council. Nonetheless, in rural areas, most of the focus is still on improving the economic and social aspects, which is understandable from a developing country's position (Burck et al., 2022; HCPM, 2020b, 2025c; Sachs et al., 2023; Samir, 2023b).

Despite the fact that rural development in the country is still a work in progress to be recognized as a sustainable one. Based on Morocco's commitment to climate change mitigation and adaptation through subscribing to the implementation of the Sustainable Development Goals Agenda 2030. It is likely that sustainable rural development will be considered and embodied in future strategies and development plans. Sustainable rural development in Morocco will improve the quality of life of the rural population, especially the marginalized ones, by developing capacities that promote community participation, food security, health and education, sustainable economic growth, and environmental protection. Thus, enabling the rural population to achieve their potential and preventing depopulation of regions affected by rural exodus. However, the current infrastructure of the rural areas is not sufficient yet to support this transition (Samir, 2023b).

2.1.2. Summary: Rural and agricultural development

The subchapter provided insights into the past and current rural development and the challenges facing the rural population in Morocco from a sustainability lens. Morocco, as

one of the major economies in the African continent, is considered to be at the crossroads of development whether to follow the traditional development path, which is often notorious for disregarding sustainability issues and resource depletion, such as what occurred in the industrial revolution periods or to benefit from the experience of other developed countries and forge a new path of development based on the fundamental concept of sustainability, taking into account all the dimensions required for a society to prosper and be suitable to the country's specificity (Samir & Pappné Vancsó, 2023).

Economically, rural areas have benefited from agricultural development plans implemented by the government in the last decades, which is considered to be the backbone of the economy in the country (Elalaoui et al., 2021). Economic growth in agriculture will further reduce poverty in rural areas, enabling a new middle class of farmers to emerge. However, the sector has long remained little diversified with a strong predominance of cereal crops (about 60% of the total agricultural lands), which makes it less resilient to climate change, exposes it to high volatility of growth, and negatively impacts the growth of the economy. The government also improved the accessibility to rural roads, public water systems, and the electrification rate in rural areas. Rural areas are still facing several issues, such as the condition of rural houses, which in many cases do not meet the minimum safety standard requirements, the low drainage lines accessibility rate, and the gender disparity of rural women perceived in the rural labor market, as most women occupy low-wage job positions, in some cases informal ones, which can be attributed to the high illiteracy rate among rural women. The high illiteracy rate also affects rural development and hinders the implementation of new sustainable practices in the agricultural sector (Samir, 2023a).

Socially, illiteracy in rural areas is still rampant, notably among Moroccan nomads. However, during the last years, the enrollment rate of the rural population at school has significantly increased. Rural poverty has also decreased substantially, largely thanks to the agricultural development plans in the last decade. In addition to the significant improvement in terms of health coverage rate due to various programs that the rural population benefited from. The structure of households according to essential equipment availability in rural areas has undergone notable improvement over the past few decades (Samir & Pappné Vancsó, 2023).

On the environmental front, the government still needs to focus on providing infrastructure and raising awareness about environmental protection, as 89.3% of waste disposal and

25.7% of wastewater disposal are still dumped in nature. This will further exacerbate the water scarcity caused by the substantial decrease in water availability facing the country in recent years. However, it should be mentioned that the task is considered rather challenging due to the high illiteracy rate in rural areas (Samir & Pappné Vancsó, 2023).

Politically, Morocco, since its independence, has implemented various projects and governmental programs focused on stimulating the development of rural communities, often with the help of foreign aid such as the *Programme d'habitat rural* (1967–1972) of UN (United Nations) involved FAO, and The 2020 Strategy for Rural Development in cooperation with UNDP (United Nations Development Programme), FAO, and the World Bank Group in collaboration with Moroccan institutions, mainly the Ministry of Agriculture, Rural Development and Maritime Fisheries (FAO, 2006; Tenzon & Fisher, 2022). As the focus of national policies has shifted to rural development outcomes, decisively pro-poor, and development plans that include participatory approaches for intervention. The country has emerged as a suitable partner for international donors, and the empowered rural communities will facilitate the transition into a sustainable development model (Ben-Meir, 2019; Doherty, 2017). However, Rural areas in Morocco still face multiple challenges from different dimensions. One way to diversify female employment is to support further the associations that target this population in order to extend their impacts, where women can learn and improve valuable skills such as traditional crafts in the same time offering educational opportunities which will support addressing gaps in access to education, improved employment opportunities, and financial support possibilities for cooperatives and entrepreneurship as a step toward rural women's integration in development (Ennaji, 2008; Tribak & Rguig, 2021). For developing countries, such as Morocco, it would be crucial to improve agricultural and rural development governance, to encourage communication development between the national, local, regional, and international actors both vertically and horizontally as well as fostering the participation of civil society organizations as a way to boost policy impacts and contribute to potential sustainable development in rural areas as well as adopting the latest sustainable development models, solutions, and practices to increase the adaptive capacity of the society as a whole (El Bilali et al., 2012; Samir & Pappné Vancsó, 2023).

2.2. CLIMATE CHANGE AND WATER RESOURCES

Globally, climate change poses a serious threat to the environment, which adversely impacts agricultural productivity. Climate change is defined as long-term changes in average temperatures and weather patterns (Mumenthaler et al., 2021). These shifts may be natural, such as through variations in the solar cycle (Dorman, 2006). However, since the Industrial Revolution began in the mid-1800s, human activities have been the main driver of climate change, primarily due to burning fossil fuels like coal, oil, and gas for fuel (P. J. G. Pearson & Foxon, 2012). Burning fossil fuels generates greenhouse gas emissions that act like a blanket wrapped around the Earth, trapping the sun's heat and raising temperatures around the globe (Desonie, 2008). Climate change impacts the economy of the whole world, and it is expected that the global GDP losses will be greater than 20% by 2100. The world's failure to tackle climate change boosts the case for urgent action on emissions (Kjellstrom et al., 2016; OECD, 2012). Additionally, even though the climate change mitigation policies aim to reduce global emissions by 2030, the significant economic damage could amount to a permanent loss of over 14% of average world consumption per capita (Fekete et al., 2021; OECD, 2012). Furthermore, while there is a meaningful commitment to reducing emissions in an effort to limit global temperatures to 1.5°C above pre-industrial levels by 2050, current policy trajectories are still not sufficient to ensure keeping the world on track for a global cost-effective pathway that keeps the temperature increase below 2°C (Dwivedi et al., 2022; Fekete et al., 2021; Samir, 2023b).

The impacts of climate change will have a disproportionately negative impact on developing countries such as Morocco; the populations of the developing world are more vulnerable as they are not prepared to withstand a deleterious impact, plus the lack of the necessary infrastructure to deal with such exigent situations, import dependence, and the difficulties in maintaining a stable macro economy (Filho et al., 2019; Tan et al., 2021). The global economic impacts are expected to be detrimental to many developing countries, even for the smallest increase in global average temperature (Stern, 2006). Some poor countries would likely suffer particularly severely, and climate change will exacerbate problems related to rapid population growth, existing poverty, and a heavy reliance on agriculture and the environment (Enete & Amusa, 2010; Seaman et al., 2014). Similarly, developing countries are considered to be more vulnerable to climate change because of their reliance on low-capital agriculture with limited financial capacity (Lybbert & Sumner, 2012). As small-scale farmers are often overlooked, they are frequently unable to implement new practices and technologies (Antwi-Agyei & Stringer, 2021). This suggests that low-capital agriculture

would have more difficulty adapting to climate change (Kalele et al., 2021). Accordingly, poor smallholder farmers are more exposed to climate risk due to their lack of adequate adaptive capacity (Archer et al., 2007; Samir, 2023b).

It is worth mentioning that agriculture is one of the few sectors that can contribute to greenhouse gas (GHG) emissions and the mitigation and sequestration of carbon emissions through sustainable production practices (Aguilera et al., 2021). In addition, agriculture has a very significant, cost-effective GHG mitigation potential to reduce GHG emissions (Smith & Olesen, 2010). This sector has the capacity to remove CO2 safely and cost-effectively from the atmosphere without reducing productivity. Furthermore, an efficient livestock production system can significantly reduce GHG emissions and enhance sinks while increasing productivity. Moreover, within the right enabling conditions, agriculture has the potential to benefit from synergies between climate change adaptation and mitigation (Aguilera et al., 2021; Samir, 2023b, 2023c, 2023a; Smith & Olesen, 2010).

Nevertheless, as the sector is of strategic importance in Morocco, and agriculture's vulnerability to temperature, humidity, wind speed, and climate variability changes is significant (Zhang et al., 2017), one of the major challenges facing the country is the impact of climate change and the increase in drought prevalence (Meliho et al., 2019). While the temperature will increase by approximately 1 to 1.5°C by 2050 in the best-projected case scenario, with reduced precipitation and an increase in the impact of drought conditions, higher temperatures will eventually reduce yields of desirable crops while encouraging weed and pest proliferation (Adeyinka et al., 2022; Dwivedi et al., 2022; Lugo et al., 2023; Welsby et al., 2021). Furthermore, the possibility of short-term crop failures and long-run production declines increases due to changes in precipitation patterns (Jang et al., 2016; Samir, 2022, 2023b, 2023a, 2023c).

While water scarcity can be defined as a structural, long-term imbalance where the demand for water exceeds the available supply, which could be due to either physical or economic scarcity, water shortages can be considered the specific, tangible deficits resulting from this scarcity, exacerbated by climate change impact, particularly drought and socioeconomic mismanagement (Faurès et al., 2012; Lund Schlamovitz & Becker, 2021; Meliho et al., 2019; Pedrero et al., 2010; Salehi, 2022; Usha et al., 2021). In this context, drought, which is mostly related to a decrease or absence of precipitation over a prolonged period, is notorious for causing a direct impact on available water resources and a detrimental effect on agricultural

productivity, subsequently increasing the vulnerability of food production and availability (Dai et al., 2018; Mishra & Singh, 2010; Raposo et al., 2023). Morocco, as of 2024, is ranked among the countries with the highest likelihood of agricultural drought globally. Its heavy reliance on agriculture as a developing country will exacerbate the potential prolonged drought impact, particularly at the socio-economic level (European Commission, 2024; Treguer, David et al., 2018). Drought impact on agriculture can be examined through the precipitation variability in relation to annual agricultural production, whereas water shortages can be measured through examining the evolution of the available water resources, such as via the evolution of Morocco's main dams' filling rate.

Despite the adverse impacts of climate change affecting both developed and developing countries, particularly with regard to the agricultural sector, due to its dependence on biodiversity, soil fertility, and water resources, the sustainable agriculture adaptive approaches that foster climate resiliency proved to be effective from both mitigation and economic perspectives and would help shift economies onto low-carbon and climate-resilient growth paths. Specifically, sustainable agriculture promotes climate change adaptation by adjusting to the actual and expected future climate. Regarding climate change mitigation, sustainable agriculture contributes by reducing emissions and stabilizing the levels of heat-trapping greenhouse gases in the atmosphere (Samir, 2023b; Taylor, 2018; Velten et al., 2015).

In terms of agricultural resilience, it can be defined generally as the ability of farming systems to withstand shocks while maintaining their core functions, mainly food production, and recover from stresses, whether from climate change, particularly drought, or others such as pests and market volatility. Beyond examining the impact resulting from events such as drought, evaluating agricultural resilience involves the examination of the capacity of the system to also adapt and transform in the face of environmental and economic pressures. In this context, agricultural adaptation refers to the active process of adjusting farming systems in response to these evolving pressures to ensure long-term productivity and food security. Agricultural adaptation can be evaluated through examining the implemented measures, such as the actions taken with regard to water resources conservation, the efficient water management associated with agricultural activities, and resilient technologies and crop varieties adoption (Berbeć, 2024; Douxchamps et al., 2017; Meuwissen et al., 2019; Rickards & Howden, 2012; Urruty et al., 2016; Walker et al., 2004).

For countries where agriculture constitutes a substantial part of their economy, such as Morocco, climate change has the potential to do significant economic harm and poses a significant challenge to their economic stability and development. As the adaptation often requires meticulous scrutiny of past and current states and future scenarios, without a further commitment to the transition to sustainable practices and technologies in the agricultural sector, the impact of climate change on agriculture will have a detrimental effect on the livelihoods of the rural population whose primary income relies on agriculture, subsequently on the quality of life and rural development (Samir, 2023b).

2.2.1. Water resources in relation to agriculture in Morocco

Climate change is perceived around the globe. Morocco, as a Mediterranean country with a mostly arid and semiarid climate, has been confronted with the escalating impacts of climate change in recent decades, particularly regarding water resources availability, which impacts agricultural activities. The following subsection will discuss climate change, specifically examining water resources availability in relation to agriculture in Morocco.

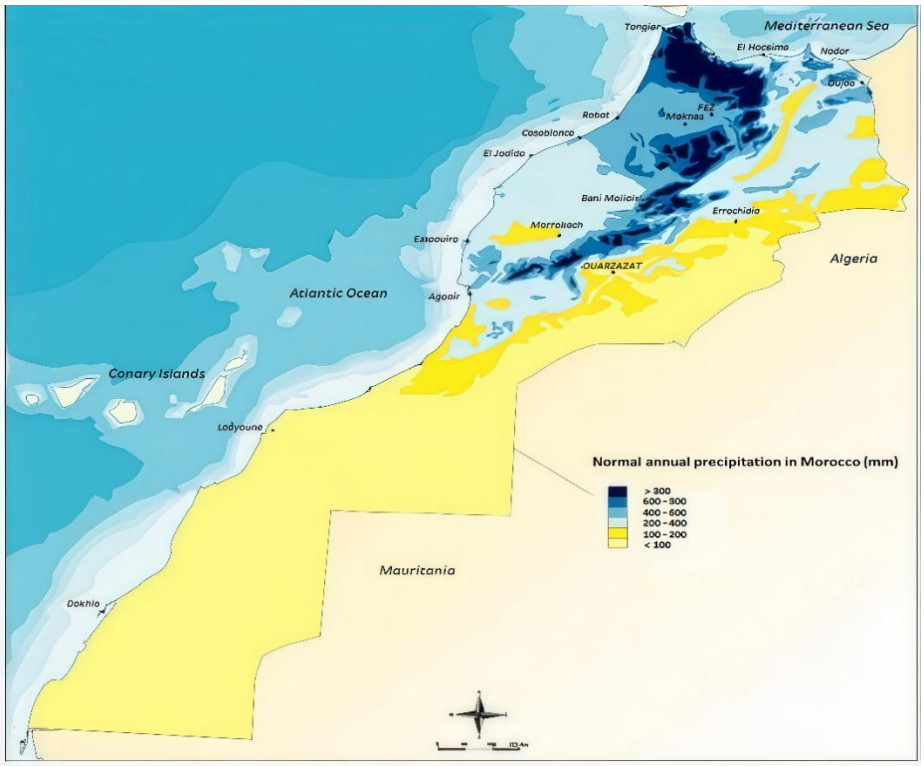

Figure 11: Map presenting the precipitation variability in Morocco

Sources: (Azemzi, 2025; MEWM, 2023a)

Based on Figure 11, Morocco's average annual precipitation varies from less than 100 mm in the southeast and southern regions to approximately 1000 mm in the Middle Atlas mountains and even higher in the Rif mountains located in the northern part of the country. Currently, Morocco's water resources situation is considered as a chronic water scarcity, which intensified into acute water shortages due to drought and climate change. The country has been experiencing drought since the beginning of the last century, characterized by a cyclic temporal frequency of around eleven years on average. However, over the last four decades, the intensity, duration, and frequency of the phenomenon have increased, subsequently leading its temporal persistence to increase, particularly in the spring season (Alami, 2025; Azemzi, 2025; Benassi, 2008; IMIS, 2025; MEWM, 2023a, 2024; Orfi et al., 2025; Schilling et al., 2012; Taheripour et al., 2020). The following Figure 12 presents the distribution of agricultural land depending on the type of irrigation.

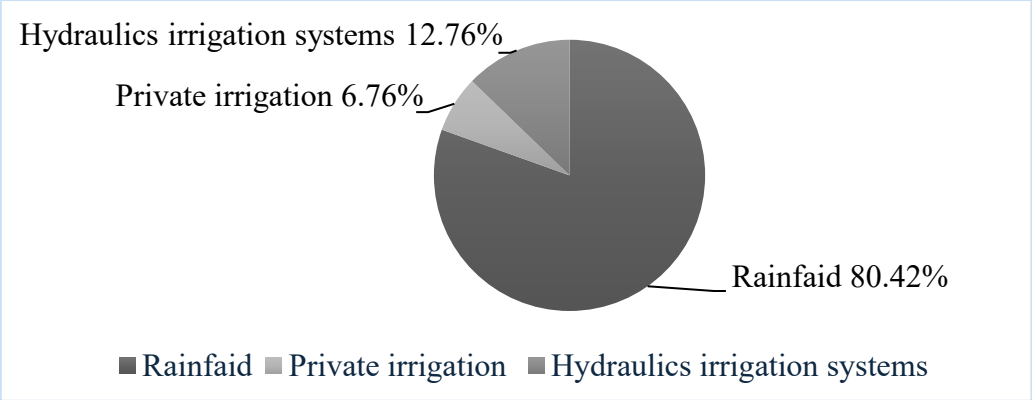

Figure 12: Distribution of agricultural land depending on the type of irrigation (2019-2023)

Source: (MAFM, 2019, 2021; MAFRD, 2023)

Agriculture is under increasing pressure due to climate variability and change. A strong decline was observed in rainfall since 1980 (-15% to -20%) with a decrease in river runoff (-30% to -40%), water resources availability is already under severe pressure with experienced rain deficits since 2015 (M. Alaoui, 2013; Benassi, 2008; Hadria et al., 2019; HCPM, 2025c; WBG, 2017). Additionally, the unirrigated areas are the dominant cultivated lands. As the irrigated land represents about 1.8 million ha, occupying only 19.58% of the cultivated area, a high vulnerability was perceived to the increased rainfall variability on the crop production that's primarily rainfed on the rest of the agricultural area, which represents 80.42%, particularly for barley and wheat (MAFM, 2021; MAFRD, 2023). This

predominance of rainfed land makes the agricultural sector more vulnerable to climate change and variations that negatively affect crop yields, especially during prolonged drought. Furthermore, irrigated agriculture is also impacted as the water needs for these crops can increase from 7% to 12% due to rising temperatures and evapotranspiration (Fadlaoui et al., 2016; HCPM, 2020a; Samir, 2022, 2023a, 2023c).

The following Table 8 presents the main dams' filling rate evolution in the country, including in the main agricultural region (Marrakesh-Safi region), indicating that the dams' filling rate has sharply decreased in the last decade.

Table 8: Morocco's main dams' filling rate, including in the Marrakesh-Safi region as of December 14 (2016-2022)

	Morocco			Marrakesh-Safi, the main agricultural region		
	The normal capacity of dams (Mm3)	Dams reserve (Mm3)	Filling rate (%)	The normal capacity of dams (Mm3)	Dams reserve (Mm3)	Filling rate (%)
2016	15,212.2	7,705.0	50.65%	163.79	129.80	79.25%
2017	15,212.2	5,342.4	35.12%	163.79	74.88	45.72%
2018	15,137.3	9,499.9	62.76%	163.80	101.40	61.90%
2019	15,597.0	7,272.1	46.62%	227.19	81.64	35.93%
2020	15,597.2	5,666.2	36.33%	227.19	78.43	34.52%
2021	16,122.6	5,555,2	34.46%	227.24	76.88	33.83%
2022	16,122.6	4,121,7	25.56%	227.24	90.67	39.90%

Source: (MEWM, 2023b)

Given the future climate change's severe and negative effects, the country may fall well below the 'extreme level of water scarcity' in the coming years. Since the sudden change in precipitation occurred around 1980, annual surface water availability has already decreased significantly (Bouslihim & Torra, 2020; WBG, 2017). As 2022 has marked one of the worst droughts in decades for the country, with annual rain deficits experienced since 2015. Chronic shortages have been a result of these consecutive drought years, resulting in a reduction in the water supply to dams and dwindling groundwater reserves (Alami, 2025; M. Alaoui, 2013; Fadlaoui et al., 2016; HCPM, 2025c; Sraïri, 2021; WBG, 2017, 2021). The groundwater is extracted well beyond the level of sustainable abstraction. on this subject, the World Resources Institute recognized the Moroccan case as a country from high water stress in 2010 to extremely high water stress by 2040 (Luo et al., 2015). The ongoing decline in available water resources is compounded by the deterioration in water quality, which

stems from diffuse agricultural pollution, improper wastewater treatment, and the loss of regulated reservoirs volumes as a result of sedimentation (Bouslihim & Torra, 2020; Samir, 2022, 2023a, 2023c; WBG, 2017). Despite the recorded improvement by the end of April 2025, with an average of the dams' filling rate exceeding 40%, several dams are still in a critical situation, such as the second-largest dam in the country (Al Massira Dam), with a filling rate of less than 5% (IMIS, 2025).

Considering that Morocco was ranked 22nd as a high water-stressed country by the World Resources Institute (2019) a National Program for Drinking and Irrigation Water Supply (2020-2027) was implemented to cope with these circumstances, by building new dams and increasing the volume of wastewater collection, treatment, and reuse, including agricultural water reuse and investing in desalination plants for both irrigation and drinking water (HCPM, 2025c; Hofste et al., 2019; Lachheb et al., 2016; MEWM, 2019; Sinan & Belhouji, 2016). The wastewater treatment rate reached 56% in 2020 compared to 7% in 2006. As the annual volume of waste water produced is projected to reach 900 million m3 per year by 2030, and the volume of wastewater collected has increased sharply in recent decades, the National Plan for Shared Sanitation and Reuse of Treated Wastewater was introduced in 2018 to replace the National Sanitation Program (2005), National Program for the Reuse of Sewage, and the National Rural Sanitation Program (2013). Additionally, five dams are under construction via the National Program for Drinking and Irrigation Water Supply 2020-2027, which will be operating alongside the 149 dams currently functioning to meet the country's need for water resources, totaling 19.3 billion cubic meters, with a goal to reach 170 operating dams by 2030 (Belloulid, 2018; Boutagayout et al., 2025; HCPM, 2020a, 2025c; Latrach, 2018; Lemfarrak et al., 2025; MCCM, 2021; NEG, 2018). It is important to mention that the reason for the table not covering the years 2023 and 2024, given that the government is now releasing a rather general digitalized summarized data about dams' filling rate in their new platform under the title "Maghreb-assoudoud" instead of the previously provided official documents with detailed data releases, that are needed for the study elaboration (MEWM, 2023b; Samir, 2022, 2023a, 2023c).

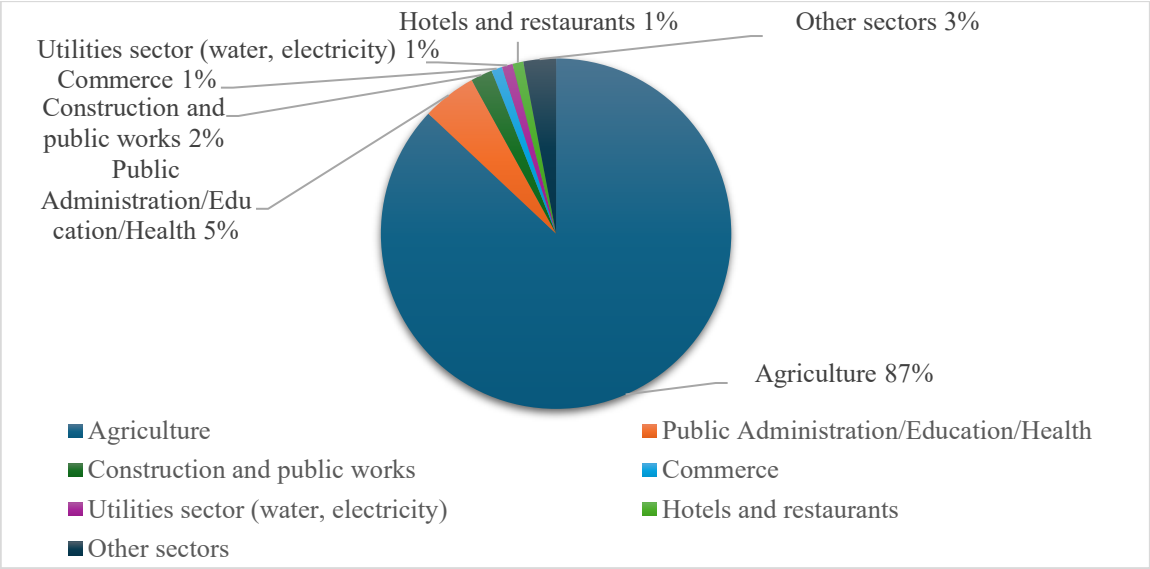

Figure 13: Distribution of annual direct water consumption by sector (2020)

Sources: (Azemzi, 2025; Sahim, 2020)

Based on Figure 13, the data on direct water consumption revealed that the amount of water consumed by the primary sector, mostly the agriculture sector (87%), is much greater than that consumed by the industrial and service sectors. As the water consumption is about 9 billion cubic meters per year, the other sectors consume only a fraction limited to about 1.28 billion cubic meters. Based on the figures, agriculture is considered the primary user of water resources in Morocco (up to 87.8% of total water consumption), which can further demonstrate the potential impact of drought that will exacerbate the situation. Furthermore, it could be also perceived through the evolution of cereal production over the years (Azemzi, 2025; Sahim, 2020; Samir, 2022, 2023a, 2023c).

Table 9: Cereal Production in Morocco periods (2020,2021,2022)

	2015-2019 average	2019	2020	Change 2020/2019	2016-2020 average	2020	2021	Change 2021/2020	2017-2021 average	2021	2022 estimate	Change 2022/2021
	000 Metric ton			%	000 Metric ton			%	000 Metric ton			%
Wheat	5,868	4,100	2,560	-37.56%	4,765	2,560	7,540	194.53%	5,712	7,540	2,500	-66.84%
Barley	2,099	1,161	640	-44.87%	1,548	640	2,780	334.37%	1,981	2,780	690	-75.18%
Maize	101	41	50	21.95%	92	50	100	100.00%	82	100	30	-70.00%
Others	99	95	105	10.53%	99	105	93	-11.43%	102	93	98	5.38%
Total	8,167	5,397	3,355	-37.84%	6,504	3,355	10,513	213.35%	7,877	10,513	3318	-68.44%

Source: (FAO, 2023). Percentage Change: %Increase =Increase/Original Number×100

Based on Table 9, in 2021, as the precipitations were adequately distributed over time and space to facilitate sowing and early crop development, the cereal production exceeded the

five-year average by over 60 percent. In contrast, the 2020 and 2022 harvests were among the lowest recorded in the last 20 years, as they were characterized by poor rainfall in terms of amount and distribution. The cereal production decreased by about 60 percent relative to the previous five-year average of these two years and 38% to 70% below the prior year's harvest. In 2023, even though cereal production increased, with a substantial recovery, if compared to the 2022 harvest, it is still about 15% below the five-year average because of the widespread and prolonged dry weather conditions. In addition, 2024 winter crop production prospects were also unfavorable, due to below-average cumulative rainfall amounts until early March, with a temperature above average, and widespread drought conditions resulting in stress to crops due to soil moisture deficits in their vegetative stage. Moreover, the available water for irrigation was limited because major dams' water levels remained low to the average (FAO, 2024). It is noteworthy that it has been shown that the conversion of rainfed land from cereal crops sensitive to climatic variability to arboriculture enhances climate resilience and improves productivity, particularly for fruit trees. Whereas in the field, farmers' practices show that it is the production systems that have evolved to combine arboriculture with cereals as an intercropping agriculture system, which is considered a sustainable farming practice (FAO, 2023; HCPM, 2025c; MAFM, 2021; Samir, 2022, 2023a, 2023c).

It is clear that climate change effects, particularly consecutive years of drought, put increased pressure on water availability, especially for the development of the agricultural sector. Based on the available literature, many recommendations were proposed for the Moroccan case that align with the Integrated Water Resources Management framework, such as the introduction of a more rigorous regulatory framework to improve groundwater management, promoting sustainable agricultural practices, enhancing water governance through strengthening decentralization and effective coordination across sectors, as well as considering local insights in policy development in order to improve sustainable water management strategies and environmental awareness (Abdessadak & Zeggaf Tahiri, 2025; Azemzi, 2025; Azemzi & Erraoui, 2020; Bayed et al., 2025; Turton et al., 2007).

2.2.2. Summary: Climate change and water resources

The subchapter aimed to present climate change effects, particularly regarding water resources availability and its subsequent impact on the agricultural sector and its development. The consecutive years of drought and water shortages' potential impact on the

agricultural development in Morocco is now established from a literature review perspective, which underscores the relevance of the transition to more sustainable agricultural methods and practices to increase resiliency regarding water shortages. The transition is also relevant for the main agricultural region of the country, which is the focus of the qualitative and quantitative parts of the research.

It is also important to mention that the IPCC climate projections for precipitation and average temperatures show that between 2010 and 2050, aridity is gradually increasing in Morocco due to the projected 11% decrease in rainfall and the increase in temperature of approximately 1.3°C (Amiri et al., 2021; MAFM, 2021). Increased aridity has negative impacts on agriculture, including the loss of soil fertility due to water, wind erosion, and the decline of organic matter. Irrigated agriculture is also impacted, as the reduced availability of irrigation water can reach up to 25% at the reservoir level, while the reduced yields of non-irrigated crops can reach up to 10% in some regions. Furthermore, the decline in animal production is also expected due to negative impacts on crop production and declining water resources (MAFM, 2021; Samir, 2023b).

Given that the temperature will increase by about 1.0 to 1.5°C by 2050 in the best-projected case scenario, with reduced precipitation, and increased incidence of drought conditions (Welsby et al., 2021). Climate change will have an adverse impact on Morocco's agricultural yield (Meliho et al., 2019). Climate variability and change are putting increased pressure on agriculture. Under a high emissions scenario, the average annual temperature is expected to increase by approximately 5.5°C on average by the end of the century (from 1990 to 2100). As a result, the water resources that are in jeopardy will cause a breakdown in the food systems in Morocco. And even if the emissions decrease rapidly, the temperature will still rise about 1.6°C in this century, thus negatively impacting the agricultural yield in Morocco (Samir, 2023b, 2023c; UNFCCC & WHO, 2016). The next subchapter is dedicated to exploring sustainable agriculture and examining Moroccan investment in the adaptability and transition to sustainable agriculture methods and practices.

2.3. SUSTAINABLE AGRICULTURAL DEVELOPMENT

In recent years, more developing countries have been inclined to invest in sustainable agriculture methods and practices. While economic viability, environmental protection, and social equity are considered the main fundamental pillars for agriculture to achieve its sustainability, these basic dimensions can be complemented by institutional, cultural, and

technological sustainability dimensions (Bathaei & Štreimikienė, 2023; Schoor et al., 2023; Spangenberg et al., 2002). Sustainable agriculture is regarded as an integrated system of crop and livestock production practices that produce adequate amounts of high-quality food, protect its resources, and be both environmentally safe and profitable (López-Sánchez et al., 2021; Velten et al., 2015). Agricultural sustainability can be evaluated through the rate of adoption and implementation of sustainable methods and practices within the sector, as well as the impact of the adoption on the long-term ecology, economic viability, and farmers' resilience.

Even though the vulnerable populations in emerging economies, especially poor smallholder farmers, are still at risk due to their lack of adequate adaptive capacity, sustainability in agricultural systems has reduced food poverty and improved food production in over fifty developing countries in Asia, Latin America, and Africa by adopting practices and technologies that are affordable, available locally, and environmentally conscious (Archer et al., 2007; Ojo et al., 2024; Pretty et al., 2003). The different challenges faced during this transition and agricultural transformation prompted the emergence of various approaches for agricultural extension to help facilitate the implementation of the introduced techniques and practices and promote existing ones deemed sustainable (Obibuaku, 1983; Z. Wang et al., 2021). As agricultural extension focuses on reducing the information, technology, and innovations gap between farmers and researchers through farmer education, the farmers' empowerment becomes one of the focal points of these services. And the participatory element becomes more relevant in the proposed approaches, such as the participatory extension approach. Many tools and techniques were emphasized to support achieving the latter, such as Participatory Technology Development (PTD), which focuses on the collaboration involving farmers in testing new farming practices and in agricultural problems analysis, and Farmer Field Schools (FFS), which entail hands-on learning during farmers' group meetings to promote the adoption of alternative and improved farming practices (Hamasalih & Layeeq, 2023; Massimi et al., 2021; Quizon et al., 2001; W. M. Rivera et al., 2022; Saini et al., 2023; Sethi & Sharma, 2012).

As the sector's adaptation and food security concerns often drive countries toward considering the transition to sustainable agriculture. Sustainable food and agriculture (SFA) strives as an integrated approach to tackle both challenges, be it agricultural sustainability and food security. The SFA approach launched by the Food and Agriculture Organization (FAO) identified sustainability as a process instead of an endpoint. The approach, which

consists of five supporting principles, aims to enable conditions for sustainability by identifying the transition pathways tailored to the different political, agroecological, and socioeconomic circumstances (FAO, 2018, 2019, 2020). In this regard, Morocco, like many other countries, has shown interest in the process of transformation and its commitment to adaptation through international collaboration and implementation of SFA guidelines in order to contribute to the ambitious Sustainable Development Goals (SDGs), specifically the second goal of ending all forms of malnutrition and hunger by 2030 (FAO, 2017, 2019). However, it is relevant to note that there is a gap in scientific literature reviews regarding food systems transformation to sustainability in Morocco (Benayad et al., 2024).

It is also important to mention the potential usefulness of political ecology perspectives regarding the current socio-economic situation of agricultural development in Morocco, specifically the vulnerability of smallholder farming communities. In terms of political ecology, as it is defined as the field that examines the complex interaction between political, economic, and social aspects with environmental issues and changes. One of its main priorities on agricultural development is the vulnerability of smallholder farmers, which has a significant influence on climate-smart responses (Chandra et al., 2017; Robbins, 2019; Samir, 2023a).

It is evident that social injustices hinder agricultural development, where political ecology is useful, since it is largely concerned with the marginalization of smallholder farming communities that increases their vulnerability to climate hazards. In addition, it would help in understanding the inequalities, power structures, and social injustices that might emerge during the transition to sustainable agriculture, including the adoption of climate-smart solutions, by critically examining the ethical dimension of issues affecting smallholder farmers, rather than perpetuating a repetitive cycle of marginalization. Political ecology will shed light on the injustices, such as the high illiteracy rate, lack of equitable opportunities, and outsider investors profiting from cheap local labor for agriculture, with cases of unrestricted access to groundwater, while locals are left with the long-term ecological consequences. These insights can serve as guidance for future policies and decisions. Consequently, sustainable agricultural methods and practices investments will be oriented toward making more sweeping changes and optimizing economic, social, and environmental co-benefits (Chandra et al., 2017; Elder, 2022; Robbins, 2019; Samir, 2023a).

Political ecology perspectives will help spot and identify the existing and potential emerging inequalities and vulnerabilities, which result in the marginalization of smallholders during and after the transition to sustainable agriculture methods and practices. The next subsection focuses on presenting the efforts towards the adaptation of agriculture and the transition to sustainable methods and practices in the Moroccan context.

2.3.1. Sustainability and adaptation in Moroccan agriculture

Based on the previous findings, the adaptation of the sector through the transition to sustainable agricultural practices is becoming increasingly imperative. The ensuing subsection will tackle the adaptation and sustainability efforts relating to the agriculture sector in Morocco.

In a broad sense, climate adaptation and mitigation initiatives in Africa have taken shape in different international conferences, collaborations, and partnerships to promote the adoption of sustainable development practices, technologies, and solutions. As African countries are in the process of integrating the United Nations Sustainable Development Goals (SDGs) into their development plans. Morocco's awareness of the threat of climate change has prompted it not only to adhere to the 2030 Agenda for the Sustainable Development Goals but also to organize many international conferences, such as COP 7 (2001) and COP 22 (2016). Since the agricultural sector is of strategic importance in Morocco, the country has also presented on the occasion of COP 22 (2016) the Initiative for the Adaptation of African Agriculture to Climate Change (AAA Initiative), which was supported by 38 African countries and was recognized by the Heads of States of the African Union. The initiative fosters the implementation of concrete projects to improve agricultural water management, soil management, climate risk management, and financing capacities. (FAO, 2016; Samir, 2022, 2023a, 2023c; World Bank, 2013, 2019; World Bank et al., 2018).

In the context of international cooperation and partnerships, Morocco has benefited from various international financial supports, including an investment concerning climate-smart agriculture. Climate-smart agriculture is regarded to be very effective in tackling climate challenges as it is defined by the World Bank as an integrated approach to address the interlinked challenges of food security and climate change, which could be translated as the incorporation of intensification, adaptation and mitigation goals (Samir, 2023a, 2023c; Taylor, 2018).

Morocco Climate-Smart Agriculture Investment Plan, which the World Bank and FAO supported for the current decade, was launched to effectively support sustainable agriculture, boost productivity, and achieve food security. In order to contribute to climate-smart agriculture, the investment plan aims specifically to support the intensification of the most productive land, soil conservation to maintain longer-term fertility and conserve carbon, agro-forestry, integrated crop-livestock management, improved agricultural water management, erosion control, reducing the deforestation and reforestation to preserve watersheds, restoration of degraded lands and improved pest and disease management. In addition, the current program, Green Generation Strategy (2020-2030), which constitutes Morocco's primary agricultural strategy, is designed to improve agricultural development and foster sustainable agriculture by streamlining climate-smart practices. The technical extension assists farmers in adopting climate-smart agricultural practices, with the aim of targeting 12,000 farmers. As the government is currently investing in Agriculture 4.0 adoption plan and precision farming to modernize and digitalize the sector, as well as other previous collaborative initiatives such as the adoption of the Land Data Assimilation System (LDAS-MOROCCO), focusing on applying advanced remote sensing and data assimilation technologies to improve water resource management and climate change adaptation, specifically for the water and agriculture sector. It is clear to the government that the next step for the agricultural development sector is to increase the adoption of climate-smart technologies and practices, subsequently fostering the adaptation to the current and future climate scenarios (Benbahria et al., 2021; CRTS, 2015; El Haddadi et al., 2025; IRES, 2024; Samir, 2023a, 2023c; Seif-Ennasr et al., 2021; World Bank, 2019; World Bank et al., 2018).

Morocco, holding the 6th rank in the Climate Change Performance Index (2026), has promoted sustainable methods and practices in agriculture, including the wise use of water resources for irrigation, soil conservation, and the use of renewable energy (Burck et al., 2025; Maatala et al., 2020). Additionally, smallholders, who represent 70% of farms, still rely on traditional agricultural practices that have proven to be sustainable for soil conservation, such as natural fertilizer (e.g., manure), crop rotation, and agricultural water reuse (Lachheb et al., 2016; MEFM, 2019). These sustainable traditional practices gained the support of the state (MAFM, 2021). Furthermore, Morocco's agricultural development strategy has encouraged other sustainable practices such as crop diversification and drip irrigation over traditional surface irrigation for more efficiency, with an ambition to convert one million ha to drip irrigation by 2030 (Boularbah et al., 2017; MAFRD, 2023), the

introduction of the National Direct Seed Program (PNSD) as a part of the Green Generation Strategy (2020–2030) to foster the adoption of the direct seeding method, and the conversion to agriculture that is resilient to climate hazards (HCPM, 2025c; MAFM, 2019; Mengoub et al., 2021; Samir, 2022, 2023a, 2023c; Toujgani et al., 2021). The following Figure 14 presents the evolution of the drip-irrigated area in the country.

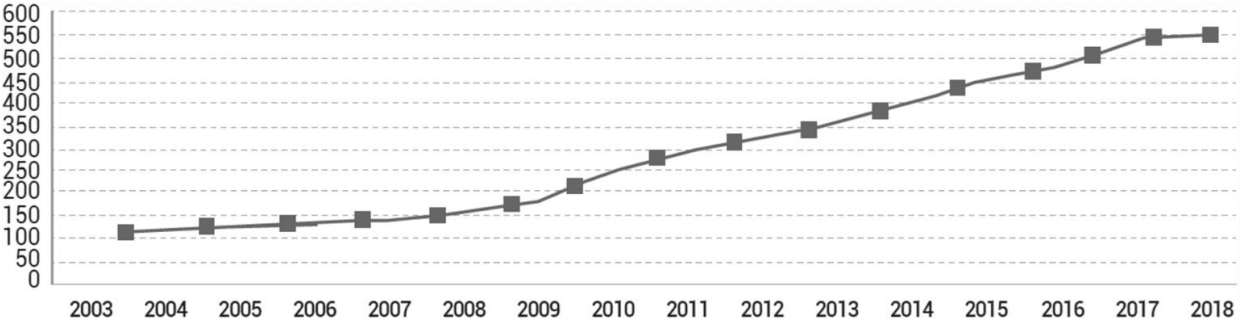

Figure 14: The evolution of the drip-irrigated area (Kha)

Source: (MAFM, 2019)

The Green Morocco Plan (2008-2020) of the last decade fostered the conversion of irrigated land to drip irrigation, reaching nearly 560,000 ha and increasing from 9% in 2008 to 36% of the share of the irrigated land at the end of 2018. Nevertheless, the irrigated areas remain primarily surface irrigation areas with low efficiency (about 50% less efficient). Drip irrigation has enabled 80% of farmers with wells to reduce the pumping of groundwater, and 50% of them have abandoned irrigation from wells. As a result, farmers were able to produce more with less water. These statistics regarding the evolution of drip irrigation were published and made available online in July 2021 (MAFM, 2019, 2021). The conversion to sustainable practices relating to water management is highly relevant, given that the country is facing drought and a deficit in precipitation in recent years (Samir, 2022, 2023a, 2023c).

Introduction of new crop varieties

Notably, cereal grains, including durum wheat, comprise the majority of the seed market and are considered vital for national food security. Given that one of the priorities is to fortify the genetic base of staple crops, particularly fostering drought-tolerant crops. In this regard, remarkable progress has been made for more than two decades. Based on the latest available data, the National Institute for Agricultural Research has currently created 42 new varieties, which are the following: seven varieties of soft wheat, six of durum wheat, five of barley, five of rapeseed (or canola), five of oats, four of triticale, three of lentil, three of chickpea,

three of broad bean (or faba bean), and one of field bean (or horse bean). Only thirteen of these varieties have been transferred to seed companies for their multiplication, and the rest (29) remain to be licensed (Amamou, 2024; Idrissi et al., 2019; INRA, 2017, 2023, 2025). The following Table 10 is a presentation of some of the available relevant crop varieties data.

Table 10: New crop varieties with their relevant characteristics

Species	Variety			Grain yield (q/ha)			
		Date of registration	Date of transfer	Rainfall	Semi-arid	Drought tolerance	Length of growing cycle
Durum wheat	Karim	1985	Already transferred	52	32	Moderate resistance	147.73 days
	Faraj	2007	2014	59	38	Moderate resistance	154 days
	Itri	2016	2020	54	35	Tolerant	150 days
	Hammadi	2017	2020	56	40	Moderately Tolerant	151 days
	Nachit	2018	Not yet	59	41	Tolerant	150 days
	Jawahir	2022	Not yet	57	42	Highly tolerant	150 days
Bread wheat (soft wheat)	Arrehane	1996	Already transferred	59	38		Early-Maturing (short)
	Malika	2016	2020	60	42	Tolerant	147 days
	Snina	2017	2020	63	43	Tolerant	143 days
	Lina	2020	Not yet	63	44	Tolerant	153 days
	Ibtissam	2022	Not yet	58	42	Tolerant	153 days
	Irchad	2023	Not yet	65	45	Tolerant	85 days
Species	Variety	Launch date	Date of transfer	Potential grain yield (q/ha)		Drought tolerance	Length of growing cycle
Barley	Amalou	1997	Already transferred	65		Moderately Tolerant	
	Chifaa	2016	Not yet	65		Moderately Tolerant	Average duration
	Khnata	2017	2020	90		Tolerant	Early-maturing (short)
	Ksaiba	2017	Not yet	70		Tolerant	Semi-Early maturing
	Assiya	2016	2020	65		Moderately Tolerant	Average duration
Legumes	Lentil "Extra"	2019	2020	30		Good tolerance to water deficit	Very early-maturing (very short)
	Lentil "Karam"	2024	Not yet	30		Good yield stability during drought years	Semi-early maturing
	Chickpea "Taounate"	2021	Not yet	37		Tolerant	Early-maturing (short)
Rapeseed	Marina	2023	Not yet	25		Moderately Tolerant	Early-maturing (short)
	Redana	2023	Not yet	27		Moderately Tolerant	Semi-early maturing

Sources: (Amamou, 2024; INRA, 2005, 2017, 2023, 2025)

While there is an effort to create crops with shorter growing cycles for adaptation purposes, the varieties were allocated to different parts of the country based on their adaptation potential, usefulness, and production objectives. For instance, in terms of durum wheat, the Hammadi and Itri varieties were intended for favorable zones, Jawahir for semi-arid zones, and Nachit for mountain areas. In the case of bread wheat's new varieties, Malika, Snina, Irchad, and Lina, which have good grain quality, are recommended for semi-arid zones. For barley varieties, Khnata and Kssaiba are recommended for semi-arid zones, while Chifaa and Assiya are recommended for favorable zones. As achieving the right grain production requires using a carefully chosen variety, the rate of certified seed use remains low, even though there has been an increase of 11 to 24% between 2009 and 2021. It is worth mentioning that the leading company in Morocco's seed sector is also a state-owned company under the name SONACOS (Société Nationale de Commercialisation des Semences), or National Seed Marketing Company, which is under the aegis of the Ministry of Agriculture, Maritime Fisheries, Rural Development and Water and Forests, and is responsible for the production and marketing of selected certified seeds for cereals, sugar beets, forage crops, food legumes, potatoes, and other vegetable products. Similarly, some private companies from southern Europe have recently introduced several varieties that are currently under commercialization (Amamou, 2024; INRA, 2017, 2023, 2025).

It is clear that Morocco had already made considerable efforts both in terms of adaptation and transition to sustainable agricultural practices. However, due to climate change effects and the escalating water shortages, the situation calls for more investments in the agriculture sector's adaptation, particularly with regard to conservation agriculture and water management practices, along with the adoption of crops with stable yield and drought tolerance in order to reach the Generation Green objectives, such as attaining an average of 30 q/ha by 2030 for cereal production (Amamou, 2024).

2.3.2. Summary: Sustainable agricultural development

The subchapter aimed to explore the sustainable agriculture concept and presented the Moroccan government's efforts regarding the adaptation of agriculture and fostering the transition to sustainable methods and practices amidst the persistent water shortages.

Morocco has been actively involved in many international cooperations and initiatives, such as those related to climate adaptation and mitigation initiatives, particularly the Climate-Smart Agriculture Investment Plan, as well as relevant technology adoption efforts and the

modernization of the sector. The country also supported sustainable traditional practices, along with fostering the adoption of sustainable agricultural methods and practices, such as crop diversification, the direct seeding method, and drip irrigation in the previous and current agricultural plans.

Considering the climatic context, including the predominance of rainfed land, which makes the agricultural sector more vulnerable to climate change and prolonged drought, the government has also invested in developing drought-tolerant crops for decades, with an incremental shift from moderately tolerant to tolerant crops investment focus in the last decade.

It is clear that the next agricultural development path for Morocco will be the consideration of the investment in more implementation of climate-smart technologies and practices, conservation agriculture, and particularly further adoption of sustainable methods and practices relating to water management and advanced irrigation, subsequently increasing agricultural resiliency regarding water shortages and fostering adaptation to the current and future climate scenarios.

2.4. SUMMARY OF LITERATURE REVIEW

The literature review chapter aimed to address the *Sub-question 1: What is Morocco's past and current agricultural development status concerning the sustainability aspects of this sector and water resources?* To do so, the first subchapter focused on exploring agricultural development in rural areas in the context of rural development from the lens of the sustainability pillars, the second subchapter discussed climate change effects, focusing on water resources availability, particularly regarding its relevance and impact on the agricultural sector, and the last subchapter presented sustainable development efforts in the agriculture sector for the Moroccan context.

Based on the previous and current Moroccan development trends, the government is well aware of the importance of the sustainability aspect, and it will likely be emphasized in future rural development plans. Agriculture is essential to most rural economies and is still prominent for Morocco's economic growth as a developing country (13% of total GDP). As agriculture is quite vulnerable to climate variability, much of rural prosperity in recent years has been associated with the transition to sustainable agriculture and the resulting economic benefits (M. Rivera et al., 2018; Zhang et al., 2017). However, the strong predominance of cereal crops (about 60% of the total agricultural lands) in Morocco makes the sector less

resilient to climate change and negatively impacts the growth of the economy. The available data also indicated that climate change will have an adverse impact on Morocco's agricultural yield, particularly with regard to water resources availability during the consecutive drought years. Nevertheless, the transition to sustainable methods and practices positively impacted agriculture, such as fostering approaches geared towards agricultural adaptation and sustainable water management, consequently promoting productivity and reducing the volatility of Agricultural Value Added over the past decade. Conversely, challenges such as high illiteracy and low adoption of technology and sustainable practices contribute to the vulnerability of the sector facing the water shortages issue and to the broader impact of climate change. As a result, more effort remains to be implemented in order to keep promoting sustainable practices and fostering resiliency and adaptation of the sector regarding the current and future projected climate change scenarios, particularly amidst persistent water shortages (Samir, 2023b, 2023a, 2023c).

2.5. HYPOTHESIS DEVELOPMENT

Based on the literature analysis and experts' opinions, it is revealed that water issues present a primary challenge facing the sector. The following are the hypotheses formulated and presented with their null hypotheses counterparts.

Climate change constitutes a major challenge to agricultural development in Morocco due to the increase in drought frequency, the rise in temperature, and heightened climate variability (Alami, 2025; M. Alaoui, 2013; Amiri et al., 2021; Azemzi, 2025; Benassi, 2008; Fadlaoui et al., 2016; HCPM, 2020a; IMIS, 2025; MAFM, 2021; MEWM, 2023a, 2024; Orfi et al., 2025; Schilling et al., 2012; Sinan & Belhouji, 2016; Taheripour et al., 2020). In view of the impacts, the following (*H1)* was developed:

> *$H1_1$: The extent to which farmers' inclination for sustainable practices adoption is influenced by the degree of the perceived climate change's impact on the farms.*
>
> *$H1_0$: The extent to which farmers' inclination for sustainable practices adoption is not influenced by the degree of the perceived climate change's impact on the farms.*

It is evident from the literature analysis and experts' opinions that climate change is a significant factor influencing farmers' decisions to adopt sustainable practices. It is therefore important to explore this relationship. The study examined whether there is an association between the number of consequences of climate change observed and dealt with by farmers

and their decision to adopt sustainable practices, with climate change as a key influencing factor. To rephrase, it is an attempt to assess if the level of awareness regarding climate change impacts in their work is associated with their level of inclination toward transitioning to sustainable practices, with climate change as the main driver. Therefore, the sample was examined for this association.

Given the persistent challenge of water shortages faced by farmers, the limited available water for irrigation from the main dams, the impact of precipitation variability on the agricultural yield, and the government efforts in fostering adaptive irrigation practices, including the traditional ones, such as agricultural water reuse (Bouslihim & Torra, 2020; FAO, 2023, 2024; HCPM, 2020a; IMIS, 2025; Lachheb et al., 2016; MAFM, 2019, 2021; MEFM, 2019; Mengoub et al., 2021; MEWM, 2023b; Vitry et al., 2015), the following (*H2*) was developed:

> *$H2_1$: The extent to which farmers' inclination for sustainable practices adoption is influenced by the number of practices already applied to conserve water on the farms.*
>
> *$H2_0$: The extent to which farmers' inclination for sustainable practices adoption is not influenced by the number of practices already applied to conserve water on the farms.*

The second hypothesis examines whether there is an association between the number of already applied practices for water conservation efficiency purposes and the inclination for sustainable practices adoption, with the improvement of water use efficiency as a key influencing factor. This is to explore the extent of the farmers' existing commitment to water conservation (through the number of applied practices for water conservation), acting as positive reinforcement and a driver for adopting new, more comprehensive sustainable practices, to improve water use efficiency. This is also based on the potential perception gap between adopters and non-adopters of conservation methods (McCollum et al., 2022).

Given the government's state-led investment in agricultural development and its modernization, including multiple initiatives on fostering the adoption of sustainable methods and practices, primarily via the Green Morocco Plan (2008–2020), followed by the Green Generation Strategy (2020–2030) (Akesbi, 2012; Boularbah et al., 2017; El Haddadi et al., 2025; Elalaoui et al., 2021; HCPM, 2020a; IRES, 2024; MAFM, 2019, 2021; Mengoub et al., 2021; Vitry et al., 2015; World Bank, 2019; World Bank et al., 2018), the following (*H3*) was developed:

$H3_1$: The extent to which farmers' inclination for sustainable practices adoption is influenced by the support opportunities offered by the government for the farms.

$H3_0$: The extent to which farmers' inclination for sustainable practices adoption is not influenced by the support opportunities offered by the government for the farms.

The third hypothesis aims to examine whether there is an association between the farm previously benefited from government support and the farmer's inclination to adopt sustainable practices, with access to the government's financial support programs as a key influencing factor. The inclusion of this hypothesis stems from the importance given to support as an approach to drive favorable change, deduced from the in-depth interviews conducted and the literature analyzed.

Given the high rural illiteracy rate of 38% (2024), smallholders, who represent 70% of farms, are often unable to implement new practices and technologies, resulting in the management of water resources that is insufficiently rationalized, low irrigation efficiency, and low adaptive and productive capacity. Illiteracy is also considered by the government as one of the main hindrances to the modernization and the adaptation of the sector (El Fartassi et al., 2023; Gailhard & Bavorova, 2014; Harvey et al., 2014; HCPM, 2025b; He et al., 2016; MAFM, 2021; Maini et al., 2021; MEFM, 2019). Based on these implications, the following (*H4*) was developed:

$H4_1$: The number of practices already applied to conserve water on the farms is influenced by the level of education attained by the farmers.

$H4_0$: The number of practices already applied to conserve water on the farms is not influenced by the level of education attained by the farmers.

The last hypothesis aims to examine whether there is an association between the number of practices already applied to conserve water on the farms (for water efficiency) and the farmers' level of education. The inclusion of this hypothesis is because education may encourage farmers to adopt a more proactive approach to farm management, which involves seeking and implementing new solutions instead of relying only on traditional methods. Also, educated farmers may have better access to information and be more inclined to seek out information on new technologies and conservation methods. The following Figure 15 presents a conceptual illustration of the hypotheses.

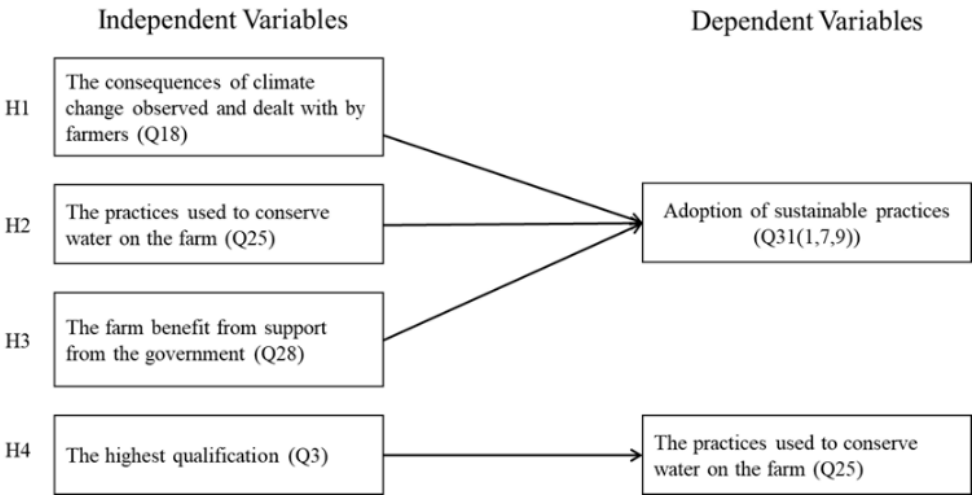

Figure 15: Conceptual illustration of the hypotheses

Source: Author's own work, 2025

In terms of the exact dependent variable, it is the inclination to adopt sustainable practices and could be defined as the composite score derived from question 31, which aimed to measure the perceived influence of multiple factors (climate, drought, support, etc.) on the farmer's decision-making process.

The next chapter is dedicated to presenting the methodology of the research, related qualitative interviews, and the quantitative survey parts of the study.

3. METHODOLOGY

As the introductory chapter stated, the thesis is guided by a research design that encompasses multiple levels. Based on Table 1 (see page 21), the following Figure 16 depicts the stages of the research process and its internal connections.

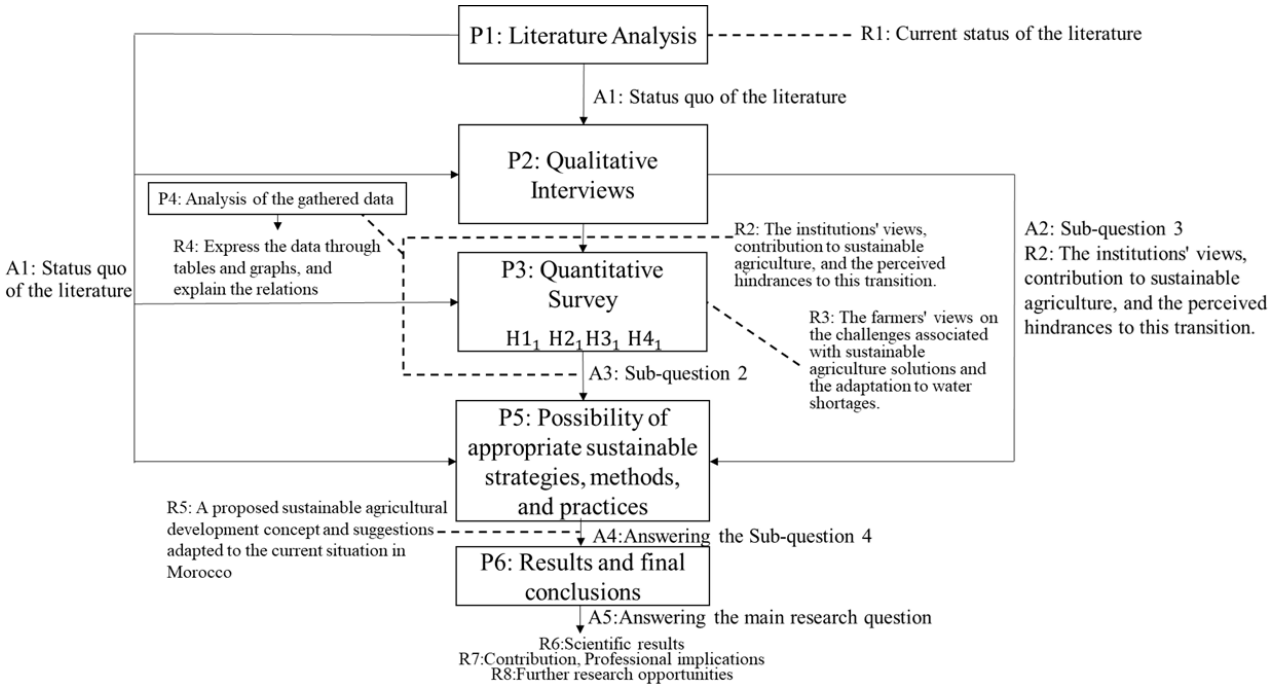

Figure 16: Thesis' methodology flow chart

Source: Author's own research, 2024

In terms of transparency, the research strived to clearly explain the methods, findings, and limitations, which also ensure the integrity of the study. The individual phases of the research process are explained in the following subchapters, along with their objectives and the studied results.

3.1. QUALITATIVE INTERVIEWS

In order to gain a deeper understanding of the research field's complexity, qualitative research methods are employed. Therefore, the outcome *R2: The institutions' views, their contribution to Morocco's transition to sustainable agriculture, and the perceived hindrances to this transition* is intended to make a significant contribution to answering *A2: Answering the Sub-question 3.*

The presentation of social circumstances in a comprehensible manner is one of the benefits of qualitative survey methods. This can be used to support hypothesis generation and be

incorporated into theory development. Qualitative research can also contribute to the modification and partial testing of hypotheses and theories (Babbie, 2013; Corbière & Larivière, 2014; Mayring, 2014).

Qualitative interviews are usually classified as either individual or group interviews. In scholarly work, guided interviews are the common form of interview, while focus groups are the common form of group discussion. In general, the range can vary from a narrative interview (an unstructured conversation) to semi-structured interviews and guided, structured interviews. Whether interviews are conducted in person or online, it is crucial that the object of research can be discussed or represented through an interview, which will play a role in the process of selecting the appropriate interview methodology (Babbie, 2013; Corbière & Larivière, 2014; Mayring, 2014).

In qualitative research, it is challenging to accurately predict the number of participants who will be part of the study. In this regard, it is suggested that 5 to 25 participants may be necessary, while specifying the need to continue interviews until there is redundancy in the data (Corbière & Larivière, 2014; Townsend, 2013). However, a heterogeneous population necessitates at least 25 to 30 interviews, as J. W. Creswell (2007) suggested. Regarding semi-structured in-depth interviews, a sample of 5 to 25 would be appropriate (J. W. Creswell, 2007; Saunders, 2012). Furthermore, according to Bryant et al. (2007), the more specific and targeted the interview's content, the better the quality of the data; therefore, fewer interviews are necessary, and thus fewer participants are required. In brief, the number of participants can be estimated based on the characteristics of the research protocol (Bryant et al., 2007; Morse, 1994; Richards & Morse, 2013).

The process of selecting interview partners is given special attention. Heterogeneity or homogeneity of the interviewees relies on the research design’s focus, which is either resolved in advance to represent corresponding characteristic features or determined during the research process. It is necessary that the interview partners have the ability and willingness to discuss the topic, express themselves in an argumentative manner, and have sufficient time resources (Babbie, 2013; Corbière & Larivière, 2014; Mayring, 2014).

Due to the research design of this study, a semi-structured interview with relevant participants and experts was adopted to explore the research field. This methodological approach was chosen because individual interviews have an advantage over group methods (focus groups), allowing for processing and focusing on a single person's opinion without it

being influenced by other members of the group. As the semi-structured interview offers flexibility in asking follow-up questions when necessary to delve further into relevant areas and gain a more in-depth understanding of the topic. It also provides the possibility to compare the results of different interviews while ensuring the necessary degree of open discussion. The main guiding questions were formulated in advance in order to define the interview's framework (Babbie, 2013; Corbière & Larivière, 2014; Wildemuth, 2016).

The qualitative interviews aimed to reassemble the experiences and knowledge of the interviewees regarding the research field. Interviewed individuals should be related to the research area and preferably possess both theoretical and practical knowledge in their fields of work, as the selection of interviewees directly affects the survey results. An expert can be defined as an individual who possesses specialized and profound knowledge regarding social issues. The qualitative research subchapter will cover more details about the list of experts and interviewees. It's noteworthy that semi-structured interviews may not fully address the requirements for non-influence and openness, leading to potential deficiencies in the theoretical-methodological foundation of the method. Therefore, as with any form of survey, there are both positive and negative aspects that must be taken into consideration (Babbie, 2013; Corbière & Larivière, 2014; W. J. Creswell & Creswell, 2017; Wildemuth, 2016).

While the semi-structured interview method enables the possibility of adjusting the questions as the interview progresses. It also allows the modification of the order of the guided questions based on what seems most appropriate. In addition, the wording of the questions can be modified, and particular questions that seem inappropriate for a specific interviewee can be omitted, or additional questions can be included. Furthermore, the method is suitable for eliciting information on the research topic from the perspective of each participant, as the interviewer can ask additional probing questions to have interviewees clarify or elaborate further on a specific topic (Berg, 2001; Gauthier, 2009; Lobe et al., 2022; Richards & Morse, 2013; Robson, 2002; Wildemuth, 2016). Moreover, as the in-depth interviews were conducted in-person with either a digital recorder or a human note taker, or both, it allowed for enhanced rapport and engagement, the ability to gather nonverbal cues, and flexibility in exploring new insights. However, it may also present challenges such as potential interviewer bias or higher costs (Lobe et al., 2022).

The development of guided questions was based on the research questions of this dissertation and the literature analysis related to the research field. Therefore, the guiding questions aimed to cover the following topics:

- The perceived challenges and the most important issues facing agricultural development
- The changes noticed in the sector after the adoption of the Moroccan Green Plan (2008-2020) and/or Green Generation Strategy (2020-2030)
- The government's agricultural development plan in terms of the transition to sustainable agriculture
- The challenges and potential for the transition to sustainable agriculture, and strengthening the resiliency of the sector (water shortages challenge)
- Farmers' adoption of sustainable farming practices, their knowledge and ability to appropriately adapt

The open-ended guiding questions helped guide the flow of conversation, and the question regarding the water shortage challenge was not explicitly asked until either the interviewee addressed it first or after the second question, as a follow-up probing question by the interviewer, to gain a better understanding of the level of awareness of the issue.

To evaluate the in-depth interviews, qualitative content analysis was chosen because it is suitable for the present work and the research questions that were developed. Patton (2002, p. 453) defined the research method as "any qualitative data reduction and sense-making effort that takes a volume of qualitative material and attempts to identify core consistencies and meanings". The qualitative content analysis methodology is appropriate for analyzing written data, ideally when there is already background knowledge of the topic explored and some preconceived notions about what is expected to be discovered from the data, or when there is a specific theory to investigate. Qualitative content analyses also have an advantage over other qualitative analysis methods, because they don't remain attached to the text but rather take into account and assess the information obtained within the research context (Corbière & Larivière, 2014; Mayring, 2014; Wildemuth, 2016).

To prevent irrational and arbitrary interpretations, it is important to prioritize quality criteria in qualitative research. Conducting an open conversation that is centered mostly around openly formulated questions without bias constitutes the basic principle, which is that of openness. Comprehensibility (intersubjective comprehensibility) and reliability

(dependability) involve the documentation of the research process. The involvement of more than one researcher or expert in the research process stages promotes the reliability of conclusions. Including other researchers and experts can help minimize researcher bias and strengthen the rigor of the study. Additionally, with the incorporation of literature analysis (triangulation), it would also increase the validity (credibility) of the research (Gagnon, 2012; Kakar et al., 2023). In general, the common relevant quality criteria are the following: credibility, transferability, dependability, and confirmability (Lim, 2025). However, it is worth noting that there is no consensus on the terminology used to evaluate the quality of a qualitative inquiry. In summary, although qualitative research results may not be indicative of representative populations, validity (credibility) and reliability (dependability) are reasonable criteria for guiding qualitative research (Babbie, 2013; Corbière & Larivière, 2014; Wildemuth, 2016).

Qualitative content analysis provides the following methodological approaches presented in Table 11:

Table 11: The qualitative content analysis approaches according to the coding differences

Method of content analysis	The study starts with	When to define keywords or codes	Source of keywords or codes
Conventional content analysis	Observation	Code defined during the data analysis	Codes are derived from data
Directed content analysis	Theory	Code defined during or before data analysis	Codes are derived from relevant research findings or theory
Summative content analysis	Keywords	Keywords defined during or before data analysis	Keywords are derived from the interest of researchers or a review of the literature

Sources: Based on (Dany, 2016; Hsieh & Shannon, 2005)

The selected summative approach for qualitative content analysis begins with word counting (keyword frequency), which appears to be a quantitative approach in the early stages. However, it goes beyond that to include latent content analysis, which in this context means looking for underlying meanings, themes, or patterns, and providing basic insights into how words are used. Additionally, exploring the usage of words (sets of codes/keywords) in an inductive manner helps identify alternative terms used for keywords (alternative keywords), as well as examining the contexts within which alternative and direct keywords are used (Hsieh & Shannon, 2005; Wildemuth, 2016).

Based on the literature analysis, the organizing themes (categories) and codes (keywords) were formulated with an adaptation to the Moroccan case. As evidence of trustworthiness, the organizing themes (categories) and codes (keywords) were approved by two agricultural experts from the National Institute for Agricultural Research, Marrakesh-Safi region of Morocco, and a professor from Sopron University in Hungary, for the validation process by content experts. Additionally, the study strived for consistency of the textual evidence ("manageable corpus" translated summary of the in-depth interviews conducted) with the interpretation for internal consistency and credibility. Furthermore, with the research process documented, the intended meaning of the words used, especially concerning codes (keywords and alternative keywords), was also immediately checked with the participants during or at the end of the interviews conducted for clarification (Babbie, 1992; Hsieh & Shannon, 2005; Lincoln & Guba, 1985; Weber, 1990; Wildemuth, 2016).

The keywords are classified under categories to facilitate analysis, revision, interpretation, and evaluation. In the following, Figure 17 presents a simplification of the relationship between the keywords, organizing themes, and the global one.

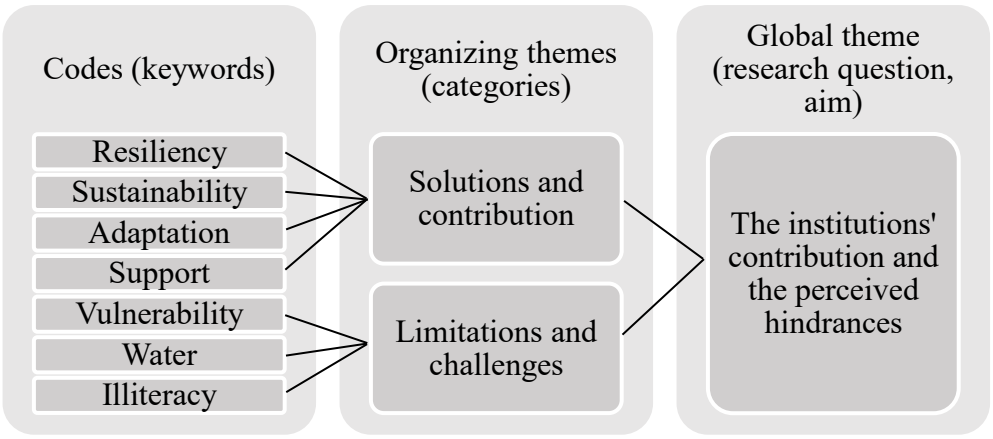

Figure 17: Simplification of the relationship of the keywords, organizing and global themes

Source: Author's own research, 2024

The logical reason behind selecting the mentioned keywords:

- Sustainability and water resources constitute the main concerns of this study
- Adaptation, vulnerability, and resiliency were chosen as keywords since they are considered closely related to the sustainability concept and to this study from a literature analysis perspective.

- Support and illiteracy were added as keywords since they are considered economically and socially by the government as one of the main keys and hindrances to the modernization and the adaptation of the sector (MEFM, 2019).

The following Table 12 consists of the operationalized definitions of the keywords with the identified alternative keywords that appeared in the data.

Table 12: The operationalized definition of the keywords (codes)

Keywords (alternative keywords)	Explanation
Adaptation (to adapt, adapted, adapting, adaptive)	To adapt, adapted, adapting, adaptive The process of adjustment to the current and expected climate and its effects on human systems involves modifying or avoiding harm or exploiting beneficial opportunities.
Illiteracy (illiterate, education)	Illiterate, education The inability to read and write, uneducated, or the individual's ability that is considered below the functional level in any given society.
Resiliency (Resilience, resilient)	Resilience, resilient The ability of the farmers to handle and overcome the effects of shocks and stresses that impact their agricultural production and livelihoods.
Support (subsidy, subsidies, training, supported, supporting)	Subsidy, subsidies, training, supported, supporting Programs that target the farmers' population in order to provide help and assistance.
Sustainability (sustainable)	Sustainable The capability of a farm or agricultural system to produce agricultural products without affecting, harming, or depleting the resources on which it depends.
Vulnerability (vulnerable)	Vulnerable The degree to which an agricultural system is prone to or incompetent to deal with the damaging effects of climate change and extreme weather events.
Water (rain, rainwater, rainfall, precipitation, groundwater)	Rain, rainwater, rainfall, precipitation, groundwater a crucial element needed for the process of agricultural production.

Source: Author's own research, 2024

The "summary" as a basic form of qualitative content analysis is applied for in-text analysis. An effort has therefore been made to reduce the text material as much as possible in order to obtain a "manageable corpus". The in-depth interviews were conducted in either French, Arabic, the Moroccan dialect, or a combination of these languages and were summarized before being translated into a manageable corpus in English. Furthermore, as the summative

approach is considered deductive, starting with a set of specific codes or categories, the following Figure 18 was used to help guide the analysis (Corbière & Larivière, 2014; Hsieh & Shannon, 2005; Mayring, 2014).

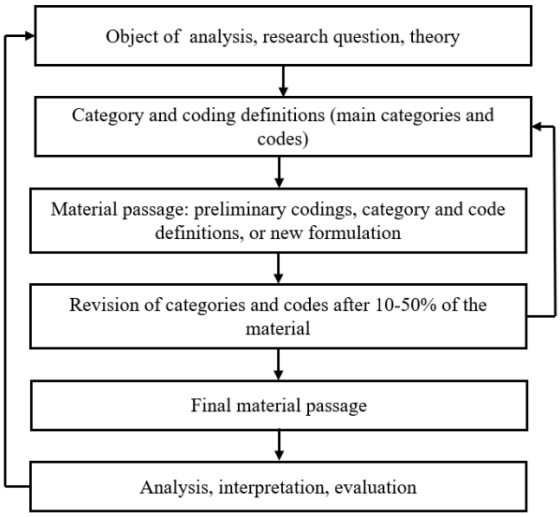

Figure 18: Steps of deductive category and code assignment

Source: Based on (Mayring, 2014)

The research relied on purposive sampling to select the organizations that are related to controlling policy, finance, and research, as well as practitioners who implement the adaptation strategies.

In terms of data saturation, it was reached for the open-ended guiding questions, evidenced by the answers from the related institutions becoming redundant. With regard to the potential institutional bias, the interviewees from the government's institutions tended to emphasize the success of government agricultural programs and plans, while the heads of the farmers' associations and cooperative were inclined toward highlighting the shortcomings and the practical barriers. The comparison of these different viewpoints allowed for a better identification of the divergence between policy intent and field reality, which contributes to addressing *A2: Answering the Sub-question 3* and is considered during the formation of hypotheses in the present work.

3.2. QUANTITATIVE SURVEY

The dissertation aims to address the relevance of transitioning to sustainability to enhance resiliency regarding water shortages. This entails analyzing farmers' views on sustainability, its challenges, and adaptation to the water issue. A quantitative survey is applied to address

the research goal *A3: Answering the Sub-question 2*. Thus, reaching the outcome *R3: The farmers' views on the challenges associated with sustainable agriculture solutions and the adaptation to water shortages.* Many authors have regarded quantitative studies as an endeavor that applies variables and/or variables related to each other for analysis via statistical methods. Before verifying or predicting empirical relationships between variables, scientific research discusses the reliability and validity of the applied instrument and describes the main concepts (Babbie, 2013; Neuman, 2011; Singh, 2007). To present quantitative methodology comprehensively, the subchapter was divided into two main subsections: the data collection method and timeline subsection, and the data collection procedure and questionnaire distribution method subsection.

3.2.1. Data collection method and timeline

Surveys can generally measure the characteristics of specific features and associate them with each other. To ensure that answers to the questions are standardized and that the statements of the participants can be comparable, questionnaires have become established. Furthermore, statistical methods can be used to objectively present facts and prove or reject associations (Babbie, 2013; W. J. Creswell & Creswell, 2017; Singh, 2007).

The survey was conducted in the Marrakesh-Safi region, as it is considered the largest region in terms of agricultural land surface (see Table 2, page 27), and it is the same region where in-depth interviews were conducted with relevant experts from different institutions and organizations. Since the present survey's population can be considered to be all active farmers in this region of Morocco, and there is no official figure regarding the number of farmers, only the number of agricultural holdings is available, reaching 285,000 in the region (Nejjari & Lebzar, 2018). A representative study was not conducted, considering the challenging and confusing parameters; rather, the questionnaire was administered using the snowball method. The resulting ad hoc sample does not provide any conclusions being drawn about a particular population; therefore, it does not claim representativeness. Nevertheless, the sample can provide analogies for further research (Apparicio & Gelb, 2023; Babbie, 2013; W. J. Creswell & Creswell, 2017; Singh, 2007).

The use of snowball sampling is acknowledged as a major limitation; consequently, the implications for external validity are significant. The sample may be skewed in favor of:

- Farmers who are more socially connected.
- Those who belong to specific networks.

- And might not fully represent isolated smallholders.

The choice of sampling method was also due to field constraints in the studied region:

- Trust and access: The referral method of snowball sampling was necessary to establish the trust required to get accurate, honest survey responses, and also due to the difficulty of accessing an up-to-date farmer registry in the specific region.
- Resource constraints: Snowball sampling allowed for a faster, more cost-effective method to identify engaged and communicative farmers within the timeframe.

An attempt to mitigate this limitation was through the referral chain, which was actively diversified by initiating the snowball process from different and distinct starting points across different geographic sub-regions (provinces), with the aim to broaden the overall network reach.

The data collection instrument was designed based on a literature analysis and questionnaires developed by renowned institutions (e.g., European Union institutions), which are acknowledged for their reliability and validity in the field. The questionnaires were administered during the summer of 2023 (July-August) and completed in person (face-to-face survey) with the farmers (the target population), ensuring confidentiality.

A. Study population and survey basis

Several criteria were considered when selecting the sample, such as being as representative as possible, suitability for the type of study, appropriateness for the analysis to be conducted, ensuring that the results could serve as a reference for other studies, and bearing in mind the sample selection in a way that the error in the result could be as small as possible, which entails the diversification of the sample population (e.g., age group, socioeconomic backgrounds, and gender), encouraging honest responses, and careful analysis of the data. Other elements were taken into account for the sample determination, including the population units participating in the study, the sub-region/locality, the time span, and the elements of the sample. The sampling is also directed toward selecting individuals (farmers) who are in the age group of over 18 years old to obtain complete, accurate, and reliable information.

To effectively manage the complexity of the study, the survey strategy encompasses the following stages: defining the study's purpose, selecting the methodology, planning, conducting the survey, and reporting the research, as outlined in the literature. It is also noted

that the appropriateness of the methodology determines the quality of the study, including the instrument used and the survey strategy. Additionally, if the phenomenon being studied is affected by the number of respondents, then it is suggested that the researcher consider increasing the number as much as possible (Babbie, 2013; Cohen et al., 2007, 2018; W. J. Creswell & Creswell, 2017; Gorard, 2003).

While the desired level of precision is the acceptable error level for sample estimates. The difference regarding the sample selected and the population statistics in the study variables is referred to as a sampling error and is part of the study error. Considering the acceptable error level and the population size, the study decides whether to select a sample or survey the entire population studied (Cochran, 1977; Cohen et al., 2007). In general, the higher the number of respondents, the more accurate the data analysis will be, and thus the greater the generalizability. Regarding sample size, the survey was launched with an initial goal of reaching 400 respondents. However, due to time and cost constraints, the nature of the population studied and considering the purpose of the study, the survey conducted through the snowball method (a non-probability sampling method) was directed instead to reach as many potential respondents as possible who met the study requirements (Apparicio & Gelb, 2023; Babbie, 2013; Neuman, 2011; Singh, 2007).

B. Construction of the study instrument

The questionnaire under the title "Sustainability to enhance agricultural development resiliency regarding water shortages in Morocco," aimed to be as comprehensive as possible, while taking into account respondent fatigue, striving to avoid ambiguous language and jargon, and providing clear, concise, and easy-to-understand questions. The questions were organized based on a logical flow, starting with more general questions and placing sensitive ones toward the end while avoiding bias in phrasing and leading questions (Babbie, 2013; Cohen et al., 2018; Neuman, 2011).

To avoid making the questionnaire monotonous, a combination of closed-ended questions (binary, multiple-choice, and Likert scale types) and open-ended questions was used to gather different types of data as needed. However, due to the fact that open-ended questions require more creativity and a greater willingness to respond, often resulting in an uncompleted questionnaire, the majority of questions are set to be closed-ended. The Likert scale was mainly applied to questions regarding the factors that influence the decision to adopt sustainable agriculture practices, which helped elicit the respondents' attitudes toward

the topic and provided an advantage in the mathematical calculability of the collected data. While closed-ended questions ensured the use of quantitative research methods, open-ended options were primarily applied to multiple-choice questions in cases where farmers applied a method or practice that was not included as an option to answer the questions, or in cases where the respondent would like to elaborate further. The questionnaire also provided an opportunity for respondents to share their thoughts, remarks, and suggestions at the end after the last question.

It is worth noting that the questionnaire strived to measure a combination of perception and adoption to predict inclination. Regarding the perception, it is mainly related to the farmers' subjective assessment of climate change impact (*H1*) and the perceived utility of government support (*H3*). Concerning the adoption, it is mainly related to the number of water conservation practices currently adopted (*H2* and, to a lesser extent, *H4*). Furthermore, behavioral intention was also considered, which translates into the inclusion of the inclination for future adoption and is represented as the dependent variable in the study, influenced by the perceptions and adoption levels mentioned previously.

It is also important to mention that “sustainability transition” was not operationalized as a single concept but rather as the adoption of different practices, such as question 14 (soil fertility management), question 15 (pest control), and question 25 (water conservation).

The questions were divided into multiple pages for better readability, grouping as many questions of the same nature as possible on the same pages (Babbie, 2013; Cohen et al., 2018; Neuman, 2011).

The questionnaire is divided into the following parts:

- The first part consists of more general introductory questions regarding the farm and the socio-economic situation of the respondent, and serves as an introduction to the main parts, where the study focuses.
- The second part is regarding climate change and water resources. The climate change questions serve as transitional questions before delving into water resources, management, and shortages questions, and how they are dealt with.
- The third part is specifically regarding the ability and willingness to transition to more sustainable agricultural practices, and tackling the main reasons that could encourage it and the obstacles that could hinder it.

More details are provided covering all the items, with all the collected data, analyzed, summarized, and discussed in the quantitative part of the results chapter.

C. Validity and the reliability of the study instrument

In quantitative studies, to ensure the quality and trustworthiness of research findings, validity and reliability were considered for the study instrument. In the following, the research process highlights both concepts to help establish the accuracy, consistency, and meaningfulness of the data and presents how the research was standardized. The standardization of the research improves validity, enhances reliability, reduces bias, ensures comparability, increases generalizability, and facilitates replication, especially if the research procedure is clearly documented (Babbie, 2013; Cohen et al., 2018; W. J. Creswell & Creswell, 2017).

Validity

Validity is defined as the extent to which any measuring instrument accurately measures what it is designed to measure. Several means for establishing validity include face validity, content validity, convergent validity, construct validity, and criterion validity (Babbie, 2013; Bryman & Bell, 2011).

The study addressed content validity via the review of literature and by adapting existing instruments from previous research to ensure that the questionnaire items cover the intended domain adequately.

The questionnaire was based on the WP4 Survey on irrigation water use of the European Territorial Cooperation Programme (ETCP), Greece-Italy 2007-2013, co-funded by the European Union (European Regional Development Fund (ERDF)) and by National Funds of Greece & Italy (ETCP, 2007). Additionally, the questionnaire was also reviewed by two agricultural experts from the National Institute for Agricultural Research, Marrakesh-Safi region, Morocco, using the French version of the questionnaire since French is the working language in Morocco, and also reviewed by two professors from Sopron University of Hungary, with sufficient experience and knowledge in this field, to evaluate the questionnaire's clarity, content, and relevance to the construct, and ensure that each item measures exactly what was intended to be measured. All the questionnaire versions (English, French, and Arabic) have been shared. The suggested necessary revisions from the experts were implemented, the questions were refined, and the final version of the questionnaire was validated. Furthermore, before the full-scale administration of the questionnaire to the

targeted sub-regions, and due to time and cost constraints, the research instrument was tested only with the interviewers who assisted in administering the questionnaire (approximately 10 from each sub-region), which helped in evaluating the clarity and flow of the instrument. The interviewers are individuals living in the targeted parts of the region; in many cases, they are natives and farmers, or have practiced farming, or are descendants of families of farmers, and are connected to the following farmers' associations: Katrato Maa Association (or Drop of Water Association) and Ahdane Attabea Cooperative in the El Kelâa des Sraghna sub-region, and the Tamatilte Association of water users for agricultural purposes in the Al Haouz sub-region. Considering their comments and suggestions for achieving the instrument's validity. The test yielded the following precautions: due to the different jargon used for agricultural methods in the dialect of each part of the region (e.g., surface irrigation, drip irrigation), the personal questionnaire copy given to interviewers provides the equivalent local name used to refer to the methods concerned in that part of the region. It is important to emphasize that all questionnaires were standardized across all sub-regions. The test also resulted in creating a detailed explanation regarding question 31, which consists of twelve Likert scale sub-questions. The explanation was distributed alongside the questionnaire, available in the appendix in Arabic, the commonly used language (see Appendix 1).

In terms of precision and accuracy, the questionnaire was standardized for administration and was provided with clear and concise instructions to the respondents. The questions were also designed with consideration of respondents' tendencies to minimize social desirability bias. And well-defined response options, as the response options considered mutual exclusivity, comprehensiveness, alignment with the objective, avoiding double-barreled questions, and applying skip logic for efficiency and to be tailored to individual respondents. In addition, in order to minimize human error, which can also have an impact on the validity and reliability of the collected data, clear instructions were provided, explaining the questionnaire objectives and emphasizing the accuracy and precision to the interviewers. To maintain consistency, the same procedure was followed by the data collectors, providing explanations as needed while respecting the order of questions. The data collection process was also continuously monitored in order to detect and address any recurring errors (Babbie, 2013; Cohen et al., 2018; Neuman, 2011).

Reliability

The reliability of the study instrument refers to the consistency of the collected data from the sample members. In terms of reliability assessment, Cronbach's alpha coefficient (α) for internal consistency was applied. The score is considered acceptable if it falls between $0.6 \leq \alpha < 0.7$, $0.7 \leq \alpha < 0.8$ is good, and $\alpha \geq 0.9$ indicates an excellent score for internal consistency (Cohen et al., 2018; Streiner, 2003). Also, it should be noted that Cronbach's alpha coefficient for a scale consisting of multiple dimensions will generally underestimate the true reliability (Gerbing & Anderson, 1988; Widhiarso & Ravand, 2014). The results are the following:

The Cronbach's α coefficient for the climate change and water resources part, using both binary and binary-coded questions, stands at 0.632. For the sustainability transition part, the Cronbach's α coefficient is 0.785. And the last part consisted of general questions with less than 0.2 (0.182). For the total calculation of all questionnaire items, the result is 0.655 for all binary and binary-coded questions. And for all ordinal questions, the Cronbach's α coefficient is 0.756. The separation allowed the calculation of McDonald's omega (ω) coefficient for the ordinal section (using Andrew Hayes' OMEGA macro ML (Maximum Likelihood Factor Analysis) on SPSS), which stands at 0.770 and is generally considered a good level of reliability. The Cronbach's α coefficient was also calculated for the list of questions that were directly involved in hypothesis testing (Q3, Q18, Q25, Q28, and Q31), and the result is 0.661. Note that Q6, an open-ended question, was reduced from place of residence to three subregion options where the questionnaire was conducted for calculation purposes, and the problematic Q5, the open-ended sub-question (Q31(12)), open-ended options, and other remarks and suggestions were omitted in the calculation. The questionnaire is available in the appendix (see Appendix 1).

3.2.2. Data collection procedure and questionnaire distribution method

In terms of the data collection procedure, the snowball method was particularly useful for this study to mitigate non-response, as participants proved to be more inclined to participate when referred by someone they know, which leads to a higher response rate, and given the geographical dispersion, in cases where the farmer fields were dispersed or harder to locate, which makes it challenging to collect a sample through traditional methods. This could be a result of several factors, including socio-cultural and historical factors, economic and political factors, land structure and suitability, traditional farming systems, and natural

factors, such as rough topography, climatic variations, and water availability, influencing the use and distribution of agricultural land (Babbie, 2013; Cohen et al., 2018; Shahi, 2022; Ting et al., 2025).

For the questionnaire administration, a written face-to-face interviewer-administered questionnaire method was selected due to the nature of the research study and the suitability and advantages of the medium (Blair et al., 2014). The following Table 13 presents the different characteristics of the questionnaire methods of distribution:

Table 13: The different methods of questionnaire administration:

Methods / Characteristics	Interviewer-administered questionnaire		Self-administered questionnaire		
	Face-to-face	By phone	Distributed	By the post	Online
Cost	High (time and travel)	Low to high	Low	Low to high	Very low
The geographical extent of the sample	Narrow	Wide	Narrow	Wide	Wide (but limited to those with internet access)
Duration required for data collection	Medium to long	Short	Very short	Long	Very short
Questionnaire size	Short to long	Short (max. 15 min)	Short	Medium to long	Short to medium
Complexity of questions	Simple to complex	Very simple	Simple	Simple	Simple
Risk of error in the answers	Low (clarification is possible)	High	Medium	Medium	High
Risk of bias in answers	High (influence of the interviewer, social-desirability bias)	Low to very high	Low to very high	Low	Low
Data processing	Complex	Simple to complex	Simple to complex	Complex	Very simple

Source: Based on (Blair et al., 2014)

A written, face-to-face, interviewer-administered questionnaire method is distinguished by the physical presence of the interviewer in order to ask the questions and record the respondent's answers. This allows for direct interaction with farmers during the process and

the opportunity to explain complex questions, providing clarifications and avoiding misunderstandings, to enable more accurate data collection. The method is also useful to minimize the number of uncompleted questionnaires, achieve high response rates, and allow the completion of a long, comprehensive questionnaire with over thirty questions, revealing deeper insights, while maintaining the confidentiality of the respondents (Babbie, 2013; Blair et al., 2014; Cohen et al., 2018).

Given that rural areas generally have more limited technology and online access, very few online farmers' networks where the survey can be disseminated, and low literacy levels and a higher illiteracy rate (38% in 2024), the selected questionnaire administration method proved to be the most appropriate for this study (El Fartassi et al., 2023; HCPM, 2025b).

The survey was conducted in the summer of 2023 (July, August) following the accepted plan in the wake of the comprehensive exam (complex exam) and using the Arabic version of the questionnaire, the common language in the country. A second attempt was made in December of the same year to increase the number of collected questionnaires from the part of the region with the lowest number collected (El Kelâa des Sraghna sub-region). However, it failed, as it was challenging to find local assistance and other farmers willing to cooperate for this work. Therefore, the research relied on the initial questionnaires completed. The results were also compared with the relevant research results and reliable existing data found through literature analysis.

3.3. DATA ANALYSIS AND FRAMEWORK DEVELOPMENT

Due to the nature of the research study, the research questions, the hypotheses formulated, and the data obtained from the completed questionnaire, the professors consulted, suggested and assisted in the application of the following statistical analysis methods:

Descriptive analysis, applied to summarize and describe the main characteristics of the dataset, is a method that provides a better understanding of the dataset. This entails the process of organizing, analyzing, and presenting data in a meaningful manner, which is intended to uncover trends, patterns, and characteristics. Combined with graphical analysis, they form the foundation for virtually all quantitative data analysis.

The chi-square test of independence is applied to establish if there is a statistically significant association between two categorical variables. The statistical method starts with the assumption that the two variables being examined are independent (null hypothesis). A small

p-value (typically ≤ 0.05) suggests strong evidence against the null hypothesis, resulting in its rejection, and the variables are considered to be associated. A large p-value (typically > 0.05) implies insufficient evidence to reject the null hypothesis and to conclude an association between the variables. However, the statistical method only indicates if there is a relationship and assesses the significance of an association. Measures such as the Gamma coefficient provide additional information, indicating the strength and direction of the association.

Goodman and Kruskal's gamma is employed to determine the association between two ordinal variables and evaluate the strength and direction of the relationship. The gamma coefficient's values can fall between -1 and 1. A strong positive association is implied when the value is closer to 1. A strong negative association is concluded if the value is closer to -1. In the case where the value is equal to 0, no association between the variables can be deduced.

The data analysis process relied on the following software programs: the data extracted from the conducted questionnaire were analyzed using SPSS software (version 20). For the initial coding of the in-text analysis of the qualitative interviews, it was performed with the assistance of NVivo software (release 1.7.1, October 2022). The questionnaire and the in-depth interview questions can be found in the appendix (see Appendices 1 and 2).

In order to address the research objective *A4:Answering the Sub-question 4* "Are there any appropriate sustainable strategies, methods, and practices to enhance the resilience of agricultural development facing water shortages in Morocco?", suggestions and an attempt to develop them into a concept were made, which were first derived from the literature analysis *R1: Current status of the literature* and secondly from the qualitative and quantitative research results: *R2: The institutions' views, their contribution to Morocco's transition to sustainable agriculture, and the perceived hindrances to this transition* and *R3: The farmers' views on the challenges associated with sustainable agriculture solutions and the adaptation to water shortages.* Therefore, the research objective *R5: a proposed sustainable agricultural development concept and suggestions adapted to the current situation in Morocco* could be accomplished.

The aim was an attempt to present a possible conceptual approach to support the conclusions and suggestions provided for a balanced, sustainable agricultural development overview,

suitable for the water shortages situation, and taking into account the main concerns and challenges at stake, such as food security.

Limitations of the study

Like with any other study, this one has its limitations. The following are a few of them.

a. The reliance on snowball sampling constitutes a major limitation.

b. While the study is focused on Moroccan agriculture in the Marrakesh-Safi region, there is a risk that individuals' responses may have a tendency to be more subjective.

c. The data collection's duration and period can have an effect and may have been influenced by personal circumstances and events that occurred during that time.

d. Lastly, the lack of other studies relating to the transition to sustainable agriculture regarding water shortages from socio-economic perspectives in the same region studied prevents comparison of this study's results with those of similar studies conducted in this field.

4. QUALITATIVE AND QUANTITATIVE ANALYSIS AND FINDINGS

The following chapter presents the findings from the qualitative and quantitative analyses. At first, qualitative interviews were conducted to explore the research field within the context of the dissertation's multi-phase structure. The hypotheses were formed based on the results of the qualitative analysis and literature review. Then, they were verified through statistical test procedures using the quantitative survey results. The presentation of results follows this logic.

4.1. QUALITATIVE RESEARCH

The interviewees were selected based on their professional expertise, access and willingness to disclose information. The following questions were taken into account in the process of choosing the interviewees and experts (Patton, 2002):

- Who has relevant information?
- Who is most likely able to give precise information?
- Who is the most willing to provide information?
- Who among the informants is available?

Based on the research questions, the number of interviews was decided (see Table 14, page 88). Participants representing both public and private institutions, as well as farmers' organizations. Gender-specific characteristics are random and in no way arbitrary. Before conducting the interviews, the participants were asked for their consent to record the interviews and have their names mentioned in the research.

Multiple potential interviewees were contacted, including three failed attempt with farmers' associations and cooperatives, one private company serves as a connector between farmers and potential customers abroad for agricultural products export (https://africa-farmers.com), and three professors from universities, related to this field, which one of them conducted but had to be discarded because it did not meet all the requirements, and the questions were not fully addressed. An attempt was also made to contact the representative of the Ministry of Agriculture, Maritime Fisheries, Rural Development and Water and Forests at the Regional Office for Agricultural Development of Haouz, Marrakesh (ORMVAH). However, in the second attempt, a message was received from the representative office to conduct an in-depth interview instead with the head of the Partnership and Development Support Division at the Regional Directorate of Agriculture in the Marrakesh-Safi region, which was then

conducted. The following Table 14 provides details regarding the number of in-depth interviews conducted.

Table 14: The details regarding the number of in-depth interviews conducted

	The potential interviewees who were contacted	In-depth interviews that were successfully conducted	In-depth interviews discarded	In-depth interviews that will be considered in the dissertation	In-depth interviews recorded
The number of in-depth interviews	22	16	1	15	3

Source: Author's own research, 2023

The in-depth interviews were conducted in January and February 2023, for the Farmers' associations and cooperative interviews, they were conducted in July and August of the same year. The interviews were conducted following these steps: interview planning, contact organization, interview initiation, narrative and inquiry phase, interview conclusion, and documentation. To reach a consistent language, the text was paraphrased, the text was also freed from mentions that are not related to the research focus, highlighting the most important statements, and finally summarized (Cohen et al., 2018; Mayring, 2014; Patton, 2002). The following are the provided details with regard to the interviewees and their affiliation:

Organization 1: Provincial Directorate of Agriculture of Marrakesh, Morocco (n=1)

In-depth interview with an agricultural engineer with mid-level experience (seven years of experience in this field) from the Projects Implementation Service for Agricultural Production Sectors (for more clarification: Service for the implementation of agricultural production chain projects) (Arjdal Abdellah, email: abdellah.arjdal@yahoo.fr, phone number: +212 639-284710).

Organization 2: Regional Office for Agricultural Development of Haouz, Marrakesh, Morocco (ORMVAH) (n=1)

In-depth interview with an agricultural engineer at the agricultural production service, a senior-level engineer with twelve years of experience at ORMVAH (Aziz Kanane, email: aziz.kanane@gmail.com, phone number: +212 661-550837).

Organization 3: Crédit Agricole Morocco Regional Bank, Marrakesh-Safi region (n=1)

In-depth interview with a business manager in agriculture-agronomy with two years of experience in this institution (Yassir Zaaiter, email: yassir.zaaiter@creditagricole.ma, phone number: +212 699-849508).

Organization 4: Regional Directorate of Agriculture, Marrakesh-Safi region (n=2)

An interview with the head of the Partnership and Development Support Division, a senior-level official holding this position for more than ten years, and a plant biotechnology Ph.D. holder (Fatiha Aissam, email: aissamfatiha@gmail.com, phone number: +212 657-832027).

And an interview with the head of the Department of Agricultural Investment Promotion, a senior-level agro-economist engineer, with twenty years of experience in agricultural and rural development (El Houssaine Houmaid, email: houmaid.houssaine@gmail.com, phone number: +212 662-721863).

Organization 5: National Institute for Agricultural Research, Marrakesh-Safi region (n=2)

In-depth interview with the head of the Research and Development department, a senior-level agricultural engineer, with over thirty years of experience (Youssef Alaoui Rachid, email: youssef.lalaouirachidi@inra.ma, phone number: +212 661-231206).

An in-depth interview with a senior-level agronomist engineer from the same department, with 33 years of experience, and 30 years in this institution (Ahmed Ait Hmida, email: ahmedaithmida@gmail.com, phone number: +212 655-460933).

Organization 6: Farmers' associations and cooperative (n=2)

In-depth interview with the head of both the Katrato Maa (or drop of water) association, founded in 2019, which consists of many farmers, and the Ahdane Attabea (roughly translated as embrace of nature) cooperative, founded in 2017 in El Kelâa des Sraghna sub-region (Mohamed Al Alami, email: alamed1169@gmail.com, phone number: +212 641-701920).

And in-depth interview with the head of the Tamatilte Association of Water Users for agricultural purposes for irrigation of about 700 hectares of agricultural lands founded in 2009 in Al Haouz province and specifically in Ait Ziayad area, who is also an ex-member of the Agriculture Chamber aimed to represents and defends the interest of the farmers in the region to local authorities and the government (Mohamed Anzaline, email: Mohamedanzaline@gmail.com, phone number: +212 673-862892).

Organization 7: Chamber of Agriculture, Marrakesh-Safi region (n=3)

Three in-depth interviews were conducted in this institution that represents and defends the interests of farmers and ranchers to local authorities. An interview with the head of the Financial Administration Service, a senior-level agricultural engineer with 14 years of experience and 12 years in this organization holding the mentioned position (Salah Talidi, email: salah.talidi@gmail.com, phone number: +212 661-281875). And two interviews with two senior-level administrators. The first one is a 2nd-grade administrator at the organization with 11 years of experience, and the second has 13 years of experience and is a farmer who grew up in rural areas (Abdeljalil Gaddari, Hamide Aaorfa).

Organization 8: Regional Directorate of the National Office of Agricultural Advisory, Marrakesh-Safi region (n=3)

Three in-depth interviews were conducted in this institution, which embodies the framework of the consultation and support system for an effective support for farmers. An interview with a senior-level chief engineer with 35 years of experience in this institution. And interviews with an agricultural engineer with two and a half years of experience in this organization (Sara Benzaghar, email: Sara.benzaghar01@gmail.com) and a beginner state engineer at the Regional Center for Young Agricultural and Agri-Food Entrepreneurs from the same organization.

The following Table 15 presents the organizations and institutions and their potential role in the transition:

Table 15: Stakeholder typology table

Stakeholders' groups	Organizations and institutions	The number of in-depth interviews	Potential role in the transition
Governance and policy	Provincial Directorate of Agriculture of Marrakesh, Morocco	1	Local policy implementation
Governance and policy	Regional Office for Agricultural Development of Haouz, Marrakesh, Morocco (ORMVAH)	1	Infrastructure (including water allocation)
Governance and policy	Regional Directorate of Agriculture, Marrakesh-Safi region	2	Regional strategy planning

Governance and policy	Chamber of Agriculture, Marrakesh-Safi region	3	Farmer representation and policy feedback
Finance	Crédit Agricole Morocco Regional Bank, Marrakesh-Safi region	1	Financing adaptation technology
Research	National Institute for Agricultural Research, Marrakesh-Safi region	2	Developing drought-resilient solutions
Advisory and practice	Regional Directorate of the National Office of Agricultural Advisory, Marrakesh-Safi region	3	Farmer education, training, and technical support
Practice	Farmers' associations and cooperative	2	Implementation and adoption
Total		15	

Source: Author's own research, 2026

4.1.1. Limitations of qualitative research

In this dissertation, the choice of interviewees was made with the intention to include experts from the fields of agriculture, development, sustainability, and environment from public and private organizations. One of the most significant limitations regarding the methodology is the process of selecting and identifying experts (Bogner et al., 2009). The number of experts interviewed and their field of focus may also have an influence on the research results, as well as the current global or local situation, which may influence their statements.

Nevertheless, qualitative interviews are retained since they have proved useful in exploring research fields and developing hypotheses (Babbie, 2013; Cohen et al., 2018; Patton, 2002).

4.1.2. Results of the qualitative research

In the following subsection, before delving into the results of the qualitative interviews, the steps taken prior to presenting the summarized results are outlined and discussed. The summarized results are presented and analyzed, contributing to hypothesis generation. The results are presented in a condensed form based on the thematic complexes described in the methodology chapter.

In terms of word frequency, it is presented in word cloud format (Figure 19), indicating that the terms "farmers", "development", "agricultural", and "water" are the most relevant from a frequency standpoint.

Figure 19: Word Cloud (frequencies of words) from the in-depth interviews data

Source: Made with the NVivo software (Release 1.7.1, October 2022)

The following Table 16 presents an analysis of the interviews conducted according to keywords. The results indicate that "water" was the most mentioned keyword in the data, especially in the interviews conducted with farmers' associations along with "support" keyword. The keyword "adaptation" was also a key theme in the interviews with the agricultural advisory office, which works directly with farmers seeking assistance to get subsidies and provides training.

Table 16: Analysis of the interviews conducted in different organizations and institutions according to keywords (not the alternative ones)

Keywords (codes)	Provincial Directorate of Agriculture of Marrakesh (n=1)	Regional Office for Agricultural Development of Haouz (n=1)	Crédit Agricole Morocco Regional Bank (n=1)	Regional Directorate of Agriculture, Marrakesh-Safi region (n=2)	National Institute of Agricultural Research, Marrakesh-Safi region (n=2)	Farmers' associations and cooperative (n=2)	Chamber of Agriculture, Marrakesh-Safi region (n=3)	Regional Directorate of the National Office of Agricultural Advisory, Marrakesh-Safi region (n=3)
Water	7	4	3	17	10	33	7	12
Support	2	0	0	3	6	9	3	3
Adaptation	4	1	0	2	1	1	1	8
Sustainability	4	0	3	0	2	0	0	3
Resiliency	0	0	0	1	1	0	0	0
Illiteracy	0	0	0	1	0	0	0	2
Vulnerability	0	0	0	0	0	0	0	0

Source: Made with the NVivo software (Release 1.7.1, October 2022)

The absence of the term "vulnerability" could be due to it being a less explored or considered concept by the interviewees in relation to agricultural development, sustainability, or water availability, compared to adaptation. The following Table 17 is a summary focused on the keywords and their alternatives from a frequency standpoint.

Table 17: Frequencies of keywords and their alternatives from the interviews collected data

Word	Length	Count	Weighted Percentage (%)
water	5	93	1.70
training	8	31	0.57
support	7	26	0.47
subsidies	9	23	0.42
sustainable	11	21	0.38
adaptation	10	18	0.33
Precipitation	13	15	0.28
Adapt	5	12	0.22
Resilient	9	12	0.22
Sustainability	14	12	0.22
Resilience	10	7	0.13
Groundwater	11	5	0.09
Rainfall	8	5	0.09
Education	9	5	0.09
Adapted	7	3	0.05
Illiteracy	10	3	0.05
Supported	9	3	0.05
Supporting	10	3	0.05
Rain	4	2	0.04
Rainwater	9	2	0.04
Resiliency	10	2	0.04
Adapting	8	1	0.02
Adaptive	8	1	0.02
Illiterate	10	1	0.02
Subsidy	7	1	0.02

Water = 122 Support = 87 Adaptation = 35 Sustainability = 33 Resiliency = 21 Illiteracy = 9 Vulnerability = 0

Source: Made with the NVivo software (Release 1.7.1, October 2022)

Considering the keywords and their alternative counterparts from the table, compared to other keywords, “water” clearly dominated the discussion, along with “support”, as shown by the keywords’ frequencies. This is notable, since the water issue was not explicitly

included in the main questions of the in-depth interviews. The following Table 18 presents the coding intersection from the collected data.

Table 18: Coding intersection of the provided keywords with consideration of the alternative keywords

	A: Adaptation	B: Illiteracy	C: Resiliency	D: Support	E: Sustainability	F: Vulnerability	G: Water
1: Adaptation		0	2	6	3	0	9
2: Illiteracy	0		0	2	0	0	0
3: Resiliency	2	0		4	3	0	2
4: Support	6	2	4		8	0	9
5: Sustainability	3	0	3	8		0	4
6: Vulnerability	0	0	0	0	0		0
7: Water	9	0	2	9	4	0	

Source: Made with the NVivo software (Release 1.7.1, October 2022)

The most prominent intersection of applied terms in the data analysis, indicating that the terms were raised and discussed in the same context by the interviewees during the interviews, is the combination of "water" and "adaptation" or “support” keywords, followed by "support/sustainability" and "support/adaptation". The following Table 19 consists of the operationalized definitions of the tone applied to the keywords and their alternatives.

Table 19: The operationalized definition of the tone for the keywords

Tone	Explanation
Negative tone	The variable is not associated, or it's not considered important, relevant or related to the context of the issue.
Positive tone	The variable is associated, or it is considered important, relevant or related to the context of the issue.
Neutral tone	The variable does not fall in either of the tones mentioned above. Or in some cases, it was unclear.

Source: Author’s own research, 2024

The previous table serves as a basis for understanding the next table. The following Table 20 consists of a detailed overview of interviewees' related characteristics and views, relying on keywords with their alternatives in consideration. Note that experts are considered the interviewees who hold a high degree, such as an engineering or Ph.D. degree, with at least five years of experience in the field. Fieldwork entails interviewees being frequently in direct contact with the farmers.

Table 20: Analysis of the interviews conducted in different organizations and institutions according to interviewees' related characteristics and views

Variables	Tone	Provincial Directorate of Agriculture of Marrakesh (n=1)	Regional Office for Agricultural Development of Haouz (n=1)	Crédit Agricole Morocco Regional Bank (n=1)	Regional Directorate of Agriculture, Marrakesh-Safi region (n=2)	National Institute for Agricultural Research, Marrakesh-Safi region (n=2)	Farmers' associations, cooperative (n=2)	Chamber of Agriculture, Marrakesh-Safi region (n=3)	Regional Directorate of the National Office of Agricultural Advisory, Marrakesh-Safi region (n=3)
Water	Negative tone	0	0	0	0	0	0	0	0
	Positive tone	1	1	1	2	2	2	3	3
	Neutral tone	0	0	0	0	0	0	0	0
Support	Negative tone	0	0	0	0	0	0	0	0
	Positive tone	1	1	1	2	2	2	3	3
	Neutral tone	0	0	0	0	0	0	0	0
Adaptation	Negative tone	0	0		0	0	0	0	0
	Positive tone	1	1		1	1	2	1	3
	Neutral tone	0	0		1	1	0	2	0
Sustainability	Negative tone	0		0	1	0	0		0
	Positive tone	0		1	1	1	1		2
	Neutral tone	1		0	0	1	1		1
Resiliency	Negative tone		0		0	0	0	0	0
	Positive tone		1		2	2	1	1	2
	Neutral tone		0		0	0	1	2	1
Illiteracy	Negative tone				0				0
	Positive tone				1				3
	Neutral tone				1				0
Farmer	yes	0	0	0	0	1	2	1	0
	no	1	1	1	1	1	0	2	3
Expert	yes	1	1	0	2	2	0	1	1
	no	0	0	1	0	0	2	2	2
Fieldwork	yes	0	0	0	0	2	2	2	2
	no	1	1	1	2	0	0	1	1

Source: Author's work, made with the assistance of NVivo software (Release 1.7.1, October 2022)

The interviewees and experts all agree on the relevance of "water" and "support" for the Moroccan agricultural context. "Water" is considered a main challenge, while "support" is a provided solution, a work in progress, and an area for improvement. The two keywords and their counterparts received a positive tone across all interviews, with the highest frequencies. For interviewees and experts, "support" is considered a key force, an essential component that propels the desired change and brings about a result, whether for facing the water shortages challenges through a successful adaptation or even for a full-scale transition to sustainable agricultural practices. With some experts putting emphasis on the adaptation of the farmers, while others adopting a rather broad view, the successful adaptation of the sector. It is worth mentioning that the water issue was mentioned in almost every opportunity by the interviewees responding to the set of open-ended questions, while "vulnerability" was not referred to or mentioned, and "resiliency" was mostly regarded in a positive tone.

One interviewee (expert from the Regional Directorate of Agriculture, Marrakesh-Safi region) expressed a rather negative tone regarding sustainability while emphasizing the

importance of adaptability as a key solution for the sector and elaborating on the government's past efforts in the same context. Additionally, “illiteracy” and low education level were given special attention and discussed mainly by the interviewees from the Regional Directorate of the National Office of Agricultural Advisory, Marrakesh-Safi region. Their emphasis on this challenge stems from the fact that they are more in frequent and direct contact with farmers in the context of providing assistance, guidance, and trainings, which further supports the argument of the relevance of the challenge hindering the adaptability efforts and transition to sustainable agriculture in general, as it was also mentioned by the government in the context of the modernization of the sector (MEFM, 2019).

The study was also supported by exploring nonverbal cues, which were particularly useful in strengthening the findings from the in-depth interviews with farmers' associations and cooperative. The following are the nonverbal cues considered in the analysis: Kinesics (facial expressions, body posture, and hand gestures) and paralanguage (tone of voice, pitch and volume, vocal pace, and pauses and silences). The methods employed for documenting and analyzing nonverbal cues are as follows: Documentation and Memos, which were taken during and/or immediately after the interviews regarding the observed nonverbal cues, while keeping the context of how they relate to interviewees' verbal responses. And a holistic analysis, during the qualitative analysis, looking for patterns where nonverbal cues align or contradict the verbal data collected (Corbière & Larivière, 2014; Dash, 2022; Neuman, 2013; Poyatos, 1984; Qizi, 2025; Temirova, 2020).

In terms of keywords, the importance given by interviewees and experts to “water” and “support” was matched by a change in facial expressions (change between smile to frown matching the discussion), body posture (leaning forward indicating engagement), hand gestures (enthusiastic hand movements), tone of voice (natural tone instead of monotone voice suggesting a level of sincerity), pitch and volume (louder voice when discussing government efforts, and “support” conveying excitement, and lower voice when tackling challenges, and “water” indicating seriousness), and vocal pace (a slow pace when discussing challenges, “water” implying thoughtful consideration).“Adaptation”, “resiliency”, and “illiteracy” received similar engagement, except “sustainability” in some interviews where it was also matched with a rapid pace that could imply a desire to get through the topic quickly.

Regarding the interviewees from farmers' associations and cooperative, when implicitly or explicitly referring to the common marginalization sentiment among farmers. A change matched with facial expressions (a serious expression suggesting a deep engagement), a low voice indicating seriousness, a slow pace implying thoughtful consideration, and a short pause indicating careful consideration of their words and thoughts. Similarly, when the actions taken by the government were discussed, we noted a more hand gesture indicating enthusiasm and their effort to explain their points of view, also in the context of emphasizing the importance of collaboration with farmers through a participative approach, and regarding the course of actions that they are dissatisfied with, particularly when it comes to asking for support initiatives from the government during years of drought, to help them create more farmers' associations, more agricultural assistance, and to provide support for digging wells, because it is expensive, as they need to dig approximately 360 meters deep in the El Kelâa des Sraghna sub-region to reach enough groundwater at a cost of roughly 700,000 MAD, about 65,946.15 EUR, which was done through collaboration between farmers and relying only on their own means. This also aligns with the expert statement from the National Institute for Agricultural Research, Marrakesh-Safi region. As the expert mentioned, in the Chichaoua sub-region, the farmers have also grouped to dig wells and have to dig at least 350 to 400 meters deep to reach groundwater. This is based only on the data collected from the interviews. The interviewer posed follow-up questions. However, we did not ask too probing questions when it seemed that would lead to the risk of the interviewees becoming more defensive.

In conclusion, it is clear from the findings that water is considered a major challenge for the sector’s development, and support is regarded as a means to achieve adaptation to the current circumstances. However, emphasizing support alone could result in ineffective solutions, particularly when neglecting farmers' local and practical knowledge. Also, farmers' willingness to adopt new practices is greatly influenced by their perceptions of risk and benefit. Suppose they are not sufficiently involved in the design and implementation of the new strategies. In that case, they may be less likely to trust it, or feel a sense of ownership, and perceive it as risky, resulting in a low adoption rate. Therefore, a support approach will require a successful collaboration with farmers for it to be effective. It is worth noting that besides the interviewees from farmers' associations and cooperative, only those from the Regional Directorate of the National Office of Agricultural Advisory highlighted the collaboration with farmers. Collaboration will foster a two-way flow of information, one

from experts providing scientific and technical knowledge, and the second from farmers offering their local and practical knowledge, resulting in the development of more robust, context-specific solutions. Additionally, incorporating the collaboration with farmers in the process of developing practices and technologies will foster their adoption in the long term, as farmers would be more aware and confident in their benefits. As a result, their collaboration, contribution, and insights would be essential to designing and implementing effective plans and policies to increase resiliency facing water shortages (Ahsan et al., 2021; Apraku et al., 2021; El Fartassi et al., 2023; El Mansoum & Chfadi, 2025; Faysse et al., 2018; M. T. Islam & Nursey-Bray, 2017; Prager, 2022; Velten et al., 2021).

Institutions' perspectives, the transition to sustainable agriculture and development

The in-depth interviews with the relevant institutions were summarized into useful insights. The semi-structured interviews were organized around eight open-ended questions related mainly to the current state and agricultural development challenges, the transition to sustainable practices, and the prospects. Based on the results, the main challenge confronting agricultural development is drought, including water shortages as a common denominator, which was raised and discussed by the interviewees. For instance, the planned agricultural projects in areas that rely mainly on expected precipitation between 200 and 300 mm of rainfall were facing difficulties in achieving their goals. This demonstrates the need to adapt the planned future projects and consider the current and future climate change scenarios. The increase in temperature was also indicated and regarded as one of many climate change consequences that will push the sector into adaptation. In terms of adaptation challenges, one of the interviewed experts from the National Institute for Agricultural Research stated that, based on their recent fieldwork, which involved direct engagement with farmers in the Chichaoua sub-region, it was revealed that farmers struggle to implement effective adaptation measures and find alternative crops to adapt to water shortages. In addition, the interviewees also emphasized other challenges, such as the lack of adaptation knowledge, training, the use of modern means and agricultural methods, marketing of agricultural products, adequate support for farmers, and the need for an effective organization among farmers to defend their interests.

Furthermore, the lack of an effective participatory approach and the high illiteracy rate are also suspected of contributing to the mismatch between the institutions' planned goals and the farmers' needs, resulting in building water channels in places with no water resources as

in this case the project in the Haouz sub-region was not based on a sufficient study with no clear vision of the area, and without consideration of input from the concerned farmers. The government also supported olive tree cultivation in some parts of the same sub-region areas, where the cultivation will rely mainly on precipitation, and they cooperated with companies to provide support for farmers concerning olive tree irrigation in the first 2 years. However, some farmers did not even want olive tree cultivation. In some cases, the high illiteracy also hinders the process of effective agricultural knowledge transfer in the training provided, such as in Farmer Field School (FFS) programs organized by the government's institutions. Additionally, the small and fragmented agricultural lands hinder future investment in some parts of the region. Also, ownership status issues, such as shared or tribal lands or when the generation of farmers usually does not update the ownership status from their parent or grandparent to them, create further difficulties in the administrative process, including obtaining loans and support from the available governmental programs. Moreover, rural exodus, in many cases has a negative impact on agriculture adaptation since it hinders the transmission of rural people's knowledge from the previous generation to the next generation. The loss of local knowledge has a detrimental effect, rendering young people less able to adapt to the current challenges or sometimes less motivated to work in collaboration with other organizations to find alternative solutions and adaptation instead of opting for rural-urban migration.

Regarding the transition to sustainable agriculture, it is mainly considered and regarded for its adaptation potential, as well as its premise to contribute to food security, which constitutes a major concern and priority for the state. The transition is addressed through several measures: the granting of water-saving irrigation subsidies, which can go up to 100% for small farmers and in the framework of collective projects. A special attention was given to alternative crops adapted to climatic conditions: olive, almond, carob, argan, caper. The encouragement of water and soil conservation practices, including rainwater harvesting, and the adoption of an extensive direct seeding method program, pastoralism improvement projects, including the planting of the Atriplex. And the development of cactus cultivation and its restoration after the cochineal plague. In addition, specific available subsidies for adopting drip irrigation and direct seeding methods were provided. For instance, by offering 100% subsidies for acquiring the equipment to farmers who possess 5 hectares or less to purchase hydraulic equipment, and if they possess 10 hectares or more, they still receive 80 % subsidies on hydraulic equipment. Furthermore, institutional measures were established

by creating the National Agency for the Development of Oases and Argan Areas (ANDZOA) and the Directorate of the Development of Mountain Areas. Also, the implementation of integrated development projects to improve the resilience of agriculture, and the protection of natural resources and the environment.

In terms of the provided suggestions based on the interviewees' perspectives and experiences, there is a common sentiment regarding the necessity of boosting the resilience of the agricultural sector in the current climate change context. Any strategy must first consolidate the previous achievements. Similarly, it was suggested that it would be necessary to further strengthen the means of saving irrigation water, and the use of unconventional water, including the desalination of seawater, in which the country is making great progress in that direction. Additionally, to invest in research to find new crop varieties that only require a short time to cultivate, such as the different crop varieties in olive tree cultivation. Crop diversification to improve disease and pest control. Furthermore, it was recommended to strengthen the counseling and support for farmers and to promote sustainable farming practices adoption, which can be done through targeted agricultural advisory, investment incentives (subsidies), and the organization of farmers. Professional organizations of small farmers will support the diversification of their products and create economic interest groups that already exist in olive cultivation. The transition to resilient agriculture will support efforts for the sector's modernization. Also, the illiteracy and the qualification level, remain to be improved, as well as encouraging the inclusion of young people and women in the rural development process. However, representatives of farmers' associations interviewed from two different parts of the region tend to agree on some level on the marginalization of the farmers, the dissatisfaction, and the disagreement with the course pursued in the government's plan, which underscores the need for an effective participatory approach. Although the need for a participatory approach has been recognized and incorporated into previous and current agricultural plans, it has not yet achieved sufficient effectiveness from their perspectives. Therefore, considering the farmers' knowledge and field experience in decision-making, including their voiced needs, would significantly enhance the success rate of agricultural projects in rural communities. Similarly, besides facilitating the administrative process for obtaining the available support and fostering land consolidation when needed, there is an existing need for guidance to be provided, particularly when farmers are confronted with the consequences of climate change, especially drought challenges.

The explanations and the insights drawn from the analyses of the in-depth interviews and the relevant literature contributed to the following findings and possible applicable recommendations: policymaking must incorporate an effective participatory approach, where the government consistently takes into account farmers' experience in the field. Participatory approaches were included in agricultural development strategies. However, the interviews indicate that it is still not effective and does not achieve the goals for which it was created. Thus, this creates a gap between the alignment of the government's goals and the farmers' interests. The difficulty of participatory approach integration in the agriculture research system has been recognized since 1995 within the framework of the National Institute for Agricultural Research-International Center for National Agricultural Research project, and relevant participation approaches were considered in the agricultural research and development programs elaboration, as presented in Table 21 (INRA, 2012).

Table 21: The different participatory approaches considered during the research and development programs elaboration

Types	Characteristics
Passive participation	Farmers participate in meetings but are only informed by the researchers. Their opinions are not taken into account.
Participation in information-giving	Farmers are surveyed via questionnaires. The data is analyzed and recorded in reports without feedback to the farmers.
Participation by consultation	Farmers are consulted to get their opinions on a given action without obligation to take it into account.
Functional participation	Farmers participate in decision-making. They are consulted on the implementation of the program.
Interactive participation	Farmers are partners. They participate in the development of action plans and their implementation.
local initiative (or self-mobilization)	Farmers take local initiatives in terms of development, organization, and management of the land independently from state structures.

Source: (INRA, 2012; Pretty, Jules N., 1995)

However, based on the current situation exacerbated by drought challenges and other climate change consequences, there is an urgent need for an improvement in the application of participatory approaches in the field, as it is required to increase the efficiency of agricultural development projects in achieving their goals. Therefore, the Participatory Extension Approach (PEA) proposition could address the need. The evolution of the national extension system was first marked by the creation of the Department of Education, Training and Research (DETR) within the Ministry of Agriculture in 2010. Since then, the government has been more involved in agricultural extension mainly via the National Office of

Agricultural Advisory. In the same vein, some of PEA's participatory tools and techniques, such as providing FFS programs, were already implemented. Nevertheless, some degree of marginalization of farmers' experience and their needs was identified in the in-depth interviews, suggesting a need for an agricultural extension improvement rooted in a participatory approach solution (El Bilali et al., 2012, 2013).

The top-down and expert-driven approaches, such as most traditional extension approaches, have been questioned for their ineffectiveness in adequately tackling farmers' needs and challenges. Therefore, a promising alternative for addressing these issues is the PEA, which emphasizes farmers' active participation in the extension process. Through cooperating with extension agents and guided by participation, empowerment, and ownership principles, this bottom-up and participatory approach acknowledges farmers as experts in their contexts and encourages co-creating knowledge and solutions (Saini et al., 2023; Sethi & Sharma, 2012). Nevertheless, the hindrance that could affect the efficiency of the approach in the Moroccan context is the high illiteracy rate (38% in 2024) and the qualification level in rural areas. However, it is fundamental and crucial to include farmers in the decision-making process effectively (HCPM, 2018a, 2018b, 2018c, 2025b).

Regarding food security, as discussed by the interviewees, even if it is considered one of the top priorities as it must be and a major concern for the government, it should not be to the detriment of a long-term adaptation of the agricultural sector, its resilience to climate variability, drought, and the availability of water resources. Because, due to food security concerns, the government fostered the retransition of agricultural lands to cereal, from the initial plan to support the transition to more resilient crops. An alternative approach to help manage these different concerns could be based on the integrated approach of Sustainable Food and Agriculture (SFA), as it was promoted by the Food and Agriculture Organization of the United Nations (FAO) along with the elaborated guidelines for food and agriculture transformation to achieve the Sustainable Development Goals (SDGs). Morocco has already created a steering committee consisting of focal points from different government institutions to guide the FAO's work in diagnosing the sustainability of agriculture in the country and presided over the implementation of the recommendations resulting from the diagnosis and the suggested guidelines. However, based on the comparison between the years 2012 and 2022 on the Food Security Index results, a deterioration was perceived in agricultural research and development, along with a stagnation in the volatility of agricultural production, and food security and access policy commitments, which remain to

be improved at the availability level, and a stagnation in the water indicator at the sustainability and adaptation pillar. Therefore, it is suggested that further efforts should be made to address the integration of cross-cutting issues based on SFA principles, which would help the transformation of the agricultural sector and ensure food security (FAO, 2017, 2018, 2019, 2020; GFSI, 2022).

It is worth mentioning that the agricultural export policy, as discussed by the interviewees, also requires further adjustment to align with the national interests of supporting the transition to a sustainable agricultural development strategy, since the government still allows high water-consuming crops to the detriment of the available water resources, for export interest as the agriculture sector is considered crucial to support balancing the country's trade balance. The following Table 22 presents the evolution of Moroccan agricultural export products.

Table 22: The evolution of Moroccan agricultural export products

Products (in thousand tons)	2009	2019	Variation
Tomatoes:	396.5	545.5	38%
The round tomato	295.9	282.9	-4%
Segmentation tomato	100.6	262.6	x2.6
Vegetables, including:	258.2	395.4	53%
Green beans	112.6	135.4	20%
Pepper and chilli	61.8	118.0	91%
Potatoes	8.7	51.2	x5.9
Zucchini	48.0	46.8	-2.5%
Fruits, including:	105.9	321.2	x3
Watermelons	7.8	166.6	x21
Melons	56.2	45.5	-19%
Raspberries	1.3	33.3	x27
Blueberries	0.6	24.4	x41
Strawberries	20.7	22.4	8%
Avocado	1.9	17.5	x9.1
Total	760.6	1262.1	66%
Products (in thousand tons)	2009	2019	Variation
Citrus export	460.6	607.2	32%

Sources: (HCPM, 2025c; MAFM, 2024)

Although there has been a remarkable improvement in agricultural exports during the last decade, many of the endorsed crops, such as watermelons, a high water-consuming crop, whose exports have increased by twenty-one-fold, are not favorable for climate adaptation and could be unsustainable in the long run, considering the current water resources

availability and the projected climate scenarios. The availability of water resources will likely be more in jeopardy if the current trend holds. Therefore, it is suggested to consider the issue in future endorsement of this type of crop cultivation (Li et al., 2018; Rashidi & Gholami, 2008). The agricultural sector in Morocco clearly requires further investigation to deepen the understanding and tackle the obstacles to its adaptation and development. As the PEA will facilitate benefiting from the local knowledge and farmers' experience in both research and decision-making, the alignment of the future export policies and the improvement of sustainable agriculture and food security policies integration could be fostered through the three priority areas mentioned by the Royal Institute for Strategic Studies (IRES) to adapt the sector to water shortages, which are: optimizing governance in the agricultural sector, ensuring food sovereignty, and strengthening the sustainability and resilience of Moroccan agriculture (IRES, 2024).

4.1.3. Summary of the qualitative research

The main results from the qualitative interviews were compactly summarized as follows:

Result 1:

Policy making must incorporate an effective participatory approach, where the government consistently takes into account farmers' experiences in the field. There is a participatory approach included in the agricultural development strategies. However, based on the interviews, it is not effective and does not reach the goals for which it was created, thus creating a gap between the alignment of the government’s goals and the farmers' interests. An effective participatory approach will contribute to the efficiency of the agricultural development projects in reaching their goals.

Result 2:

The agricultural export policy must align with the national interests of supporting the transition to a sustainable agricultural development strategy. Because the government still places importance on water-consuming crops to the detriment of the available water resources for export interests, since the agriculture sector is considered crucial to support balancing the trade balance of the country.

Result 3:

Assuring food security even if it is considered one of the top priorities and concerns for the government, should not be to the detriment of a long-term adaptation of the agricultural

sector and its resiliency to climate variability, drought, and with regard to water resources availability (because food security was a concern, the government fostered the retransition of the agricultural lands to cereal, from the initial plan to support the transition to more resilient crops).

The qualitative analysis results contributed to the formulation of hypotheses. The following quantitative research subchapter will build on and further support the findings.

4.2. QUANTITATIVE RESEARCH

In order to address the dissertation's aim *A3: Answering the Sub-question 2* "How do farmers view sustainable agriculture solutions, and what are the perceived challenges associated with this transition? How do farmers cope with and adapt to water shortages?" the quantitative survey and its analysis are carried out. The objective was to achieve the research outcomes *R3: The farmers' views on the challenges associated with sustainable agriculture solutions and the adaptation to water shortages,* and *R4: Express the data through tables and graphs, and explain the relations*. To obtain the results, hypotheses were developed based on the prior findings (*R1* and *R2*) from (*P1* and *P2*) and tested.

It should be noted that specific questions regarding the cooperation/collaboration between farmers and organizations (government institutions, associations, cooperatives, NGOs…) were not included. This was due to time constraints and the fact that the questionnaire was formulated and conducted before the in-depth interviews were completely analyzed.

The following Figure 20 is the presentation of the Marrakesh-Safi region and its sub-regions (provinces). The region was selected for conducting the quantitative survey due to its significance as the main region in terms of the agricultural land surface (22.26% of the total agricultural surface of the country) (HCPM, 2025c; MAFRD, 2023).

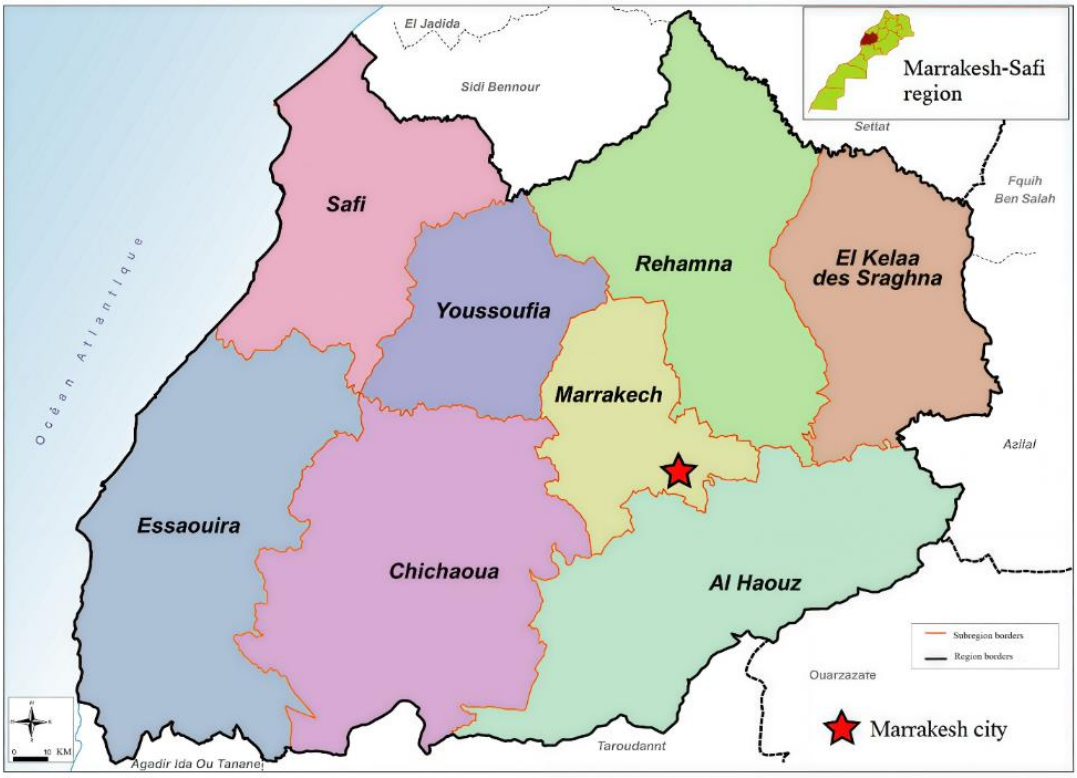

Figure 20: Presentation of sub-regions (provinces) of the Marrakesh-Safi region

Source: (HCPM, 2015)

The study was focused on three sub-regions: Al Haouz, Chichaoua, and El Kelâa des Sraghna localities. The following Figure 21 presents the location of rainfed and irrigated agriculture in the region.

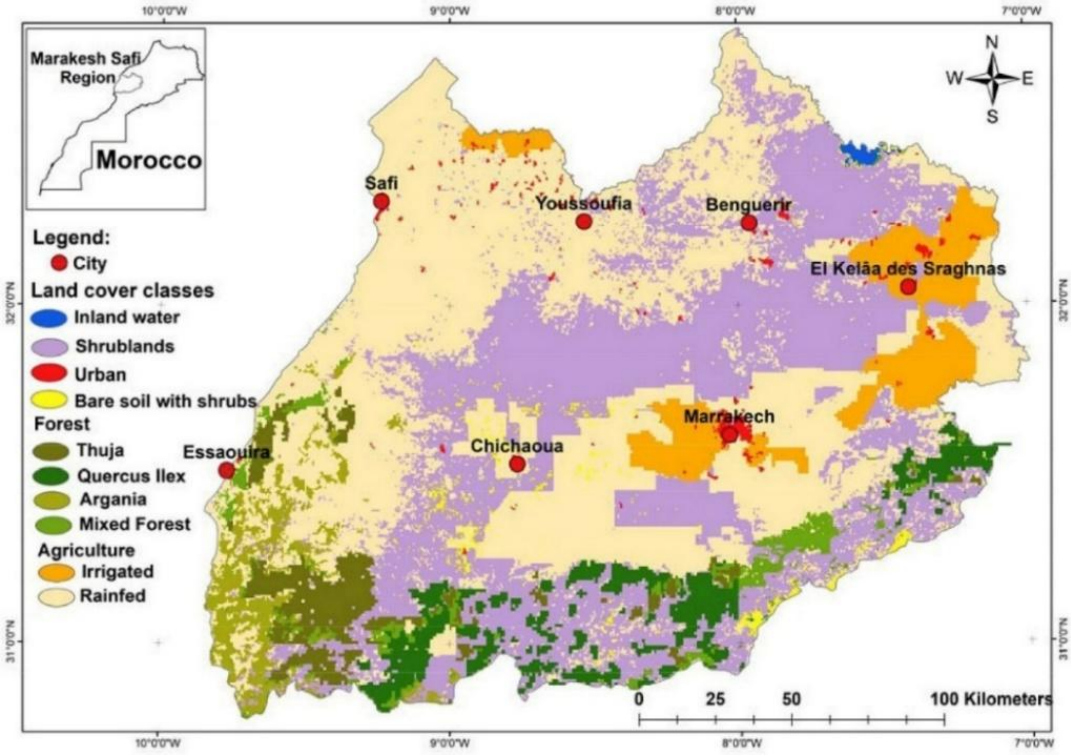

Figure 21: Hybrid map of land cover of Marrakesh Safi-Region. The area is dominated by agriculture and shrublands, while forests are located in the South. (2018)

Source: (Ghazi et al., 2018)

The selected sub-regions are where most of the irrigated agriculture is located in the region. The areas were chosen with the aim of including farmers from both irrigated and rainfed farms, as well as for their proximity and cost-effectiveness. The following Table 23 presents the results of the quantitative survey based on the number of questionnaires collected from each sub-region.

Table 23: The quantitative survey results based on the number of questionnaires collected from each sub-region

	Marrakesh-Safi region			
Sub-regions (provinces)	Al Haouz	Chichaoua	El Kelâa des Sraghna	Total
Total	103	102	51	256

Source: Author's own work, 2025

Although we attempted to achieve a balanced sample size from each sub-region while collecting as many questionnaires as possible, El Kelâa des Sraghna yielded results that are

approximately half of those from other sub-regions. This is due to the challenge of finding farmers willing to cooperate for this work in that part of the region.

The following Table 24 presents the analysis of the remarks and suggestions provided by farmers based on the selected keywords and their counterparts.

Table 24: Analysis of the questionnaires' remarks and suggestions according to keywords frequency (including their counterparts)

Keywords (codes) (including alternative keywords)	Al Haouz (n=20)	Chichaoua (n=0)	El Kelâa des Sraghna (n=0)
Adaptation	0		
Illiteracy	0		
Resiliency	0		
Support	9		
Sustainability	0		
Vulnerability	0		
Water	4		

Source: Author's own work and analysis, 2025

The questionnaires' remarks and suggestions were translated, summarized, and analyzed using NVivo software (release 1.7.1, October 2022). Based on the data, the remarks and suggestions were collected only from the Al Haouz sub-region (n=20). Only two keywords and their counterparts were identified: "support" (n=9) and "water" (n=4). The findings align with the previous qualitative research results, which also indicated the dominance of these two keywords.

The findings are centered around the farmers asking for support, specifically "direct support" (n=4) for small farmers, with a request that administrative procedures for support be facilitated (n=1). Other requests included assistance with land consolidation (n=3) and providing training sessions (n=1). Farmers also emphasized their need for fodder (n=3) at a reasonable price and in sufficient quantity (n=2), particularly in years of drought (n=1), and their reliance on "precipitation" (n=3). They mentioned using traditional production methods (n=1) and the challenges of having small (n=2) or scattered plots (n=1) of land, which makes it difficult to benefit from agriculture.

One farmer has a higher education level (two years at university level). Who owns a surface-irrigated farm (less than 1 ha), works on the field, raises livestock, and cultivates cereals, arboriculture, and vegetables, provided the following statement:

"Our country's government must decide to stop exporting tropical fruit crops to Europe, and the cultivation of tropical fruits must be stopped in semi-arid climate areas, such as bananas, avocados, and watermelons in Agadir (Souss area), as an example."

The statement also aligns with the previous findings from the qualitative research results.

The open-ended options provided for multiple-choice questions were also translated, summarized, and analyzed. The data collected are from Al Haouz and Chichaoua, and the significant statements were organized based on their frequency and categorized into two groups: those related to water shortages and all others. The results are presented in Table 25 as follows:

Table 25: The data collected from the open-ended options provided for multiple-choice questions are categorized and organized based on their frequency

Groups	Results
Water shortages	Wells: • When rivers dried up, we relied on wells (Q21) (n=1) (Al Haouz) • Not enough water supply from wells for irrigation (Q24) (n=1) (Al Haouz) • We dig more wells for irrigation (Q19) (Q25) (n=2) (Al Haouz) Rivers: • The river dries up, and the lack of snow (Q26) (n=1) (Al Haouz) • The rivers dry up (Q23) (Q24) (Q26) (n=3) (Al Haouz) • We rely on the river for irrigation. (Q22) (n=3) (Al Haouz) • The river dries up in the summer (Q24) (Q26) (n=4) (Al Haouz) Precipitation: • Lack of precipitation (Q32) (n=1) (Al Haouz) • A large part of the land relies on precipitation only (Q23) (n=1) (Al Haouz) • Low snow precipitation in winter results in rivers drying up in summer (Q26) (n=1) (Al Haouz) • Consecutive years of drought because of the lack of precipitation (Q26)(n=1) (Al Haouz) • Low snow precipitation (Q26) (n=2) (Al Haouz) • Lack of rain in winter and lack of snow (Q26) (n=5) (Al Haouz) Others: • Lack of water throughout the year (Q23) (n=1) (Al Haouz) • I don't sell yield because I don't have water on the farm (Q30) (n=1) (Chichaoua)

	• The interruption of the flow of water supplying the water channels (Q24) (n=1) (Al Haouz) • Water was always available all around the year, except for the last few years (Q21) (n=1) (Al Haouz) • Water shortages particularly in summer (Q23) (Q24) (n=19) (Al Haouz)
All others	• The far distance between the fragmented lands and their small size (Q24) (n=1) (Al Haouz) • The far distance between the fragmented lands and inefficient irrigation. (Q24) (n=1) (Al Haouz) • The lack of trust between farmers and the relevant institutions of this sector. (Q32) (n=1) (Al Haouz) • The reliance on traditional methods for tillage and production (Q32) (n=1) (Al Haouz) • Land consolidation for the fragmented land as a challenge to invest in transition to sustainable practices (Q32) (n=1) (Al Haouz) • Small agricultural land as a hindrance to investing in the transition to sustainable practices (Q32) (n=3) (Al Haouz) • Self-sufficiency from the yield has not been achieved. (Q30) (n=3) (Al Haouz) • The agricultural yield became mainly just for self-sufficiency (Q30) (n=10) (Al Haouz) • The agricultural yield is mainly for personal use (Q30) (n=19) (Al Haouz).

Source: Author's own work and analysis, 2025

The findings are centered around the farmers, emphasizing the increased severity of the water shortages, particularly in summer, along with the lack of precipitation and snow during winter, resulting in the rivers drying up in the summer because the gradual melting of snowpack during spring and early summer used to provide a steady, prolonged supply of water to rivers, acting as a natural water storage system.

The farmers also highlighted the wells as alternatives, despite the insufficient water supply in one case. And the far distance between the fragmented lands, their small size, their reliance on traditional methods for tillage and production, and inefficient irrigation. While self-sufficiency from the yield was not achieved in some cases, there is also a lack of trust between farmers and the relevant institutions of this sector. It is worth mentioning that farmers who respond to the question regarding selling their yield with either "self-sufficiency" or "personal use" still sell a portion of it in the market or directly to consumers. However, the yield becomes more directed to meet the needs.

It should also be noted that multiple-choice questions were binary-coded for each option for statistical analysis purposes in the SPSS software (version 20).

4.2.1 Limitations of quantitative research

The methodological approach and the ad hoc sample selection can result in limitations in the results. Despite the significant associations found regarding the hypotheses tested, the sample is not representative of any population. Future research could seek more representativeness. Additionally, imbalances, such as those related to the gender ratio in the sample, should be reported and taken into consideration. It is necessary to take these circumstances into account, which call for further research.

4.2.2 Results of the quantitative analysis

To address the research objective *A3: Answering the Sub-question 2*, Phases 3 and 4 were executed. Thus, *R3* and *R4* are achieved. In accordance with the research design of the present study, the results of the quantitative analysis, particularly the hypothesis testing, are incorporated into the implementation of processes *P5: Possibility of appropriate sustainable strategies, methods, and practices,* and *P6: Results and final conclusions*.

The results were divided into descriptive analysis and hypothesis testing subsections.

A. Descriptive statistics and analysis

The descriptive analysis subsection focused on presenting the most relevant results from the structured questionnaire, which consisted of 32 questions as follows:

The first part:

The first part was divided into farmers' demographic data (Age, gender, marital status, etc.), socio-economic data (working situation, salary), and farm-related characteristics.

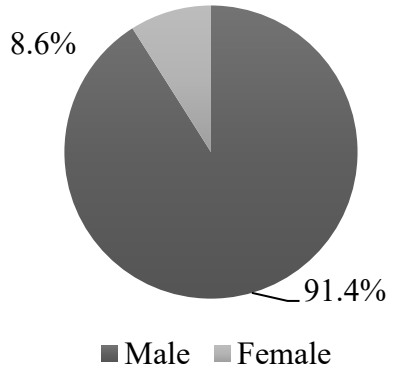

Figure 22: The farmers' demographic data 1. Sex

Source: Author's own work, 2026

Based on Figure 22, in terms of the gender ratio among the respondents, it is unbalanced (8.6% women and 91.4% men), which does not reflect the proportion of the population working in agriculture (52.2% women and 47.8% men; OECD, 2021), and could be explained by the cases of informal employment of women, the exceptionally high rate of illiteracy within the sector, and their lack of ownership role.

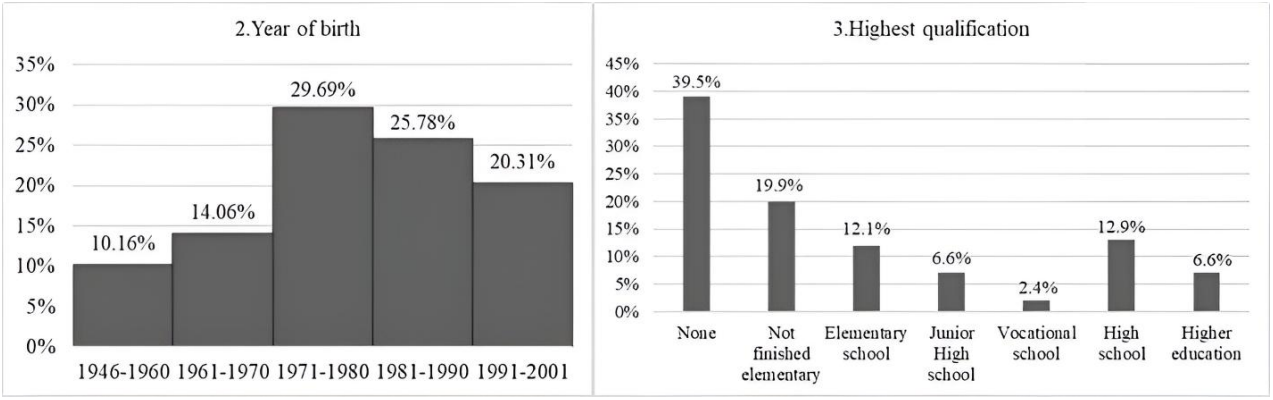

Figure 23: The farmers' demographic data, age range, and educational level

Source: Author's own work, 2026

Based on Figure 23, with regard to the age range of the respondents, the survey aimed to cover all the different age groups within the sector, from young farmers to those with long-standing experience. In terms of the respondents' educational level, 39.5% are illiterate. This also aligns with the national census results (2024) concerning the illiteracy rate, which stood at 38% in rural areas (HCPM, 2025b). However, 19.9% of the respondents did not finish elementary school, which usually applies to the 7-13 age group, so we can conclude that

more than half of the respondents are probably illiterate. The high illiteracy rate is relevant, as it could influence farmers' attitudes towards changes or their access to subsidies, thus affecting their adaptability.

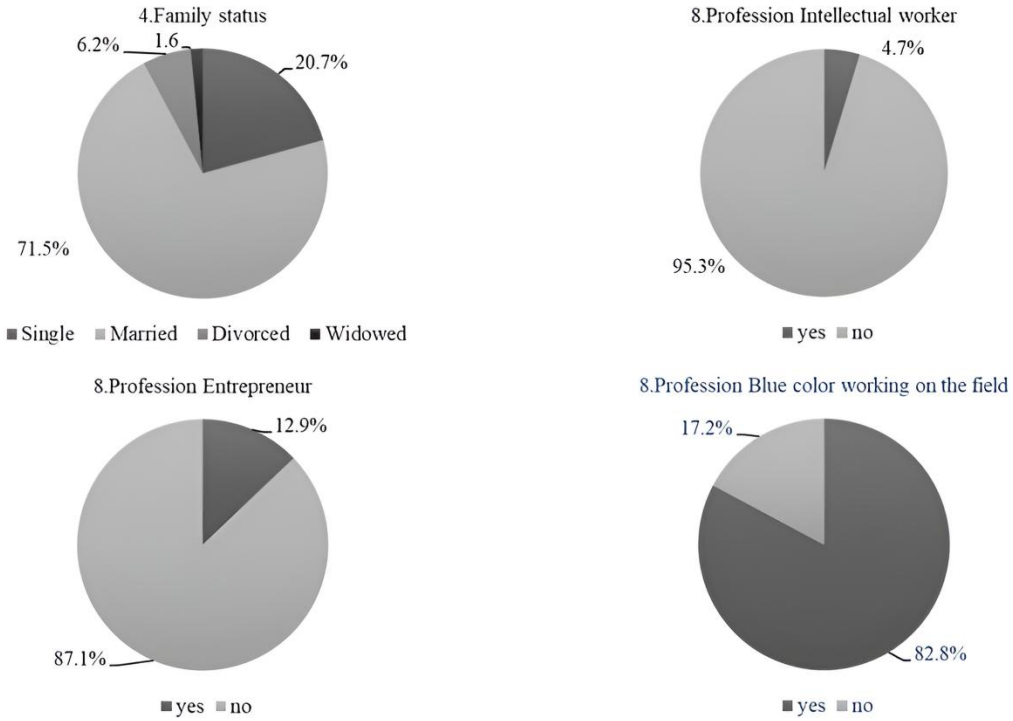

Figure 24: The farmers' demographic data, marital status and professional profile

Source: Author's own work, 2026

Based on Figure 24, in terms of marital status, 71.5% of respondents are married, and about 68.4% have at least two children. The survey also aimed to target respondents who work in the field (82.8%), those who directly experience the agricultural challenges of this profession.

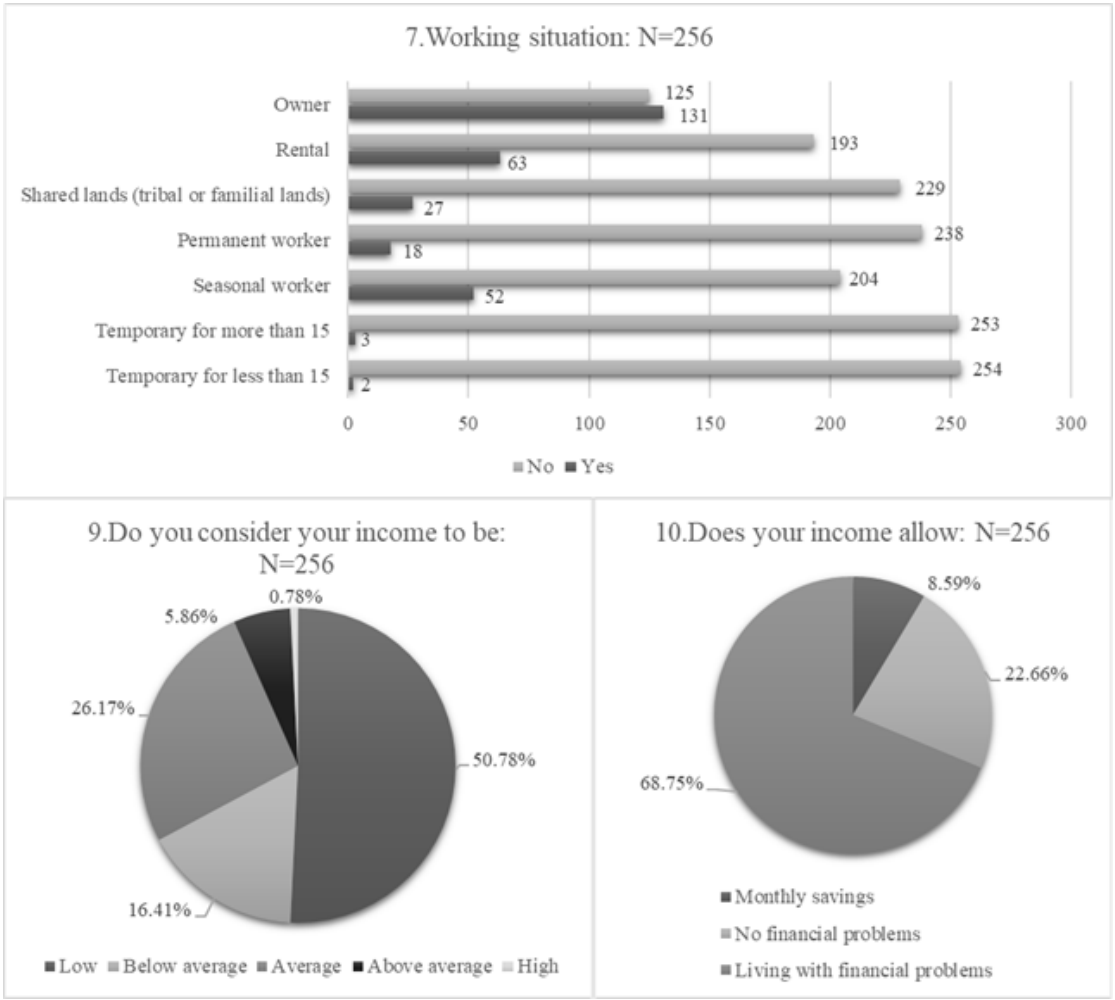

Figure 25: Farmers' related characteristics (working situation and income)

Source: Author's work, 2025

Based on Figure 25, the survey aimed to target farmers in more stable situations, for whom their farms are their main source of livelihood. 51.2% of respondents are farm owners, while 24.6% are farm tenants, 10.5% work in their shared tribal or familial lands, 20.3% are seasonal, 7% are permanent and 2% are temporary employees in this profession.

Additionally, 67.19% (172) of the participants reported that their income is below average, and 68.75% (176) stated that they are experiencing financial difficulties. Only 8.59% (22) stated that their income allowed for monthly savings, and 6.64% (17) of the respondents consider their income to be above average.

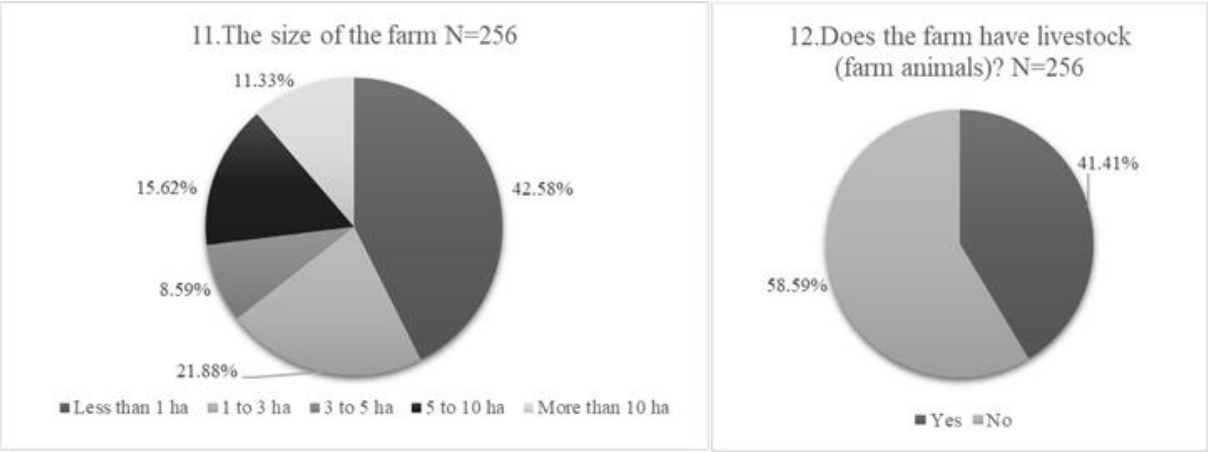

Figure 26: Farms' related characteristics: size and livestock

Source: Author's work and analysis, 2025

Based on Figure 26, in terms of the farm size, 88.67% are 10 ha or less, and 42.58% of the respondents' farms are smaller than one hectare. Land fragmentation hinders the transition to modernized agriculture, as mentioned by the interviewees from the in-depth interviews conducted and by the farmers themselves in the remarks and suggestions section of the questionnaire. Therefore, it can be assumed that this circumstance, in addition to illiteracy, may also hinder technological innovation (MEFM, 2019). Regarding livestock, 41.41% of farmers raise them. Specifically, 73.8% (76 out of 103) in Al Haouz, 28.4% (29 out of 102) in Chichaoua, and only one farmer out of 51 surveyed in the El Kelâa des Sraghna sub-region. This also aligns with the interviewee's statement from the farmers' association in El Kelâa des Sraghna, who emphasized the difficulty farmers face in continuing to raise livestock due to the current water shortages challenge and consecutive years of drought.

Table 26: Farms' related characteristics: crops cultivated

6.Place of residence		Cereals		Total	Arboriculture		Total	Fodder		Total	Legumes		Total	Vegetables		Total
		Yes	No		Yes	No		Yes	No		Yes	No		Yes	No	
Chichaoua	Count	38	64	102	74	28	102	5	97	102	3	99	102	39	63	102
	% within 6.Place of residence	37.3%	62.7%	100%	72.5%	27.5%	100%	4.9%	95.1%	100%	2.9%	97.1%	100%	38.2%	61.8%	100%
Al Haouz	Count	103	0	103	17	86	103	31	72	103	10	93	103	64	39	103
	% within 6.Place of residence	100%	0%	100%	16.5%	83.5%	100%	30.1%	69.9%	100%	9.7%	90.3%	100%	62.1%	37.9%	100%
El Kelâa des Sraghna	Count	18	33	51	48	3	51	9	42	51	0	51	51	0	51	51
	% within 6.Place of residence	35.3%	64.7%	100%	94.1%	5.9%	100%	17.6%	82.4%	100%	0%	100%	100%	0%	100%	100%
Total	Count	159	97	256	139	117	256	45	211	256	13	243	256	103	153	256
	% within 6.Place of residence	62.1%	37.9%	100%	54.3%	45.7%	100%	17.6%	82.4%	100%	5.1%	94.9%	100%	40.2%	59.8%	100%

Source: Author's work and analysis, 2025

Based on Table 26, in terms of the crops cultivated, over 60% of the respondents are cultivating cereals, which are generally considered not naturally well-adapted to water shortages (except for cases such as sorghum, pearl millet, etc.). This is particularly evident in the Al Haouz sub-region, with a 100% adoption rate. However, it is encouraging that half of the farms also cultivate woody crops (54.3%) and vegetables (40.2%), with at least one of these crop types produced in every sub-region.

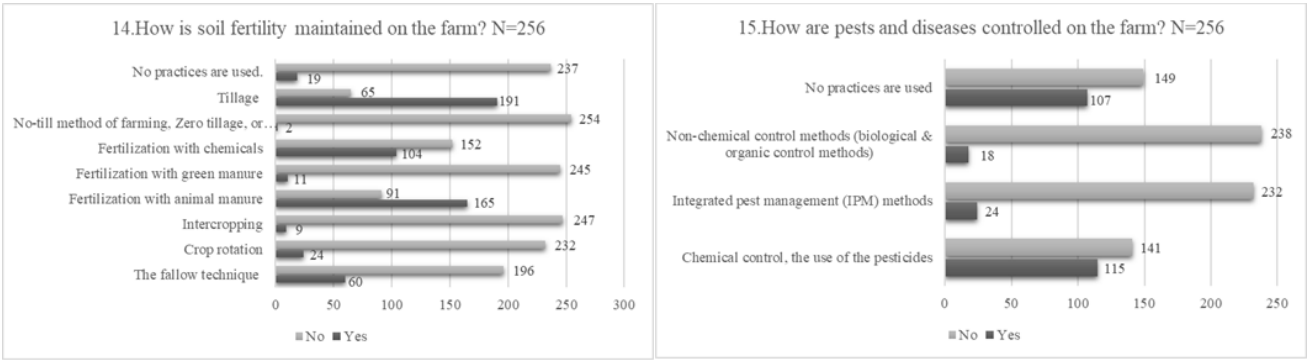

Figure 27: Farms related characteristics: soil fertility, and the control of pests and diseases.

Source: Author's work, 2025

Based on Figure 27, in terms of how soil fertility is maintained on the farm, 74.61% (191) apply conventional tillage (which generally does not contribute to long-term soil fertility), and 40.62% (104) use chemicals, which is concerning. Regarding conservation tillage practices, only two farmers apply no-tillage, the direct seeding method, despite the emphasis on an extensive direct seeding method program in government agricultural plans and by interviewees from related institutions. However, 23.44% (60) apply the fallow technique, and 64.45% (165) use animal manure for fertilization, which is encouraging since it presents an opportunity to capitalize on the synergy that exists between crops and livestock to create a circular food system, combined with the crop rotation method (only 9.37% (24) of the current application) to keep the soil healthy.

In terms of the knowledge of adaptive agricultural practices for the control of pests and diseases. The situation in this regard is concerning, as 41.79% (107) do not use any methods, and 44.92% (115) apply chemical control, the use of pesticides, which undermines soil health and subsequently crop quality (Zhou et al., 2025). Based on the in-depth interviews and literature review, it is essential to incorporate the local expertise of the farmers about

their specific area. Nevertheless, the questionnaires revealed that a large number of farmers do not possess any special adaptive knowledge or habits, except for the possibility of promoting the application of the fallow technique and animal manure for fertilization, with the viability of the latter uncertain, as the number of farmers raising livestock is dwindling. Consequently, one is led to the assumption that previous generations also worked with the portfolio that most improved their income at the time, and self-sufficiency (farm resiliency) was not the focus. It appears that there was no individual's interest in preserving the farmland's quality in the long term or planning to plant adaptive varieties that are the most suitable for their location. It seems that farmers are providing insufficient consideration for the issue of adaptation. Therefore, it is important to explore their knowledge regarding the available agricultural support opportunities.

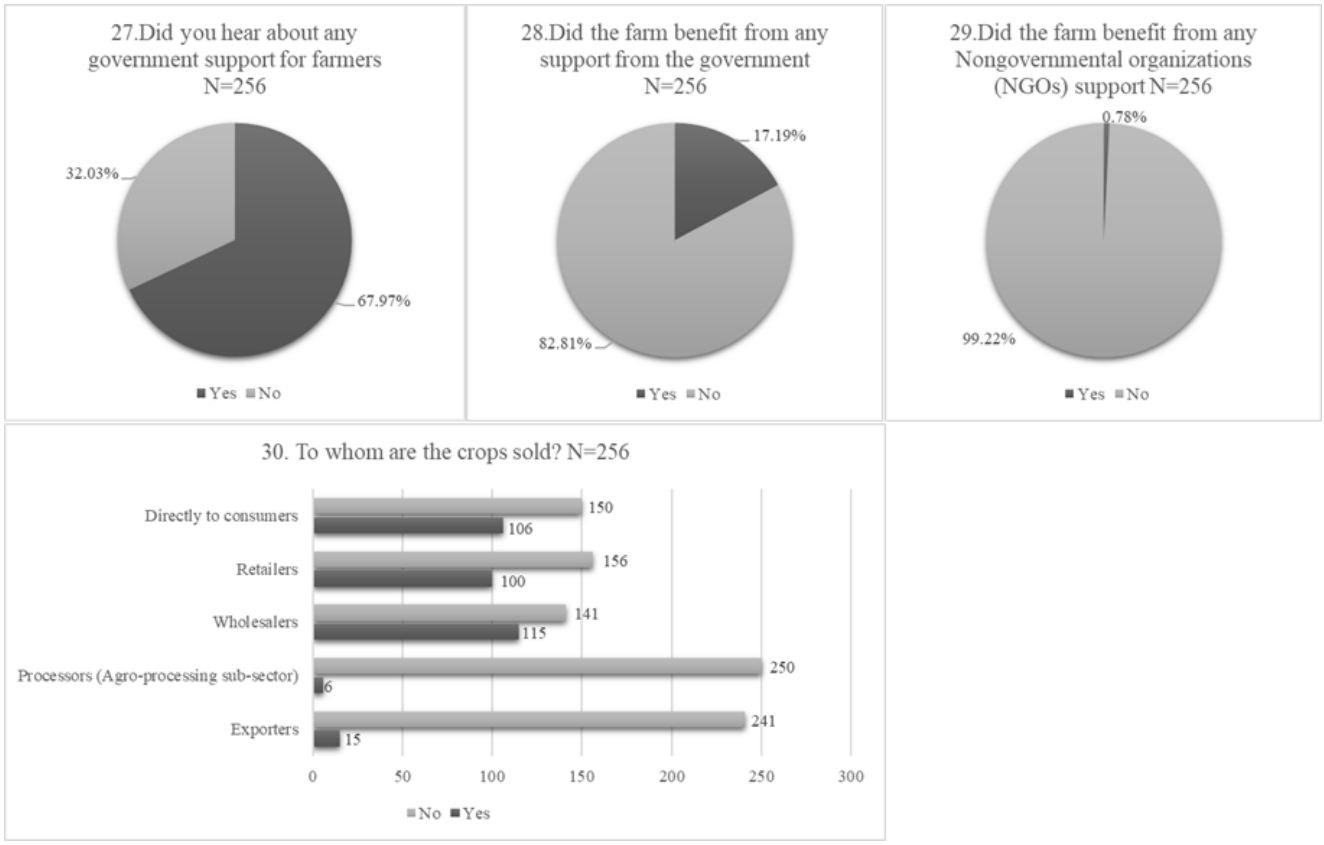

Figure 28: Support related questions and to whom the crops are sold

Source: Author's work, 2025

Based on Figure 28, although 67.97% (174) of farmers have heard about the government support programs, 82.81% (212) have not yet benefited from them. And only two respondents reported that their farms benefited from non-governmental organizations'

(NGOs') support. This could explain the limited adoption of the no-tillage, direct seeding method, despite its support in the government agricultural plans.

In terms of the buyers of the crops, the farmers indicated that they sold their yield to wholesalers (44.92%, 115), retailers (39.06%, 100), and directly to consumers (41.41%, 106). Additionally, the farmers mentioned in the open-ended option of the question that they also sell at the weekly markets. However, it is unclear whether the wholesalers' target market is domestic or export-oriented.

The second part:

The second part tackles the climate change perceived impact, with the focus on water resources and challenges.

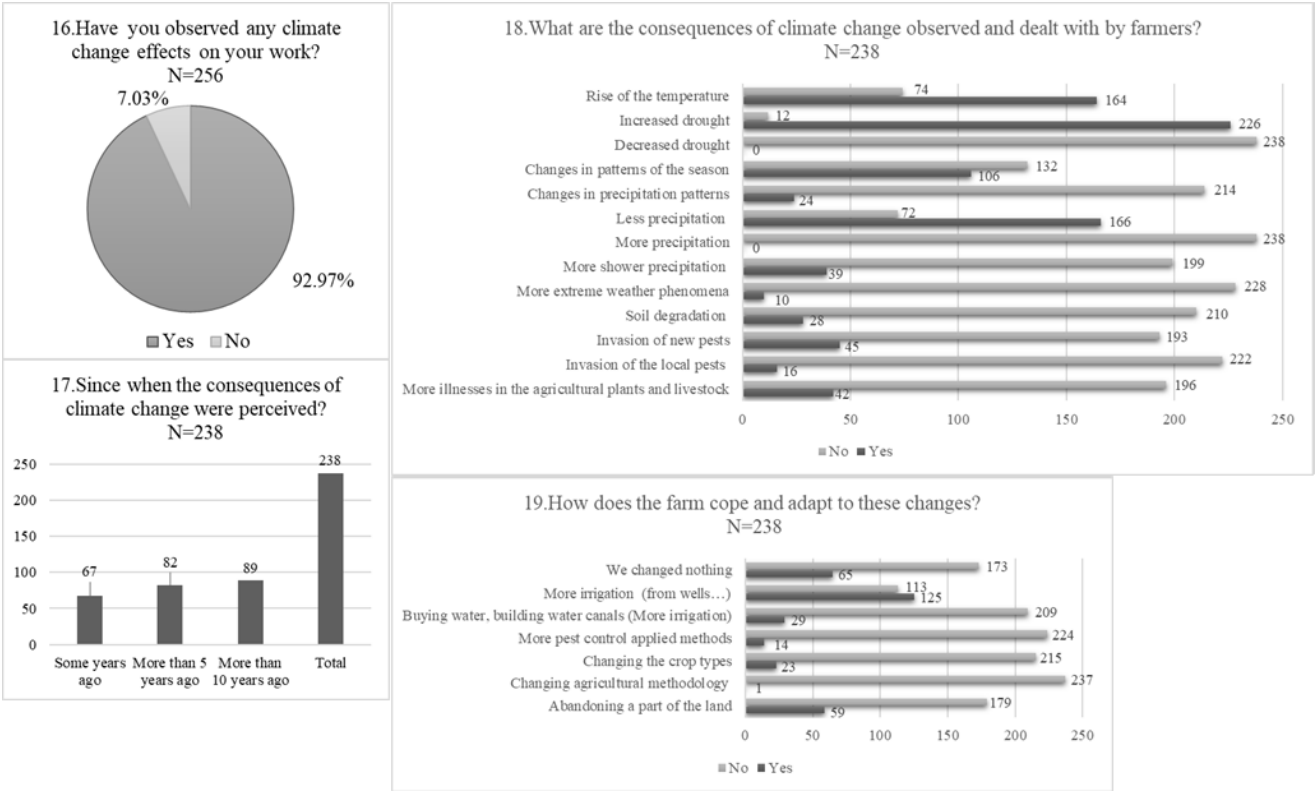

Figure 29: Climate change-related questions

Source: Author's work, 2025

Based on the results from Figure 29 regarding the observed climate change effects on farmers' work, 92.97% (238) perceived some phenomenon related to climate change. In terms of when the consequences of climate change were perceived, the total number of

respondents who perceived the consequences of climate change more than 5 years ago is 171 (71.85%), while 89 (37.39%) of respondents perceived it more than 10 years ago.

In terms of the consequences of climate change observed and dealt with by farmers, the vast majority agreed that the increased drought (94.96%, 226 respondents) was a major consequence. Numerous respondents also agreed on the following consequences: less precipitation (69.75%, 166), a rise in temperature (68.91%, 164), and changes in patterns of the season (44.54%, 106). The agreement among the respondents was significantly lower for other consequences, with mentions of the invasion of new pests (18.91%, 45), more illnesses in agricultural plants and livestock (17.65%, 42), more shower precipitation (16.39%, 39), and soil degradation (11.76%, 28). Accordingly, although the majority perceived change, the core of this consensus seems demonstrably centered on the increase in drought. This finding is significant because the drought, as a key issue, is substantiated not only by the reviewed literature and the insights of the interviewees but also by farmers who are directly confronted with the situation.

Regarding how the farm copes and adapts to these changes, the majority opted for more irrigation (64.71%, 125+29=154 respondents). Other responses included mainly making no changes (27.31%, 65) and abandoning a portion of the land (24.79%, 59) for efficiency purposes. In conclusion, it is evident that farmers perceive irrigation as the principal solution to the escalation in drought frequency.

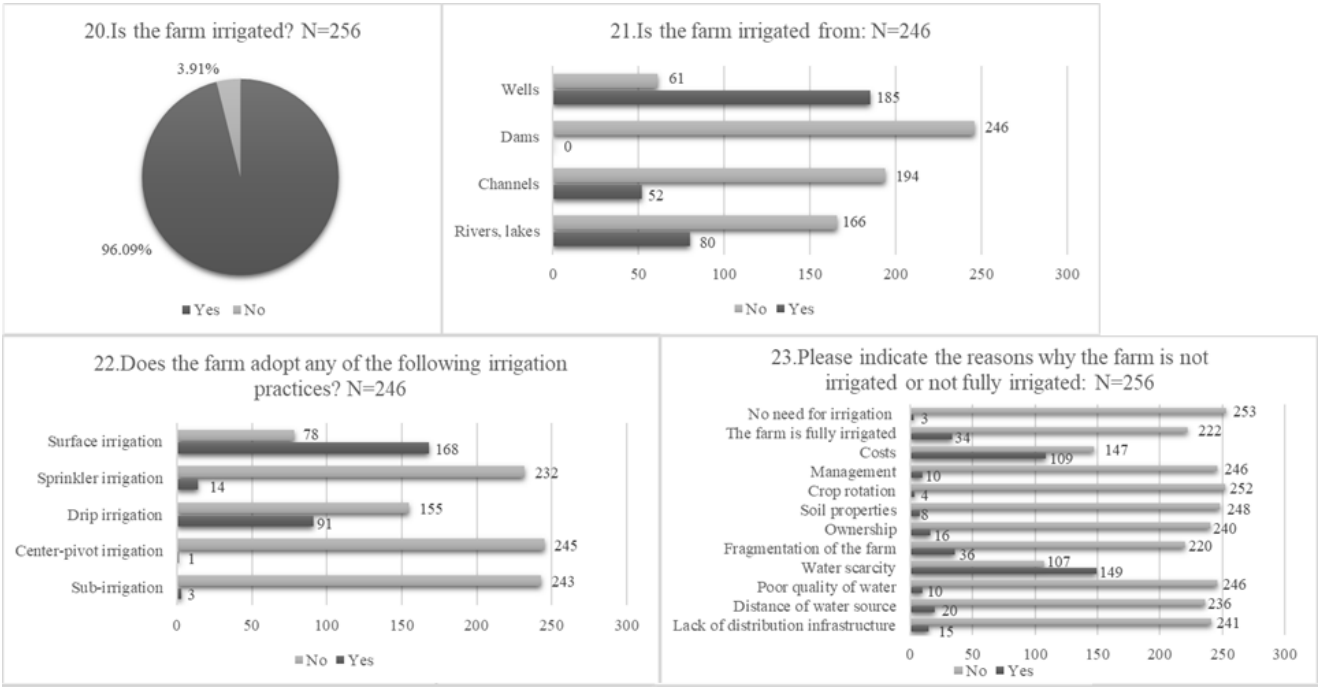

Figure 30: General questions regarding the irrigation of the farms

Source: Author's work, 2025

It is no mere coincidence that the questionnaire covered the issues of irrigation and water shortage extensively. Based on Figure 30, 96.09% (246) of surveyed farmers work on irrigated farms. As they endeavor to alleviate the impact related to water shortages, 75.2% (185) of respondents irrigate from wells, which contributes to groundwater depletion and is likely unsustainable in the long term since the natural recharge rate of the aquifer in years of drought is also impacted, subsequently requiring more regulation and monitoring of groundwater pumping rates to match the aquifer's recharge capacity (Azemzi, 2025). The rest is irrigated from nearby rivers and lakes (32.52%, 80) and from available water channels (21.14%, 52). With respect to the irrigation practices, the least efficient method is employed in contrast to the available options domestically. Surface irrigation, a traditional practice that is less water-efficient and less sustainable, is adopted by the majority, 68.29% (168). Drip irrigation, conversely, is adopted by only 91 (36.99%) farmers, and sprinkler irrigation by 14 (5.69%). The adoption of other water-efficient methods is insignificant, consisting of three applications of sub-irrigation and one application of center-pivot irrigation methods.

Upon further investigation, the data indicate that despite the majority of farms being irrigated, only 13.82% (34) of the irrigated farms achieve full-area irrigation coverage. Concerning the reasons why the farms are not irrigated or not fully irrigated, farmers would

consider the expansion of irrigation desirable. However, due to water scarcity (58.2%, 149), the costs associated with irrigation and water extraction (42.58%, 109), and farm fragmentation (14.06%, 36), they do not perceive any further opportunities for expansion. Other reasons were chosen insignificantly.

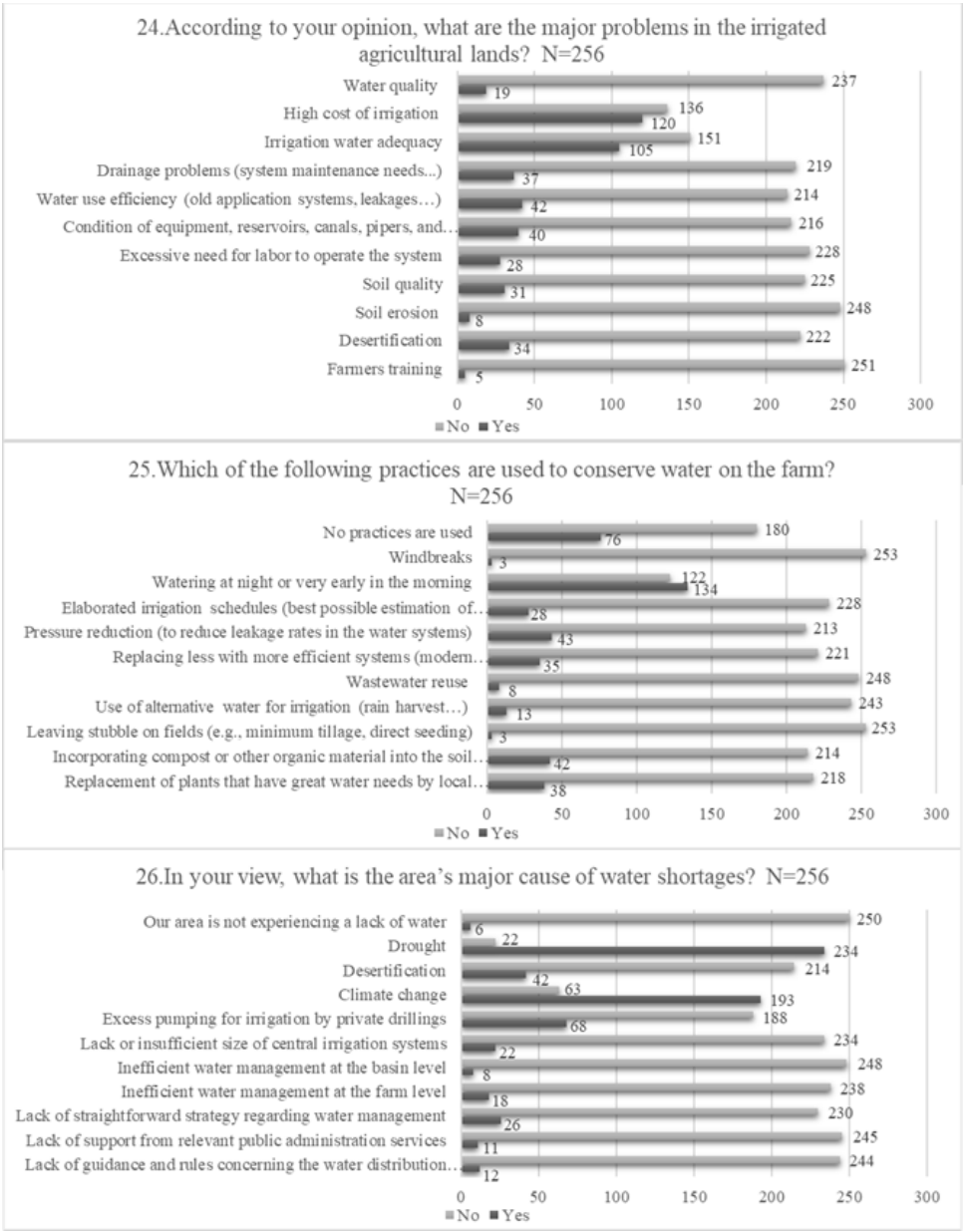

Figure 31: Questions regarding the challenges in irrigated agricultural lands, the practices applied for water conservation purposes, and the area's major causes of water shortages

Source: Author's work, 2025

Based on Figure 31, regarding the major problems in irrigated agricultural lands, the highest proportion of respondents identified the high cost of irrigation (46.87%, 120), irrigation water adequacy (41.01%, 105), and, to a lesser extent, water use efficiency (16.41%, 42), the condition of equipment, reservoirs, canals, pipes, and other structures (15.62%, 40), and drainage problems (system maintenance needs, etc.) (14.45%, 37). Notably, only five respondents considered the lack of farmers' training an issue, suggesting that they do not perceive training as an efficacious solution to the existing challenges.

With respect to the practices used to conserve water on the farm, 70.31% (180) reported the adoption of such practices, which are namely watering at night or very early in the morning (52.34%, 134), pressure reduction (to reduce leakage rates in the water systems) (16.79%, 43), and incorporating compost or other organic material into the soil to improve soil water retention (soil amendments) (16.41%, 42). To a smaller extent, the respondents reported the replacement of plants that have high water needs with local plants or, in general, plants with fewer water needs (14.84%, 38), replacing less efficient systems with more efficient ones (modern sprinklers, micro-irrigation systems, etc.) (13.67%, 35), and the elaboration of irrigation schedules (best possible estimation of water needs, use of soil characteristics, frequency, duration, time of application, etc.) (10.94%, 28). Conversely, the application of wastewater reuse was indicated by only eight farmers, and only three farmers reported leaving stubble on fields (e.g., minimum tillage, direct seeding) for soil water retention.

Concerning the area’s major causes of water shortages, 97.66% (250) reported that their area is experiencing a lack of water. In the same vein, farmers identified drought (91.41%, 234) and climate change (75.39%, 193) as major causes of water shortages, and to a lesser extent, excess pumping for irrigation by private drillings (26.56%, 68), desertification (16.41%, 42), and lack of a straightforward strategy regarding water management (10.16%, 26). However, only 7.03% (18) recognized inefficient water management at the farm level as a major contributing factor to water shortages, which implies that they primarily attribute the scarcity to external factors (e.g., drought, climate change) and might suggest a potentially limited awareness of the significant contribution of the practices applied at the farm level to the broader water shortages issue. This perception could represent a significant barrier to the transition to more sustainable water management practices. Subsequently, if farmers perceive water shortages only due to drought and climate change, and only 7.03% of farmers recognize inefficient water management at the farm level as a contributor to the issue. In that case, they will logically prioritize calling for government intervention plans over proactively

seeking alternatives, investing, and adopting more efficient agricultural practices and technologies. In a similar vein, only twelve respondents (4.69%, 12) identified the lack of guidance and rules concerning water distribution management as also a major contributing factor to water shortages in their area, which might suggest that the majority do not necessarily perceive that the effectiveness of regulations regarding water distribution management could significantly influence the issue.

To conclude, it can be stated that the prevailing adaptive strategy among farmers facing drought and general water shortages is the increase in water abstraction. At the same time, this trend is unfortunately coupled with less efficient irrigation practices. A critical barrier is the underestimation of the farmers' training, as well as the insufficient consideration of water distribution management and the adoption of more efficient irrigation practices that would enhance their long-term agricultural resilience regarding the issue.

The third part:

The last part focused on the factors that could influence the transition to sustainable practices and the challenges associated with it.

The following Table 27 presents the relevant factors that could influence the decision to adopt sustainable agriculture practices, which were rated by farmers based on 5-point Likert rating scales.

Table 27: Q31.How strongly do the following factors influence the decision to adopt sustainable agriculture practices? N=256

Factors	I don't know	Strongly negative	Negative	Neutral	Positive	Strongly positive
Climate change	5	0	3	26	20	202
Climate variability of the last five years e g: inadequate distribution of precipitation	11	0	1	8	32	204
Drought	6	2	0	6	26	216
Soil degradation	19	15	14	25	52	131
Feed supply for livestock	40	20	16	46	80	54
Invasive pests	35	26	15	42	70	68
The improvement of water use efficiency	33	27	34	31	76	55
The improvement of agricultural yield	51	25	32	28	75	45

Access to the government's financial support programs	50	32	27	31	76	40
Access to loan opportunities from banks	67	29	32	42	59	27
Access to support from associations and nongovernmental organizations (NGOs)	66	36	28	43	60	23

Source: Author's work and analysis, 2025

Based on the results, drought (84.37%, 216), followed by climate variability of the last five years (79.69%, 204), and climate change (78.91%, 202) received the highest selection of the "strongly agree" (strongly positive) option by the respondents. Additionally, the same ranking of the factors applies when summing "agree" (positive) and "strongly agree" selections on the scale. Furthermore, with only half of the respondents selected "agree" and "strongly agree" options for the improvement of water use efficiency factor (51.17%, 76+55=131), the results also indicate the overwhelming influence of external factors (e.g., drought, climate change) on farmers, which shape both their perception of the water shortages issue and their readiness to transition to more sustainable agricultural practices. Regarding other factors, the rating selection results were less relevant. However, soil degradation has recorded 71.48% (52+131=183) of the total "agree" and "strongly agree" selection options, which is puzzling since the majority do not believe that climate change contributes to soil degradation (89.06%, 210+18=228 from question 18). This suggests that either farmers do not attribute soil degradation to climate change, or they were struggling with the issue prior to the perceived increase in the impact of climate change on their work.

Notably, the drought factor has the lowest total number of respondents who selected the "neutral" and "I don't know" options (4.69%, totaling 12). Conversely, the factors "access to loan opportunities from banks" (26.17%, 67) and "access to support from associations and non-governmental organizations (NGOs)" (25.78%, 66) had the highest selection of the "I don't know" option. In the same vein, the factor "feed supply for livestock" had the highest selection of the "neutral" option (17.97%, 46).

Regarding the combined selection of "disagree" (negative) and "strongly disagree" (strongly negative), the response distribution shows that they were selected largely for the factors "access to support from associations and non-governmental organizations (NGOs)" (25%, 36+28=64), followed by "access to loan opportunities from banks" (23.83%, 29+32=61),

"the improvement of water use efficiency" (23.83%, 27+34=61), and "access to the government's financial support programs" (23.05%, 32+27=59). Notably, factors relating to support (e.g., subsidies) had the highest selection of the "strongly disagree" option, which are "access to support from associations and non-governmental organizations (NGOs)" (14.06%, 36), followed by "access to the government's financial support programs" (12.5%, 32), and "access to loan opportunities from banks" (11.33%, 29). This suggests that the influencing power of financial resources is unclear using this approach and may signal a plausible lack of trust among farmers in institutions and subsidy mechanisms, given previous findings regarding a certain degree of common marginalization sentiment and the need for an effective participatory approach. The lack of trust might also be contributing to the situation that, even though 67.97% (174) of farmers have heard about the government support programs, 82.81% (212) have not benefited from them. It is important to highlight that the respondents were provided with the opportunity to add factors they deemed important under "other reasons" as an open-ended option rated on the same Likert scale system. However, no farmer presented other relevant factors.

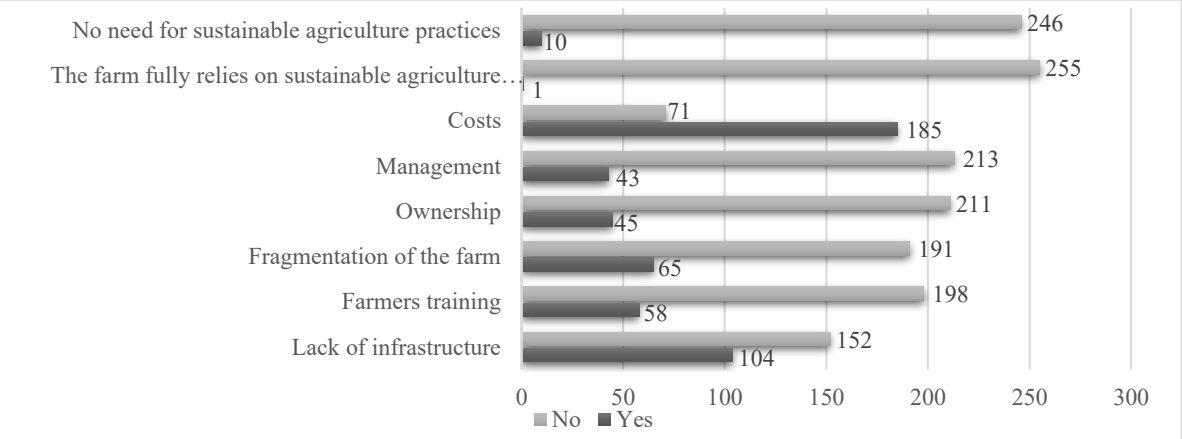

Figure 32: Q32. The challenges associated with the transition to sustainable agriculture practices, N=256

Source: Author's own work, 2025

Finally, based on Figure 32, the obstacles farmers consider to be the most important in transitioning to more sustainable agricultural practices (e.g., use of green manure or organic manure, crop diversification, introduction of drip irrigation, intercropping, biological and organic control methods of pests and diseases, etc.) were examined.

Almost all farmers agreed that the adoption of sustainable agricultural practices is needed (96.09%, 246). The results also reveal that the costs of the transition (72.26%, 185), the “lack of infrastructure” (40.62%, 104), and the “fragmentation of the farm” (25.39%, 65) were the main obstacles emphasized. Additionally, just under a quarter (22.66%, 58) of the respondents considered the need for training to be important. Accordingly, based on the previous findings, a notable disparity could be inferred. While the data indicate that farmers have a common view that financial resources can instigate change, it appears that there is a lack of trust in the efficacy of subsidies. This may reflect not only poor access but also distrust and alienation. And could explain the disparity between farmers' need for financial resources and their inability or reluctance to access the existing subsidy mechanisms. Conversely, external factors (e.g., drought, climate change) are the main influencing factors that can force adaptation in all sub-regions where the survey was conducted.

The descriptive statistics and analysis subsection aimed to provide an overview of the sample characteristics, mainly focusing on farmers and their farms, their perceptions and adaptations to the impacts of climate change, and particularly investigating water resources and shortages. The study also explored the factors influencing the transition to sustainable agricultural practices and the challenges associated with it. The following subsection presents the hypothesis testing.

B. Hypothesis testing

The following subsection is focused on presenting the hypothesis testing results. It is worth mentioning that questions 18 and 25 have been transformed into the number of observed climate change categories and the number of practices already applied for water conservation efficiency categories for calculation and analysis purposes.

Hypothesis 1

Table 28: The observed climate change categories and climate change as a factor that influences the decision to adopt sustainable agriculture practices. Crosstabulation, chi-square, and symmetric measures: gamma

			How strongly the following factors influence the decision to adopt sustainable agriculture practices, Climate change			
			Negative	Neutral	Positive	Total
observed climate change categories	1.00	Count	0	2	14	16
		% within observed climate change categories	0.0%	12.5%	87.5%	100.0%
	2.00	Count	3	19	35	57
		% within observed climate change categories	5.3%	33.3%	61.4%	100.0%
	3.00	Count	0	5	123	128
		% within observed climate change categories	0.0%	3.9%	96.1%	100.0%
	4.00	Count	0	0	31	31
		% within observed climate change categories	0.0%	0.0%	100.0%	100.0%
	5.00	Count	0	0	19	19
		% within observed climate change categories	0.0%	0.0%	100.0%	100.0%
Total		Count	3	26	222	251
		% within observed climate change categories	1.2%	10.4%	88.4%	100.0%

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	55.966[a]	8	.000
Likelihood Ratio	51.138	8	.000
Linear-by-Linear Association	22.775	1	.000
N of Valid Cases	251		

a. 8 cells (53.3%) have expected count less than 5. The minimum expected count is .19.

		Value	Asymp. Std. Error[a]	Approx. T[b]	Approx. Sig.
Ordinal by Ordinal	Gamma	.778	.055	5.443	.000
N of Valid Cases		251			

a. Not assuming the null hypothesis.

b. Using the asymptotic standard error assuming the null hypothesis.

Source: Author's own work and analysis, 2024

The farmers' respondents had to check how many of the proposed perceived climate change consequences were observed in their work. Then the answers were categorized from one to five of the number of observed effects on the farms. The results' association was tested with another question asked, which is on how strongly climate change as a factor influences the decision to adopt sustainable agriculture practices, and relies on a Likert scale. As presented in Table 28 and based on the chi-square test of independence, since the p-value is far less than the chosen significance level ($\alpha = 0.05$), we reject the null hypothesis. As a result, the number of observed climate change consequences dealt with in their work is associated with

climate change as a factor that influences the decision to adopt sustainable agriculture practices. This association is described as a strong positive one, since the gamma in the value column is equal to 0.778.

Table 29: How strongly the following factor influences the adoption of sustainable agriculture practices: climate change. Frequency table

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Negative	3	1.2	1.2	1.2
	Neutral	26	10.2	10.4	11.6
	Positive	222	86.7	88.4	100.0
	Total	251	98.0	100.0	
Missing	I don't know	5	2.0		
Total		256	100.0		

Source: Author's own work, 2024

Based on Table 29, the results show that almost all respondents (86.7%) consider climate change a factor that influences their decision to adopt sustainable agriculture practices. In addition, based on the previous results, there is a strong positive association between the number of observed climate change consequences dealt with in their work and climate change as a factor that influences the decision to adopt sustainable agriculture practices.

Table 30: Place of residence and how strongly the following factor influences the decision to adopt sustainable agriculture practices: drought. Crosstabulation

			How strongly the following factors influence the decision to adopt sustainable agriculture practices, Drought					
			I don't know	Strongly negative	Neutral	Positive	Strongly positive	Total
Place of residence	Chichaoua	Count	3	0	5	4	90	102
		% within Place of residence	2.9%	0.0%	4.9%	3.9%	88.2%	100.0%
	Al Haouz	Count	0	0	1	6	96	103
		% within Place of residence	0.0%	0.0%	1.0%	5.8%	93.2%	100.0%
	El Kelâa des Sraghna	Count	3	2	0	16	30	51
		% within Place of residence	5.9%	3.9%	0.0%	31.4%	58.8%	100.0%
Total		Count	6	2	6	26	216	256
		% within Place of residence	2.3%	0.8%	2.3%	10.2%	84.4%	100.0%

Source: Author's own work, 2024

Based on Table 30 and given that nearly all responses were positive (which stood at 94.6% of the total respondents), regardless of the location where the questionnaire was conducted, with Al Haouz sub-region reaching 99% of positive responses, it is therefore safe to conclude

that the respondents consider drought a factor that influences their decision to adopt sustainable agriculture practices, a strong one as 84.4% of the farmers responded as such.

Hypothesis 2

Table 31: Water efficiency categories and the improvement of water use efficiency as a factor that influences the decision to adopt sustainable agriculture practices. Crosstabulation, chi-square, and symmetric measures: gamma

			How strongly the following factors influence the decision to adopt sustainable agriculture practices, The improvement of water use efficiency			
			Negative	Neutral	Positive	Total
water efficiency categories	nothing	Count	27	8	31	66
		% within water efficiency categories	40.9%	12.1%	47.0%	100.0%
	1	Count	27	11	47	85
		% within water efficiency categories	31.8%	12.9%	55.3%	100.0%
	2	Count	5	7	27	39
		% within water efficiency categories	12.8%	17.9%	69.2%	100.0%
	more than 2	Count	2	5	26	33
		% within water efficiency categories	6.1%	15.2%	78.8%	100.0%
Total		Count	61	31	131	223
		% within water efficiency categories	27.4%	13.9%	58.7%	100.0%

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	18.939[a]	6	.004
Likelihood Ratio	21.447	6	.002
Linear-by-Linear Association	16.393	1	.000
N of Valid Cases	223		

a. 1 cells (8.3%) have expected count less than 5. The minimum expected count is 4.59.

		Value	Asymp. Std. Error[a]	Approx. T[b]	Approx. Sig.
Ordinal by Ordinal	Gamma	.358	.082	4.179	.000
N of Valid Cases		223			

a. Not assuming the null hypothesis.

b. Using the asymptotic standard error assuming the null hypothesis.

Source: Author's own work and analysis, 2024

In terms of the water efficiency categories, it consists of the question presented to the respondents, regarding the different practices used for water conservation on the farm. The categories range from no practices to more than two practices applied. Based on the results presented in Table 31, since the p-value is far less than the chosen significance level ($\alpha = 0.05$), we reject the null hypothesis. Also, we conclude that there is an association between the water efficiency categories (the number of practices used for water conservation on the farm) and the factor that influences the decision to adopt sustainable agriculture practices,

which is the improvement of water use efficiency. This association is described as a moderate positive one, since the gamma in the value column is equal to 0.358.

Table 32: How strongly the following factor influences the decision to adopt sustainable agriculture practices: the improvement of water use efficiency. Frequency table

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Negative	61	23.8	27.4	27.4
	Neutral	31	12.1	13.9	41.3
	Positive	131	51.2	58.7	100.0
	Total	223	87.1	100.0	
Missing	I don't know	33	12.9		
Total		256	100.0		

Source: Author's own work, 2024

Based on Table 32, the results show that more than half of the respondents (51.2%) consider improving water use efficiency as a factor that influences their decision to adopt sustainable agriculture practices. In addition, based on the previous results, there is a moderate positive association between how many practices are applied on the farm for water conservation and the factor of improving water use efficiency to influence the decision of the adoption of sustainable agriculture practices.

Hypothesis 3

Table 33: If the farm previously benefited from any governmental support and the access to the government's financial support programs as a factor that influences the decision to adopt sustainable agriculture practices. Crosstabulation and chi-square test of independence

			How strongly the following factors influence the decision to adopt sustainable agriculture practices, Access to the government's financial support programs			
			Negative	Neutral	Positive	Total
Did the farm benefit from any support from the government	yes	Count	5	7	23	35
		% within Did the farm benefit from any support from the government	14.3%	20.0%	65.7%	100.0%
	no	Count	54	24	93	171
		% within Did the farm benefit from any support from the government	31.6%	14.0%	54.4%	100.0%
Total		Count	59	31	116	206
		% within Did the farm benefit from any support from the government	28.6%	15.0%	56.3%	100.0%

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	4.383[a]	2	.112
Likelihood Ratio	4.862	2	.088
Linear-by-Linear Association	3.064	1	.080
N of Valid Cases	206		

a. 0 cells (.0%) have expected count less than 5. The minimum expected count is 5.27.

Source: Author's own work, 2024

The third tested hypothesis results concern the association of the opportunity to access the government's financial support programs as a factor that influences the decision to adopt sustainable agriculture practices, with whether or not the farm has previously benefited from any governmental support. Based on Table 33, as the p-value is much higher than the chosen significance level ($\alpha = 0.05$), we cannot reject the null hypothesis. Thus, we conclude that there is not enough evidence to suggest an association between whether the farm previously benefited from any governmental support and the mentioned factor that could influence the decision to adopt sustainable agriculture practices.

Table 34: How strongly the following factor influences the decision to adopt sustainable agriculture practices: access to the government's financial support programs. Frequency table

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Negative	59	23.0	28.6	28.6
	Neutral	31	12.1	15.0	43.7
	Positive	116	45.3	56.3	100.0
	Total	206	80.5	100.0	
Missing	I don't know	50	19.5		
Total		256	100.0		

Source: Author's work, 2024

Based on Table 34 regarding the access to the government's financial support programs as a factor that influences the decision to adopt sustainable agriculture practices, it is unclear if the mentioned indicator could influence the decision to transition to sustainable practices (since only 45.3% of the respondents' answers were positive). These results could be due to the fact that the sample size was not large enough to clearly infer the result. As a consequence, it is safe to assume that the government's financial support programs are not necessarily a decisive factor in the decision to adopt sustainable agricultural practices, nor are they associated with whether the farm previously benefited from any governmental support.

Hypothesis 4

Table 35: Water efficiency categories and the highest qualification attained by the farmers (education level). Crosstabulation, chi-square, and symmetric measures: gamma

			Highest qualification							
			none	Not finished elementary	Elementary school	Junior High school	Vocational school	High school	Higher education	Total
water efficiency category	nothing	Count	38	19	10	1	0	8	0	76
		% within water efficiency category	50.0%	25.0%	13.2%	1.3%	0.0%	10.5%	0.0%	100.0%
	1	Count	47	16	12	8	0	5	7	95
		% within water efficiency category	49.5%	16.8%	12.6%	8.4%	0.0%	5.3%	7.4%	100.0%
	2	Count	8	12	6	4	2	8	3	43
		% within water efficiency category	18.6%	27.9%	14.0%	9.3%	4.7%	18.6%	7.0%	100.0%
	more than 2	Count	8	4	3	4	4	12	7	42
		% within water efficiency category	19.0%	9.5%	7.1%	9.5%	9.5%	28.6%	16.7%	100.0%
Total		Count	101	51	31	17	6	33	17	256
		% within water efficiency category	39.5%	19.9%	12.1%	6.6%	2.3%	12.9%	6.6%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	64.000[a]	18	.000
Likelihood Ratio	69.759	18	.000
Linear-by-Linear Association	38.365	1	.000
N of Valid Cases	256		

a. 8 cells (28.6%) have expected count less than 5. The minimum expected count is .98.

Symmetric Measures

		Value	Asymp. Std. Error[a]	Approx. T[b]	Approx. Sig.
Ordinal by Ordinal	Gamma	.385	.060	6.031	.000
N of Valid Cases		256			

a. Not assuming the null hypothesis.

b. Using the asymptotic standard error assuming the null hypothesis.

Source: Author's work and analysis, 2025

The last hypothesis tested concerns the association between the number of practices already applied to conserve water on the farms and the level of education attained by the farmers. Based on Table 35, since the p-value is far less than the chosen significance level ($\alpha = 0.05$), we reject the null hypothesis. Thus, we conclude that there is an association between the number of practices already applied to conserve water on the farms and the level of education attained by the farmers. This association is described as a moderate positive one, since the gamma in the value column is equal to 0.385.

The questionnaire was distributed using the snowball method, which does not necessarily permit any conclusions to be drawn about the specific population and therefore does not claim representativeness. Nonetheless, analogies for further research can be derived from the sample. The survey allowed us to assume that out of the indicators analyzed, only the number of observed consequences of climate change on the farms by farmers and the number of practices already applied for water conservation and efficiency are related to their

respective factors that influence the decision to adopt sustainable agricultural practices. Additionally, we can deduce that climate change, including drought, and the improvement of water use efficiency are factors that influence the decision to adopt sustainable practices, since over half of the respondents' answers were positive on these particular indicators.

In terms of the third hypothesis regarding whether there is an association between the farm previously benefited from government support and the farmer’s inclination to adopt sustainable practices, with access to the government's financial support programs as a key influencing factor. We cannot reject the null hypothesis. Thus, we conclude that there is not enough evidence to suggest this association. This result could be due to the lack of a larger sample size, which reduces statistical power (a high chance of a type II statistical error). Additionally, only 17.2% of the total sample of farmers received government support, as shown in the following Table 36:

Table 36: Question 28 from the questionnaire regarding whether the farm previously benefited from any support from the government

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	yes	44	17.2	17.2	17.2
	no	212	82.8	82.8	100.0
	Total	256	100.0	100.0	

Source: Author’s own work, 2025

The last hypothesis result concluded a positive association between the level of education attained by farmers and the number of practices already applied to conserve water on the farms. As a result, while the illiteracy rate decreases and educational attainment rises within rural communities, it is anticipated that farmers' awareness of the relevance of adaptation will grow, leading to increased adoption of efficient water conservation methods and practices in the face of water shortages.

In conclusion, based on the current context, fostering the transition to sustainable agricultural practices calls for further emphasis on climate change and water use efficiency in future plans. This also requires a clear articulation of the plans and initiatives with the aim of promoting successful cooperation with farmers, along with improving farmers' education. Thus, increasing farmers' resilience to water shortages.

The implications of water shortages on Moroccan agriculture are demonstrated and established, and the collaboration of farmers for an urgent plan to transition to sustainable agriculture and tackle water scarcity is a necessary and highly feasible undertaking. The following Table 37 presents a summary of the hypotheses assessed:

Table 37: Summary of hypotheses assessed

Hypotheses	Relationship	Results
H1	The extent to which farmers' inclination for sustainable practices adoption is influenced by the degree of the perceived climate change's impact on the farms.	Supported
H2	The extent to which farmers' inclination for sustainable practices adoption is influenced by the number of practices already applied to conserve water on the farms.	Supported
H3	The extent to which farmers' inclination for sustainable practices adoption is influenced by the support opportunities offered by the government for the farms.	Not supported
H4	The number of practices already applied to conserve water on the farms is influenced by the level of education attained by the farmers.	Supported

Source: Author's own research and analysis, 2025

4.2.3 Summary of the quantitative research

The main results from the quantitative survey were compactly summarized as follows:

Result 1:

The analysis of the responses demonstrates that the farmers are inclined to cooperate in adopting and transitioning to sustainable agriculture practices if it is intended to help tackle the prevalence of drought challenges and adapt to climate change. Additionally, it can be stated that the prevailing adaptive strategy among farmers facing drought and general water shortages is the increase in water abstraction. At the same time, this trend is unfortunately coupled with less efficient irrigation practices. A critical barrier is the underestimation of the farmers' training, as well as the insufficient consideration of water distribution management and the adoption of more efficient irrigation practices that would enhance their long-term agricultural resilience regarding the issue.

The results appear to be significantly influenced by climate variability and the inadequate distribution of precipitation in the last five years, including a strong positive association between the number of observed climate change consequences dealt with on the farms and how strongly climate change as a factor is influencing the decision to adopt sustainable

agriculture practices. Additionally, a moderate positive association was identified between how many of the practices already applied on the farm for water conservation and the decision to adopt sustainable agriculture practices, with the improvement of water use efficiency as a key influencing factor. As a result, the extent of the farmers' existing commitment to water conservation may be acting as a positive reinforcement, which could be due to a perception gap between adopters and non-adopters of water conservation methods, a factor already documented in the literature (McCollum et al., 2022).

Result 2:

Out of the mentioned potential challenges to implementing sustainable agriculture practices, which were based on the in-depth interviews conducted and the literature analyzed. Besides the lack of infrastructure and fragmentation of the farm, the costs of the transition constitute the common denominator across the sub-regions where the survey was conducted. Notably, the availability of support, including financial support from the government or other proposed organizations, does not necessarily influence the decision for sustainable agriculture practices adoption.

Additionally, it is safe to assume that the government's financial support programs are not necessarily a decisive factor in the decision to adopt sustainable agricultural practices, nor are they associated with whether the farm previously benefited from any governmental support.

While the data indicate that farmers have a common view that financial resources can instigate change, it appears that there is a lack of trust in the efficacy of subsidies. This may reflect not only poor access but also signal a plausible lack of trust among farmers in the institutions and subsidy mechanisms, given the previous findings imply a certain degree of common marginalization sentiment and the need for an effective participatory approach. And could explain the disparity between farmers' need for financial resources and their inability or reluctance to access the existing subsidy mechanisms.

Result 3:

Based on the results, there is a moderate positive association between the level of education attained by farmers and the number of practices already applied to conserve water on the farms (for water efficiency). Accordingly, this implies that improving educational attainment and reducing illiteracy among farmers and rural communities will not only be favorable for

development but also will likely lead to increased adoption of efficient water conservation methods and practices in the face of water shortages. This entails that farmers will likely seek and implement new solutions instead of relying only on traditional methods, since they may have better access to information and be more inclined to seek out information on new technologies and conservation methods.

The next subchapter consists of the culmination of all findings along with further developed suggestions, recommendations, and a proposed concept.

4.3. DISCUSSION OF THE RESEARCH RESULTS

Based on the findings from the literature review (*R1*), as well as the qualitative and quantitative results (*R2, R3, R4*), the study's aim *A4: Answering the Sub-question 4* "Are there any appropriate sustainable strategies, methods, and practices to enhance the resilience of agricultural development facing water shortages in Morocco?" can now be addressed. Accordingly, phase *P5: Possibility of appropriate sustainable strategies, methods, and practices* was completed. The process attempts to achieve the result *R5: A proposed sustainable agricultural development concept and suggestions adapted to the current situation in Morocco*, of the present study. The following subsections are a summary of the key insights and suggestions for sustainable agricultural development in the Marrakech-Safi region of Morocco, followed by a proposed concept.

The key suggestions were consolidated under the following four primary areas:

- Fostering the deployment of drought-resilient crop varieties
- Improving the effectiveness of the participatory approach and targeted farmer advisory services
- Improving farmers' education and technology adoption
- Ensuring the alignment of food security and the agricultural export policy with the sustainability and adaptation objectives of the agriculture sector

Suggestion 1: Fostering the deployment of drought-resilient crop varieties

The first suggestion is also based on the in-depth interviews' insights and the questionnaire results with regard to facing drought, the escalating water shortages, and the perceived impact of climate change on the farms (*H1*). As it was discussed in the literature review chapter, the government has already been investing in crop varieties development for multiple decades. However, based on the findings, more attention needs to be paid to

accelerating investment in developing and the full-scale adoption of highly tolerant crop varieties to drought, such as “Jawahir” durum wheat crop (Amamou, 2024; INRA, 2023, 2025). This includes fostering crop varieties with shorter growing cycles for drought escape (early flowering time, a shorter vegetative phase, etc), as it was also emphasized by the experts interviewed and mentioned that the Green Generation Strategy (2020-2030) also favored the adoption of alternative crops such as cactus, quinoa (a naturally well-adapted drought-tolerant pseudocereal), and investment in resilient alternative crops (Akram et al., 2024; Iqbal et al., 2018; Maestro-Gaitán et al., 2023; Shavrukov et al., 2017). In the same vein, since around 59% of agricultural lands cultivate cereal crops, this shift would be more impactful if it also focused on introducing highly tolerant cereal varieties (Amamou, 2024; MAFM, 2019; MEFM, 2019).

Similarly, more consideration needs to be given to fostering a larger adoption of naturally drought-tolerant crops, such as pearl millet and sorghum (cereals), chickpeas and cowpeas (legumes), and cassava and sweet potatoes (root crops). Increasing the cultivation of these crops will significantly contribute to the resiliency of agriculture facing water shortages. Additionally, focusing on ones with more stable yield and profitability, which can be incrementally fostered for market adjustment to accommodate the change through government involvement, as well as exploring opportunities at both the domestic level and internationally for export purposes (Agbicodo et al., 2009; Ameer, 2024; Ashraf, 2010; Hadebe et al., 2017; Motsa et al., 2015; Zhao et al., 2015).

It is worth noting that rapidly scaling the distribution and the adoption could be fostered through an effective cooperation with seed companies, particularly with SONACOS, the state-owned company and the leading company in the seed sector. Conversely, in terms of the farmers' unwillingness to use certified seeds (including the newly developed varieties), it could be attributed to factors such as the cost of the seeds, ineffective communication, and bad seed distribution. It is also worth mentioning that in cases where farmers couldn’t find the variety that they wished to cultivate, they tended to purchase traditional varieties that were familiar to them (ancient varieties, such as the durum wheat Karim released in 1985) from a reliable neighbor or from the market (Amamou, 2024; INRA, 2005, 2017). Investing in a successful transition to the developed and adapted varieties is crucial not only to increase resilience in the face of water shortages but also to contribute to food security objectives. Similarly, with the prevalence of smallholders, improving the effectiveness of the

participatory approach and targeted farmer advisory services will directly contribute to the efforts regarding the efficient deployment of drought-resilient crop varieties.

Suggestion 2: Improving the effectiveness of the participatory approach and targeted farmer advisory services

The second suggestion is also based on the in-depth interviews' insights and the quantitative results with regard to the participatory approach discussion and benefiting from the governmental support. Based on the findings, the improvement of the already implemented Participatory Extension Approach (PEA) is suggested to enhance the efficiency of the existing efforts. It would be essential to apply a more effective participatory approach in policymaking, where the decision-makers consistently take into account the experiences and insights of farmers when developing the support system, emphasizing the principles of sustainable agriculture. The PEA considers farmers as experts in their contexts, emphasizing farmers' active participation in the extension process, integrating local insights, and encouraging co-creating knowledge and solutions. Improving the effectiveness of the participatory approach, along with a better articulation of agricultural policies and facilitating the support process for farmers, would also help alleviate the potential distrust and common marginalization sentiment among farmers toward organizations, particularly governmental ones, as the results indicated. Since the lack of trust could be contributing to the situation that, even though almost all farmers agreed that the adoption of sustainable agricultural practices is needed (96.09%), 72.26% consider the costs a challenge associated with the transition, and 67.97% of farmers have heard about the government support programs, a staggering 82.81% have not yet benefited from the support programs. The effectiveness of the interventions in the context of agricultural projects would also be improved through enhancing participatory approaches via identifying the most suitable, locally preferred, resilient crops, methods, and practices, avoiding cases such as building water channels in places with no water resources without consideration of input from the concerned farmers, and the support of olive tree cultivation by the government against local preferences since some farmers did not even want olive tree cultivation (Azemzi, 2025; Azemzi & Erraoui, 2020; El Bilali et al., 2012, 2013; El Mansoum & Chfadi, 2025; Saini et al., 2023; Sethi & Sharma, 2012).

It is also important to mention the necessity of considering investing more in targeted advisory support, proactive outreach, and direct engagement for farmers based on their

specific situation to boost the effectiveness of the already implemented government support efforts, since it would be more effective than relying solely on the current methods. Although the direct transfer of information regarding subsidies or adaptive methods is human resources-intensive, the severity and urgency of the situation justify this intervention, which will also allow obtaining insights regarding the farmers' attitudes and perceptions on the challenges. However, a more robust agricultural extension system would also be necessary (El Mansoum & Chfadi, 2025; L. J. Pearson & Dare, 2021; Sraïri et al., 2011).

In conclusion, improving the effectiveness of the participatory approach will contribute to the efforts regarding the deployment of drought-resilient crop varieties while alleviating common marginalization sentiment and distrust among farmers. This will also strengthen the government-farmer cooperation, subsequently contributing to the success of the current and future agricultural plans and fostering the successful introduction and adoption of new technologies, methods, and practices.

Suggestion 3: Improving farmers' education and technology adoption

The third suggestion is also based on the in-depth interviews' insights and the questionnaire results with regard to the importance of improving technology and the level of education attained by the farmers (*H4*). The results indicated a positive association between the level of education attained by farmers and the number of practices already applied to conserve water on the farms (for water efficiency). This supports the argument for the importance of elevating the level of education and fostering efforts to reduce the illiteracy rate in rural areas, particularly among farmers (MEFM, 2019). Elevating farmers' education will positively affect their ability to self-organize and to defend their own interests, to better adapt to the current and future challenges, and to adopt a more proactive approach to farm management, including seeking and implementing new solutions, thus improving their adaptive capacity. These improvements will bolster current and future agricultural plans, including the transition to sustainable agriculture, and positively impact government-farmer cooperation and the efficiency of initiatives such as farmer field school (FFS) programs, facilitating the adoption of new technologies.

Furthermore, as the country is moving toward Agriculture 4.0, particularly with the launch of the Digital Pole of Agriculture (*Pôle d'Agriculture Digitale*) initiative in 2023, elevating the farmers' level of education, along with improving access to digital technologies in rural areas, will foster digital literacy among farmers (Benabdelouahab et al., 2024; Roberto et al.,

2025). It is also worth mentioning that there is ongoing research to overcome the illiteracy barrier faced by farmers via using voice interfaces and providing an intelligent virtual assistant, which is an attempt to democratize access to expert agronomic data (Iounousse & Temsamani, 2024). Similarly, it is crucial to invest in technologies tailored to the Moroccan agricultural context to modernize the sector and to introduce tools geared towards climate adaptation, subsequently increasing resilience in the face of the persistent water shortages.

Suggestion 4: Ensuring the alignment of food security and the agricultural export policy with the sustainability and adaptation objectives of the agriculture sector

The last suggestion is also based on the insights from in-depth interviews regarding the implications of food security and the agricultural export policy. Food sovereignty constitutes a major concern and a top priority for the government, including avoiding heavily import-dependent situations and the geopolitical concerns entailed, thereby influencing policies and decision-making. Efforts relating to the alignment of food security policy with the sustainability and adaptation objectives of the agricultural sector are fundamental in the long term to achieving strategic self-sufficiency. Additionally, sustainable agriculture offers a viable pathway to enhance productivity, improve adaptation, stabilize yield, conserve natural resources, and optimize resources in the face of climate change, persistent water shortages, and land degradation, while fostering the sector's modernization through technological adoption, which is crucial in order to reach a self-sufficient and resilient food system in Morocco (Garba, 2023; IRES, 2024; S. Islam, 2025; Rehman et al., 2022; Shanoyan et al., 2025; Sommerville et al., 2014; Zarouali, 2025).

In the same vein, there is an urgent need for the alignment of the agricultural export policy with the sustainability and adaptation objectives of the agriculture sector, considering the water scarcity conundrum. The agriculture sector is still of strategic importance and vital to the national trade balance. However, with the previous agricultural plan prioritizing agricultural intensification, more profitable and export-oriented crops, while encouraging high-input farming and monoculture, it has resulted in increased pressure on water resources. Subsequently, the current agricultural strategy is facing the challenge of maintaining export competitiveness without further compromising the water security of the country, which requires a shift to prioritizing the sustainability and adaptation of the agriculture sector, particularly with regard to promoting water use efficiency, non-conventional water sources, and resilient crops, while preventing further environmental degradation. As the mentioned

measures are practical in the short term, there is a need for decoupling from high-value crops such as watermelons and tomatoes in the long term for export purposes and investing in coordinating studies on international demand and developing a product portfolio compatible with adaptive systems (Akesbi, 2012; Azemzi, 2025; Nsiri et al., 2025).

In terms of the potential operationalization of the suggestions, they should be implemented with consideration of the current agricultural plan in the country. In addition, this would require generally around a five-year implementation roadmap for the main relevant suggestions: the first year for legal and regulatory adjustment, the second and third years for institutional capacity building, and the fourth and fifth years for nationwide scaling. With regard to fostering the deployment of drought-resilient crop varieties, as discussed previously, the relevant agricultural organizations, including SONACOS, must cooperate for a successful transition, including agricultural cooperatives and associations, with the support of the relevant financial institutions, such as Crédit Agricole Morocco Bank. The regulatory change can include the amendment of local aquifer contracts with farmers to include strict quotas on high water-consuming crops, which can be backed by satellite-based monitoring, “remote sensing”.

Concerning the improvement of the effectiveness of the participatory approach, farmers' education and technology adoption, it would involve most of the relevant agricultural organizations, with the emphasis on the role of the Chamber of Agriculture, the National Office of Agricultural Advisory, and farmers' associations and cooperatives in order to facilitate the implementation of efforts such as Digital Farmer Field Schools (DFFS) fostering peer-to-peer learning, and a knowledge transfer requirement, which will mandate knowledge sharing from the large-scale farmers who have successfully adopted sustainable methods and practices through documented technical support and trainings provided to the local farmers’ associations and cooperatives.

Regarding ensuring the alignment of food security and the agricultural export policy with the sustainability and adaptation objectives of the agriculture sector, a primary lever for change could be through applying a requirement that the agricultural exports must receive a "Water Sustainability Certificate" provided in collaboration with the Ministry of Agriculture and the Ministry of Equipment and Water, proving that these farmers are applying verified sustainable methods and practices; otherwise, the exports will have to face higher tariffs. This will compel the large-scale agricultural exporters to adhere to and contribute to the

scaling up of the adoption of sustainable methods and practices in the country. Additionally, the higher tariffs collected from non-certified exports could be redirected in order to create a fund to further subsidize drip irrigation for smallholders.

It is also important to mention that the experts from the Regional Directorate of Agriculture, Marrakesh-Safi region, also provided the following measures: the redefinition of Moroccan agricultural exports and the restriction to crops that consume less water (limit the export of citrus, tomatoes, watermelon, and melon). The ban on water-consuming crops in arid and semi-arid areas (watermelon and melon). The operationalization of the Water Police for the control and regulation of private pumping (the use of groundwater). The definition of agricultural vocations in large agricultural regions and the orientation of agriculture according to the availability of water.

In conclusion, based on the current context, fostering the transition to sustainable agricultural methods and practices necessitates further emphasis on climate change adaptation and water use efficiency in future plans. This also requires improving the effectiveness of the participatory approach, targeted farmer advisory services, and a clear articulation of the plans and initiatives with the aim of promoting successful cooperation with farmers, scaling up highly drought-resilient crop adoption, along with improving farmers' education and technology adoption, and the alignment of food security and the agricultural export policy with the sustainability and adaptation objectives of the agriculture sector. Ultimately, the mentioned measures will contribute to increasing the resilience of farmers and the agriculture sector to water shortages.

The following Figure 33 is a proposed concept that is based on the literature review, qualitative interviews, and quantitative survey results contributing to R5 of the research process. The concept's purpose is an attempt to incorporate the findings into a more concise, practical presentation and can serve as a stepping stone for future research that focuses on fostering the adaptability and sustainability of agriculture and strengthening the sector’s resilience regarding the persistent water shortages.

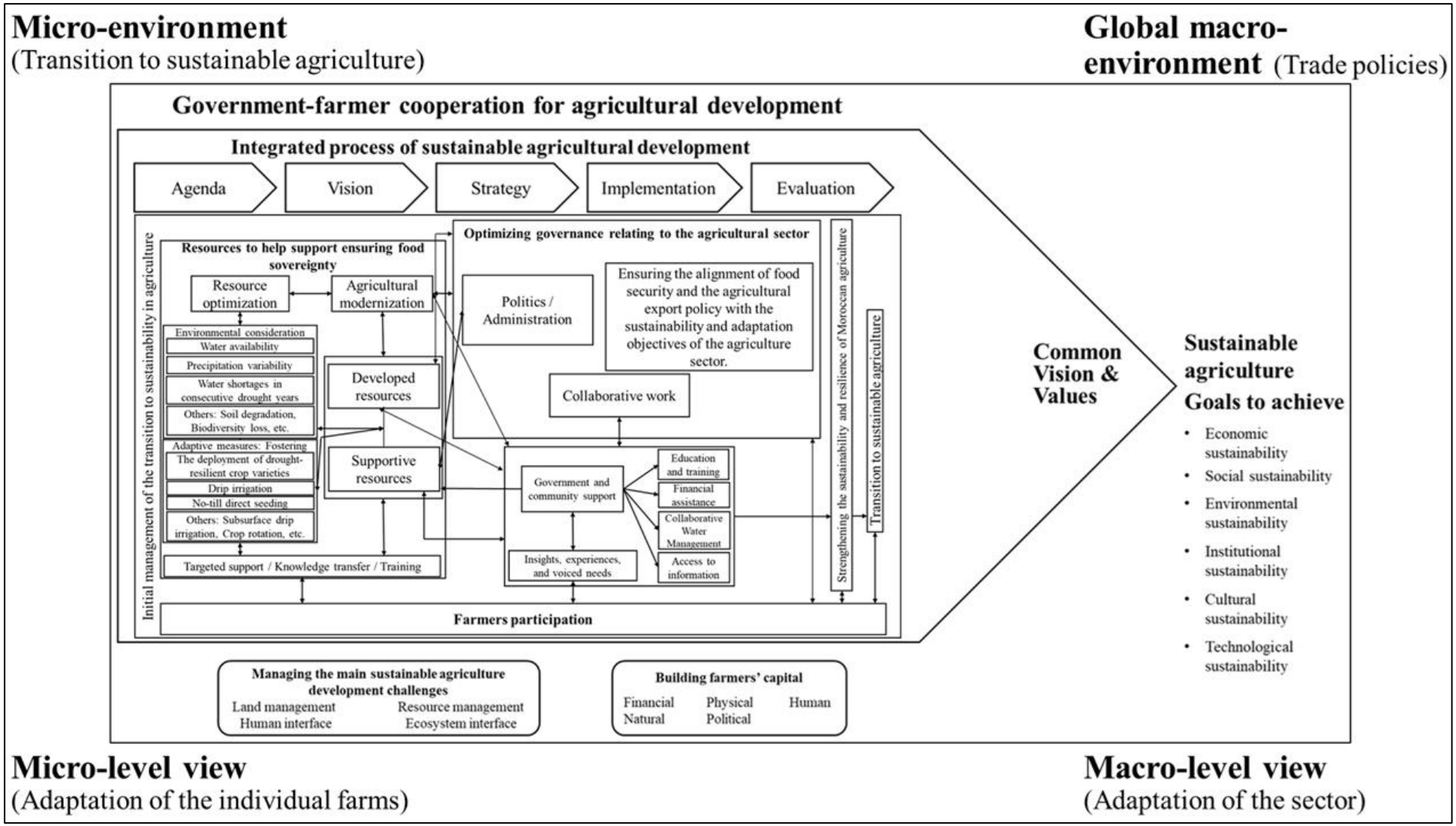

Figure 33: A balanced sustainable agricultural development concept focused on strengthening the government-farmer cooperation and the sector's resiliency regarding water shortages through fostering the transition to sustainable methods and practices

Sources: Author's own research and analysis, 2025, based on (Amparo-Salcedo et al., 2025; Aryal et al., 2024; Azemzi, 2025; Bathaei & Štreimikienė, 2023; Benayad et al., 2024; Brinkerhoff & Goldsmith, 1990; de Souza et al., 2025; El Bilali et al., 2012, 2013; El Fartassi et al., 2023, 2025; El Mansoum & Chfadi, 2025; FAO, 2018; Faysse et al., 2018; IRES, 2024; M. T. Islam & Nursey-Bray, 2017; S. Islam, 2025; Kaiss et al., 2025; MAFM, 2019, 2021; MEFM, 2019; Nsiri et al., 2025; Oyeagu & Lewu, 2025; Pfahl, 2005; Prager, 2022; Samir, 2022, 2023a, 2023c; Samir & Pappné Vancsó, 2025; Schoor et al., 2023; Shelef et al., 2018; Toumi, 2016; Velten et al., 2021; Zarouali, 2025)

The concept is an attempt to strengthen agricultural development resilience in the face of the persistent water shortages through fostering the transition to sustainable methods and practices while improving the government-farmer cooperation. It emphasizes the active participation of farmers, their involvement in the agricultural development process, and the consideration of their insightful experiences and voiced needs, which are integrated into the development of supportive resources. The improvement of farmers' participation could rely on the already existing organizations, such as the Chamber of Agriculture and the National Office of Agricultural Advisory, while focusing on fostering the scaling up of the adaptive measures and the consideration of the integration of all the sustainable agriculture dimensions. The concept also took into consideration the three priority areas discussed by the Royal Institute for Strategic Studies (IRES) to adapt the sector to water shortages, which are optimizing governance in the agricultural sector, ensuring food sovereignty, and strengthening the sustainability and resilience of Moroccan agriculture (Bathaei & Štreimikienė, 2023; IRES, 2024; Schoor et al., 2023).

It is also worth considering the investment in fostering the adoption of Integrated Pest Management (IPM), Integrated Soil Fertility Management (ISFM), and particularly Subsurface Drip Irrigation (SDI) for the optimization of irrigation. Although SDI is considered more expensive with an initial higher cost compared to Surface Drip Irrigation (the predominant method in Morocco) in the micro-irrigation classification, it enhances water redistribution through the wet bulb, prevents evaporation loss, and reduces input waste. Additionally, Surface Drip Irrigation is vulnerable to sun degradation and physical damage compared to SDI, resulting in the SDI having a relatively lower replacement frequency and making it more adaptive to arid and semiarid climates and suitable for addressing persistent water shortages over the long term (Douh & Boujelben, 2012; Lamm & Camp, 2007; Martínez & Reca, 2014).

Similarly, promoting existing practices that are deemed sustainable, including crop diversification, is equally important. Fostering existing practices, such as animal manure (64.45% of adoption) for soil fertilization, while raising the importance of the adoption of more sustainable practices is significant, particularly since 40.62% still use chemicals to maintain soil fertility. In the same vein, promoting sustainable practices relating to pest control is a necessity, since 41.79% do not use any methods, and 44.92% apply chemical control, the use of pesticides, which undermines soil health and subsequently crop quality (Zhou et al., 2025). Furthermore, it is important to consider fostering other cost-effective, adaptive, and sustainable practices, such as intercropping (3.52% of adoption) and crop rotation (9.37% of adoption), which contribute significantly to both maintaining soil fertility and pest control (Al-Musawi et al., 2025; Mir et al., 2022).

In terms of farmers' organizations, since the cooperatives were successfully incorporated in the previous and ongoing agricultural plans, as a continuation and reinforcement of current policy, they could also play an important role in fostering the active participation of farmers in extension services and strengthening government-farmer cooperation. Given that the cooperatives are assuming their roles in the implementation of the current and future agricultural development strategies, they can also contribute to scaling up the adoption of digital and adaptive methods, practices, and measures, while providing opportunities for capacity building, farmers' leadership, and a more collaborative framework between farmers and local government authorities (Y. M. Alaoui & Zouiten, 2022; Faysse et al., 2012; Ibourk & El Aynaoui, 2023; Lebdaoui, 2022).

Notably, to alleviate distrust among farmers and foster their active participation, a strategic shift from the traditional top-down governance approach in the public agricultural extension service system, which can present a barrier to the creation of mutual trust, and incorporating more collaboration elements into government-farmer cooperation would nurture a culture of mutual engagement, collective responsibility, and shared decision-making. While a top-down cooperative approach is effective for achieving specific short-term goals, such as providing subsidies for a specific crop and fostering specific behaviors, thus reinforcing a top-down, security-driven relationship, it does not cultivate a high level of accountability and ownership among farmers. An attempt to mitigate this could be through evolving Morocco's agricultural aggregation model beyond a transactional commercial framework. It is true that Morocco's agricultural aggregation model, in its attempt to solve agricultural land fragmentation, provides an opportunity for the co-creation of production plans between

aggregators, such as a large agro-industrial company offering market access and managerial capacity, and the aggregated farmers committing to producing crops and livestock. However, fostering farmer-led initiatives, farmers' empowerment, and active co-creation through the incorporation of a bottom-up approach and collaboration elements would lead to higher levels of ownership, community involvement, and reduced resistance to change. The successful incorporation of more collaboration elements into government-farmer cooperation, coupled with investment in listening forums, transparent communication, and long-term commitment, would help alleviate the marginalization sentiment and build trust over time, therefore contributing to the cultivation of a resilient and sustainable agricultural future (Ahsan et al., 2021; Akesbi, 2012; Azaguagh & El-Ayachi, 2021a; El Mansoum & Chfadi, 2025; Velten et al., 2021).

In terms of potential cooperation opportunities with other Mediterranean countries, further collaboration with Israel presents a great opportunity for Morocco to further foster the modernization of the sector, agricultural knowledge, and technology transfer. Beyond the geopolitical calculations and regional normalization, the Morocco-Israel relationship is considered historical due to a significant number of the Moroccan Jewish population that migrated to Israel in the last century (Ben-Meir et al., 2022; MITVIM, 2018). Moroccan policy is also oriented towards economic development purposes, such as the country's involvement in the 2022 Negev Summit, which focused on economic challenges associated with climate change, water shortages, and food and energy security, with participation from the United States, Israel, Bahrain, and the United Arab Emirates. Since the normalization, Moroccan-Israeli cooperation has expanded more into agriculture, water, military, and renewable energy. Additionally, the exports from Israel to Morocco increased significantly, rising from $3.9 million in 2019 to $30 million in 2021 and reaching $94.94 million in 2024 (Maghraoui, 2025; UN Comtrade, 2025).

As Morocco and Israel are both Mediterranean nations, they are considered to share similarities in climate, particularly in terms of arid and semi-arid conditions. Israel's agriculture is also recognized as developed and highly technologically advanced, particularly in terms of water management and water use efficiency, driven by the necessity to overcome water scarcity. The Morocco-Israel cooperation constitutes a great opportunity for Morocco to benefit from the Israeli experience as a key partner in international agricultural development. This partnership would help foster the transition to more adapted and sustainable agriculture through knowledge, technology, and expertise transfer,

particularly in terms of smart agriculture, precision farming, drip irrigation, agri-biotechnology, subsurface drip irrigation (SDI), and the use of alternative water resources. The potential cooperation in agriculture was even discussed in the 2018 report published by the Israeli Institute for Regional Foreign Policies, showing the strategic potential of this partnership, with the greenhouse technology and drip irrigation already imported to Morocco, notably with the establishment of the Israeli Netafim company in 2017 in Morocco, specializing in irrigation through drip systems. The partnership has already gained momentum, specifically within the agriculture sector. Furthermore, the cooperation will bolster the existing initiatives and adaptation efforts already implemented by the Moroccan government (Chtatou, 2023; Girel, 2025; MITVIM, 2018).

The following Table 38 offers a comparative perspective on Morocco and two other North African countries, with the aim of providing a general regional context and comparative insights.

Table 38: Comparative insights into the hydrological and economic contexts of Morocco, Egypt, and Tunisia

Comparative dimensions	Morocco	Egypt	Tunisia
Water resources dependency context	High pluviometric dependency (surface dams and aquifers)	Riparian (the Nile River basin)	Groundwater-dominant (precipitation and aquifers)
Major vulnerability	Pluviometric volatility (precipitation and water shortages)	Geopolitical transboundary inflow	Aquifer depletion and salinization
Agricultural GDP contribution	~13%	~13%	~9%
Agricultural labor	High around ~35%	High around ~32%	Low around ~15%
Economic diversity	Moderate (more agriculturally dependent)	More diversified and industrial	Highly diversified
General export profile	High water-intensity crops (e.g., citrus, watermelon, and avocado)	Mixed (e.g., grains, cotton, and fruits)	Low water-intensity crops compared to Morocco (e.g., olive oil and fish)

Resilience challenges	Strategic water adjustment in exports	Geopolitical water security (due to shared transboundary basin dependency)	Aquifer depletion and salinity

Sources: (El Fartassi et al., 2023; ETF, 2021; Intikhab, 2017; MAFM, 2021; Martín et al., 2017; Satoh & Aboulroos, 2017; Thabet et al., 2024; Trabelsi et al., 2007)

In terms of comparative insights with other North African countries, namely Egypt and Tunisia, while Egypt is also facing acute water shortages, its agriculture is structured toward a major river system (the Nile River), whereas Morocco relies more on surface dams and aquifers. This emphasizes that while sustainable practices such as drip irrigation are universally applicable, the reality is that the political economy of water allocation in Egypt and Morocco is fundamentally different; it varies dramatically based on the water source (Egypt is river-basin-based, while Morocco is more pluviometric-dependent).

In the same vein, agriculture in Morocco is more important in terms of livelihood dependency compared to Tunisia with regard to the scale and importance. Additionally, Tunisia's agricultural export is structured around lower water-intensity crops compared to the prevalence of higher water-intensity crops in Morocco. Nevertheless, the insights and the findings presented in the study, such as the relevance of fostering the deployment of drought-resilient crop varieties or improving the effectiveness of the participatory approach, can serve as a stepping stone for future research that focuses on fostering the adaptability and sustainability of agriculture and strengthening the sector's resilience regarding the persistent water shortages in the other countries of the region.

The subchapter aimed to present suggestions and recommendations that were based on the literature review, the qualitative interviews, and the quantitative survey results. The recommendations were mainly organized into four main suggestions, followed by presenting a concept adapted to the country's agricultural development context, emphasizing the adaptation and fostering the transition to sustainable agricultural methods and practices to increase the resiliency facing water shortages. The next chapter presents the scientific results, professional implications, and further research opportunities related to the study.

5. NEW SCIENTIFIC RESULTS AND FUTURE RESEARCH

Finally, the dissertation furnishes the following: *R6: Scientific results*, *R7: Contribution and professional implications*, and *R8: Further research opportunities* that stem from the work.

5.1. SCIENTIFIC RESULTS

The dissertation has highlighted several challenges and potentials that warrant consideration when researching the enhancement of agricultural development resilience amidst persistent water shortages in Morocco, specifically related to the Marrakesh-Safi region, through the transition to sustainable agricultural methods and practices. The following section discusses the main findings of the current work and provides its scientific contribution, *R6: Scientific results*.

Both qualitative interviews and the quantitative survey were conducted in the Marrakesh-Safi region, as it is considered the largest region in terms of agricultural land surface (see Table 2, page 27). The population gap and empirical gap were also identified from the socio-economic research field relating to agricultural development and sustainability in the face of water shortages in this particular region, which was discussed in the introduction chapter of the study (Miles, 2017; Müller-Bloch & Kranz, 2015; Robinson et al., 2011). Consequently, the specific scientific outcomes are mainly related and based on the collected data from the main agricultural region. However, they also reflect the state of the agriculture sector in the country and could be extrapolated to other regions with comparable socio-economic, environmental, and climatic conditions. The new scientific findings were organized into the following three parts.

New scientific findings 1:

According to my research results and based on the results from the qualitative part of the research, specifically related to the Marrakesh-Safi region, the following findings constitute the first outcomes of the study:

1. Policy making must incorporate an effective participatory approach, where the government consistently takes into account farmers' experiences in the field. An effective participatory approach will contribute to the efficiency of the agricultural development projects in reaching their goals and closing the gap between the government’s goals and the farmers' interests.

2. The agricultural export policy must align with the national interests of supporting the transition to a sustainable agricultural development strategy.
3. Assuring food security, even if it is considered one of the top priorities and concerns for the government, should not be to the detriment of a long-term adaptation of the agricultural sector and its resiliency to climate variability, drought, and with regard to water resources availability.

New scientific findings 2:

According to my research results, based on the previous findings and the quantitative part of the research, specifically related to the Marrakesh-Safi region, the following constitute the second outcomes of the study:

1. Drought, as a key issue, is substantiated not only by the insights of the interviewees from different relevant organizations, including governmental ones, but also by farmers who are directly confronted with the situation.
2. Farmers are inclined to cooperate in adopting and transitioning to sustainable agriculture practices if it is intended to help tackle the prevalence of drought challenges and adapt to climate change.
3. The prevailing adaptive strategy among farmers facing drought and general water shortages is the increase in water abstraction. At the same time, this trend is unfortunately coupled with less efficient irrigation practices. A critical barrier is the underestimation of the farmers' training, as well as the insufficient consideration of water distribution management and the adoption of more efficient irrigation practices that would enhance their long-term agricultural resilience regarding the issue.
4. The results appear to be significantly influenced by climate variability and the inadequate distribution of precipitation in the last five years, including a strong positive association between the number of observed climate change consequences dealt with on the farms and how strongly climate change as a factor is influencing the decision to adopt sustainable agriculture practices.
5. A moderate positive association was identified between how many of the practices already applied on the farm for water conservation and the decision to adopt sustainable agriculture practices, with the improvement of water use efficiency as a key influencing factor. As a result, the extent of the farmers' existing commitment to

water conservation may be acting as a positive reinforcement, which could be due to a perception gap between adopters and non-adopters of water conservation methods.

6. Besides the lack of infrastructure and fragmentation of the farm, the costs of the transition constitute the common denominator challenge to implementing sustainable agriculture practices perceived by farmers.
7. The availability of support from the government or other proposed organizations does not necessarily influence the decision to adopt sustainable agriculture practices. Similarly, it is safe to assume that the government's financial support programs are not necessarily a decisive factor in the decision to adopt sustainable agricultural practices, nor are they associated with whether the farm previously benefited from any governmental support.
8. While the data indicate that farmers have a common view that financial resources can instigate change, it appears that there is a lack of trust in the efficacy of subsidies. This may reflect not only poor access but also signal a plausible lack of trust among farmers in the institutions and subsidy mechanisms, given the previous findings imply a certain degree of common marginalization sentiment and the need for an effective participatory approach. And could explain the disparity between farmers' need for financial resources and their inability or reluctance to access the existing subsidy mechanisms.
9. Improving educational attainment and reducing illiteracy among farmers and rural communities will not only be favorable for development but also will likely lead to increased adoption of efficient water conservation methods and practices in the face of water shortages. This entails that farmers will likely seek and implement new solutions instead of relying only on traditional methods, since they may have better access to information and be more inclined to seek out information on new technologies and conservation methods.

New scientific findings 3:

The last part consists of the provided suggestions, according to my research results, specifically based on the previous findings in the Marrakesh-Safi region, which were consolidated under the following four primary areas: Fostering the deployment of drought-resilient crop varieties; improving the effectiveness of the participatory approach and targeted farmer advisory services; improving farmers' education and technology adoption;

and ensuring the alignment of food security and the agricultural export policy with the sustainability and adaptation objectives of the agriculture sector.

The research also proposed the following concept (Figure 34), which is an attempt to incorporate the findings into a more concise, practical presentation, with the focus on fostering the adaptability and sustainability of agriculture and strengthening the government-farmer cooperation to increase the sector's resilience regarding the persistent water shortages.

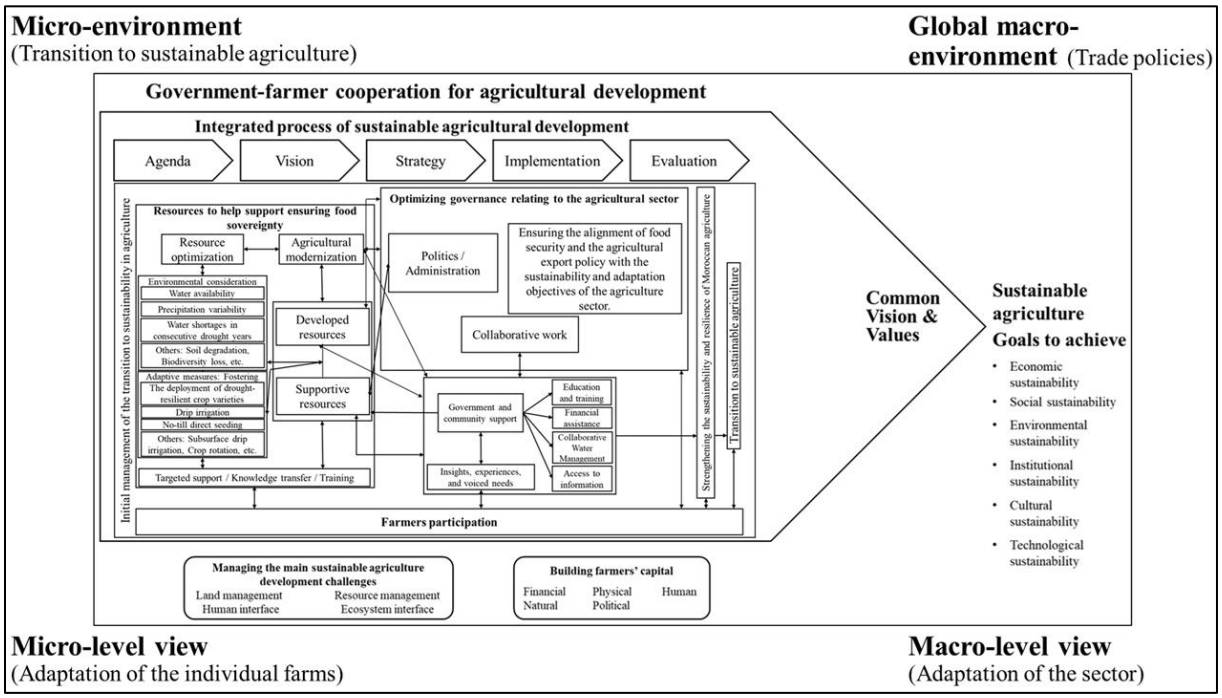

Figure 34: A balanced sustainable agricultural development concept focused on strengthening the government-farmer cooperation and the sector's resiliency regarding water shortages through fostering the transition to sustainable methods and practices (small version)

Source: Please find the large version of the concept with all sources on page 144.

The study also discussed other suggestions relating to sustainable agricultural methods and practices suitable for the Moroccan context; the potential role of cooperatives in fostering the active participation of farmers in extension services and strengthening the government-farmer cooperation; the relevance of the incorporation of more collaboration elements into government-farmer cooperation; and the potential of further cooperation opportunities with Israel to advance the modernization of the sector, agricultural knowledge, and technology

transfer, with the purpose of transitioning to more adapted and sustainable agriculture facing the persistent water shortages.

5.2. PROFESSIONAL IMPLICATIONS

Based on the findings presented in the study, outcomes for practical implementation can be formulated. Accordingly, the result *R7: Contribution and professional implications* was achieved.

The following are the relevant professional implications derived from the findings with regard to the transition to sustainable agricultural methods and practices and the enhancement of agricultural development resilience amidst persistent water shortages:

- Policy making must incorporate an effective participatory approach, where the government consistently takes into account farmers' experiences in the field.
- Besides the lack of infrastructure and fragmentation of the farm, the costs of the transition constitute the common denominator challenge to implementing sustainable agriculture practices perceived by farmers. While the data indicate that farmers have a common view that financial resources can instigate change, it appears that there is a lack of trust in the efficacy of subsidies, including a certain degree of common marginalization sentiment, implying the need for improving the effectiveness of the participatory approach, targeted farmer advisory services, and the incorporation of more collaboration elements into government-farmer cooperation.
- The agricultural export and food security policies must align with the national interests of supporting the transition to a sustainable agricultural development strategy.
- Farmers are inclined to cooperate in adopting and transitioning to sustainable agriculture practices if it is intended to help tackle the prevalence of drought challenges and adapt to climate change, implying that the emphasis on these elements in the communication will contribute to scaling up the adoption of sustainable methods and practices, including the deployment of drought-resilient crop varieties.
- The extent of the farmers' existing commitment to water conservation may be acting as a positive reinforcement for the decision to adopt sustainable agriculture practices, with the improvement of water use efficiency as a key influencing factor. This implies a positive trajectory and suggests an opportunity to encourage the adoption of broader adaptive sustainable practices.

- The prevailing adaptive strategy among farmers facing drought and general water shortages is the increase in water abstraction. At the same time, this trend is unfortunately coupled with less efficient irrigation practices. A critical barrier is the underestimation of the farmers' training, as well as the insufficient consideration of water distribution management and the adoption of more efficient irrigation practices that would enhance their long-term agricultural resilience in the face of the persistent water shortages. This entails the need for further efforts to raise awareness among farmers about the mentioned issues and provide the necessary training and support regarding water management.
- Improving educational attainment and reducing illiteracy among farmers and rural communities will not only be favorable for development but also will likely lead to increased adoption of efficient water conservation methods and practices in the face of water shortages.
- Cooperation with other Mediterranean countries, such as Israel, presents a great opportunity to further foster the modernization of the sector, as well as agricultural knowledge and technology transfer.

5.3. GENERAL PROSPECTS AND FURTHER RESEARCH OPPORTUNITIES

Based on the research findings, other research opportunities were discussed. Therefore, the result *R8: Further research opportunities* was achieved.

The following are the proposed main areas relating to the study for further research opportunities:

Research regarding the alignment of food security and the agricultural export policy with the agricultural sector's sustainability and adaptation objectives would be beneficial for future policymaking concerning the water-food-export nexus.

Notably, further research regarding water management efficiency, precision agriculture, and highly drought-tolerant crop varieties is similarly strongly recommended.

More research with regard to farmers' engagement, empowerment, extension services, and participatory approaches would be beneficial for the current Moroccan context.

There are also further research opportunities to be emphasized concerning the potential to enhance cooperation with other Mediterranean countries, particularly Israel, for the purpose

of knowledge and technology transfer and the modernization and adaptation of the agricultural sector.

Importantly, research regarding the socio-economic and geographical barriers that could hinder the efforts of raising the education level and reducing illiteracy in rural areas would be beneficial and a strategic necessity for both agricultural modernization and sustainable rural development.

A further recommendation is that in the near future, it will be necessary to also support research regarding the quality of life in rural areas. This is not only to prevent a serious rural exodus but also to positively impact agricultural development through youth engagement and labor retention, social and physical infrastructure's operational efficiency, and fostering rural residents with a secure livelihood, who will be better positioned to invest in sustainable agriculture.

6. SUMMARY AND CONCLUSION

The present work sought to answer the research question: *How can the transition to sustainable agriculture be effectively fostered to enhance agricultural development resilience in Morocco amidst persistent water shortages?* To this end, it was divided into four sub-questions: Sub-question 1 explored Morocco's past and current agricultural development status concerning the sustainability aspects of this sector and water resources. Sub-question 2 examined mainly farmers' views on sustainable agriculture solutions, the perceived challenges associated with this transition, and how farmers cope with and adapt to water shortages. Sub-question 3 examined the institutions' views and their contributions to Morocco's transition to sustainable agriculture, as well as the perceived hindrances to this transition. Sub-question 4 addressed possible and appropriate sustainable strategies, methods, and practices to enhance the resilience of agricultural development facing water shortages and proposed a preliminary concept pertaining to this challenge (see page 144).

To address the main research question, a 6-step research design was selected, which relied on performing a literature review, qualitative interviews, and a quantitative survey (see page 21). Based on the literature review and qualitative interviews, the hypotheses were generated, which were subsequently tested using data from the conducted survey (see page 126).

The literature review was structured around the research questions and focused on the topics of (1) rural and agricultural development, (2) climate change and water resources, and (3) sustainable agricultural development. The results indicate that drought and, particularly, water shortages constitute a major challenge and threat to agricultural development for this decade and the following. Similarly, the drought, as a key issue, is substantiated not only by the reviewed literature and the insights of the interviewees from the in-depth interviews conducted, but also by farmers who are directly confronted with the situation based on the survey findings. The results also indicate that there is a potential distrust and common marginalization sentiment among farmers toward organizations, particularly governmental ones. The illiteracy, low level of education, and low technology adoption also constitute important challenges for the sector's development and its transition to sustainable practices. Additionally, the results imply that improving educational attainment and reducing illiteracy among farmers and rural communities will not only be favorable for development but also will likely lead to increased adoption of efficient water conservation methods and practices

in the face of water shortages. It is also evident that more effort needs to be made to consider farmers' experience and voiced needs in both research and decision-making, and improving the effectiveness of the participatory approach and targeted farmer advisory services was suggested to increase the efficiency of the already implemented efforts. Furthermore, the results indicate the need for the alignment of food security policies and the transition to sustainable agriculture, which could be based on the principles of Sustainable Food and Agriculture (SFA) established by the Food and Agriculture Organization (FAO), and the alignment of the agricultural export policies with the national interests of supporting this transition.

The findings also revealed that farmers are inclined to cooperate in adopting and transitioning to sustainable agriculture practices if it is intended to help tackle the prevalence of drought challenges and adapt to climate change. Additionally, it can be stated that the prevailing adaptive strategy among farmers facing drought and general water shortages is the increase in water abstraction. At the same time, this trend is unfortunately coupled with less efficient irrigation practices. Furthermore, a moderate positive association was identified between how many of the practices already applied on the farm for water conservation and the decision to adopt sustainable agriculture practices, with the improvement of water use efficiency as a key influencing factor. As a result, the extent of the farmers' existing commitment to water conservation may be acting as a positive reinforcement, which could be due to a perception gap between adopters and non-adopters of water conservation methods. Moreover, out of the proposed potential challenges to implementing sustainable practices, costs constitute the common denominator in the sub-regions where the survey was conducted, even though the availability of support, including financial support, from the government or other proposed institutions does not necessarily influence the decision to adopt sustainable practices.

To convey the research findings and translate them into a discourse that is relevant to both practice and science, based on the findings, the proposed suggestions cover four main areas: fostering the deployment of drought-resilient crop varieties, improving the effectiveness of the participatory approach and targeted farmer advisory services, improving farmers' education and technology adoption, and ensuring the alignment of food security and the agricultural export policy with the sustainability and adaptation objectives of the agriculture sector. Finally, a proposed concept was presented as a culmination of all findings related to agricultural sustainability, adaptation, and resilience to water shortages, particularly to foster

government-farmer cooperation. On the one hand, the concept provides a basis for future research, and on the other hand, it can act as the groundwork for practical implementation in future plans and decision-making.

The dissertation's final chapter presented the scientific contribution, the practical implications, and general prospects and further research opportunities arising from the findings (see page 150). Finally, it should be noted that the greatest research and development potential is perceived in the discourse and the application of the adaptive measures, along with economic, social, environmental, institutional, cultural, and technological dimensions of sustainable development premises, to ensure the resilience of agriculture to water shortages in the long term. It is concluded that sustainability in the sector can only be achieved if there is an effective commitment to this transition and the existing social, structural, and export policy hurdles are overcome.

7. References:

Abdessadak, J., & Zeggaf Tahiri, A. (2025). Innovative Solutions to Water Scarcity in Moroccan Agriculture: A Decision Framework for Evaluating Criteria. In M. Ezziyyani, J. Kacprzyk, & V. E. Balas (Eds.), *International Conference on Advanced Intelligent Systems for Sustainable Developent (AI2SD 2024)* (pp. 955–969). Springer Nature Switzerland. https://doi.org/10.1007/978-3-031-91337-2_84

Adeyinka, A. A., Kath, J., Nguyen-Huy, T., Mushtaq, S., Souvignet, M., Range, M., & Barratt, J. (2022). Global disparities in agricultural climate index-based insurance research. *Climate Risk Management*, *35*, 100394. https://doi.org/10.1016/j.crm.2022.100394

Agbicodo, E. M., Fatokun, C. A., Muranaka, S., Visser, R. G. F., & Linden van der, C. G. (2009). Breeding drought tolerant cowpea: Constraints, accomplishments, and future prospects. *Euphytica*, *167*(3), 353–370. https://doi.org/10.1007/s10681-009-9893-8

Aguilera, E., Reyes-Palomo, C., Díaz-Gaona, C., Sanz-Cobena, A., Smith, P., García-Laureano, R., & Rodríguez-Estévez, V. (2021). Greenhouse gas emissions from Mediterranean agriculture: Evidence of unbalanced research efforts and knowledge gaps. *Global Environmental Change*, *69*, 102319. https://doi.org/10.1016/j.gloenvcha.2021.102319

Ahsan, D., Brandt, U. S., & Faruque, H. (2021). Local agricultural practices to adapt with climate change. Is sustainability a priority? *Current Research in Environmental Sustainability*, *3*, 100065. https://doi.org/10.1016/j.crsust.2021.100065

Akesbi, N. (2012). Une nouvelle stratégie pour l'agriculture marocaine: Le «Plan Maroc Vert». *New Medit, A Mediterranean Journal of Economics, Agriculture and Environment, 2012 n. 2*, *New Medit, Vol 11, nn. 2, (June 2012), pp. 12–23*(2012 n. 2), 12.

Akram, M. Z., Libutti, A., & Rivelli, A. R. (2024). Drought Stress in Quinoa: Effects, Responsive Mechanisms, and Management through Biochar Amended Soil: A Review. *Agriculture*, *14*(8), 1418. https://doi.org/10.3390/agriculture14081418

Alami, A. E. (2025). La Sécheresse de 2018-2025 au Maroc: Impacts sur les ressources en eau et rôle de l'IA dans la préservation des ressources et l'adaptation aux changements climatiques. *Revue de l'Intelligence Artificielle et du développement territorial durable*, *1*(02), 264–285.

Alaoui, M. (2013). Water Sector in Morocco: Situation and Perspectives. *Journal of Water Resources and Ocean Science*, *2*(5), Article 5. https://doi.org/10.11648/j.wros.20130205.18

Alaoui, Y. M., & Zouiten, M. (2022). Du coopérativisme au Maroc: Évolution, contraintes et opportunités. *Revue Française d'Economie et de Gestion*, *3*(11). https://www.revuefreg.fr/index.php/home/article/view/901

Al-Musawi, Z. K., Vona, V., & Kulmány, I. M. (2025). Utilizing Different Crop Rotation Systems for Agricultural and Environmental Sustainability: A Review. *Agronomy*, *15*(8), 1966. https://doi.org/10.3390/agronomy15081966

Amamou, A. (2024). For resilient cereal production in the context of climate change: A genetic and agronomic option. *African and Mediterranean Agricultural Journal - Al Awamia*, (143), 67–80. https://doi.org/10.34874/IMIST.PRSM/afrimed-i143.48161

Ameer, M. (2024). Drought-Resistant Crops: A Sustainable Solution To Climate Change. *International Research Journal of Plant Science*, 1–3. https://doi.org/http:/dx.doi.org/10.14303/irjps.2024.32

Amiri, N., Lahlali, R., Amiri, S., EL Jarroudi, M., Khebiza, M. Y., & Messouli, M. (2021). Development of an Integrated Model to Assess the Impact of Agricultural Practices and Land Use on Agricultural Production in Morocco under Climate Stress over the Next Twenty Years. *Sustainability*, *13*(21), Article 21. https://doi.org/10.3390/su132111943

Amparo-Salcedo, M., Pérez-Gimeno, A., & Navarro-Pedreño, J. (2025). Water Security Under Climate Change: Challenges and Solutions Across 43 Countries. *Water*, *17*(5), Article 5. https://doi.org/10.3390/w17050633

Antwi-Agyei, P., & Stringer, L. C. (2021). Improving the effectiveness of agricultural extension services in supporting farmers to adapt to climate change: Insights from northeastern Ghana. *Climate Risk Management*, *32*, 102319. https://doi.org/10.1016/j.crm.2021.100304

Apparicio, P., & Gelb, J. (2023). *Méthodes quantitatives en sciences sociales: Un grand bol d'R*. Institut national de la recherche scientifique. https://doi.org/10.5281/zenodo.10407775

Apraku, A., Morton, J. F., & Apraku Gyampoh, B. (2021). Climate change and small-scale agriculture in Africa: Does indigenous knowledge matter? Insights from Kenya and South Africa. *Scientific African*, *12*, e00821. https://doi.org/10.1016/j.sciaf.2021.e00821

Archer, E., Mukhala, E., Walker, S., Dilley, M., & Masamvu, K. (2007). Sustaining agricultural production and food security in Southern Africa: An improved role for climate prediction? *Climatic Change*, *83*(3), 287–300. https://doi.org/10.1007/s10584-006-9192-5

Aryal, J. P., Rahut ,Dil B., Sonobe ,Tetsushi, Tortajada ,Cecilia, & and Chhay, P. (2024). Water resource management in agriculture for achieving food and water security in Asia. *International Journal of Water Resources Development*, *40*(3), 319–322. https://doi.org/10.1080/07900627.2024.2332222

Ashraf, M. (2010). Inducing drought tolerance in plants: Recent advances. *Biotechnology Advances*, *28*(1), 169–183. https://doi.org/10.1016/j.biotechadv.2009.11.005

Atkinson, C. (2017). *Rural Development*. https://doi.org/10.1007/978-3-319-31816-5_1014-1

Atkinson, C. L., & Atkinson, A. M. (2023). Impacts of Climate Change on Rural Communities: Vulnerability and Adaptation in the Global South. *Encyclopedia*, *3*(2), Article 2. https://doi.org/10.3390/encyclopedia3020052

Azaguagh, I., & El-Ayachi, M. (2021a). Agricultural Land Management in Morocco: "Anti-commons" and sustainable development. *African Journal on Land Policy & Geospatial Sciences*, *4*(5), 730. https://doi.org/10.48346/IMIST.PRSM/ajlp-gs.v4i5.26065

Azaguagh, I., & El-Ayachi, M. (2021b). Management du Foncier agricole au Maroc 'Anti-commons' et développement durable. *African Journal on Land Policy and Geospatial Sciences*, *4*(5), 730–751. https://doi.org/10.48346/IMIST.PRSM/ajlp-gs.v4i5.26065

Azemzi, H. (2025). Governance and policy approaches for addressing water scarcity: Insights from Morocco. *Euro-Mediterranean Journal for Environmental Integration*, *10*(4), 2431–2442. https://doi.org/10.1007/s41207-025-00768-4

Azemzi, H., & Erraoui, E. H. (2020). Irrigation water management and collective action: Understanding the shift from community management to participatory management in Souss-Massa (Morocco). *Euro-Mediterranean Journal for Environmental Integration*, *6*(1), 1. https://doi.org/10.1007/s41207-020-00207-6

Babbie, E. R. (1992). *The Practice of Social Research*. Wadsworth Publishing Company.

Babbie, E. R. (2013). *The Practice of Social Research, 13th Edition*. Wadsworth Cengage Learning.

Baraj, B., Mishra, M., Sudarsan, D., Silva, R. M. da, & Santos, C. A. G. (2024). Climate change and resilience, adaptation, and sustainability of agriculture in India: A bibliometric review. *Heliyon*, *10*(8). https://doi.org/10.1016/j.heliyon.2024.e29586

Bates, B., Kundzewicz, Z., & Wu, S. (2008). *Climate Change and Water*. Intergovernmental Panel on Climate Change Secretariat. https://www.taccire.sua.ac.tz/handle/123456789/552

Bathaei, A., & Štreimikienė, D. (2023). Renewable Energy and Sustainable Agriculture: Review of Indicators. *Sustainability*, *15*(19), 14307. https://doi.org/10.3390/su151914307

Bayed, N., Benrezzouq, N., & Ghanmate, H. (2025). Repenser le mode de gouvernance de la pénurie hydrique: Nécessité ou option au Maroc ? *Revue Internationale de la Recherche Scientifique (Revue-IRS)*, *3*(3), 2316–2324. https://doi.org/10.5281/zenodo.15462285

Belete, T., & Yadete, E. (2023). Effect of Mono Cropping on Soil Health and Fertility Management for Sustainable Agriculture Practices: A Review. *Journal of Plant Sciences*, *11*(6), Article 6. https://doi.org/10.11648/j.jps.20231106.13

Belloulid, M. O. (2018). National Program of Sanitation and Wastewater Treatment in Morocco: Objectives, Achievements and Challenges. *Environmental and Water Sciences, public Health and Territorial Intelligence Journal*, *2*(1), Article 1. https://doi.org/10.48421/IMIST.PRSM/ewash-ti-v2i1.10956

Benabdelouahab, T., Elaissaoui, A., Lionboui, H., Mouaaid, A., Elame, F., Ismaili, M., Touzani, M., Bouslihim, Y., & Alami, I. T. (2024). Enhancing Agricultural Resilience in the Digital Era: The Benefits and Limitations of Digital Agriculture. *African and Mediterranean Agricultural Journal - Al Awamia*, (143), 201–217. https://doi.org/10.34874/IMIST.PRSM/afrimed-i143.48172

Benassi, M. (2008). Drought and climate change in Morocco. Analysis of precipitation field and water supply. *Options Méditerranéennes. Série A : Séminaires Méditerranéens (CIHEAM)*, *Drought management: scientific and technological innovations*(80), 83–86.

Benayad, A., Bikri, S., Hindi, Z., Lafram, A., Belfakira, C., Yassif, F.-Z., El Bilali, H., & Aboussaleh, Y. (2024). Transition toward Sustainability in the Moroccan Food System: Drivers, Outcomes, and Challenges. *World*, *5*(3), Article 3. https://doi.org/10.3390/world5030032

Benbahria, Z., Sebari, I., Hajji, H., & Smiej, M. (2021). *Apport des algorithmes d'apprentissage supervisé pour la cartographie intelligente des zones irriguées à partir des images satellite à haute résolution spatiale*.

Benďáková, V., Nagy, H., Turčeková, N., Adamičková, I., & Bielik, P. (2024). Assessing the Climate Change Impacts on Maize Production in the Slovak Republic and Their Relevance to Sustainability: A Case Study. *Sustainability*, *16*(13), Article 13. https://doi.org/10.3390/su16135573

Ben-Meir, Y. (2019). Empowering Rural Participation and Partnerships in Morocco's Sustainable Development. *Journal of Global Initiatives: Policy, Pedagogy, Perspective*, *14*(2). https://digitalcommons.kennesaw.edu/jgi/vol14/iss2/13

Ben-Meir, Y., Skalski-Fouts, J., & Hernandez, E. (2022). Agricultural Development as an Interfaith Bridge in Morocco. *Peace Review*, *34*(1), 120–130. https://doi.org/10.1080/10402659.2022.2023439

Berbeć, A. K. (2024). Agricultural resilience and agricultural sustainability – which is which? *Current Agronomy*, *53*(1), 10–22. https://doi.org/10.2478/cag-2024-0002

Berg, B. L. (2001). *Qualitative Research Methods for the Social Sciences*. Allyn and Bacon.

Biswas, A., Sarkar, S., Das, S., Dutta, S., Choudhury, M. R., Giri, A., Bera, B., Bag, K., Mukherjee, B., Banerjee, K., Gupta, D., & Paul, D. (2025). Water scarcity: A global hindrance to sustainable development and agricultural production – A critical review of the impacts and adaptation strategies. *Cambridge Prisms: Water*, *3*, e4. https://doi.org/10.1017/wat.2024.16

Blair, J., Czaja, R. F., & Blair, E. A. (2014). *Designing Surveys: A Guide to Decisions and Procedures* (3rd edition). SAGE Publications, Inc. https://doi.org/10.4135/9781071909904

Bogner, A., Littig, B., & Menz, W. (2009). *Interviewing Experts*. Palgrave Macmillan UK.

Bolan, S., Padhye, L. P., Jasemizad, T., Govarthanan, M., Karmegam, N., Wijesekara, H., Amarasiri, D., Hou, D., Zhou, P., Biswal, B. K., Balasubramanian, R., Wang, H., Siddique, K. H. M., Rinklebe, J., Kirkham, M. B., & Bolan, N. (2024). Impacts of climate change on the fate of contaminants through extreme weather events. *Science of The Total Environment*, *909*, 168388. https://doi.org/10.1016/j.scitotenv.2023.168388

Boularbah, S., Hammani, A., Bouarfa, S., & Kuper, M. (2017). Analyse de la première expérience de reconversion collective vers l'irrigation localisée: Cas du secteur pilote de Tadla. *Revue Marocaine des Sciences Agronomiques et Vétérinaires*, *5*(1), 76–82.

Bouslihim, A., & Torra, M. (2020). Problématique des ressources en eau au Maroc. *Journal d'Economie, de Management, d'Environnement et de Droit*, *3*(3), Article 3. https://doi.org/10.48398/IMIST.PRSM/jemed-v3i3.25037

Boutagayout, A., Hamdani, A., Boutgayout, I., & Adiba, A. (2025). Towards sustainable water management in Morocco: Assessing resources, challenges, and adaptation strategies. *Frontiers in Sustainable Food Systems*, *9*. https://doi.org/10.3389/fsufs.2025.1666555

Brinkerhoff, D. W., & Goldsmith, A. A. (1990). *Institutional Sustainability in Agriculture and Rural Development: A Global Perspective*. Bloomsbury Academic.

Bryant, A., Charmaz, K., & Morse, J. M. (2007). Sampling in Grounded Theory. In *The SAGE Handbook of Grounded Theory* (pp. 229–244). SAGE Publications Ltd. https://doi.org/10.4135/9781848607941

Bryman, A., & Bell, E. (2011). *Business Research Methods 3e*. OUP Oxford.

Burck, J., Uhlich, T., Bals, C., Höhne, N., Nascimento, L., Tavares, M., & Strietzel, E. (2022, November 14). *The Climate Change Performance Index 2023: Results*. Climate Action Network, Germanwatch e.V., NewClimate Institute. https://ccpi.org/wp-content/uploads/CCPI-2023-Results-3.pdf

Burck, J., Uhlich, T., Bals, C., Höhne, N., Wong, J., de Villafranca, M. J., & Hambrecht, L. (2025, November 18). *The Climate Change Performance Index 2026: Results*. Climate Action Network, Germanwatch e.V., NewClimate Institute. https://ccpi.org/download/climate-change-performance-index-2026/

CESE. (2017). *Développement du monde rural, défis et perspectives*. Economic, Social and Environmental Council of Morocco. ISBN: 978-9954-635-33-9. ISSN: 2335-9234. https://www.cese.ma/docs/developpement-du-monde-rural-defis-et-perspectives/

Chambers, R. (2013). *Rural Development: Putting the last first*. Routledge. https://doi.org/10.4324/9781315835815

Chandra, A., McNamara, K. E., & Dargusch, P. (2017). The relevance of political ecology perspectives for smallholder Climate-Smart Agriculture: A review. *Journal of Political Ecology*, *24*(1), Article 1. https://doi.org/10.2458/v24i1.20969

Chartzoulakis, K., & Bertaki, M. (2015). Sustainable Water Management in Agriculture under Climate Change. *Agriculture and Agricultural Science Procedia, Efficient Irrigation Management and Its Effects in Urban and Rural Landscapes*, *4*, 88–98. https://doi.org/10.1016/j.aaspro.2015.03.011

Chromý, P., Jančák, V., Marada, M., & Havlíček, T. (2011). Rural Areas – Living Space: Regional Differences in the Perceptions of Representatives of Rural Municipalities in Czechia Regarding Rural Areas. *Geografie*, *116*(1), 23–45. https://doi.org/10.37040/geografie2011116010023

Chtatou, M. (2023). The Moroccan-Israeli Geostrategic Relationship: From a Harmonious Past to a Promising Future. *Orbis, Middle East and North Africa*, *67*(2), 228–246. https://doi.org/10.1016/j.orbis.2023.03.006

Cochran, W. G. (1977). *Sampling Techniques*. Wiley.

Cohen, L., Manion, L., & Morrison, K. (2007). *Research Methods in Education* (6th ed.). Routledge. https://doi.org/10.4324/9780203029053

Cohen, L., Manion, L., & Morrison, K. (2018). *Research Methods in Education* (8th ed.). Routledge. https://doi.org/10.4324/9781315456539

Corbière, M., & Larivière, N. (2014). *Méthodes qualitatives, quantitatives et mixtes: Dans la recherche en sciences humaines, sociales et de la santé*. Presses de l'Université du Québec.

Courbage, Y. (1996). Le Maroc de 1962 à 1994: Fin de l'explosion démographique ? *Maghreb - Machrek*, *153*(3), 69–87. https://doi.org/10.3917/machr1.153.0069

Creswell, J. W. (2007). *Qualitative Inquiry and Research Design: Choosing Among Five Approaches*. SAGE.

Creswell, W. J., & Creswell, J. D. (2017). *Research Design: Qualitative, Quantitative, and Mixed Methods Approaches*. SAGE Publications.

CRTS. (2015). *LDAS-MAROC : Intégration de la Télédétection dans la Gestion des Ressources en Eau et l'Agriculture*. Royal Center for Remote Sensing. https://crts.gov.ma/rapport.html

Dai, A., Zhao, T., & Chen, J. (2018). Climate Change and Drought: A Precipitation and Evaporation Perspective. *Current Climate Change Reports*, *4*(3), 301–312. https://doi.org/10.1007/s40641-018-0101-6

Dany, L. (2016). Analyse qualitative du contenu des représentations sociales. In *Les représentations sociales* (version 1, (hal-01648424)). https://amu.hal.science/hal-01648424

Dash, B. B. I. H. a. R. I. (2022). *Significance of Nonverbal Communication and Paralinguistic Features in Communication: A Critical Analysis*. https://doi.org/10.2015/IJIRMF/202204029

de Souza, P. M., Zeghmane, A., Daihi, D., Ouedraogo, D. D., ElKindoussy, F., Gandiya, F., Rasaq, H. O., Temesgen, M., Ebrahim, M., Tinashe, M., & Saidi, R. (2025). Morocco's agrifood transformation: A regional model for sustainable agricultural development. *Outlook on Agriculture*, 00307270251360431. https://doi.org/10.1177/00307270251360431

Desonie, D. (2008). *Climate: Causes and Effects of Climate Change*. Infobase Publishing.

Doherty, G. (2017). *Exclusionary Development Knowledge and Accessibility in Rural Morocco—Thesis* [The Faculty of The Columbian College of Arts and Sciences of The George Washington University]. https://www.proquest.com/openview/30d21095be5aca8f3f36b4940f49707c/1?pq-origsite=gscholar&cbl=18750

Dorman, L. I. (2006). Long-term cosmic ray intensity variation and part of global climate change, controlled by solar activity through cosmic rays. *Advances in Space Research, Particle Acceleration; Space Plasma Physics; Solar Radiation and the Earth's Atmosphere and Climate*, *37*(8), 1621–1628. https://doi.org/10.1016/j.asr.2005.06.032

Douh, B., & Boujelben, A. (2012). *Subsurface drip irrigation and water management under semiarid climate* (pp. 181–198). https://www.researchgate.net/publication/270341653_Subsurface_drip_irrigation_and_water_management_under_semiarid_climate

Douxchamps, S., Debevec, L., Giordano, M., & Barron, J. (2017). Monitoring and evaluation of climate resilience for agricultural development – A review of currently available tools. *World Development Perspectives*, *5*, 10–23. https://doi.org/10.1016/j.wdp.2017.02.001

Dwivedi, Y. K., Hughes, L., Kar, A. K., Baabdullah, A. M., Grover, P., Abbas, R., Andreini, D., Abumoghli, I., Barlette, Y., Bunker, D., Chandra Kruse, L., Constantiou, I., Davison, R. M., De', R., Dubey, R., Fenby-Taylor, H., Gupta, B., He, W., Kodama, M., … Wade, M. (2022). Climate change and COP26: Are digital technologies and information management part of the problem or the solution? An editorial reflection and call to action. *International Journal of Information Management*, *63*, 39. https://doi.org/10.1016/j.ijinfomgt.2021.102456

El Bilali, H., Berjan, S., Driouech, N., Ahouate, L., Abouabdillah, A., Najid, A., Rouini, I., & Azim, K. (2012). Agricultural and rural development governance in Morocco.

Third International Scientific Symposium "Agrosym Jahorina 2012," Book of proceedings, 6. http://dx.doi.org/10.13140/RG.2.2.35533.64485

El Bilali, H., Driouech, N., Berjan, S., Capone, R., Abouabdillah, A., Ahouate, L., Azim, K., & Najid, A. (2013, September). Agricultural extension system in Morocco: Problems, resources, governance and reform. *Conference: 21st European Seminar on Extension Education (ESEE) – "Extension Education Worldwide: Trends, Challenges and Cases"At: Antalya , Turkey Volume: Proceedings*. https://www.academia.edu/34706917/Agricultural_extension_system_in_Morocco_problems_resources_governance_and_reform

El Chami, D., Daccache, A., & El Moujabber, M. (2020). How Can Sustainable Agriculture Increase Climate Resilience? A Systematic Review. *Sustainability*, *12*(8), Article 8. https://doi.org/10.3390/su12083119

El Fartassi, I., Metcalfe, H., El Alami, R., Diarra, A., Alonso-Chavez, V., Waine, T. W., Zawadzka, J., Milne, A. E., & Corstanje, R. (2025). Adaptations in agricultural water management in arid regions: Modelling farmer behaviour and cooperation on irrigation sustainability in Morocco. *Agricultural Water Management*, *319*, 109789. https://doi.org/10.1016/j.agwat.2025.109789

El Fartassi, I., Milne, A. E., El Alami, R., Rafiqi, M., Hassall, K. L., Waine, T. W., Zawadzka, J., Diarra, A., & Corstanje, R. (2023). Evidence of collaborative opportunities to ensure long-term sustainability in African farming. *Journal of Cleaner Production*, *392*, 136170. https://doi.org/10.1016/j.jclepro.2023.136170

El Haddadi, M., Lahjouji, H., & Tabaa, M. (2025). The Nexus Between Economic Growth and Water Stress in Morocco: Empirical Evidence Based on ARDL Model. *Sustainability*, *17*(15), 6990. https://doi.org/10.3390/su17156990

El Mansoum, R., & Chfadi, T. (2025). Innovation without participation? Moroccan farmers' perspectives on Haouz Mejjat aquifer contract. *Groundwater for Sustainable Development*, *30*, 101477. https://doi.org/10.1016/j.gsd.2025.101477

Elalaoui, O., Fadlaoui, A., Maatala, N., & Ibrahimy, A. (2021). Agriculture and GDP Causality Nexus in Morocco: Empirical Evidence from a VAR Approach. *International Journal of Agricultural Economics*, *6*(4), Article 4. https://doi.org/10.11648/j.ijae.20210604.17

Elder, A. D. (2022). The Green Morocco Plan in Boudnib: Examining Effects on Rural Livelihoods. *The Journal of Environment & Development*, *31*(3), 275–299. https://doi.org/10.1177/10704965221098149

Enete, A. A., & Amusa, T. A. (2010). Challenges of Agricultural Adaptation to Climate Change in Nigeria: A Synthesis from the Literature. *Field Actions Science Reports. The Journal of Field Actions*, (Vol. 4), Article Vol. 4. https://journals.openedition.org/factsreports/678

Ennaji, M. (2008). Steps to the Integration of Moroccan Women in Development. *British Journal of Middle Eastern Studies*, *35*(3), 339–348. https://doi.org/10.1080/13530190802525114

Essa, Y. H., Hirschi, M., Thiery, W., El-Kenawy, A. M., & Yang, C. (2023). Drought characteristics in Mediterranean under future climate change. *Npj Climate and Atmospheric Science*, *6*(1), 1–13. https://doi.org/10.1038/s41612-023-00458-4

ETCP. (2007). *WP4 Survey on irrigation water use of European Territorial Cooperation Programme, ETCP Greece-Italy 2007-2013, IRMA, Efficient Irrigation Management Tools for Agricultural Cultivations and Urban Landscapes, Subsidy Contract No: I3.11.06*. European Territorial Cooperation Programme. https://mdpi-res.com/d_attachment/environsciproc/environsciproc-25-00014/article_deploy/environsciproc-25-00014-s001.zip?version=1680505794

ETF. (2021). *L'avenir des compétences: Étude de cas sur le secteur agroalimentaire au Maroc*. European Training Foundation. https://share.google/evtVOjz5jDkSbOuie

European Commission. (2024). *Agricultural drought probability worldwide by country 2024* [Dataset]. European Commission (Joint Research Center). https://www.statista.com/statistics/1395566/agricultural-drought-probability-worldwide-by-country/

Fadlaoui, A., Elame, F., & Doukkali, M. R. (2016). Modélisation économique de l'impact des changements climatiques sur les ressources en eau: Cas du bassin de Souss-Massa (Maroc). *New Medit, A Mediterranean Journal of Economics, Agriculture and Environment, 2016 n. 3*, *New Medit, Vol 15, nn. 3, (September 2016), pp. 10–18*(2016 n. 3), 9.

FAO. (2006). *Implementation Status of the 2020 Strategy for Rural Development*. FAO. https://www.fao.org/documents/card/en?details=e6c6c7ca-dda0-5bbb-a4d6-799f6d6659d2

FAO. (2016). *Regional Initiatives for Africa*. Food and Agriculture Organization of the United Nations (FAO). https://www.fao.org/family-farming/detail/en/c/409858/

FAO. (2017). *Vers une agriculture et une alimentation durables au Maroc dans le cadre du Programme de développement durable à l'horizon 2030. Diagnostic rapide de la*

durabilité de l'agriculture au Maroc. Food and Agriculture Organization of the United Nations. FAO. https://www.fao.org/fileadmin/user_upload/FAO-countries/Maroc/docs/Document_maroc_lowres_I7442FR_1_07.17.pdf

FAO. (2018). *Sustainable Food and Agriculture: An integrated approach. Food and Agriculture Organization of the United Nations*. FAO. https://doi.org/10.1016/C2016-0-01212-3

FAO. (2019). *Transforming Food and Agriculture to Achieve the SDGs, 20 interconnected actions to guide decision-makers—Revised edition. Food and Agriculture Organization of the United Nations*. FAO. https://openknowledge.fao.org/items/c9e24113-a17f-4a2b-8dad-c84890a73ac4

FAO. (2020, April 27). *A summary to assess synergies and trade-offs among the twenty interconnected sustainable food and agriculture (SFA) actions. Food and Agriculture Organization of the United Nations*. FAO. https://openknowledge.fao.org/server/api/core/bitstreams/b06c9ea2-49ad-4116-b1f0-11f58ca8204a/content

FAO. (2023, July 26). *Global Information and Early Warning System on Food and Agriculture—GIEWS Country Briefs Morocco 2010-2023*. Food and Agriculture Organization of the United Nations. https://www.fao.org/giews/countrybrief/country/MAR/pdf_archive/MAR_Archive.pdf

FAO. (2024, March 21). *Global Information and Early Warning System on Food and Agriculture—GIEWS Country Briefs Morocco 2024*. Food and Agriculture Organization of the United Nations. https://www.fao.org/giews/countrybrief/country/MAR/pdf/MAR.pdf

Faurès, J.-M., Hoogeveen, J., & Winpenny, J. T. (2012). *Coping with Water Scarcity: An Action Framework for Agriculture and Food Security*. Food and Agriculture Organization of the United Nations.

Faysse, N., Sellika, I. E., Rinaudo, J.-D., & Errahj, M. (2018). Participatory scenario planning for sustainable irrigated agriculture when actors seldom communicate: An experiment in Morocco. *International Journal of Water Resources Development*, *34*(6), 982–1000. https://doi.org/10.1080/07900627.2017.1322500

Faysse, N., Sraïri, M. T., & Errahj, M. (2012). Local Farmers' Organisations: A Space for Peer-to-Peer Learning? The Case of Milk Collection Cooperatives in Morocco. *The*

Journal of Agricultural Education and Extension, *18*(3), 285–299. https://doi.org/10.1080/1389224X.2012.670053

Fekete, H., Kuramochi, T., Roelfsema, M., Elzen, M. den, Forsell, N., Höhne, N., Luna, L., Hans, F., Sterl, S., Olivier, J., van Soest, H., Frank, S., & Gusti, M. (2021). A review of successful climate change mitigation policies in major emitting economies and the potential of global replication. *Renewable and Sustainable Energy Reviews*, *137*, 110602. https://doi.org/10.1016/j.rser.2020.110602

Filho, W. L., Balogun, A.-L., Olayide, O. E., Azeiteiro, U. M., Ayal, D. Y., Muñoz, P. D. C., Nagy, G. J., Bynoe, P., Oguge, O., Yannick Toamukum, N., Saroar, M., & Li, C. (2019). Assessing the impacts of climate change in cities and their adaptive capacity: Towards transformative approaches to climate change adaptation and poverty reduction in urban areas in a set of developing countries. *Science of The Total Environment*, *692*, 1175–1190. https://doi.org/10.1016/j.scitotenv.2019.07.227

Fosset, R. (1973). Les caractères démographiques et géographiques de la population du Maroc en 1971. *Maghreb - Machrek*, *1973/3*(N° 57), 30–38. https://doi.org/10.3917/machr1.057.0030

Gagnon, Y.-C. (2012). *L'étude de cas comme méthode de recherche, 2e édition* (2nd ed.). Presses de l'Université du Québec. ISBN 978-2-7605-3333-2. https://doi.org/10.2307/j.ctv18ph7wf

Gailhard, İ. U., & Bavorova, M. (2014). Innovation at Rural Enterprises: Results from a Survey of German Organic and Conventional Farmers. *Technology & Innovation*, *16*(1), 3–17. https://doi.org/10.3727/194982414X13971392823190

Garba, K. (2023). Food security for Nigerians through sustainable agriculture. *Nutrition & Food Science*, *54*(2), 269–284. https://doi.org/10.1108/NFS-07-2022-0230

Gauthier, B. (2009). *Recherche sociale: De la problématique à la collecte des données*. PUQ.

Gerbing, D. W., & Anderson, J. C. (1988). An Updated Paradigm for Scale Development Incorporating Unidimensionality and Its Assessment. *Journal of Marketing Research*, *25*(2), 186–192. https://doi.org/10.1177/002224378802500207

GFSI. (2022). *Global Food Security Index 2022: Morocco country report. The Economist Group supported by Corteva Agriscience*. The Economist Group 2022. https://impact.economist.com/sustainability/project/food-security-index/explore-countries/morocco

Ghazi, H., Messouli, M., Yacoubi Khebiza, M., & Egoh, B. N. (2018). Mapping regulating services in Marrakesh Safi region—Morocco. *Journal of Arid Environments,*

Ecosystem Services in Dryland Systems of the World, *159*, 54–65. https://doi.org/10.1016/j.jaridenv.2018.03.005

Girel, M. (2025). Israel as a global leader in smart agriculture: Technology development and transfer mechanisms. *ENVIRONMENT. TECHNOLOGY. RESOURCES. Proceedings of the International Scientific and Practical Conference*, *1*, 197–203. https://doi.org/10.17770/etr2025vol1.8626

Gorard, S. (2003). *Quantitative Methods in Social Science Research*. A&C Black.

Hadebe, S. T., Modi, A. T., & Mabhaudhi, T. (2017). Drought Tolerance and Water Use of Cereal Crops: A Focus on Sorghum as a Food Security Crop in Sub-Saharan Africa. *Journal of Agronomy and Crop Science*, *203*(3), 177–191. https://doi.org/10.1111/jac.12191

Hadria, R., Boudhar, A., Ouatiki, H., Lebrini, Y., Elmansouri, L., Gadouali, F., Lionboui, H. L. H., & Benabdelouahab, T. (2019). Combining Use of TRMM and Ground Observations of Annual Precipitations for Meteorological Drought Trends Monitoring in Morocco. *American Journal of Remote Sensing*, *7*(2), Article 2. https://doi.org/10.11648/j.ajrs.20190702.11

Haile, G. G., Tang, Q., Reda, K. W., Baniya, B., He, L., Wang, Y., & Gebrechorkos, S. H. (2024). Projected impacts of climate change on global irrigation water withdrawals. *Agricultural Water Management*, *305*, 109144. https://doi.org/10.1016/j.agwat.2024.109144

Hamasalih, C. M., & Layeeq, T. M. (2023). The importance of agricultural extension program in technology transfer for rural farmers: A review. *Zagazig Journal of Agricultural Research*, *50*(3), 387–394. https://doi.org/10.21608/zjar.2023.313661

Hansen, K., & Heinse, R. (2022). Water Resilience in Agriculture. In Q. Zhang (Ed.), *Encyclopedia of Smart Agriculture Technologies* (pp. 1–8). Springer International Publishing. https://doi.org/10.1007/978-3-030-89123-7_192-3

Hardelin, J., & Lankoski, J. (2015). Climate Change, Water and Agriculture: Challenges and Adaptation Strategies. *EuroChoices*, *14*(2), 10–15. https://doi.org/10.1111/1746-692X.12085

Harvey, C. A., Rakotobe, Z. L., Rao, N. S., Dave, R., Razafimahatratra, H., Rabarijohn, R. H., Rajaofara, H., & MacKinnon, J. L. (2014). Extreme vulnerability of smallholder farmers to agricultural risks and climate change in Madagascar. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *369*(1639), 20130089. https://doi.org/10.1098/rstb.2013.0089

Hashakimana, L., Tessema, T., Niyitanga, F., Cyamweshi, A. R., & Mukuralinda, A. (2023). Comparative analysis of monocropping and mixed cropping systems on selected soil properties, soil organic carbon stocks, and simulated maize yields in drought-hotspot regions of Rwanda. *Heliyon*, *9*(9), e19041. https://doi.org/10.1016/j.heliyon.2023.e19041

HCPM. (2011, August 19). *Agriculture 2030: Quels avenirs pour le Maroc ?* The independent government statistical institution The High Commission for Planning of Morocco. https://www.hcp.ma/file/104422/

HCPM. (2015). *Monographie De La Région De Marrakech-Safi*. The independent government statistical institution The High Commission for Planning of Morocco. https://www.hcp.ma/region-marrakech/attachment/975005/

HCPM. (2016, September 23). *La population nomade au Maroc d'après les données du Recensement Général de la Population et de l'Habitat de 2014*. The independent government statistical institution The High Commission for Planning of Morocco. https://rgph2014.hcp.ma/file/182130/

HCPM. (2018a, May 16). *Haut-Commissariat Au Plan Les indicateurs Sociaux Du Maroc Éditions 2018*. The independent government statistical institution The High Commission for Planning of Morocco. https://www.hcp.ma/file/200737/

HCPM. (2018b, October 12). *Recensement Général de la Population et de l'Habitat de 2014: Caractéristiques Démographiques et Socio-Economiques de la Population—Rapport National*. The independent government statistical institution The High Commission for Planning of Morocco. https://www.hcp.ma/file/205145/

HCPM. (2018c, October 18). *Données du Recensement Général de la Population et de l'Habitat de 2014—Niveau national*. The independent government statistical institution The High Commission for Planning of Morocco. https://www.hcp.ma/file/205334/

HCPM. (2020a, September 24). *Morocco's 2020 Voluntary National Review on the implementation of the Sustainable Development Goals (English version)*. The independent government statistical institution The High Commission for Planning of Morocco. https://www.hcp.ma/Rapport-National-2020-sur-la-mise-en-oeuvre-par-le-Royaume-du-Maroc-des-Objectifs-de-Developpement-Durable_a2592.html

HCPM. (2020b, September 24). *Morocco's 2020 Voluntary National Review on the implementation of the Sustainable Development Goals (English version)*. The independent government statistical institution The High Commission for Planning of

Morocco. https://www.hcp.ma/Rapport-National-2020-sur-la-mise-en-oeuvre-par-le-Royaume-du-Maroc-des-Objectifs-de-Developpement-Durable_a2592.html

HCPM. (2021a). *Les Indicateurs Annuels d'Activité, d'Emploi et de Chômage par milieu de résidence: Marrakech-Safi 2021*. The independent government statistical institution The High Commission for Planning of Morocco. https://www.hcp.ma/region-marrakech/attachment/2296326/

HCPM. (2021b, February 2). *Haut-Commissariat Au Plan Les indicateurs Sociaux Du Maroc Éditions 2020*. The independent government statistical institution The High Commission for Planning of Morocco. https://www.hcp.ma/file/231203/

HCPM. (2022, May 20). *Haut-Commissariat Au Plan Les indicateurs Sociaux Du Maroc Éditions 2022*. The independent government statistical institution The High Commission for Planning of Morocco. https://www.hcp.ma/Les-Indicateurs-sociaux-du-Maroc-Edition-2022_a3192.html

HCPM. (2024, December). *Recensement Général de la Population et de l'Habitat 2024: Caractéristiques démographiques et socioéconomiques de la population. Note sur les principaux résultats.* The independent government statistical institution The High Commission for Planning of Morocco. https://casainvest.ma/sites/default/files/2025-02/R%C3%A9sultats%20du%20RGPH%202024.pdf

HCPM. (2025a). *Database of indicators from the 2014 General Population and Housing Census (RGPH) in the form of tables and graphs*. The independent government statistical institution The High Commission for Planning of Morocco. https://www.hcp.ma/Recensement-population-RGPH-2014_a2941.html

HCPM. (2025b). *Database of indicators from the 2024 General Population and Housing Census (RGPH) in the form of tables and graphs*. The independent government statistical institution The High Commission for Planning of Morocco. https://www.hcp.ma/Visualiser-les-resultats-du-RGPH-2024_a4032.html

HCPM. (2025c). *The High Commission for Planning of Morocco, the online statistical database 2025*. The independent government statistical institution The High Commission for Planning of Morocco. http://bds.hcp.ma/sectors

He, K., Zhang, J., Feng, J., Hu, T., & Zhang, L. (2016). The Impact of Social Capital on farmers' Willingness to Reuse Agricultural Waste for Sustainable Development. *Sustainable Development*, *24*(2), 101–108. https://doi.org/10.1002/sd.1611

Hofste, R. W., Reig, P., & Schleifer, L. (2019). *17 Countries, Home to One-Quarter of the World's Population, Face Extremely High Water Stress*.

https://www.wri.org/insights/17-countries-home-one-quarter-worlds-population-face-extremely-high-water-stress

Hsieh, H.-F., & Shannon, S. E. (2005). Three Approaches to Qualitative Content Analysis. *Qualitative Health Research*, *15*(9), 1277–1288. https://doi.org/10.1177/1049732305276687

Ibourk, A., & El Aynaoui, K. (2023). Agricultural Cooperatives' Sustainability and the Relevance of Start-Up Support Programs: Evidence from Cooperatives' Level in Morocco. *Sustainability*, *15*(4), 3460. https://doi.org/10.3390/su15043460

Idrissi, O., Sahri, A., Houasli, C., & Nsarellah, N. (2019). Breeding Progress, Adaptation, and Stability for Grain Yield in Moroccan Lentil Improved Varieties. *Crop Science*, *59*(3), 925–936. https://doi.org/10.2135/cropsci2018.07.0431

IMIS. (2025). *Eau et climat: Le Maroc à la croisée des chemins ?* The Moroccan Institute for Strategic Intelligence (IMIS). https://imis.ma/wp-content/uploads/2025/06/IMIS_EAU-ET-CLIMAT_WEB.pdf

Ingrao, C., Strippoli, R., Lagioia, G., & Huisingh, D. (2023). Water scarcity in agriculture: An overview of causes, impacts and approaches for reducing the risks. *Heliyon*, *9*(8), e18507. https://doi.org/10.1016/j.heliyon.2023.e18507

INRA. (2005, December). *La création variétale à l'INRA: méthodes, acquis et perspectives*. National Institute for Agricultural Research, made available online on November 21, 2016. ISBN 9954-0-6651-9. https://www.inra.org.ma/fr/content/la-creation-varietale-linra-methodes-acquis-et-perspectives

INRA. (2012). *L'agriculture solidaire dans les éco-systèmes fragiles au Maroc, National Institute for Agricultural Research in Morocco*. National Institute for Agricultural Research. https://www.inra.org.ma/sites/default/files/publications/ouvrages/kradi1201.pdf

INRA. (2017). *Guide pour le choix des variétés INRA de blé dur, blé tendre et orge | INRA*. National Institute for Agricultural Research, made available online on September 17, 2020. https://www.inra.org.ma/fr/content/guide-pour-le-choix-des-varietes-inra-de-ble-dur-ble-tendre-et-orge-0

INRA. (2023). *Nouvelles Obtentions Variétales INRA, édition 2023*. National Institute for Agricultural Research. https://www.inra.org.ma/fr/content/nouvelles-obtentions-varietales-inra-1

INRA. (2025). *Nouvelles Obtentions Variétales INRA, édition 2025*. National Institute for Agricultural Research. https://www.inra.org.ma/fr/content/nouvelles-obtentions-varietales-inra-2025

Intikhab, A. (2017). Geopolitics of Trans-Boundary Water Resources and Food Security. *International Research Journal of Human Resources and Social Sciences*. https://www.academia.edu/79343717/Geopolitics_of_Trans_Boundary_Water_Resources_and_Food_Security

Iounousse, J., & Temsamani, O. (2024). Development of an intelligent virtual assistant for digitalization of Moroccan agriculture. *ITM Web of Conferences*, *69*, 01003. https://doi.org/10.1051/itmconf/20246901003

Iqbal, H., Yaning, C., Waqas, M., Shareef, M., & Raza, S. T. (2018). Differential response of quinoa genotypes to drought and foliage-applied H2O2 in relation to oxidative damage, osmotic adjustment and antioxidant capacity. *Ecotoxicology and Environmental Safety*, *164*, 344–354. https://doi.org/10.1016/j.ecoenv.2018.08.004

IRES. (2024, February 28). *L'avenir de l'agriculture au Maroc dans un contexte marqué par la rareté structurelle de l'eau. Royal Institute for Strategic Studies*. L'Institut Royal des Études Stratégiques (IRES). https://www.ires.ma/fr/publications/actes-des-seminaires/lavenir-de-lagriculture-au-maroc-dans-un-contexte-marque-par-la-rarete-structurelle-de-leau

Islam, M. T., & Nursey-Bray, M. (2017). Adaptation to climate change in agriculture in Bangladesh: The role of formal institutions. *Journal of Environmental Management*, *200*, 347–358. https://doi.org/10.1016/j.jenvman.2017.05.092

Islam, S. (2025). Agriculture, food security, and sustainability: A review. *Exploration of Foods and Foodomics*, *3*, 101082. https://doi.org/10.37349/eff.2025.101082

Jang, D., Park, H., & Choi, J. (2016). Development of Future Precipitation Forecasting Program Using Probability Forecast and Climate Change Scenario. *Procedia Engineering, 12th International Conference on Hydroinformatics (HIC 2016) - Smart Water for the Future*, *154*, 645–649. https://doi.org/10.1016/j.proeng.2016.07.564

Kaiss, R., Benjouid, Z., Faiz, M., Ech-Chahed, H., Rakhimi, A., Zarouali, S. S., Maimoun, A., Hmid, A., & Cherkaoui, M. (2025). Water Stress and Regional Governance in Morocco: Pathways to Agricultural Resilience through Advanced Regionalization. *Research on World Agricultural Economy*, 957–972. https://doi.org/10.36956/rwae.v6i3.2173

Kakar, Z., Rasheed, R., Rashid, A., & Akhter, S. (2023). Criteria for Assessing and Ensuring the Trustworthiness in Qualitative Research. *Publications and Research*. https://academicworks.cuny.edu/yc_pubs/342

Kalele, D. N., Ogara, W. O., Oludhe, C., & Onono, J. O. (2021). Climate change impacts and relevance of smallholder farmers' response in arid and semi-arid lands in Kenya. *Scientific African*, *12*, e00814. https://doi.org/10.1016/j.sciaf.2021.e00814

Kjellstrom, T., Briggs, D., Freyberg, C., Lemke, B., Otto, M., & Hyatt, O. (2016). Heat, Human Performance, and Occupational Health: A Key Issue for the Assessment of Global Climate Change Impacts. *Annual Review of Public Health*, *37*(1), 97–112. https://doi.org/10.1146/annurev-publhealth-032315-021740

Lachheb, A., Idrissi, Y. A., Zouhri, N., Belhamidi, S., Taky, M., Amrani, M. E., & Elmidaoui, A. (2016). Application of Activated Sludge for Urban Wastewater Treatment and Reuse for Irrigation in Kenitra, Morocco. *American Journal of Applied Chemistry*, *4*(2), Article 2. https://doi.org/10.11648/j.ajac.20160402.11

Lamm, F. R., & Camp, C. R. (2007). 13. Subsurface drip irrigation. In *Developments in Agricultural Engineering* (Vol. 13, pp. 473–551). Elsevier. https://doi.org/10.1016/S0167-4137(07)80016-3

Latrach, L. (2018). Rural sanitation in Morocco: Situation, realizations and perspectives. *Environmental and Water Sciences, public Health and Territorial Intelligence Journal*, *2*(3), Article 3. https://doi.org/10.48421/IMIST.PRSM/ewash-ti-v2i3.13051

Lebdaoui, K. (2022). Liens familiaux au cœur des coopératives agricoles au Maroc: Quels impacts ? *Alternatives Rurales*, *9*. https://doi.org/10.60569/9-a2

Lele, U. J. (1975). *The Design of Rural Development: Lessons from Africa*. World Bank.

Lemfarrak, A., Benzakour, A., Ouhssine, M., & Benlemlih, N. (2025). Advancing treated wastewater reuse in Morocco as a pathway to sustainable water management: A review. *Ecological Engineering & Environmental Technology*, *26*(8), 247–267. https://doi.org/10.12912/27197050/207238

Li, H., Yang, X., Chen, H., Cui, Q., Yuan, G., Han, X., Wei, C., Zhang, Y., Ma, J., & Zhang, X. (2018). Water requirement characteristics and the optimal irrigation schedule for the growth, yield, and fruit quality of watermelon under plastic film mulching. *Scientia Horticulturae*, *241*, 74–82. https://doi.org/10.1016/j.scienta.2018.06.067

Lim, W. M. (2025). What Is Qualitative Research? An Overview and Guidelines. *Australasian Marketing Journal*, *33*(2), 199–229. https://doi.org/10.1177/14413582241264619

Lincoln, Y. S., & Guba, E. G. (1985). *Naturalistic Inquiry*. SAGE.

Lobe, B., Morgan, D. L., & Hoffman, K. (2022). A Systematic Comparison of In-Person and Video-Based Online Interviewing. *International Journal of Qualitative Methods*, *21*, 16094069221127068. https://doi.org/10.1177/16094069221127068

López-Sánchez, A., Luque-Badillo, A. C., Orozco-Nunnelly, D., Alencastro-Larios, N. S., Ruiz-Gómez, J. A., García-Cayuela, T., & Gradilla-Hernández, M. S. (2021). Food loss in the agricultural sector of a developing country: Transitioning to a more sustainable approach. The case of Jalisco, Mexico. *Environmental Challenges*, *5*, 100327. https://doi.org/10.1016/j.envc.2021.100327

Lugo, M. B. C., Vázquez, A. P., & Romero, G. L. (2023). Agricultural drought in the context of climate change: A bibliometric analysis. *Agro Productividad*. https://doi.org/10.32854/agrop.v16i9.2470

Lund Schlamovitz, J., & Becker, P. (2021). Differentiated vulnerabilities and capacities for adaptation to water shortage in Gaborone, Botswana. *International Journal of Water Resources Development*, *37*(2), 278–299. https://doi.org/10.1080/07900627.2020.1756752

Luo, T., Young, R. S., & Reig, P. (2015). *Aqueduct Projected Water Stress Country Rankings*. https://www.wri.org/research/aqueduct-projected-water-stress-country-rankings

Lybbert, T. J., & Sumner, D. A. (2012). Agricultural technologies for climate change in developing countries: Policy options for innovation and technology diffusion. *Food Policy*, *37*(1), 114–123. https://doi.org/10.1016/j.foodpol.2011.11.001

Maatala, N., Bekkar, Y., Hassnaoui, O. E., & Lebailly, P. (2020). Technical and Economic Efficiency of Irrigation Water Use for the Farms of Blueberry and Raspberry in the Loukkos Area in Morocco. *International Journal of Agricultural Economics*, *5*(1), Article 1. https://doi.org/10.11648/j.ijae.20200501.11

Maestro-Gaitán, I., Granado-Rodríguez, S., Poza-Viejo, L., Matías, J., Márquez-López, J. C., Pedroche, J. J., Cruz, V., Bolaños, L., & Reguera, M. (2023). Quinoa plant architecture: A key factor determining plant productivity and seed quality under long-term drought. *Environmental and Experimental Botany*, *211*, 105350. https://doi.org/10.1016/j.envexpbot.2023.105350

MAFM. (2019, April 20). *Agriculture En Chiffres 2018 Édition 2019*. Ministry of Agriculture, Maritime Fisheries, Rural Development and Water and Forests of Morocco. https://www.agriculture.gov.ma/sites/default/files/19-00145-book_agricultures_en_chiffres_def.pdf

MAFM. (2021, July 6). *LE PLAN MAROC VERT BILAN ET IMPACTS 2 0 0 8—2 0 1 8*. Ministry of Agriculture, Maritime Fisheries, Rural Development and Water and Forests of Morocco. https://www.agriculture.gov.ma/sites/default/files/2021-08/20-00529-MA_Plaquette_Bilan%20PMV_VF%286-7-21%29-compresse%CC%81.pdf

MAFM. (2024). *The evolution of Moroccan agricultural exports, based on the data from the Ministry of Agriculture in Morocco and the database from Morocco Foodex*. Ministry of Agriculture, Maritime Fisheries, Rural Development and Water and Forests of Morocco. https://www.agriculture.gov.ma/fr/programme/exportation

MAFRD. (2023). *Online available data on Moroccan agriculture from the official website of the Ministry of Agriculture, Fisheries, Rural Development, Water and Forests, Department of Agriculture of Morocco*. Ministry of Agriculture, Fisheries, Rural Development, Water and Forests, Department of Agriculture of Morocco. https://www.agriculture.gov.ma/fr/region/marrakech-safi

Maghraoui, D. (2025). The Multiple Layers of Morocco's Normalization with Israel. In G. Yang, J. Zhang, X. Xiong, & L. Liu (Eds.), *Risks, Resilience and Interdependency: Developing Countries in the Age of Uncertainties* (pp. 257–275). Springer Nature. https://doi.org/10.1007/978-981-96-7167-0_10

Maini, E., De Rosa, M., & Vecchio, Y. (2021). The Role of Education in the Transition towards Sustainable Agriculture: A Family Farm Learning Perspective. *Sustainability*, *13*(14), 8099. https://doi.org/10.3390/su13148099

Maleksaeidi, H., & Karami, E. (2013). Social-Ecological Resilience and Sustainable Agriculture Under Water Scarcity. *Agroecology and Sustainable Food Systems*, *37*(3), 262–290. https://doi.org/10.1080/10440046.2012.746767

Manimozhi, D. K., & Vidhya, J. (2021). Assessing and enhancing the quality of life of the selected village. *International Journal of Home Science*, *7*(3), 163–166.

Markland, S. M., Ingram, D., Kniel, K. E., & Sharma, M. (2017). Water for Agriculture: The Convergence of Sustainability and Safety. *Microbiology Spectrum*, *5*(3), 10.1128/microbiolspec.pfs-0014–2016. https://doi.org/10.1128/microbiolspec.pfs-0014-2016

Martín, I., Nori, Michele, & Bacchi, A. (2017). *Effects of Youth Migration on Agricultural Production and Employment in the Rural Areas of Origin in Tunisia*. https://doi.org/10.22004/AG.ECON.263007

Martínez, J., & Reca, J. (2014). Water Use Efficiency of Surface Drip Irrigation versus an Alternative Subsurface Drip Irrigation Method. *Journal of Irrigation and Drainage*

Engineering, *140*(10), 04014030. https://doi.org/10.1061/(ASCE)IR.1943-4774.0000745

Massimi, M., Tuly, N. M., & Sanga, S. (2021). *Fundamentals of Agricultural Extension and Education*. https://doi.org/10.6084/m9.figshare.16545801.v2

Mayring, P. (2014). *Qualitative Content Analysis: Theoretical Foundation, Basic Procedures and Software Solution*. Klagenfurt, Austria.

MCCM. (2021, November 2). *Le Maroc dispose de 149 grands barrages d'une capacité dépassant 19 milliards m3*. Ministry of Culture and Communication of Morocco. https://www.maroc.ma/fr/actualites/le-maroc-dispose-de-149-grands-barrages-dune-capacite-depassant-19-milliards-m3

McCollum, C., Bergtold, J. S., Williams, J., Al-Sudani, A., & Canales, E. (2022). Perceived Benefit and Cost Perception Gaps between Adopters and Non-Adopters of In-Field Conservation Practices of Agricultural Producers. *Sustainability*, *14*(19), 11803. https://doi.org/10.3390/su141911803

MEFM. (2019, July). *Le secteur agricole Marocain: Tendances structurelles, enjeux et perspectives de développement Royaume Du Maroc Ministère De L'économie Et Des Finances*. Ministry of Economy and Finance of Morocco: Department of Studies and Financial Forecasts. depf.finances.gov.ma

Meliho, M., Khattabi, A., Jobbins, G., & Sghir, F. (2019). Impact of meteorological drought on agriculture in the Tensift watershed of Morocco. *Journal of Water and Climate Change*, *11*(4), 1323–1338. https://doi.org/10.2166/wcc.2019.279

Mengoub, F. E., Lejars, C., & Doukkali, M. R. (2021). Evaluation de la contribution de l'irrigation à la croissance économique et agricole: Cas du Maroc. *European Scientific Journal, ESJ*, *17*(27), Article 27. https://doi.org/10.19044/esj.2021.v17n27p218

Meuwissen, M. P. M., Feindt, P. H., Spiegel, A., Termeer, C. J. A. M., Mathijs, E., Mey, Y. de, Finger, R., Balmann, A., Wauters, E., Urquhart, J., Vigani, M., Zawalińska, K., Herrera, H., Nicholas-Davies, P., Hansson, H., Paas, W., Slijper, T., Coopmans, I., Vroege, W., … Reidsma, P. (2019). A framework to assess the resilience of farming systems. *Agricultural Systems*, *176*, 102656. https://doi.org/10.1016/j.agsy.2019.102656

MEWM. (2019, December 25). *Approvisionnement en eau potable et l'irrigation (2020-2027) – Direction Générale de l'Eau*. Ministry of Equipment and Water of Morocco

Directorate General of Hydraulics. http://81.192.10.228/ressources-en-eau/lapprovisionnement-en-eau-potable-et-lirrigation/

MEWM. (2023a). *L'hydraulique en chiffres: 2023*. Ministry of Equipment and Water, Directorate-general for Hydraulics of Morocco. http://www.abhatoo.net.ma/maalama-textuelle/developpement-durable/environnement/eau-douce/ecosysteme-d-eau-douce/bassins-d-alimentation/l-hydraulique-en-chiffres-2023#

MEWM. (2023b). *Online available data on Morocco's main dams filling rate from the official website of the Ministry of Equipment and Water of Morocco Directorate General of Hydraulics*. Ministry of Equipment and Water of Morocco Directorate General of Hydraulics. http://81.192.10.228/patrimoine/barrages/situation-journaliere-des-principaux-grands-barrages/

MEWM. (2024). *Climat au Maroc en 2023*. Ministry of Equipment and Water of Morocco Directorate General of Hydraulics. https://www.marocmeteo.ma/fr/climat-2023

MHM. (2018). *Enquête Nationale sur la Population et la santé Familiale (ENPSF 2018): Santé de la Reproduction*. Ministry of Health of Morocco. https://www.sante.gov.ma/Documents/2022/06/Enqu%C3%AAte%20Nationale%20sur%20la%20Population%20et%20la%20Sant%C3%A9%20de%20la%20Famille%20(ENPSF%202018)%20-%20Sant%C3%A9%20de%20la%20Reproduction.pdf

Mihai, F.-C., & Iatu, C. (2020). Sustainable Rural Development under Agenda 2030. In *Sustainability Assessment at the 21st century*. IntechOpen. https://doi.org/10.5772/intechopen.90161

Miles, D. A. (2017). ARTICLE/RESEARCH: A Taxonomy of Research Gaps: Identifying and Defining the Seven Research Gaps. *Journal of Research Methods and Strategies*. https://www.academia.edu/35505149/ARTICLE_RESEARCH_A_Taxonomy_of_Research_Gaps_Identifying_and_Defining_the_Seven_Research_Gaps

Mir, M. S., Saxena, A., Kanth, R. H., Raja, W., Dar, K. A., Mahdi, S. S., Bhat, T. A., Naikoo, N. B., Nazir, A., Amin, Z., Mansoor, T., Myint, M. Z., Khan, M. R., Mohammad, I., & Mir, S. A. (2022). Role of Intercropping in Sustainable Insect-Pest Management: A Review. *International Journal of Environment and Climate Change*, 3390–3403. https://doi.org/10.9734/ijecc/2022/v12i111390

Mishra, A. K., & Singh, V. P. (2010). A review of drought concepts. *Journal of Hydrology*, *391*(1), 202–216. https://doi.org/10.1016/j.jhydrol.2010.07.012

MITVIM. (2018, September). *Israel and Morocco: Cooperation rooted in heritage*. The Israeli Institute for Regional Foreign Policies. https://mitvim.org.il/wp-content/uploads/Einat_Levi_-_Israel_and_Morocco_-_Cooperation_Rooted_in_Heritage_-_September_2018.pdf

MNTP. (2019). *Recensement général de la population et de l'habitat 2014—Principaux résultats relatifs au secteur de l'habitat –*. Ministry of National Territorial Planning, Urban Planning, Housing, and City Policy General Secretariat of Morocco. http://www.mhpv.gov.ma/wp-content/uploads/2019/12/RGPH-HABITAT.pdf

Mohamed, M. (2014). Devenir du foncier agricole au Maroc. Un cas d'accaparement des terres. *New Medit*, *13*(4), 2-11. http://newmedit.ciheam.org/share/img_new_medit_articoli/993_02mahdi.pdf.

Mohamed, M. (2020). *Incidences de l'investissement foncier agricole sur les sociétés rurales A propos de « la classe moyenne agricole »*. https://doi.org/10.13140/RG.2.2.18482.02245

Morison, J. I. L., Baker, N. R., Mullineaux, P. M., & Davies, W. J. (2008). Improving water use in crop production. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *363*(1491), 639–658. https://doi.org/10.1098/rstb.2007.2175

Morse, J. M. (1994). *Critical Issues in Qualitative Research Methods*. SAGE.

Moseley, M. (2003). *Rural Development: Principles and Practice*. SAGE.

Motsa, N. M., Modi, A. T., & Mabhaudhi, T. (2015). Sweet potato (Ipomoea batatas L.) as a drought tolerant and food security crop. *South African Journal of Science*, *111*(11–12), 1–8. https://doi.org/10.17159/sajs.2015/20140252

Müller-Bloch, C., & Kranz, J. (2015). *A Framework for Rigorously Identifying Research Gaps in Qualitative Literature Reviews*. International Conference on Interaction Sciences. https://www.semanticscholar.org/paper/A-Framework-for-Rigorously-Identifying-Research-in-M%C3%BCller-Bloch-Kranz/73596c4957deab7c7a3fd1d4261994e47be1508c

Mumenthaler, C., Renaud, O., Gava, R., & Brosch, T. (2021). The impact of local temperature volatility on attention to climate change: Evidence from Spanish tweets. *Global Environmental Change*, *69*, 102286. https://doi.org/10.1016/j.gloenvcha.2021.102286

NEG. (2018). *Ministry of foreign affairs Netherlands. Business Opportunities Report for Reuse of Wastewater in Morocco. Commissioned by the Netherlands Enterprise Agency* (p. 98). Netherlands enterprise government agency.

https://www.rvo.nl/sites/default/files/2018/06/Business-opportunities-report-for-reuse-of-wastewater-in-morocco.pdf

Nejjari, I., & Lebzar, B. (2018). Les coopératives agricoles marocaines, des entreprises socialement responsables ? Etude exploratoire qualitative. *Revue du contrôle, de la comptabilité et de l'audit*, *2*(4), Article 4. https://www.revuecca.com/index.php/home/article/view/265

Neuman, W. L. (2011). *Social Research Methods: Qualitative and Quantitative Approaches*. Pearson.

Neuman, W. L. (2013). *Social Research Methods: Qualitative and Quantitative Approaches, 7th edition*. Pearson Education.

Nsiri, N., Kleftodimos, G., & Drogué, S. (2025). Efficiency of agricultural systems in Morocco: A meta-frontier analysis of resource use and water management. *Agricultural Water Management*, *321*, 109912. https://doi.org/10.1016/j.agwat.2025.109912

Obibuaku, L. O. (1983). *Agricultural extention [extension] as a strategy for agricultural transformation*. Nsukka : Univ. of Nigeria.

Odjo, S., Traoré, F., & Zaki, C. (2023). *2023 Africa Agriculture Trade Monitor (AATM)*. AKADEMIYA2063 and International Food Policy Research Institute (IFPRI). https://doi.org/10.54067/9781737916475

OECD. (2012). *OECD Environmental Outlook to 2050 The Consequences of Inaction: The Consequences of Inaction*. OECD Publishing.

OECD. (2014). *Climate Change, Water and Agriculture: Towards Resilient Systems | OECD* (p. 104). OECD Publishing. ISBN: 978-92-64-20912-1 (print) ISSN: 2224-5081 (online) / 2224-5073 (print). https://doi.org/10.1787/9789264209138-en

OECD. (2016). *Development Centre Studies A New Rural Development Paradigm for the 21st Century: A Toolkit for Developing Countries.* Organisation for Economic Co-operation and Development Publishing.

OECD. (2020, May 6). *"The COVID-19 crisis in Morocco", Tackling Coronavirus (COVID-19), contributing to a global effort,*. Organisation for Economic Co-operation and Development. https://www.oecd.org/mena/competitiveness/The-Covid-19-Crisis-in-Morocco.pdf

OECD. (2021, July 13). *Promouvoir les réformes du climat de l'investissement dans le secteur agroalimentaire au Maroc*. Organisation for Economic Co-operation and

Development. https://www.oecd.org/fr/sites/mena/eu-oecd-mediterranean-investment/EU-Issues-paper-agri-food-Morocco-FR.pdf

Ojo, M. P., Ayanwale, A. B., Adelegan, O. J., Ojogho, O., Awoyelu, D. E. F., & Famodimu, J. (2024). Climate change vulnerability and adaptive capacity of smallholder farmers: A financing gap perspective. *Environmental and Sustainability Indicators*, *24*, 100476. https://doi.org/10.1016/j.indic.2024.100476

Orfi, T. E., Ghachi, M. E., Lebaut, S., & Haidu, I. (2025). Tendances de la sécheresse dans le Moyen Atlas marocain dans le cadre du changement climatique. *Géoporo*. https://hal.science/hal-04933903

Oulkhir, M. (2023). La gouvernance du foncier agricole au Maroc: Défis et perspectives. *REVUE ECONOMIE ET SOCIETE*, *2*(4), 5–19. https://doi.org/10.5281/zenodo.10253368

Oyeagu, C. E., & Lewu, F. B. (2025). Why Agricultural Water Productivity Matters: A Review. In T. Mabhaudhi, V. G. P. Chimonyo, A. Senzanje, & P. P. Chivenge (Eds.), *Enhancing Water and Food Security Through Improved Agricultural Water Productivity: New Knowledge, Innovations and Applications* (pp. 31–48). Springer Nature. https://doi.org/10.1007/978-981-96-1848-4_2

Patton, M. Q. (2002). *Qualitative Research & Evaluation Methods*. SAGE.

Pearson, L. J., & Dare, M. (2021). Farmer pathways to sustainability in the face of water scarcity. *Environmental Science & Policy*, *124*, 186–194. https://doi.org/10.1016/j.envsci.2021.06.016

Pearson, P. J. G., & Foxon, T. J. (2012). A low carbon industrial revolution? Insights and challenges from past technological and economic transformations. *Energy Policy, Special Section: Past and Prospective Energy Transitions - Insights from History*, *50*, 117–127. https://doi.org/10.1016/j.enpol.2012.07.061

Pedrero, F., Kalavrouziotis, I., Alarcón, J. J., Koukoulakis, P., & Asano, T. (2010). Use of treated municipal wastewater in irrigated agriculture—Review of some practices in Spain and Greece. *Agricultural Water Management*, *97*(9), 1233–1241. https://doi.org/10.1016/j.agwat.2010.03.003

Pfahl, S. (2005). Institutional sustainability. *International Journal of Sustainable Development*, *8*(1/2), 80. https://doi.org/10.1504/IJSD.2005.007376

Poyatos, F. (1984). The multichannel reality of discourse: Language-paralanguage-kinesics and the totality of communicative systems. *Language Sciences*, *6*(2), 307–337. https://doi.org/10.1016/S0388-0001(84)80022-4

Prager, K. (2022). Implementing policy interventions to support farmer cooperation for environmental benefits. *Land Use Policy*, *119*, 106182. https://doi.org/10.1016/j.landusepol.2022.106182

Pretty, J. N., Morison, J. I. L., & Hine, R. E. (2003). Reducing food poverty by increasing agricultural sustainability in developing countries. *Agriculture, Ecosystems & Environment*, *95*(1), 217–234. https://doi.org/10.1016/S0167-8809(02)00087-7

Pretty, Jules N. (1995). *Regenerating Agriculture: Policies and Practice for Sustainability and Self-Reliance*. Joseph Henry Press. https://doi.org/10.17226/4930

Qizi, N. D. B. (2025). Paralinguistic features and their role in spoken communication. *International Journal of Scientific Researchers (IJSR) INDEXING*, *13*(1), 75–78.

Quizon, J., Feder, G., & Murgai, R. (2001). Fiscal Sustainability of Agricultural Extension: The Case of the Farmer Field School Approach. *Journal of International Agricultural and Extension Education*, *8*. https://doi.org/10.5191/jiaee.2001.08102

Raposo, V. de M. B., Costa, V. A. F., & Rodrigues, A. F. (2023). A review of recent developments on drought characterization, propagation, and influential factors. *Science of The Total Environment*, *898*, 165550. https://doi.org/10.1016/j.scitotenv.2023.165550

Rashidi, M., & Gholami, M. (2008). Review of Crop Water Productivity values for tomato, potato, melon, watermelon and cantaloupe in Iran. *International Journal of Agriculture and Biology*, *10*(4), 432–436. Scopus.

R.D. Norton. (2014). *Policy Frameworks for International Agricultural and Rural Development*. 489–503. https://doi.org/10.1016/B978-0-444-52512-3.00123-6

Rehman, A., Farooq, M., Lee, D.-J., & Siddique, K. H. M. (2022). Sustainable agricultural practices for food security and ecosystem services. *Environmental Science and Pollution Research*, *29*(56), 84076–84095. https://doi.org/10.1007/s11356-022-23635-z

Richards, L., & Morse, J. M. (2013). *Readme First for a User's Guide to Qualitative Methods*. SAGE Publications, Inc. https://doi.org/10.4135/9781071909898

Rickards, L., & Howden, S. M. (2012). Transformational adaptation: Agriculture and climate change. *Crop & Pasture Science*, *63*(3), 240–250. https://doi.org/10.1071/CP11172

Rivera, M., Knickel, K., de los Rios, I., Ashkenazy, A., Pears, D. Q., Chebach, T., & Šūmane, S. (2018). Rethinking the connections between agricultural change and rural prosperity: A discussion of insights derived from case studies in seven countries.

Journal of Rural Studies, *59*, 242–251. https://doi.org/10.1016/j.jrurstud.2017.07.006

Rivera, W. M., Schram, S. G., Rivera, W. M., & Schram, S. G. (2022). *Agricultural Extension Worldwide: Issues, Practices and Emerging Priorities* (1st ed.). Routledge. https://www.perlego.com/book/3181608/agricultural-extension-worldwide-issues-practices-and-emerging-priorities-pdf

Robbins, P. (2019). *Political Ecology: A Critical Introduction*. John Wiley & Sons.

Roberto, V., Garzaron, L., Menza, G., Mounir, A., Zaccari, C., & Dolinga, M. (2025, May 7). *The state of the agri-, food-, and climate-tech innovation ecosystem in Morocco: Country report*. https://hdl.handle.net/10568/174492

Robinson, K. A., Saldanha, I. J., & Mckoy, N. A. (2011). *Frameworks for Determining Research Gaps During Systematic Reviews*. Agency for Healthcare Research and Quality (US). http://www.ncbi.nlm.nih.gov/books/NBK62478/

Robson, C. (2002). *Real World Research: A Resource for Social Scientists and Practitioner-Researchers* (2nd ed.). Wiley.

Sachs, J. D., Lafortune, G., Fuller, G., & Drumm, E. (2023). *SUSTAINABLE DEVELOPMENT REPORT 2023: Implementing the SDG Stimulus, Includes the SDG Index and Dashboards*. Dublin: University Press Dublin, Ireland. https://s3.amazonaws.com/sustainabledevelopment.report/2023/sustainable-development-report-2023.pdf

Sahim, I. (2020, September 18). *Les Brefs du Plan: Modélisation de la consommation en eau intersectorielle dans l'économie marocaine*. The independent government statistical institution The High Commission for Planning of Morocco.

Saini, S., Mallick, S., & Padhan, S. R. (2023). Participatory Extension Approach: Empowering Farmers. *Biotica Research Today*, *5*(4), Article 4.

Salehi, M. (2022). Global water shortage and potable water safety; Today's concern and tomorrow's crisis. *Environment International*, *158*, 106936. https://doi.org/10.1016/j.envint.2021.106936

Samir, Z. (2022). *Agriculture and sustainable development example of Morocco: A brief review of the literature*. Published at Spring Wind Conference 2022 in the second proceeding conference volume (XXV. Tavaszi Szél Konferencia – Tanulmánykötet - II. Kötet), the University of Pécs, Hungary. (90-103). ISBN: 978-615-6457-13-4.

Samir, Z. (2023a). *Agriculture in Morocco: Sustainable development, climate-smart Agriculture, and the potential usefulness of political ecology perspectives*. IX.

International Winter Conference of P.h.D. Students and Researchers in Economics. Óbuda University, Budapest, Hungary. Publisher: Association of Hungarian PhD and DLA Students – TéKa. (pages 130-138). ISBN: 978-80-974152-6-6.

Samir, Z. (2023b). Morocco's agriculture and rural development from sustainable development aspects. *E-CONOM Online Scientific Journal (Online Tudományos Folyóirat), Alexandre Lamfalussy Faculty of Economics, University of Sopron*, (153-169). ISSN: 2063-644X. https://doi.org/10.17836/EC.2023.1.153.

Samir, Z. (2023c). *Socio-economic Impacts of Sustainable Development on Agriculture in Morocco*. Published at Szemelvények a BGE kutatásaiból II. kötet. (pages 232-242). ISBN: 9786156342768. DOI: https://doi.org/10.29180/978-615-6342-76-8_30.

Samir, Z., & Pappné Vancsó, J. (2023). The challenges facing rural population and the potential of sustainability of rural development in Morocco. *Journal of Economy & Society (Gazdaság & Társadalom), University of Sopron*, Volume 16 (34), Issue 4 (2023), ISSN: 08657823. https://doi.org/10.21637/GT.2023.4.04

Samir, Z., & Pappné Vancsó, J. (2025). *Az aszály hatása a marokkói mezőgazdaságra – Az alkalmazkodás lehetőségei a döntéshozók szándékai és a gazdák tapasztalatai alapján / The impact of drought on Moroccan agriculture – Adaptation options based on policy makers' intentions and farmers' experiences*. https://doi.org/10.32643/fk.149.2.1

Satoh, M., & Aboulroos, S. (Eds.). (2017). *Irrigated Agriculture in Egypt: Past, Present and Future*. Springer International Publishing. https://doi.org/10.1007/978-3-319-30216-4

Saunders, M. (2012). *Choosing Research Participants* (pp. 35–52). https://doi.org/10.4135/9781526435620.n3

Schilling, J., Freier, K. P., Hertig, E., & Scheffran, J. (2012). Climate change, vulnerability and adaptation in North Africa with focus on Morocco. *Agriculture, Ecosystems & Environment*, *156*, 12–26. https://doi.org/10.1016/j.agee.2012.04.021

Schoor, M., Arenas-Salazar, A. P., Torres-Pacheco, I., Guevara-González, R. G., & Rico-García, E. (2023). A Review of Sustainable Pillars and their Fulfillment in Agriculture, Aquaculture, and Aquaponic Production. *Sustainability*, *15*(9), 7638. https://doi.org/10.3390/su15097638

Seaman, J. A., Sawdon, G. E., Acidri, J., & Petty, C. (2014). The Household Economy Approach. Managing the impact of climate change on poverty and food security in

developing countries. *Climate Risk Management*, *4–5*, 59–68. https://doi.org/10.1016/j.crm.2014.10.001

Seif-Ennasr, M., Bouchaou, L., Brouziyne, Y., Chikhaoui, M., & Choukr-Allah, R. (2021). Towards more sustainable and climate-smart water and agricultural systems: Study case of the Souss Massa Basin in Morocco. *Frontiers in Science and Engineering, International Journal*, *11*(2). https://doi.org/10.34874/IMIST.PRSM/fsejournal-v11i2.29003

Sethi, R. C., & Sharma, R. B. (2012). Effective extension approaches for sustainable agricultural development. *International Journal of Farm Sciences*, *Volume : 2, Issue : 1*(1), First page : (116) Last page : (123).

Shahi, D. K. (2022). Dispersed Mountain Settlements: An Evaluation of High Mountain of Settlement of Har ki Dun. *Research Journal of Humanities and Social Sciences*, *13*(1), 38–44. https://doi.org/10.52711/2321-5828.2022.00007

Shanoyan, A., Featherstone, A., & Khachatryan, A. (2025). Addressing food security risks due to trade constraints and geopolitical tensions: Conceptual framework and practical application. *International Food and Agribusiness Management Review*, *1*(aop), 1–14. https://doi.org/10.22434/ifamr.1207

Shavrukov, Y., Kurishbayev, A., Jatayev, S., Shvidchenko, V., Zotova, L., Koekemoer, F., de Groot, S., Soole, K., & Langridge, P. (2017). Early Flowering as a Drought Escape Mechanism in Plants: How Can It Aid Wheat Production? *Frontiers in Plant Science*, *8*, 1950. https://doi.org/10.3389/fpls.2017.01950

Shelef, O., Fernández-Bayo, J. D., Sher, Y., Ancona, V., Slinn, H., & Achmon, Y. (2018). 2—Elucidating Local Food Production to Identify the Principles and Challenges of Sustainable Agriculture. In C. M. Galanakis (Ed.), *Sustainable Food Systems from Agriculture to Industry* (pp. 47–81). Academic Press. https://doi.org/10.1016/B978-0-12-811935-8.00002-0

Sinan, M., & Belhouji, A. (2016). Impact du changement climatique sur le climat et les ressources en eau du Maroc aux horizons 2020, 2050 et 2080 et mesures d'adaptation. *La Houille Blanche*, (4), Article 4. https://doi.org/10.1051/lhb/2016037

Singh, K. (2007). *Quantitative Social Research Methods*. SAGE Publications India Pvt Ltd. https://doi.org/10.4135/9789351507741

Singh, K. (2009). *Rural Development: Principles, Policies and Management*. SAGE Publications Ltd.

Sivakumar, M. (2021). Climate Change, Agriculture Adaptation, and Sustainability. In A. Kaushik, C. P. Kaushik, & S. D. Attri (Eds.), *Climate Resilience and Environmental Sustainability Approaches: Global Lessons and Local Challenges* (pp. 87–109). Springer. https://doi.org/10.1007/978-981-16-0902-2_6

Smith, P., & Olesen, J. E. (2010). Synergies between the mitigation of, and adaptation to, climate change in agriculture. *The Journal of Agricultural Science*, *148*(5), 543–552. https://doi.org/10.1017/S0021859610000341

Sommerville, M., Essex, J., & Le Billon, P. (2014). The 'Global Food Crisis' and the Geopolitics of Food Security. *Geopolitics*, *19*(2), 239–265. https://doi.org/10.1080/14650045.2013.811641

Spangenberg, J. H., Pfahl, S., & Deller, K. (2002). Towards indicators for institutional sustainability: Lessons from an analysis of Agenda 21. *Ecological Indicators, Hyatt S.I.*, *2*(1), 61–77. https://doi.org/10.1016/S1470-160X(02)00050-X

Sraïri, M. T. (2021). Repenser le modèle de développement agricole du Maroc pour l'ère post Covid-19. *Cahiers Agricultures*, *30*, 17. https://doi.org/10.1051/cagri/2021003

Sraïri, M. T., El Jaouhari, M., Saydi, A., Kuper, M., & Le Gal, P.-Y. (2011). Supporting small-scale dairy farmers in increasing milk production: Evidence from Morocco. *Tropical Animal Health and Production*, *43*(1), 41–49. https://doi.org/10.1007/s11250-010-9652-9

Stern. (2006). The Stern Review on the Economic Effects of Climate Change. *Population and Development Review*, *32*(4), 793–798. https://doi.org/10.1111/j.1728-4457.2006.00153.x

Straka, J., & Tuzová, M. (2016). Factors Affecting Development of Rural Areas in the Czech Republic: A Literature Review. *Procedia - Social and Behavioral Sciences, 19th International Conference Enterprise and Competitive Environment 2016*, *220*, 496–505. https://doi.org/10.1016/j.sbspro.2016.05.525

Streiner, D. L. (2003). Starting at the Beginning: An Introduction to Coefficient Alpha and Internal Consistency. *Journal of Personality Assessment*, *80*(1), 99–103. https://doi.org/10.1207/S15327752JPA8001_18

Taheripour, F., Haqiqi, I., Sajedinia, E., & Tyner, W. E. (2020). *Water Scarcity in Morocco: Analysis of Key Water Challenges*. International Bank for Reconstruction and Development/The World Bank.

Tan, X., Zhu, K., Meng, X., Gu, B., Wang, Y., Meng, F., Liu, G., Tu, T., & Li, H. (2021). Research on the status and priority needs of developing countries to address climate

change. *Journal of Cleaner Production*, *289*, 125669. https://doi.org/10.1016/j.jclepro.2020.125669

Taylor, M. (2018). Climate-smart agriculture: What is it good for? *The Journal of Peasant Studies*, *45*(1), 89–107. https://doi.org/10.1080/03066150.2017.1312355

Temirova, F. T. (2020). Importance Of Paralinguistic Features In Communication And Their Theoretical Study. *The American Journal of Social Science and Education Innovations*, *2*(09), 111–116. https://doi.org/10.37547/tajssei/Volume02Issue09-15

Tenzon, M., & Fisher, A. (2022). Foreign aid for rural development: Village design and planning in post-independence Morocco. *Planning Perspectives*, *37*(5), 949–971. https://doi.org/10.1080/02665433.2022.2116594

Thabet, C., Rached, Z., & Chebil, A. (2024). Improving agricultural policies to enhance food security in Tunisia: A retrospective and prospective analysis. *New Medit, Mediterranean Journal of Economics, Agriculture, Environment and Food, 2024 n. 3*. https://doi.org/10.30682/nm2403g

Ting, H., Memon, M. A., Thurasamy, R., & Cheah, J.-H. (2025). Snowball Sampling: A Review and Guidelines for Survey Research. *Asian Journal of Business Research*, *15*. https://doi.org/10.14707/ajbr.250186

Toujgani, I., El Fatehi, S., Elmaraghi, H., Ater, M., & Hmimsa, Y. (2021). Traditional knowledge and use value for sustainability: "Castanea sativa Mill.' as a model of socio-economic recovery in northern Morocco. *Current Research in Environmental Sustainability*, *3*, 100075. https://doi.org/10.1016/j.crsust.2021.100075

Toumi, L. (2016). Sustainable Food Security in Morocco: Challenges & Opportunities. *AGROFOR*, *1*(1), Article 1. https://doi.org/10.7251/AGRENG1601030T

Townsend, K. (2013). *Saturation And Run Off: How Many Interviews Are Required In Qualitative Research?* https://www.academia.edu/98869485/Saturation_And_Run_Off_How_Many_Interviews_Are_Required_In_Qualitative_Research

Trabelsi, R., Zairi, M., & Dhia, H. B. (2007). Groundwater salinization of the Sfax superficial aquifer, Tunisia. *Hydrogeology Journal*, *15*(7), 1341–1355. https://doi.org/10.1007/s10040-007-0182-0

Tramblay, Y., Koutroulis, A., Samaniego, L., Vicente-Serrano, S. M., Volaire, F., Boone, A., Le Page, M., Llasat, M. C., Albergel, C., Burak, S., Cailleret, M., Kalin, K. C., Davi, H., Dupuy, J.-L., Greve, P., Grillakis, M., Hanich, L., Jarlan, L., Martin-StPaul, N., … Polcher, J. (2020). Challenges for drought assessment in the Mediterranean region

under future climate scenarios. *Earth-Science Reviews*, *210*, 103348. https://doi.org/10.1016/j.earscirev.2020.103348

Treguer, David, Verner, Dorte, Redwood, John, Christensen, Jens, McDonnell, Rachael, Elbert, Christine, Konishi, Yasuo, & Belghazi, Saad. (2018). *Climate Variability, Drought, and Drought Management in Morocco's Agricultural Sector. World Bank Group*. World Bank, Washington, DC. https://hdl.handle.net/10986/30603

Tribak, W., & Rguig, S. (2021). Women's Rural Cooperatives in Morocco: Challenges and Collapses. *International Journal of Interdisciplinary Gender Studies*, *Vol 2. Issue1. 2021*(Vol 2. Issue1. 2021), 19.

Turton, A. R., Hattingh, J., Claassen, M., Roux, D. J., & Ashton, P. J. (2007). Towards a Model for Ecosystem Governance: An Integrated Water Resource Management Example. In A. R. Turton, H. J. Hattingh, G. A. Maree, D. J. Roux, M. Claassen, & W. F. Strydom (Eds.), *Governance as a Trialogue: Government-Society-Science in Transition* (pp. 1–28). Springer. https://doi.org/10.1007/978-3-540-46266-8_1

Udemezue, J., & Osegbue, E. (2018). Theories and Models of Agricultural Development. *Annals of Reviews & Research*, *1*(5). https://doi.org/10.19080/ARR.2018.01.555574

UN Comtrade. (2025). *UN Comtrade Database—The United Nations*. The United Nations Comtrade database aggregates detailed global annual and monthly trade statistics by product and trading partners. https://comtradeplus.un.org/

UNESCO. (2020). The United Nations World Water Development Report 2020: Water and climate change. *United Nations Educational, Scientific and Cultural Organization (UNESCO)*. https://hdl.handle.net/20.500.12870/7402

UNFCCC & WHO. (2016). *Health and climate change: Country profile 2015: Morocco* (p. 8) [Country report]. United Nations Framework Convention on Climate Change and World Health Organization of the United Nations. https://www.who.int/publications-detail-redirect/WHO-FWC-PHE-EPE-15.10

Urruty, N., Tailliez-Lefebvre, D., & Huyghe, C. (2016). Stability, robustness, vulnerability and resilience of agricultural systems. A review. *Agronomy for Sustainable Development*, *36*(1), 15. https://doi.org/10.1007/s13593-015-0347-5

Usha, K., Kurella, S., Ajita, G., Rama Rao, K., & Bhim Charan, M. (2021). Global water challenge and future perspective. In *Green Technologies for the Defluoridation of Water* (pp. 197–212). Elsevier. https://doi.org/10.1016/B978-0-323-85768-0.00002-6

Velten, S., Jager, N. W., & Newig, J. (2021). Success of collaboration for sustainable agriculture: A case study meta-analysis. *Environment, Development and Sustainability*, *23*(10), 14619–14641. https://doi.org/10.1007/s10668-021-01261-y

Velten, S., Leventon, J., Jager, N., & Newig, J. (2015). What Is Sustainable Agriculture? A Systematic Review. *Sustainability*, *7*(6), Article 6. https://doi.org/10.3390/su7067833

Visseren-Hamakers, I. J. (2020). The 18th Sustainable Development Goal. *Earth System Governance*, *3*, 100047. https://doi.org/10.1016/j.esg.2020.100047

Vitry, C., El Hassane, A., Dugué, P., & Chia, E. (2015). Apprendre à coopérer: Un défi pour l'adhésion des agriculteurs au Plan Maroc Vert. *New Medit, A Mediterranean Journal of Economics, Agriculture and Environment, 2015 n. 2*, *New Medit, Vol 14, nn. 2, (June 2015), pp. 13–21*(2015 n. 2), 9.

VOSviewer. (2023). *VOSviewer: A software tool for constructing and visualizing bibliometric networks* (Version 1.6.19) [Computer software]. https://www.vosviewer.com/

Walker, B., Holling, C. S., Carpenter, S. R., & Kinzig, A. (2004). Resilience, Adaptability and Transformability in Social–ecological Systems. *Ecology and Society*, *9*(2). https://www.jstor.org/stable/26267673

Wang, X., Zhang, J., Shahid, S., Guan, E., Wu, Y., Gao, J., & He, R. (2016). Adaptation to climate change impacts on water demand. *Mitigation and Adaptation Strategies for Global Change*, *21*(1), 81–99. https://doi.org/10.1007/s11027-014-9571-6

Wang, Z., Wang, J., Zhang, G., & Wang, Z. (2021). Evaluation of Agricultural Extension Service for Sustainable Agricultural Development Using a Hybrid Entropy and TOPSIS Method. *Sustainability*, *13*(1), Article 1. https://doi.org/10.3390/su13010347

WBG. (2017). *Managing Urban Water Scarcity in Morocco* [Working Paper]. World Bank. https://doi.org/10.1596/29190

WBG. (2021, February 5). *Climate Risk Country Profile Morocco*. World Bank Group. https://climateknowledgeportal.worldbank.org/sites/default/files/2021-09/15725-WB_Morocco%20Country%20Profile-WEB.pdf

Weber, R. (1990). *Basic Content Analysis*. SAGE Publications, Inc. https://doi.org/10.4135/9781412983488

Welsby, D., Price, J., Pye, S., & Ekins, P. (2021). Unextractable fossil fuels in a 1.5 °C world. *Nature*, *597*(7875), Article 7875. https://doi.org/10.1038/s41586-021-03821-8

Widhiarso, W., & Ravand, H. (2014). Estimating reliability coefficient for multidimensional measures: A pedagogical illustration. *Review of Psychology*, *21*(2), 111–121.

Wildemuth, B. M. (2016). *Applications of Social Research Methods to Questions in Information and Library Science, 2nd Edition*. ABC-CLIO.

World Bank. (2013). *Unlocking Africa's Agricultural Potential. Africa region sustainable development series*. World Bank. https://doi.org/10.1596/16624

World Bank. (2019, July 28). *Morocco Digital and Climate-Smart Agriculture Program*. The World Bank. http://documents1.worldbank.org/curated/en/648291567624827368/pdf/Concept-Stage-Program-Information-Document-PID-Morocco-Digital-and-Climate-Smart-Agriculture-Program-P170419.pdf

World Bank. (2023). *Morocco Food Products Exports by country 2022. World Integrated Trade Solution (WITS)*. World Bank, World Integrated Trade Solution (WITS). https://wits.worldbank.org/CountryProfile/en/Country/MAR/Year/2022/Summarytext

World Bank, FAO, & AAA Initiative. (2018, November). *Morocco Climate-Smart Agriculture Investment Plan*. Initiative for the Adaptation of African Agriculture to climate change. https://www.aaainitiative.org/sites/default/files/2021-01/CSAIP-Morocco.pdf

Yan, J. (2021). The impact of climate policy on fossil fuel consumption: Evidence from the Regional Greenhouse Gas Initiative (RGGI). *Energy Economics*, *100*, 105333. https://doi.org/10.1016/j.eneco.2021.105333

Zarouali, S. S. (2025). Future Challenges to Food Security in Morocco Between Geostrategy and Climate Change. *Journal of Information Systems Engineering and Management*, *10*(37s), 167–182. https://doi.org/10.52783/jisem.v10i37s.6391

Zhang, P., Zhang, J., & Chen, M. (2017). Economic impacts of climate change on agriculture: The importance of additional climatic variables other than temperature and precipitation. *Journal of Environmental Economics and Management*, *83*, 8–31. https://doi.org/10.1016/j.jeem.2016.12.001

Zhao, P., Liu, P., Shao, J., Li, C., Wang, B., Guo, X., Yan, B., Xia, Y., & Peng, M. (2015). Analysis of different strategies adapted by two cassava cultivars in response to drought stress: Ensuring survival or continuing growth. *Journal of Experimental Botany*, *66*(5), 1477–1488. https://doi.org/10.1093/jxb/eru507

Zhou, W., Li, M., & Achal, V. (2025). A comprehensive review on environmental and human health impacts of chemical pesticide usage. *Emerging Contaminants*, *11*(1), 100410. https://doi.org/10.1016/j.emcon.2024.100410

8. APPENDIX

Appendix 1: Questionnaire

Sustainability to enhance agricultural development resiliency regarding water shortages in Morocco (research) English version

Place of interview:……

Date of interview:……(month/day)

1. Sex: (Only one answer is possible)
    1) Male
    2) Female
2. Year of birth:
3. Highest qualification: (Only one answer is possible)
    1) None
    2) Not finished elementary
    3) Elementary school
    4) Junior High school
    5) Vocational school
    6) High school
    7) Higher education
4. Family status: (Only one answer is possible)
    1) Single
    2) Married
    3) Divorced
    4) Widowed
5. Number of children:
6. Place of residence:
7. Working situation: (Multiple answers are possible)
    - □ Owner
    - □ Rental
    - □ Shared lands (tribal or familial lands)
    - □ Permanent worker
    - □ Seasonal worker
    - □ Temporary for more than 15
    - □ Temporary for less than 15
8. Profession: (Multiple answers are possible)
    - □ Intellectual worker (white color)
    - □ Entrepreneur
    - □ Blue color working on the field
9. Do you consider your income to be: (Only one answer is possible)
    1) Low
    2) Below average
    3) Average
    4) Above average
    5) High
10. Does your income allow: (Only one answer is possible)
    1) Monthly savings.
    2) No financial problems
    3) Living with financial problems
11. The size of the farm is: (Only one answer is possible)
    1) Less than 1 ha

2) 1 to 3 ha
3) 3 to 5 ha
4) 5 to 10 ha
5) More than 10 ha

12. Does the farm have livestock? (farm animals): (Only one answer is possible)
    1) Yes
    2) No
13. Which crops are cultivated on the farm? (Multiple answers are possible)
    - □ Cereals
    - □ Arboriculture
    - □ Fodder
    - □ Legumes
    - □ Vegetables
    - □ Others, please specify:
14. How is soil fertility maintained on the farm? (Multiple answers are possible)
    - □ No practices are used.
    - □ Tillage (loosens and aerates the soil, which allows for the deeper penetration of roots. It controls weeds and mixes organic matter, fertilizer, and manure with the soil.)
    - □ No-till method of farming, Zero tillage, or direct drilling (less moisture evaporation, decreases the amount of soil erosion tillage causes in certain soils, especially in sandy and dry soils on sloping terrain. Other possible benefits include an increase in the amount of water that infiltrates into the soil, soil retention of organic matter, and nutrient cycling.) (French expression: le semi-direct)
    - □ Fertilization with chemicals
    - □ Fertilization with green manure
    - □ Fertilization with animal manure
    - □ Intercropping (Cultivation of two or more dissimilar types of crops in the same area in the same season)
    - □ Crop rotation (Cultivation of a series of dissimilar types of crops in the same area in sequential seasons)
    - □ The fallow technique (in which arable land is left without sowing for one or more vegetative cycles. The goal of fallowing is to allow the land to recover and store organic matter while retaining moisture and disrupting pest life cycles)
    - □ Others, please specify:
15. How are pests and diseases controlled on the farm? (Multiple answers are possible)
    - □ No practices are used.
    - □ Non-chemical control methods (Biological & organic control methods) please specify
    - □ Integrated pest management (IPM) methods (pesticides are used only when needed and in combination with other approaches for more effective (e.g. organic methods, long-term control. Pesticides are selected and applied in a way that minimizes their possible harm to people, nontarget organisms, and the environment.)
    - □ Chemical control, the use of the pesticides (treatment), specify if possible:
    - □ For other methods please specify :
16. Have you observed any climate change effects on your work? (Only one answer is possible) (If the answer is No go to question 20)

1) Yes
2) No

17. Since when the consequences of climate change were perceived (Only one answer is possible)
    1) Some years ago
    2) More than 5 years ago
    3) More than 10 years ago
18. In your view, what are the consequences of climate change observed and dealt with by farmers? (Multiple answers are possible)
    - □ Rise in temperature
    - □ Increased drought
    - □ Decreased drought
    - □ Changes in patterns of the season
    - □ Changes in precipitation patterns
    - □ Less precipitation
    - □ More precipitation
    - □ More shower precipitation (a mode of precipitation characterized by an abrupt start and end and by rapid variations in intensity)
    - □ More extreme weather phenomena
    - □ Soil degradation
    - □ Invasion of new pests
    - □ Invasion of the local pests (Climate change can accelerate the introduction and spread of invasive species, based on information from invasivespeciescentre.ca)
    - □ More illnesses in agricultural plants and livestock
    - □ Others, please specify:
19. How does the farm cope and adapt to these changes: (Multiple answers are possible)
    - □ We changed nothing.
    - □ More irrigation (from wells…)
    - □ Buying water, building water canals (More irrigation)
    - □ More pest control applied methods
    - □ Changing the crop types.
    - □ Changing agricultural methodology please specify:
    - □ Abandoning a part of the land.
    - □ Others, please specify:
20. Is the farm irrigated? (Only one answer is possible) (If the answer is No go to question 23)
    1) Yes
    2) No
21. Is the farm irrigated from: (Multiple answers are possible)
    - □ Wells
    - □ Dams
    - □ Channels
    - □ Rivers, lakes
    - □ Others, please specify:
22. Does the farm adopt any of the following irrigation practices? (Multiple answers are possible)
    - □ Surface irrigation
    - □ Sprinkler irrigation
    - □ Drip irrigation
    - □ Center-pivot irrigation

□ Sub-irrigation
□ Others, please specify:

23. Please indicate the reasons why the farm is not irrigated or not fully irrigated: (Multiple answers are possible)
□ No need for irrigation
□ The farm is fully irrigated
□ Costs
□ Management
□ Crop rotation
□ Soil properties
□ Ownership
□ Fragmentation of the farm
□ Water scarcity
□ Poor quality of water
□ Distance of water source
□ Lack of distribution infrastructure
□ Others, please specify:

24. According to your opinion, what are the major problems in the irrigated agricultural lands? (Multiple answers are possible)
□ Water quality
□ High cost of irrigation
□ Irrigation water adequacy
□ Drainage problems (system maintenance needs...)
□ Water use efficiency (old application systems, leakages…)
□ Condition of equipment, reservoirs, canals, pipes, and other structures
□ Excessive need for labor to operate the system.
□ Soil quality
□ Soil erosion
□ Desertification
□ Farmers training
□ Others, please specify:

25. Which of the following practices are used to conserve water on the farm? (Multiple answers are possible)
□ No practices are used
□ Windbreaks
□ Watering at night or very early in the morning
□ Elaborated irrigation schedules (best possible estimation of water needs, use of soil characteristics, frequency, duration, time of application…)
□ Pressure reduction (to reduce leakage rates in the water systems)
□ Replacing less efficient systems with more efficient ones (modern sprinklers, micro-irrigation systems...)
□ Wastewater reuse
□ Use of alternative water for irrigation (rain harvest…), please specify:

□ Leaving stubble on fields (e.g., minimum tillage, direct seeding)
□ Incorporating compost or other organic material into the soil to improve soil water retention (soil amendments)
□ Replacement of plants that have high water needs with local plants or, in general, plants with fewer water needs.
□ Other water-saving methods or devices, please specify:

26. In your view, what is the area's major cause of water shortages? (Multiple answers are possible)
    - □ Our area is not experiencing a lack of water
    - □ Drought
    - □ Desertification
    - □ Climate change
    - □ Excess pumping for irrigation by private drillings
    - □ Lack or insufficient size of central irrigation systems
    - □ Inefficient water management at the basin level
    - □ Inefficient water management at the farm level
    - □ Lack of a straightforward strategy regarding water management
    - □ Lack of support from relevant public administration services
    - □ Lack of guidance and rules concerning the water distribution management
    - □ Others, please specify:
27. Did you hear about any government support for farmers? (Only one answer is possible)
    1) Yes
    2) No
28. Did the farm benefit from any support from the government? (Only one answer is possible)
    1) Yes
    2) No
29. Did the farm benefit from any Nongovernmental organizations (NGOs) support? (Only one answer is possible)
    1) Yes
    2) No
30. To whom are the crops sold? (Multiple answers are possible)
    - □ Directly to consumers
    - □ Retailers
    - □ Wholesalers
    - □ Processors (Agro-processing sub-sector)
    - □ Exporters
    - □ Others, please specify:
31. Please mark, how strongly the following factors influence the decision to adopt sustainable agriculture practices!

	Strongly negative Neutral Strongly positive	I don't know
Climate change	-2 -1 0 +1 +2	
Climate variability of the last five years e g: inadequate distribution of precipitation	-2 -1 0 +1 +2	
Drought	-2 -1 0 +1 +2	
Soil degradation	-2 -1 0 +1 +2	
Feed supply for livestock	-2 -1 0 +1 +2	
Invasive pests. E.g: The cochineal (Dactylopius opuntiae) to the prickly pear cactus in Morocco	-2 -1 0 +1 +2	

The improvement of water use efficiency	-2_____-1_____0_____+1_____+2	
The improvement of agricultural yield	-2_____-1_____0_____+1_____+2	
Access to the government's financial support programs	-2_____-1_____0_____+1_____+2	
Access to loan opportunities from banks	-2_____-1_____0_____+1_____+2	
Access to support from associations and nongovernmental organizations (NGOs)	-2_____-1_____0_____+1_____+2	
Other reason:	-2_____-1_____0_____+1_____+2	

32. In your view, what are the challenges associated with the transition to sustainable agriculture practices: (e.g.: crop diversification, drip irrigation, intercropping, biological & organic control methods of pests and diseases...) (Multiple answers are possible)

    - □ No need for sustainable agriculture practices
    - □ The farm fully relies on sustainable agriculture practices
    - □ Costs
    - □ Management
    - □ Ownership
    - □ Fragmentation of the farm
    - □ Farmers training
    - □ Lack of infrastructure
    - □ Others, please specify :

Other remarks, and suggestions:

LE QUESTIONNAIRE

La durabilité pour améliorer la résilience du développement agricole face aux pénuries d'eau au Maroc (recherche) (French version of the questionnaire)

Le lieu de l'entretien : .....

La date de l'entretien : .....(mois/jour)

1. Le sexe : (Une seule réponse possible)
    1) Homme
    2) Femme
2. L'année de naissance :
3. Le niveau de scolarité : (Une seule réponse est possible)
    1) Aucun
    2) N'a pas terminé l'école primaire
    3) L'école primaire
    4) Le collège
    5) La formation professionnelle
    6) Le lycée
    7) L'enseignement supérieur
4. La situation familiale : (Une seule réponse est possible)
    1) Célibataire
    2) Marié(e)
    3) Divorcé(e)
    4) Veuf(ve)
5. Le nombre d'enfants :
6. Le lieu de résidence :
7. La situation professionnelle : (Plusieurs réponses sont possibles)
    - □ Un(e) propriétaire
    - □ Un(e) locataire(rice)
    - □ Des terres partagées (exemple : des terres tribales ou familiales)
    - □ Un travailleur(se) permane
    - □ Un travailleur(se) saisonnier
    - □ Un(e) travailleur(se) temporaire pour plus de 15 ans
    - □ Un(e) travailleur(se) temporaire pour moins de 15 ans
8. La profession : (Plusieurs réponses sont possibles)
    - □ Un(e) cadre et une profession intellectuelle supérieure
    - □ Un(e) entrepreneur(se)
    - □ Un(e) agriculteur(ice) (travail dans les champs exemple : ouvrier agricole, agriculteur exploitant)
9. Considérez-vous votre revenue : (Une seule réponse est possible)
    1) Faible
    2) Inférieur à la moyenne
    3) Moyen
    4) Supérieur à la moyenne
    5) Élevé
10. Votre revenue, vous permet-il : (Une seule réponse est possible)
    1) De faire une épargne à chaque mois
    2) Aucun problème financier
    3) De vivre avec des difficultés financières
11. La taille de l'exploitation agricole est : (Une seule réponse est possible)
    1) Moins de 1 ha
    2) De 1 à 3 ha

3) 3 à 5 ha
4) De 5 à 10 ha
5) Plus de 10 ha

12. L'exploitation possède-t-elle du bétail ? (Les animaux de la ferme) (Une seule réponse est possible)
    1) Oui
    2) Non
13. Quelles sont les cultures pratiquées dans l'exploitation agricole ? (Plusieurs réponses sont possibles)
    - Les céréales
    - l'arboriculture
    - Les fourrages
    - Les légumineuses
    - Les légumes
    - Autres, veuillez préciser si c'est possible :
14. Comment la fertilité du sol est-elle maintenue dans l'exploitation ? (Plusieurs réponses sont possibles)
    - Aucune pratique n'est utilisée.
    - Le travail du sol (le labour (ou labourage)) (ameublit et aère le sol, ce qui permet aux racines de pénétrer plus profondément) contrôle les mauvaises herbes et mélange la matière organique, les engrais et le fumier au sol. Il permet de lutter contre les mauvaises herbes et de mélanger les matières organiques, les engrais et le fumier au sol).
    - Les techniques sans labour (TCSL) (exemple : les techniques culturales simplifiées, le travail du sol superficiel, et le semis direct) (moins d'évaporation de l'humidité, moins d'érosion du sol causée par le labour dans certains sols, en particulier dans les sols sablonneux et secs sur les terrains en pente. Parmi les autres avantages possibles, citons l'augmentation de la quantité d'eau qui s'infiltre dans le sol, la rétention de la matière organique dans le sol et le cycle des éléments nutritifs).
    - La fertilisation avec des produits chimiques
    - La fertilisation avec de l'engrais vert
    - La fertilisation avec du fumier animal
    - La culture intercalaire (culture de deux ou plusieurs types de cultures différentes dans la même zone et à la même saison)
    - La rotation des cultures (culture d'une série de types de cultures différents dans la même zone au cours de saisons successives)
    - La jachère (une technique agricole qui consiste à ne pas ensemencer les terres agricoles pendant une ou plusieurs périodes végétatives)
    - Autres, veuillez préciser si c'est possible :
15. Comment les ravageurs et les maladies sont-ils contrôlés dans l'exploitation ? (Plusieurs réponses sont possibles)
    - Aucune pratique n'est utilisée.
    - Les méthodes de lutte non chimique (méthodes de lutte biologique et organique), veuillez préciser :
    - Les méthodes de lutte intégrée (IPM) (les pesticides ne sont utilisés qu'en cas de besoin et en combinaison avec d'autres approches pour un contrôle plus efficace (par ex. méthodes biologiques, contrôle à long terme). Les pesticides sont sélectionnés et appliqués de manière à réduire au minimum leurs effets

nocifs possibles sur les personnes, les organismes non ciblés et l'environnement).

 La lutte chimique (l'utilisation de pesticides synthétiques, inorganiques…) (traitement), veuillez préciser si possible :

 Pour les autres méthodes, veuillez préciser si c'est possible :

16. Avez-vous observé des effets du changement climatique sur l'exploitation agricole ? (Une seule réponse est possible) (Si la réponse est Non, veuillez passer directement à la question 20)
    1) Oui
    2) Non
17. Depuis quand les conséquences du changement climatique ont été perçues (Une seule réponse est possible)
    1) Il y a moins de cinq ans
    2) Entre 5 et 10 ans
    3) Il y a plus de 10 ans
18. Selon vous, quelles sont les conséquences du changement climatique observées et traitées par les agriculteurs ? (Plusieurs réponses sont possibles)
    - L'augmentation de la température
    - L'augmentation de la sécheresse
    - La diminution de la sécheresse
    - Les changements dans les schémas saisonniers
    - Les changements dans les régimes de précipitations
    - Moins de précipitations
    - Plus de précipitations
    - Plus de précipitations convectives (ou averses) (un mode de précipitation caractérisé par un début et une fin brusques et par des variations rapides d'intensité)
    - L'augmentation des phénomènes météorologiques extrêmes
    - La dégradation des sols
    - L'invasion de nouveaux ravageurs
    - L'invasion des ravageurs locaux (le changement climatique peut accélérer l'introduction et la propagation d'espèces envahissantes d'après le site invasivespeciescentre.ca)
    - L'augmentation des maladies des plantes agricoles et du bétail
    - Autres, veuillez préciser si c'est possible :
19. Comment l'exploitation agricole fait-elle face et s'adapte-t-elle à ces changements : (plusieurs réponses sont possibles)
    - Nous n'avons rien changé.
    - Plus d'irrigation (à partir de puits...)
    - L'achat d'eau, la construction de canaux (plus d'irrigation)
    - Plus de méthodes de lutte contre les parasites
    - Le changement des types de cultures.
    - Le changement de méthodologie agricole (veuillez préciser) :
    - L'abandon d'une partie des terres.
    - Autres, veuillez préciser si c'est possible :
20. L'exploitation est-elle irriguée ? (Une seule réponse est possible) (Si la réponse est non, veuillez passer directement à la question 23)
    1) Oui
    2) Non

21. L'exploitation est-elle irriguée à partir de : (plusieurs réponses sont possibles)
    - Les puits
    - Les barrages
    - Les canaux
    - Les rivières, les lacs
    - Autres, veuillez préciser si c'est possible :
22. L'exploitation adopte-t-elle l'une des pratiques d'irrigation suivantes ? (Plusieurs réponses sont possibles)
    - L'irrigation de surface (l'irrigation gravitaire)
    - L'irrigation par aspersion
    - L'irrigation au goutte-à-goutte
    - L'irrigation à pivot central
    - L'irrigation goutte à goutte enterrée
    - Autres, veuillez préciser si c'est possible :
23. Veuillez indiquer les raisons pour lesquelles l'exploitation n'est pas irriguée ou n'est pas entièrement irriguée : (plusieurs réponses sont possibles)
    - Pas de besoin d'irrigation
    - L'exploitation est entièrement irriguée
    - Les coûts
    - La gestion de l'exploitation (équipements et matériels)
    - La rotation des cultures
    - Les propriétés du sol
    - La propriété
    - La fragmentation de l'exploitation
    - La rareté de l'eau
    - La mauvaise qualité de l'eau
    - La distance de la source d'eau
    - Le manque d'infrastructures de distribution
    - Autres, veuillez préciser si c'est possible :
24. Selon vous, quels sont les principaux problèmes des terres agricoles irriguées ? (Plusieurs réponses sont possibles)
    - La qualité de l'eau
    - Le coût élevé de l'irrigation
    - L'adéquation de l'eau d'irrigation
    - Les problèmes de drainage (le besoin d'entretien du système...)
    - L'efficacité de l'utilisation de l'eau (anciens systèmes d'application, fuites...)
    - L'état de l'équipement, des réservoirs, des canaux, des tuyaux et autres structures
    - Le besoin excessif de main-d'œuvre pour faire fonctionner le système.
    - La qualité du sol
    - L'érosion du sol
    - La désertification
    - La formation des agriculteurs
    - Autres, veuillez préciser si c'est possible :
25. Parmi les pratiques suivantes, lesquelles sont utilisées pour conserver l'eau dans l'exploitation ? (Plusieurs réponses sont possibles)
    - Aucune pratique n'est utilisée.
    - Les brise-vent
    - L'arrosage le soir ou très tôt le matin

- □ Des programmes d'irrigation élaborés (meilleure estimation possible des besoins en eau, utilisation des caractéristiques du sol, fréquence, durée, heure d'application...)
- □ La réduction de la pression (pour réduire les fuites dans les systèmes d'eau d'irrigation)
- □ Le remplacement des systèmes les moins efficaces par des systèmes plus efficaces (les arroseurs modernes, les systèmes de micro-irrigation...)
- □ La réutilisation des eaux usées en agriculture
- □ L'utilisation d'eau alternative pour l'irrigation (La collecte des eaux pluviales...), veuillez préciser si c'est possible :
- □ De laisser les chaumes sur les champs (par exemple : le travail minimum du sol, les techniques sans labour (TCSL), le semis direct…)
- □ L'incorporation de compost ou d'autres matières organiques dans le sol pour améliorer la rétention d'eau (les amendements du sol)
- □ Le remplacement des cultures qui ont besoin de grandes quantités d'eau par des cultures locales ou, en général, par des cultures qui nécessitent moins d'eau.
- □ Autres techniques ou méthodes d'économie d'eau, veuillez préciser si c'est possible :

26. Selon vous, quelle est la principale cause de pénurie d'eau dans la région ? (Plusieurs réponses sont possibles)
    - □ Notre région ne connaît pas de pénurie d'eau
    - □ La sécheresse
    - □ La désertification
    - □ Le changement climatique
    - □ Le pompage excessif pour l'irrigation par des forages privés
    - □ L'absence ou taille insuffisante des systèmes d'irrigation centraux
    - □ La gestion inefficace de l'eau au niveau du bassin
    - □ La gestion inefficace de l'eau au niveau de l'exploitation agricole
    - □ L'absence de stratégie claire en matière de gestion de l'eau
    - □ Le manque de soutien de la part des services de l'administration publique concernés
    - □ Le manque d'orientations et de règles concernant la gestion de la distribution de l'eau
    - □ Autres, veuillez préciser :
27. Avez-vous entendu parler d'une aide gouvernementale aux agriculteurs ? (Une seule réponse est possible)
    1) Oui
    2) Non
28. L'exploitation a-t-elle bénéficié d'une aide du gouvernement ? (Une seule réponse est possible)
    1) Oui
    2) Non
29. L'exploitation a-t-elle bénéficié du soutien d'une organisation non gouvernementale (ONG) ? (Une seule réponse est possible)
    1) Oui
    2) Non
30. À qui les récoltes sont-elles vendues ? (Plusieurs réponses sont possibles)
    - □ Directement aux consommateurs
    - □ Aux détaillants

- □ Aux grossistes
- □ Aux transformateurs agroalimentaires
- □ Aux exportateurs
- □ Autres, veuillez préciser :

31. Veuillez indiquer dans quelle mesure les facteurs suivants influencent fortement la décision d'adopter des pratiques agricoles durables !

	Fortement négatif Neutre Fortement positif	Je ne sais pas
Le changement climatique	-2_____-1_____0_____+1_____+2	
La variabilité du climat au cours des cinq dernières années, par exemple : La répartition inadéquate des précipitations	-2_____-1_____0_____+1_____+2	
La sécheresse	-2_____-1_____0_____+1_____+2	
La dégradation du sol	-2_____-1_____0_____+1_____+2	
L'approvisionnement en aliments pour le bétail	-2_____-1_____0_____+1_____+2	
Les ravageurs invasifs. Par exemple, la cochenille (Dactylopius opuntiae) sur le figuier de Barbarie au Maroc.	-2_____-1_____0_____+1_____+2	
L'amélioration de l'efficacité de l'utilisation de l'eau	-2_____-1_____0_____+1_____+2	
L'amélioration du rendement agricole	-2_____-1_____0_____+1_____+2	
L'accès aux programmes de soutien financier gouvernementaux	-2_____-1_____0_____+1_____+2	
L'accès aux possibilités de prêts bancaires	-2_____-1_____0_____+1_____+2	
L'accès au soutien des associations et les organisations non gouvernementales (ONG)	-2_____-1_____0_____+1_____+2	
Une autre raison :	-2_____-1_____0_____+1_____+2	

32. Selon vous, quels sont les défis associés à la transition vers des pratiques agricoles durables : (par exemple : diversification des cultures, irrigation au goutte-à-goutte, cultures intercalaires, méthodes de contrôle biologique et organique des ravageurs et des maladies...) (Plusieurs réponses sont possibles)
    - □ Pas besoin de pratiques agricoles durables
    - □ L'exploitation s'appuie entièrement sur des pratiques d'agriculture durable
    - □ Les coûts
    - □ La gestion de l'exploitation
    - □ La Propriété
    - □ La fragmentation de l'exploitation
    - □ La formation des agriculteurs

- Le manque d'infrastructures
- Autres, veuillez préciser :

Autres remarques et suggestions :

ⴰⵙⵜⴰⵔⴰⵙⵜⵓⵔⵉ

الاستدامة لتعزيز مرونة التنمية الزراعية فيما يتعلق بنقص المياه في المغرب

ⵜⴰⵎⵙⵍⵉⵜ ⵖ ⵙⵎⵍⴰⵏ ⵏ ⵜⵏⵙⵢⵖ ⵜⴰⵏⵎⵓⵔⵜ ⵔ ⵓⵎⴰⵙ ⵖⵣⵣⵍ ⵙ ⵙⵔⴰⵔⵏ ⵏ ⵍⵎⴰⵏ ⵔ

ⵍⵎⵖⵔⵉⴱ

(Arabic version of the questionnaire)

مكان المقابلة:.....

تاريخ المقابلة: ..... (الشهر / اليوم)

1. الجنس:
   1) ذكر 2) أنثى

2. سنة الميلاد:

3. أعلى مستوى دراسي: (إجابة واحدة فقط ممكنة)
   1) لا شيء 2) لم تنته من المرحلة الابتدائية 3) المدرسة الابتدائية 4) المدرسة الثانوية الإعدادية
   5) المدرسة مهنية 6) المدرسة الثانوية 7) التعليم العالي

4. الحالة العائلية: (إجابة واحدة فقط ممكنة)
   1) عازب (ة) 2) متزوج (ة) 3) مطلق (ة) 4) أرمل (ة)

5. عدد الأطفال: .....

6. مكان الإقامة: (الإقليم): .....

7. الوضعية المهنية في الفلاحة: (الإجابات المتعددة ممكنة)
   ☐ مالك للأرض فلاحية ☐مستأجر للأرض فلاحية ☐ الأراضي الفلاحية المشتركة (الأراضي القبلية أو العائلية)
   ☐ عامل دائم ☐عامل موسمي ☐ عامل مؤقت لأكثر من 15 يوما ☐عامل مؤقت لأقل من 15 يوما

8. المهنة: (الإجابات المتعددة ممكنة)
   ☐ مُوَظَّفٌ إدَارِيٌّ، مهندس فلاحي ☐ مُقَاوِل(ة) ☐
   مزارع(ة)، عامل(ة)في الحقول

9. هل تعتبر دخلك: (إجابة واحدة فقط ممكنة)
   1) منخفض 2) أقل من المتوسط 3) المتوسط 4) أعلى من المتوسط إلى مرتفع
   5) مرتفع

10. هل يسمح دخلك: (إجابة واحدة فقط ممكنة)
    1) بالادخار وتوفير المال كل شهر 2) بالعيش دون إكراهات مالية 3) بالعيش بإكراهات مالية

11. حجم المزرعة هو: (إجابة واحدة فقط ممكنة)
    1) أقل من 1 هكتار 2) من 1 إلى 3 هكتار 3) من 3 إلى 5 هكتار
    4) من 5 إلى 10 هكتار 5) أكثر من 10 هكتار

12. هل المزرعة بها ماشية؟ (حيوانات المزرعة) (إجابة واحدة فقط ممكنة)
1) نعم 2) لا

13. ما هي المحاصيل التي تزرع وتنتج في المزرعة؟ (الإجابات المتعددة ممكنة)
☐ الحبوب ☐ زراعة الأشجار ☐ الأعلاف ☐البقوليات ☐ خضروات
☐ أخرى، يرجى التحديد:.....

14. كيف يتم الحفاظ على خصوبة التربة في المزرعة؟ (الإجابات المتعددة ممكنة)
☐ لا يتم استخدام أي ممارسات.
☐ الحرث
☐ الزراعة بلا حرث أو الزرع المباشر(le semi-direct)
☐ بالأسمدة الصناعية الكيميائية
☐ بالسماد العضوي الأخضر
☐ بالسماد العضوي الحيواني
☐ الزراعة البينية (زراعة نوعين مختلفين أو أكثر من المحاصيل في نفس المنطقة في نفس الموسم)
☐ تناوب المحاصيل (زراعة سلسلة من أنواع مختلفة من المحاصيل في نفس المنطقة في المواسم المتتالية)
☐ الإبَارة أو إراحة الأرض (تقنية زراعية تُترك فيها الأراضي الصالحة للزراعة دون بذر لدورة نباتية واحدة أو أكثر)
☐ لطرق أخرى، يرجى التحديد:.....

15. كيف يتم مكافحة الآفات والأمراض في المزرعة؟ (الإجابات المتعددة ممكنة)
☐ لا يتم استخدام أي ممارسات .
☐ طرق المكافحة غير الكيميائية (طرق المكافحة البيولوجية والعضوية) يرجى التحديد:
☐ الإدارة المتكاملة للآفات أو مكافحة الآفات المتكاملة (la lutte intégrée ou protection intégrée) (IPM)يتم استخدام الطرق العضوية واختيار المبيدات الحشرية وتطبيقها بطريقة تقلل من ضررها المحتمل على الناس والكائنات غير المستهدفة والبيئة
☐ المكافحة الكيميائية، استخدام المبيدات الحشرية، يرجى التحديد:
☐ لطرق أخرى، يرجى التحديد:.....

16. هل لاحظت أي آثار ناتجة عن تغير المناخ على عملك في المزرعة؟ (إجابة واحدة فقط ممكنة)
(إذا كان الجواب لا، فانتقل إلى السؤال 20)
1) نعم 2) لا

17. منذ متى لوحظت عواقب أو آثار تغير المناخ؟ (إجابة واحدة فقط ممكنة)
1) منذ بضع سنوات 2) أكثر من 5 سنوات 3) أكثر من 10 سنوات

18. برأيكم، ما هي عواقب أو آثار تغير المناخ الذي لاحظها المزارعون وتكيفوا معها؟ (الإجابات المتعددة ممكنة)
☐ ارتفاع درجة الحرارة ☐ زيادة الجفاف
☐ انخفاض الجفاف ☐ تغيرات في أنماط فصول السنة

☐ التغيرات في أنماط هطول الأمطار ☐ هطول أقل للأمطار
☐ هطول أكثر للأمطار ☐ هطول أمطار تتميز ببداية ونهاية مفاجئة وبتغيرات سريعة في الشدة
☐ الزيادة في الطقس المتطرف ☐ تدهور التربة
☐ ظهور آفات زراعية حديثة (آفات حشرية ...) ☐ غزو الآفات الزراعية المحلية
☐ انتشار أمراض في النباتات الزراعية والماشية
☐ لعواقب أخرى، يرجى التحديد:.....

19. كيف تتعامل المزرعة مع هذه التغييرات وتتكيف معها: (الإجابات المتعددة ممكنة)
☐ لم نغير شيئا ☐ المزيد من الري (من الآبار ...)
☐ شراء المياه وبناء قنوات المياه (المزيد من الري) ☐ المزيد من الطرق المطبقة لمكافحة الآفات الزراعية
☐ تغيير أنواع المحاصيل ☐ تغيير المنهجية الزراعية يرجى التحديد: .....
☐ التخلي عن جزء من الأرض
☐ أخرى، يرجى التحديد:.....

20. هل المزرعة مروية؟ (إجابة واحدة فقط ممكنة) (إذا كان الجواب لا، فانتقل إلى السؤال 23)
1) نعم 2) لا

21. هل المزرعة مروية من: (إجابات متعددة ممكنة)
☐ الآبار ☐ السدود ☐ قنوات المياه ☐ الأنهار والبحيرات
☐ أخرى، يرجى تحديد:.....

22. هل تتبنى المزرعة أيًا من ممارسات الري التالية؟ (الإجابات المتعددة ممكنة)
☐ الري السطحي (بالغمر) ((de surface (gravitaire) ☐ الري بالرش ☐ الري بالتنقيط (goutte-à-goutte)
☐ الري المحوري المركزي(pivot central) ☐ الري بالتنقيط تحت السطحي
☐ أخرى، يرجى التحديد
:.....

23. ما هي أسباب عدم ري المزرعة أو عدم ريها بالكامل: (الإجابات المتعددة ممكنة)
☐ لا حاجة للري ☐ المزرعة مروية بالكامل ☐ تكاليف الري
☐ تسيير المزرعة ☐ الدورة الزراعية (الدورة المحصولية) ☐ خصائص التربة
☐ مشاكل في ملكية الأرض (المزرعة) ☐ تجزؤ المزرعة (fragmentation) ☐ ندرة المياه
☐ ردائة جودة المياه ☐ المسافة بعيدة من مصدر المياه ☐ نقص البنية التحتية للتوزيع المياه
☐ أسباب أخرى، يرجى التحديد
:.....

24. برأيكم، ما هي المشاكل الرئيسية في الأراضي الزراعية المروية؟ (الإجابات المتعددة ممكنة)

☐ جودة المياه ☐ ارتفاع تكلفة الري ☐ كفاية مياه الري

☐ مشاكل الصرف (احتياجات صيانة نظام الري...)

☐ كفاءة استخدام المياه (أنظمة التطبيقات القديمة والتسربات ...)

☐ حالة المعدات والخزانات والقنوات والأنابيب وغيرها من الهياكل

☐ الحاجة المفرطة لليد العاملة لتشغيل النظام .

☐ جودة التربة ☐ تآكل التربة ☐ التصحر ☐ تدريب المزارعين

☐ مشاكل أخرى، يرجى التحديد:.....

25. ما هي الممارسات التالية المستخدمة للحفاظ على المياه في المزرعة؟ (الإجابات المتعددة ممكنة)

☐ لا يتم استخدام الممارسات.

☐ مصدات الرياح

☐ الري في الليل أو في الصباح الباكر

☐ جداول الري التفصيلية (أفضل تقدير ممكن لاحتياجات المياه، واستخدام خصائص التربة، والتردد، والمدة، ووقت التطبيق...)

☐ تخفيض الضغط (للحد من التسربات في شبكات مياه الري)

☐ استبدال الأنظمة الأقل كفاءة بأنظمة أكثر كفاءة (الرشاشات الحديثة وأنظمة الرّي الدقيق...)

☐ إعادة استخدام مياه الصرف الصحي في الزراعة

☐ استخدام المياه البديلة للري (تجميع مياه الأمطار ...) ، يرجى التحديد إن أمكن :.....

☐ ترك القش في الحقول (الحد الأدنى من الحرث، البذر المباشر (Le semis direct))

☐ دمج السماد أو المواد العضوية الأخرى في التربة لتحسين الاحتفاظ بمياه التربة (تعديلات التربة)

☐ استبدال المحاصيل التي تحتاج إلى كميات كبيرة من المياه بمحاصيل محلية أو بشكل عام بمحاصيل تتطلب كمية أقل من المياه.

☐ تقنيات أو طرق أخرى لتوفير المياه، يرجى التحديد:.....

26. برأيكم، ما هو السبب الرئيسي لنقص المياه في المنطقة؟ (الإجابات المتعددة ممكنة)

☐ منطقتنا لا تعاني من نقص المياه ☐ الجفاف

☐ التصحر ☐ تغير المناخ

☐ الضخ المفرط للري عن طريق الحفر الخاص ☐ غياب أو عدم كفاية حجم أنظمة الري المركزية

☐ إدارة المياه غير الفعالة على مستوى الحوض ☐ إدارة المياه غير الفعالة على مستوى المزرعة

☐ عدم وجود استراتيجية واضحة لإدارة المياه ☐ عدم وجود دعم من خدمات الإدارة العمومية المعنية

☐ عدم وجود مبادئ توجيهية وقواعد بشأن إدارة توزيع المياه

☐ أسباب أخرى، يرجى التحديد:.....

27. هل سمعت عن أي دعم حكومي للمزارعين؟ (إجابة واحدة فقط ممكنة)

1) نعم 2) لا

28. هل استفادت المزرعة من أي دعم من الحكومة؟ (إجابة واحدة فقط ممكنة)
1) نعم 2) لا

29. هل استفادت المزرعة من أي دعم من الجمعيات والمنظمات غير الحكومية؟ (إجابة واحدة فقط ممكنة)
1) نعم 2) لا

30. لمن تباع المحاصيل؟ (الإجابات المتعددة ممكنة)

☐ مباشرة للمستهلكين ☐ لتجار التجزئة ☐ لتجار الجملة
☐ التصنيع الزراعي ☐ للمصدرين
☐ أخرى، يرجى
التحديد:.....

31. يرجى وضع علامة على مدى تأثير العوامل التالية على قرار اعتماد الممارسات الزراعية المستدامة!

	ذات عَلاقة قوية	محايد	ليس له عَلاقة قوية	لا أدري
تغير المناخ	2+_____1+_____0_____1-_____2-			
تقلبات المناخ في السنوات الخمس الماضية. مثال: التوزيع غير الكافي لهطول الأمطار	2+_____1+_____0_____1-_____2-			
الجفاف	2+_____1+_____0_____1-_____2-			
تدهور التربة	2+_____1+_____0_____1-_____2-			
لإمدادات الأعلاف للماشية	2+_____1+_____0_____1-_____2-			
الآفات الزراعية الغازية. مثال: قِرْمزي La cochenille) (Dactylopius opuntiae) إلى صبار الكمثرى الشائك في المغرب	2+_____1+_____0_____1-_____2-			
لتحسين كفاءة و دِقَّة استخدام المياه	2+_____1+_____0_____1-_____2-			
لتحسين المحصول الزراعي	2+_____1+_____0_____1-_____2-			
للاستفادة من برامج الدعم المالي الحكومية	2+_____1+_____0_____1-_____2-			
لفرص الحصول على القروض من البنوك	2+_____1+_____0_____1-_____2-			
للحصول على المساعدات من الجمعيات و المنظمات غير الحكومية	2+_____1+_____0_____1-_____2-			
سبب آخر:	2+_____1+_____0_____1-_____2-			

32. برأيكم، ما هي التحديات المرتبطة بالانتقال إلى الممارسات الزراعية المستدامة: (على سبيل المثال: تنويع المحاصيل، الري بالتنقيط، الزراعة البينية، طرق المكافحة البيولوجية والعضوية للآفات والأمراض...) (الإجابات المتعددة ممكنة)

☐ لا حاجة للممارسات الزراعة المستدامة ☐تعتمد المزرعة بشكل كامل على الممارسات الزراعية المستدامة

☐ تكاليف التجهيز ☐تسيير المزرعة ☐ مشاكل في ملكية الأرض (المزرعة)

☐ تجزؤ المزرعة ☐ تدريب المزارعين ☐ ضعف البنية التحتية

☐ أسباب أخرى، يرجى التحديد:.....

ملاحظات واقتراحات أخرى:

.....

.....

.....

.....

.....

.....

.....

The further explanation that was distributed regarding question 31

توضيح حول السؤال 31

هل تؤثر المفاهيم التالية على قرار اعتماد أساليب الزراعة المستدامة في المزرعة؟

أساليب الزراعة المستدامة = الري بالتنقيط، وتنويع المحاصيل، واختيار المحاصيل الأقل استهلاكاً للمياه والمقاومة لارتفاع درجات الحرارة، وإدارة الآفات وخصوبة التربة بطرق عضوية

31. يرجى وضع علامة على مدى تأثير العوامل التالية على اعتماد الممارسات الزراعية المستدامة!

	ذات عَلاقة قوية		محايد		ليس له عَلاقة قوية	لا أدري
تغير المناخ	+2	+1	0	-1	-2	
تقلبات المناخ في السنوات الخمس الماضية. مثال: التوزيع	+2	+1	0	-1	-2	

لا أدري : لا يدرك الشخص العلاقة بين العامل واعتماد طرق الزراعة المستدامة

محايد : (0): يفهم الشخص العلاقة بين العامل واعتماد أساليب الزراعة المستدامة، ولكنه لا يعرف ما إذا كان يؤثر أم لا

(1 +) : يعتقد الشخص أن العامل يؤثر إلى قليلا على قرار اعتماد طرق الزراعة المستدامة

(2 +) : يعتقد الشخص أن العامل يؤثر بشدة على قرار اعتماد أساليب الزراعة المستدامة

(-1) : يعتقد الشخص أن العامل لا يؤثر كثيرا على قرار اعتماد طرق الزراعة المستدامة

(-2) : يعتقد الشخص أن العامل لا يؤثر ولا علاقة له بقرار اعتماد أساليب الزراعة المستدامة

توضيح حول السؤال 31

هل تؤثر المفاهيم التالية على قرار اعتماد أساليب الزراعة المستدامة في المزرعة؟

أساليب الزراعة المستدامة = الري بالتنقيط، وتنويع المحاصيل، واختيار المحاصيل الأقل استهلاكاً للمياه والمقاومة لارتفاع درجات الحرارة، وإدارة الآفات وخصوبة التربة بطرق عضوية

31. يرجى وضع علامة على مدى تأثير العوامل التالية على اعتماد الممارسات الزراعية المستدامة!

	ذات عَلاقة قوية		محايد		ليس له عَلاقة قوية	لا أدري
تغير المناخ	+2	+1	0	-1	-2	
تقلبات المناخ في السنوات الخمس الماضية. مثال: التوزيع	+2	+1	0	-1	-2	

لا أدري : لا يدرك الشخص العلاقة بين العامل واعتماد طرق الزراعة المستدامة

محايد : (0): يفهم الشخص العلاقة بين العامل واعتماد أساليب الزراعة المستدامة، ولكنه لا يعرف ما إذا كان يؤثر أم لا

(1 +) : يعتقد الشخص أن العامل يؤثر إلى قليلا على قرار اعتماد طرق الزراعة المستدامة

(2 +) : يعتقد الشخص أن العامل يؤثر بشدة على قرار اعتماد أساليب الزراعة المستدامة

(-1) : يعتقد الشخص أن العامل لا يؤثر كثيرا على قرار اعتماد طرق الزراعة المستدامة

(-2) : يعتقد الشخص أن العامل لا يؤثر ولا علاقة له بقرار اعتماد أساليب الزراعة المستدامة

Appendix 2: In-depth interview questions

- Please introduce yourself (to clarify the competence), which department do you belong to? how much experience do you have in this sector? with the state? in this position in the organization?
    - Pourriez-vous vous présenter (afin de clarifier la compétence), à quel département appartenez-vous ? quelle expérience avez-vous dans ce secteur ? avec l'État ? à ce poste dans l'organisation ?
    - هل يمكنكم تقديم نفسكم؟ (لتوضيح الكفاءة)، إلى أي قسم تنتمي؟ ما مدى خبرتك في هذا القطاع؟ مع الدولة؟ في هذا المنصب في المؤسسة؟
- As a member of the organization, what are the perceived challenges for agricultural development?
    - En tant que membre de l'organisation, quels sont les défis perçus en matière de développement agricole ?
    - كعضو في المؤسسة، ما هي التحديات المتصورة للتنمية الزراعية؟
- From your point of view, what is the most important issue facing agricultural development in Morocco?
    - Selon vous, quel est l'enjeu le plus important du développement agricole au Maroc ?
    - من وجهة نظركم، ما هي أهم قضية تواجه التنمية الفلاحية في المغرب ؟
- From your perspective, what changes did you notice in the sector after the adoption of the Moroccan Green Plan (2008-2020) and/or Green Generation Strategy (2020-2030) by the government?
    - De votre point de vue, quels changements avez-vous constatés dans le secteur après l'adoption du Plan Maroc Vert (2008-2020) et/ou du Plan de Génération Verte (2020-2030) par le gouvernement ?
    - من وجهة نظركم، ما هي التغييرات التي لاحظتها في القطاع بعد اعتماد مخطط المغرب الأخضر (2008-2020) و / أو استراتيجية الجيل الأخضر (2020-2030) من قبل الحكومة؟
- In your opinion, how does the government address agricultural development in terms of the transition to sustainable agriculture in its plans?
    - À votre avis, comment le gouvernement aborde-t-il le développement agricole en termes de transition vers une agriculture durable dans ses plans ?
    - في رأيكم، كيف تتناول الحكومة التنمية الزراعية من حيث الانتقال إلى الزراعة المستدامة في خططها؟
- From your perspective, what are the critical challenges for the transition to sustainable agriculture? how could be achieved successfully?
    - De votre point de vue, quels sont les principaux défis à relever pour la transition vers une agriculture durable ? Comment pourrait-on y parvenir?
    - من وجهة نظركم، ما هي التحديات الحاسمة للانتقال إلى الزراعة المستدامة؟ كيف يمكن تحقيقها بنجاح؟
- What can be done to encourage farmers to adopt sustainable farming practices? Do may have the knowledge and ability for the appropriate adaptation?
    - Que peut-on faire pour encourager les agriculteurs à adopter des pratiques agricoles durables ? Ont-ils les connaissances et les capacités nécessaires pour s'adapter ?
    - ما الذي يمكن فعله لتشجيع المزارعين على تبني ممارسات زراعية مستدامة؟ هل يمتلكون المعرفة والقدرة على التكيف المناسب؟
- What do you suggest for the next government plan to include to boost agricultural development and the transition to sustainability to strengthen the resiliency of this sector?
    - Que suggérez-vous d'inclure dans les prochains plans gouvernementaux afin de stimuler le développement agricole et la transition vers la durabilité afin de renforcer la résilience de ce secteur ?

- ما الذي تقترحون تضمينه في الخطط الحكومية المستقبلية لتحفيز التنمية الزراعية والانتقال إلى الاستدامة لتعزيز مرونة هذا القطاع؟

BIOGRAPHY OF THE AUTHOR

Zouhair Samir was born in Morocco in 1994. In 2012, he received his high school diploma (Baccalaureate Major of: Economics and Management option: Economics), followed by a Diploma of Specialized Technician in Business Management in 2014, and a bachelor's degree level (Professional Licence Option Banking Professions Branch: Management, Finance, Economy, Bank) in 2015. On December 27, 2019, he completed his University Master’s degree (Specialty: Information System and Management Control) at the National School of Commerce and Management, Cadi Ayyad University, Marrakesh, Morocco.

The author undertook multiple internships at diverse organizations in Morocco, including at the Regional Office for Agricultural Development of Haouz, in Marrakesh, and speaks three languages: English, French, and Arabic.

BIBLIOGRAPHY OF THE AUTHOR

The author has contributed during the PhD program with the following publications and participation in International Conferences.

Samir Zouhair. (2022) Conference Paper under the title: Agriculture and sustainable development example of Morocco: A brief review of the literature. Published at Spring Wind Conference 2022 in the second proceeding conference volume (XXV. Tavaszi Szél Konferencia – Tanulmánykötet - II. Kötet), the University of Pécs, Hungary. (90-103). ISBN: 978-615-6457-13-4.

Samir Zouhair. (2023) Journal article at E-CONOM Online Scientific Journal (Online tudományos folyóirat), Alexandre Lamfalussy Faculty of Economics, University of Sopron. Title of the paper: Morocco's agriculture and rural development from sustainable development aspects. (153-169). ISSN: 2063-644X. DOI: 10.17836/EC.2023.1.153.

Samir Zouhair. (2023) Conference Paper under the title: Agriculture in Morocco: sustainable development, climate-smart Agriculture, and the potential usefulness of political ecology perspectives. IX. International Winter Conference of P.h.D. Students and Researchers in Economics. Óbuda University, Budapest, Hungary. Publisher: Association of Hungarian PhD and DLA Students – TéKa. (pages 130-138). ISBN: 978-80-974152-6-6.

Samir Zouhair. (2023) Chapter in Book (Study) under the title: Socio-economic Impacts of Sustainable Development on Agriculture in Morocco. Published at Szemelvények a BGE kutatásaiból II. kötet. (pages 232-242). ISBN: 9786156342768.
DOI: https://doi.org/10.29180/978-615-6342-76-8_30

Samir Zouhair, Pappné Vancsó Judit. (2023) Journal article in the Journal of Economy & Society (Gazdaság & Társadalom), University of Sopron, Volume 16 (34), Issue 4 (2023), under the title of: The challenges facing rural population and the potential of sustainability of rural development in Morocco. ISSN: 08657823 DOI: https://doi.org/10.21637/GT.2023.4.04

Zouhair Samir, Pappné Vancsó Judit. (2025) Journal article in the Journal Földrajzi Közlemények, under the title of: Az aszály hatása a marokkói mezőgazdaságra – Az alkalmazkodás lehetőségei a döntéshozók szándékai és a gazdák tapasztalatai alapján / The impact of drought on Moroccan agriculture – Adaptation options based on policy makers' intentions and farmers' experiences. DOI: https://doi.org /10.32643/f k.149.2.1

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Sopron, March 2026

Zouhair Samir

DECLARATION ON IDENTITY

I, the undersigned Zouhair Samir, declare that **the printed and electronic versions** of the doctoral dissertation and thesis booklet **are identical in all respects**.

Sopron, 2026, March 19

signature of PhD candidate

LEGAL DECLARATION

I, the undersigned Zouhair Samir, by signing this declaration declare that "The role of sustainability transition in strengthening agricultural development resilience to water scarcity in Morocco" my PhD dissertation was my own work; during the dissertation I complied with the Act LXXVI of 1999 on the rules of copyright and the rules of the doctoral dissertation prescribed by the Doctoral School, especially regarding references and citations.[1]

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