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RESEARCH AND THEORY

Perceptions and strategies of adaptation of Moroccan farmers to climate change—case of Khemisset province

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Abstract
Climate change has emerged as one of our most pressing global challenges, with far-reaching implications for various sectors, including agriculture. The Earth's climate is undergoing significant changes, primarily driven by human activities such as burning fossil fuels and deforestation. These changes result in rising temperatures, changing precipitation patterns, and more frequent extreme weather events. Consequently, the agricultural sector, which relies heavily on stable climatic conditions, faces numerous challenges threatening global food security and livelihoods. The present study deals with the issue of climate change and its impact on yields and agricultural production in the province of Khemisset. The methodology used is a combination approach of quantitative and qualitative research. Among other tools for processing data were descriptive statistics and principal component analysis. In total, 120 research units are surveyed in the study area; the number of farmers is not homogeneous, and four categories of producers have been formed to analyze the perceptions and farmer strategies developed. They have been chosen according to the soil, vegetation, and livestock type. The main conclusions derived from the study results are: We observed a negative evolution of climate parameters during the period 1985–2015. Virtually all the producers of the area studied perceive a negative evolution of the different climatic parameters, which is consistent in most cases with the analysis of meteorological data. The changes and climate variability have negative impacts on agriculture. The local populations have a good understanding of the evolution of agricultural yields. Using fertilizers, crop rotation, early varieties of crops, and other types of adaptations are the responses of some farmers from the Zemmour tribes to the effects of climate change. Climate change is already affecting agriculture and will continue to do so. It is crucial to highlight the immediate requirement for inclusive measures to address and adjust to the consequences of climate change on agriculture to guarantee the endurance, sustainability, and food security of our agricultural systems.

Keywords Adaptation strategies · Agriculture · Climate change · Impacts · Moroccan farmers · Perceptions

Abbreviations

GDP	Gross Domestic Product
IPCC	Intergovernmental Panel on Climate Change
NIAR	National Institute for Agricultural Research
SPSS	Statistical Package for Social Science

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Introduction

In Morocco, agriculture has always been a strategic sector of the national economy. This is reflected in the priority it has given to all economic and social development plans since independence. It currently contributes 19% to the national GDP, of which 15% goes to crop and animal production and 4% to agro-industry, generates four million jobs, especially in rural areas (40% of the working population), and also has a knock-on effect on other production or service sectors (Harbouze et al. 2019; Ministère de l'agriculture 2019).

Small-scale agriculture, practiced by most Moroccan farmers, depends primarily on rainfall for the availability of water for crops, and climate change produces chaos for Moroccan farmers. Changes in the frequency and intensity of floods and droughts may provide difficulties for ranchers and farmers and a danger to food safety (USGCRP 2016;

Chaachouay et al. 2022a, b). Agriculture relies heavily on the weather and climate change, making it susceptible to weather unpredictability and climatic shifts. Rainfall rates, CO_2 concentrations, and temperature changes are projected to influence agricultural production substantially. The proportion of these variables will determine the actual consequences of climate change on agriculture (Gould and Higgs 2009).

Agriculture, forestry, and fisheries are vulnerable to the effects of climate change while simultaneously contributing to greenhouse gas emissions (Al et al. 2008). The accelerated impact of global warming on natural systems and the lives of many lifeforms has become a primary national and worldwide concern (Koetse and Rietveld 2009). Climate change is also manifesting throughout the planet, such as rising sea levels, glacier retreats, northward relocation of plant habitats, changes in animal habitats, rising ocean temperatures, and shorter winters and springs (Uleberg et al. 2014).

Moreover, climate change is projected to have varied effects on agriculture in various parts of the globe (Josephine 2007). The impact of climate change on agriculture might affect food security and the means of subsistence on which most of the population relies. Climate change may affect crop output and the sorts of crops cultivated in specific regions by influencing agricultural inputs such as water, solar radiation, and insect prevalence (Arora 2019).

Despite the various regional disparities caused by climate change, it is predicted that in many developing nations, the environment will become less favorable for the agricultural techniques they now engage in as a result of an increase in atmospheric warmth and humidity (Malhi et al. 2021; Mendelsohn 2014). Generally, climate change may make it more challenging to rear animals, cultivate crops, and catch fish in the same manner and locations as in the past (Mendelsohn 2009). Identifying weather changes over time and modifying management procedures for a better harvest are obstacles to expanding the agricultural industry.

There need to be more studies into how adaptation procedures and tactics occur in agricultural communities. To that end, this research examines the effects of climate change on small-scale farmers and the efficiency of their adaptation measures. This study also evaluates what adaptive practices those farmers believe the government should adopt.

Materials and methods

Study area

This study was carried out in the province of Khemisset, part of the Rabat–Sale–Kenitra region. It covers a total area of 8305 km^2. Khemisset province was created in 1973 by the Royal Decree of 19/08/73 (Annuaire 2020). Khemisset province is located 86 km east of Rabat at 33° 49′ 00″ north latitude and 6° 04′ 00″ west longitude at an altitude of 409 m above sea level (m.a.s.l.). It is bounded in the north by the province of Kenitra, in the south by Khenifra and Khouribga, in the west by Rabat, Salé, and Benslimane provinces, and in the east by Meknes and Ifrane provinces (Annuaire 2020).

Our major edapho-climatic systems are found in this study area: In the southeast, the humid mountainous zone (1000 mm/year) of Oulmes Cercle. In the north, the sandy location under the maritime influence in the Cercle de Tiflet, Khemisset, and Rommani (400 mm/year), and in the southwest, the arid to the semi-arid plateau of Ezhiliga (250 mm/year). The average annual rainfall is 368,109 mm. The rainy period extends from October to April, with peak precipitation in December. The summer is dry, with little rain (DMNM 2018).

The Khemisset–Khenifra axis is the cradle of an Amazigh ethnic group of the Middle Atlas (Zemmours, Zaers, and Zaïnes) rooted in the history of Morocco (Chaachouay et al. 2022a, b). According to the 2014 census, the population of the Khemisset Province is 542,221, of which 281,079 are in municipalities and urban centers and 261,142 are in rural cities (HCP 2014). This study area is one of the most important agricultural regions of the country because of the extent of its arable land, relatively favorable climate, and diversity of its edapho-climatic zones. The socioeconomic condition of this study area is entirely dependent on seasonal precipitation. Mixed farming, which includes cereal crops, forest resources, commercial crops, especially wheat, and animal husbandry, is the most prevalent kind of agriculture (Annuaire 2020; HCP 2014).

Methodology

Data collection

Data were acquired through fieldwork, private discussions, and participatory rural appraisal to highlight indigenous knowledge and empower locals to conduct their assessment, evaluation, interpretation, and planning. The sampling plan was established based on the crop, climate, and soil. The selected strata correspond to the four rural communes: Sfassif, Al Kansera, Sidi Alghandour, and Sidi Abderrazzak. Within each strate, some villages have been chosen, namely: the villages of Ait Makraz (S_1), Ait Alla (S_2), and Chbilia (S_3) in the rural commune of Sfassif; the towns of Ait Laasri (S_4), Ait Heddou (S_5), and Ait Ali O Moussa (S_6) in the rural commune of Al Kansera; the villages of Ait Hemmi (S_7) and Lalla Rahma (S_8) in the rural commune of Sidi Alghandour; and the villages of Kaabat (S_9), Ait Kassou (S_{10}), and Ait Amer O Benaissa (S_{11}) in the rural commune of Sidi Abderrazzak (Fig. 1).

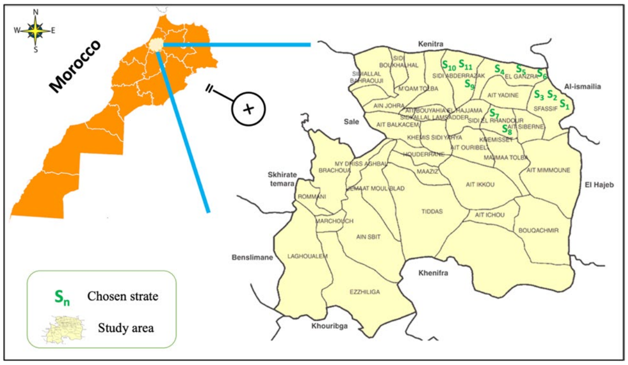

Fig. 1 Location of the strata in the study area

At the level of each stratum, a series of surveys using a pre-established questionnaire was adapted to the study area. This sheet contains information on the farmers, in particular, the profile of the respondent (sex, age, level of education, marital status). This questionnaire sheet also contains information on farmers' perceptions of changes in rainfall (thermal, solar), the frequency of pockets of drought, the causes and consequences of climate change, as well as the strategies adopted to mitigate the effects of climate change (animal husbandry, an improved variety of cereals, crop rotation, good agricultural practices, sowing date, conversion of cereals into olive trees, etc.) (Appendix A). People in the study area speak Amazigh; hence, interviews were done in Amazigh. After that, the whole of the documented data was translated into English. The duration of each interview ranged between 30 and 60 min.

Data sources

The preliminary information has been gathered via interviews with local farmers in the study area. Required data as to how climate change impacts the agricultural sector have been captured from:

- Ministry of Agriculture, Maritime Fisheries, Rural Development, and Waters and Forests, Morocco.
- The National Institute of Agronomic Research, Morocco.
- Agronomic and Veterinary Institute Hassan II, Morocco.
- The direction of National Meteorology, Morocco.
- Provincial Directorate of Agriculture, Khemisset.

Data analysis

Various themes were used to describe the results of this study. The obtained data has been analyzed and presented using diagrams, tables, and charts to illustrate multiple issues. The acquired data were processed using the Statistical Package for Social Science (SPSS) version 21 and analyzed following the investigation aims.

Results

Socio-demographic data of the respondents

In total, 120 local farmers were interviewed using semi-structured questionnaires. The samples of the surveyed farmers have been taken from 11 regions, i.e., Ait Makraz (10 farmers), Ait Alla (10 farmers), Chbilia (10 farmers), Ait Laasri (15 farmers), Ait Heddou (10 farmers), Ait Ali O Moussa (10 farmers), Ait Hemmi (10 farmers), Lalla Rahma (10 farmers), Kaabat (10 farmers), Ait Kassou (15 farmers), and Ait Amer O Benaissa (10 farmers). Most farmers surveyed in the study area were male (108 interviewed), and only 12 were female. The age of the respondents varies between 20 and 120 years, with a notable absence of official documents verifying their age for most elderly respondents. Also, young respondents shared perspectives on the climate changes they encountered and those passed down through generations by their ancestors. Farmers aged 40 to 60 years (60 farmers) exhibited a notably higher prevalence compared to their counterparts in other age groups. In addition, 30 farmers were over 60 years old, 20 were between 20 and 40 years old, and 10 were under 20 years old. Regarding marital status, among the respondents, 91 farmers were married, 19 were single, nine were widowed, and only one was divorced. Concerning instructional level, most respondents were illiterate (87 farmers), 20 attended primary school, and only 13 attended secondary instruction (Table 1). Most of the surveyed farmers (66) have two plots or fewer. Also, the number of farmers with plots between 2 and 5 was 37. In contrast, the number of farmers with more than five plots was low (11).

Farmer perceptions of climate change in the study area

The main perceptions of climate change of the four municipalities sampled by chance and in a stratified way, according to the type of soil, refer to the recent evolution of the last 20 years and concern precipitation, temperatures, pockets of drought, and winds. These perceptions are represented as follows:

- ***Farmers' perceptions of changes in rainfall***

The results show that more than 70% of the respondents in the four communes indicate a change in rainfall toward a decrease. The results show that more than 83% of respondents in the commune of Sfassif, 90.00% in Al

Table 1 The demographic data of the respondents

Study area	Name of the strate	No. of respondents	Instructional status			Sex	
			Illiterate	Primary	Secondary	Male	Female
Sfassif	Ait Makraz	10	8	1	1	9	1
	Ait Alla	10	7	2	1	9	1
	Chbilia	10	8	1	1	9	1
Al Kansera	Ait Laasri	15	10	3	2	13	2
	Ait Heddou	10	6	2	2	9	1
	Ait Ali O Moussa	10	8	1	1	9	1
Sidi Alghandour	Ait Hemmi	10	9	1	0	10	0
	Lalla Rahma	10	8	1	1	8	2
Sidi Abderrazzak	Kaabat	10	6	3	1	9	1
	Ait Kassou	15	8	4	3	14	1
	Ait Amer O Benaissa	10	9	1	0	9	1

Kansera, 93.33% in Sidi Al Ghandour, and 100% in Sidi Abderrazzak. Therefore, most farmers surveyed (85%) also indicate a late start to the rainy season over the past 20 years. However, a small proportion of the study area's population (15%) mentions an early onset of the rains.

Based on the findings, most farmers who participated in the survey (96.66%) reported a decrease in rainy days over the past two decades. The survey included:

a. Eighty-two farmers from Sfassif and Al Kansera.
b. Twenty-nine farmers from Sidi Abderrazzak.
c. Thirty farmers from Sidi Al Ghandour.

However, a small percentage of the farmers surveyed (specifically, one case in Al Kansera and two cases in Sfassif and Sidi Abderrazzak) claimed that the number of rainy days has increased. Additionally, two points from Sfassif and Sidi Abderrazzak indicated that the number of rainy days had remained the same over the past 20 years.

- ***Farmers' perceptions of the frequency of drought pockets***

Four observations of changing seasons were cited. These are the shortening of the winter, the last spring, and an increase in the intra-annual variability of the climate, implying a loss of the identity of the seasons. In other words, the seasons are less marked, and defining a typical climatic day per season is no longer possible.

Farmers pointed out that about 20 years ago, when the rains started in September, it was rare to observe 2 to 3 days without rain. However, today, after the late start of the rains toward the end of November, the rain stops in April, and May is not only noted but can reach 20 days. The results of our study show that the evolution of pockets of drought is increasing according to more than 100% of Sfassif interviewers, Sidi Abderrazzak, and according to more than 96.66% of the respondents of the two other communes, AL Kansera and Sidi Al Ghandour. The farmers pointed out that some 30 years ago, it was rare to observe 5 to 10 days without rain when the rains started in October. The analysis of these results indicates a strong farmer awareness of the increase in pockets of drought over the past 20 years, especially between two periods (1980–1985) and (1990–1995).

- ***Farmers' perceptions of thermal changes and solar***

Farmers express excessive heat by extending the time and intensifying the heat. They report a rise in severe temperatures, particularly during the warmest summer months (June, July, and August) and on chilly days. Farmers express excess heat by prolonging the duration of heat and increasing its intensity. They speak of increased extreme temperatures, especially during the hottest days of summer (June, July, and August) and on cold days. The severity of the coldest winter days (December, January, and February) also increased. However, according to those questioned (85%), winter is felt to be generally less or colder than it has been over the past 20 years. The results of our investigation confirm that approximately 97.5% of the respondents in the study region have noticed a very significant increase in temperature over the past two decades, i.e., 30 farmers in Al Kansera and Sidi Al Ghandour, 28 farmers in Sfassif, and 29 farmers in Sidi Abderrazzak.

The results of the surveys show that the majority of the farmers surveyed in the four rural communes think that the period 1995–2015 has seen an evolutionary trend. More than 93% of the farmers interviewed in the four rural communes mentioned the increase in sunshine during the season. The majority of respondents from the Sfassif region (74%), Al Kansera (59%), Sidi Alghandour, and Sidi Abderrazzak (61%) indicate an increase in the number of sunny days during the season. Moreover, about 94% of farmers in the study site believe that the number of cloudy days has decreased since 1995 until now (2015), against 4% of respondents who indicate that there is no evolutionary trend in the number of cloudy days over the past 20 years (1995–2015).

- ***Farmers' perceptions of changes in the wind***

Farmers placed less importance on wind than on other factors in this study, with only a few farmers reporting changes in wind intensity, direction, or duration. These farmers suffer mainly from the continental and hot winds from the southeast (Chergui). These winds cause low humidity and high evapotranspiration. About 70% of farmers think there has been more wind over the past 20 years in the study area. More than 24 farmers perceive the increase in the frequency of strong winds during the rainy season interviewed out of 30 in the Sfassif, Sidi Al Ghandour, and Sidi Abderrazzak communes. Still, in Al Kansera, 18 farmers interviewed indicated that there is less wind. According to the communities, the wind phenomenon appears to be a significant risk for agriculture because it buries the young shoots of cereals, burns their leaves, and increases their mortality at the beginning of the season. It also causes the shedding of the stems after the heading and destroys the plants with the fall of the trunks or branches of trees it breaks (Nassourou et al. 2018).

The causes of climate change, according to farmers surveyed

Based on the responses of surveyed farmers, they commonly link various climate change factors to the alterations they have witnessed in their farming practices and surroundings. The farmers' perception of the causes of climate change, including precipitation patterns, temperatures, wind patterns, and localized droughts, in the study area between 1995 and 2015 is attributed by the surveyed farmers to multiple factors. Young and elderly farmers may have different perspectives on the causes of climate change based on their generational experiences and knowledge. However, it is essential to note that climate change is a scientifically established phenomenon primarily caused by human activities. Here are some common perspectives on the causes of climate change as observed by young and elderly farmers:

Young farmers, who may have grown up with more exposure to climate change discussions and scientific information, often recognize human activities as the primary driver of climate change. Their perspectives may include the following:

- **Greenhouse gas emissions**: Young farmers understand that the burning of fossil fuels, such as coal, oil, and natural gas, releases large amounts of carbon dioxide (CO_2) and other greenhouse gases into the atmosphere, leading to the greenhouse effect and subsequent warming of the planet.
- **Deforestation**: They acknowledge that deforestation for agricultural expansion, logging, and other purposes contributes to climate change. Trees play a crucial role in absorbing CO_2 and maintaining the balance of gases in the atmosphere. Their removal leads to higher levels of greenhouse gases and further warming.
- **Industrial agriculture**: Young farmers recognize the environmental impact of conventional agriculture practices, including excessive use of synthetic fertilizers, pesticides, and intensive livestock farming. These practices release greenhouse gases and contribute to soil degradation, deforestation, and biodiversity loss.

In contrast, elderly farmers, who may have witnessed changes in farming practices and climate patterns over several decades, might attribute climate change to various factors, including:

- **Changing weather patterns**: Elderly farmers may have observed shifts in weather patterns, such as more frequent extreme weather events like droughts, floods, or severe storms. They may attribute these changes to natural climate variability or cycles rather than long-term human-induced climate change.
- **Traditional knowledge**: Some elderly farmers may rely on traditional knowledge and practices handed down through generations. They might attribute climate change to a disruption in natural cycles due to factors like land-use changes, the alteration of ecosystems, or environmental degradation caused by human activities.
- **Limited access to information**: Elderly farmers may have had limited exposure to scientific research or climate change education compared to younger generations. Their perspectives might be influenced by their local experiences and community narratives, which could vary depending on their geographical location.
- **ALLAH's punishment**: The elderly farmers believe climate change results from divine retribution from Allah. They believe that Allah is punishing humanity through the changing climate conditions.

It is worth noting that while perspectives may differ, the scientific consensus supports the understanding that human activities are the primary cause of climate change. The Intergovernmental Panel on Climate Change (IPCC) and numerous scientific studies provide substantial evidence to support this consensus view.

Impact of climate change on study area agriculture

The impact of climate change on agriculture in a specific study area can vary depending on several factors, including the geographic location, local climate patterns, and agricultural practices in that area. However, climate change can generally have direct and indirect effects on agriculture, significantly impacting crop yields, livestock production, and overall food security (Chaachouay et al. 2021; Kim 2012). According to interviews conducted with local farmers, the study area experiences notable effects on agriculture due to climate change. Farmers have observed changes in rainfall patterns, such as timing and distribution irregularities. These alterations, including extended droughts or heavy rainfall events, can adversely affect crop growth, water availability, and soil moisture. Consequently, rising temperatures have led to heat stress for crops and livestock, resulting in reduced yields and diminished crop quality during heat waves. Moreover, farmers have observed increased pests and diseases that thrive in warmer conditions, necessitating additional pest control measures.

Climate change also causes shifts in the length and timing of growing seasons, as reported by some farmers who have noticed earlier springs and longer frost-free periods. These changes disrupt the natural development patterns of crops and pose challenges in pest and disease management. Moreover, alterations in rainfall patterns and increased evaporation rates affect water availability for irrigation, causing concerns among farmers regarding decreased water sources, reduced river flows, and declining groundwater levels. Consequently, the scarcity of water resources impacts irrigation systems and reduces crop productivity. Farmers have also observed shifts in the prevalence and distribution of pests and diseases, with previously rare or absent problems becoming more common.

The decline in agricultural yields

The Zemmour producers surveyed have reported a widespread decrease in average crop yields, particularly for cereal crops. The reasons behind these poor outcomes vary depending on the villages and agricultural partners. The producers have observed the disappearance or decline of certain plant species in their region, such as Boubter, Maghchouch, Alouaja, chick stitch, sunflower, and others. Similarly, they have noted the emergence and proliferation of certain species, like barley and broad beans. The most crucial period affecting these cereals is during fruiting. During this time, factors such as water scarcity, excessive temperatures, inadequate use of pesticides and fertilizers, and wind-induced lodging (specifically for Boumergoud barley) have been observed, resulting in harvest losses, reduced yields, and losses at harvest.

The effects of climate change, specifically water deficits, significantly impact a large percentage of producers (approximately 95%). This impact is particularly noticeable during critical stages of the crop cycle, such as the fruit set in maize or the initiation of bean panicles. The water deficit is often accompanied by unusually high temperatures, which hurt certain cultivated species. Around 90% of farmers experience a delay or failure in seeding when rains are delayed, necessitating replanting. This shift in the crop cycle results in a chain of negative consequences. All interviewed producers in the study area reported crop losses due to underperformance caused by these factors. Adverse events like solid winds, heat waves, Chettab Errehabi, Chergui, or frost can occur at any stage of the crop cycle, but the most detrimental is when they occur later. Farmers generally have time to replant the same crop if an annual yield is destroyed at the beginning due to drought or opt for a shorter-cycle alternative. Conversely, when there is a prolonged heat wave, for instance, beans may be ready for harvest.

The appearance of plant diseases

The findings indicate that a considerable proportion of farmers in the study area (86%) reported the occurrence of distinct agricultural diseases. These diseases include downy mildew, apical necrosis, fusarium blight, wheat caries, black and brown wheat rust, wheat charcoal, cereal *Rhizoctonia*, foot rot, wheat helminthosporiose, wheat powdery mildew, midge, *Septoria*, and *Orobanche*. In particular, all farmers in the Sfassif and Sidi Alghandour regions experienced mildew disease affecting soft wheat. In contrast, 80% of farmers in the Al Kansera commune suffered from a wheat black rust disease.

Impacts of climate change on livestock

Like the physical environment and crops, livestock is subject to the impact of present-day climatic changes (Thornton et al. 2009). Extreme weather events such as excessive rainfall, cold spells, prolonged droughts, and heat waves have significant implications for the well-being of animals (Baumgard et al. 2012; Gaughan and Cawdell-Smith 2015). The quantity of rain experienced within a specific timeframe can promote the reemergence of particular diseases, leading to the loss of numerous animals during the cold months of January and February, as reported by farmers in the study area (Ellyali). As indicated by the farmers interviewed, the primary outcome of climate change on livestock is the escalation of certain conditions.

The impacts of climate change on agriculture can have significant economic consequences for farmers. Reduced crop yields, increased production costs, and the need for additional investments in adaptation measures can strain farmers' incomes and livelihoods. Consequently, some farmers have expressed the need for financial support and access to insurance plots to manage the risks associated with climate change. It is important to note that the specific impacts of climate change on agriculture may differ across regions and local conditions. The experiences and concerns expressed by farmers in the study area during the interviews serve as valuable insights, emphasizing the necessity for resilience-building in the face of climate change.

Local farmers' adaptation strategies to climate change

Adaptation to climate change and variability occurs in two stages: the first requires that local people perceive a difference in the weather, and the second requires developing adaption strategies (Deressa et al. 2011; Gbetibouo 2009; Cochrane et al. 2009; Kimani and Bhardwaj 2015). In response to the effects of climate change, farmers are developing adaptations to diversify their sources of income. It concerns farming, good agricultural practices, trade, artisanship (Zemmourya carpet), apiculture, fertilizer use, and other adaptations. However, a sizable percentage of the population (60%) has no plan to deal with climate change. As a result, most people still need to adjust their cultural systems.

Livestock breeding

Based on the information provided by local farmers, livestock farming is regarded as one of the most efficient approaches to tackle the challenges of climatic fluctuations in the study area. This effectiveness can be attributed to an agroecological environment that is particularly well-suited for this agricultural practice, which is a defining characteristic of the province of Khemisset. The distribution of breeders across different municipalities and the types of animals they rear can be observed in Table 2.

Improvement of the variety of cereals

The results show that 60% of the farmers surveyed chose to adopt new crop varieties in their crop systems. Local farmers primarily prioritize the adoption of new crop varieties, with a particular emphasis on common wheat, which serves as the leading staple food for the population. Drought- and pest-resistant cereal varieties common in the study region are available on the market. They were developed by the National Institute for Agricultural Research (NIAR) in the 1990s. The recommended types and their descriptions are documented in Table 3.

Good agricultural practices

Local farmers who were interviewed emphasize that implementing good agricultural practices is crucial to mitigating the impacts of climate change. These practices include maintaining soil fertility through fertilizers or compost, carefully determining the seeds to sow, and effectively controlling weed growth. The farmers stressed the significance of weed control, stating that it plays a vital role in ensuring successful crop cultivation. They explained that if weeds are in the field, it is essential to treat them just before sowing by employing non-selective herbicides. This ensures that the weeds are effectively eliminated without harming the emerging crop. Additionally, selective herbicides can tackle weed growth at the three-leaf stage of the crop, explicitly targeting the unwanted plants while preserving the cultivated ones.

- ***Weed control***

The findings reveal that 65% of the interviewed farmers employ a "weed control" strategy to manage their crops effectively. This strategy encompasses two methods: manual weeding, where laborers intervene to remove weeds when the crop is less than 2 months old to minimize damage to young plants, and chemical weeding, which involves the use of pesticides. Farmers advocate for the utilization of contact

Table 3 Bread wheat varieties recommended for adaptation to climate change in the study region (DPA 2015)

Variety	Breeder	Seller	Main feature
Arrehane	NIAR	SONACOS	Midge resistance
Rajae	NIAR	SONACOS	*Septoria* resistance
Mehdia	NIAR	SONACOS	High-temperature resistance

SONACOS: National Seed Marketing Company

Table 2 Livestock as an adaptation strategy developed by the farmers in the study area

	Cattle breeding	Sheep breeding	Goat breeding	Poultry farming
Sfassif	30	22	0	26
AL Kansera	27	24	9	29
Sidi Al Ghandour	28	16	3	28
Sidi Abderrazzak	28	03	0	12
Total = 120	113	065	012	095

herbicides and the retention of intercrop residues as effective measures to minimize both evaporation and erosion.

- ***The seedling doses***

Based on our investigation findings, it has been determined that the optimal dosage suggested by farmers interviewed for certified seed when using direct seeding is 1.5 quintals (equivalent to 120 to 150 kg) per hectare. However, non-certified seeds should be used in a quantity of two quintals (equal to 150 to 200 kg/ha), as the farmers in the study area recommended. It is worth noting that when it comes to maize, a lower dosage is preferred compared to other cereal crops, and this dosage is considered shallow.

- ***Mineral fertilization***

According to the findings, more than 90% of the farmers have adopted the strategy of mineral fertilization. The local farmers emphasized the importance of considering the initial soil richness, determined through soil analysis, and the expected crop yield when applying nitrogen, phosphorus, and potassium fertilizers. The farmers recommended conducting soil testing at least once every 3 years to assess soil conditions accurately. Moreover, they stressed that nitrogen fertilization should be carefully planned based on rainfall conditions. The application of nitrogen fertilizers is deemed beneficial only when favorable rainfall conditions are present during the specific growth stage of the crop.

- ***Control of diseases and pests***

Most of the local farmers interviewed (70%) experienced a significant decline in crop yields due to the prevalence of various diseases. For instance, diseases such as wheat powdery mildew, *Orobanche*, cereal *Rhizoctonia*, black and brown wheat rust, wheat caries, *Septoria*, fusarium blight, verticilliosis, and bacteriosis have been causing extensive damage to olive trees and cereals at the regional level. Additionally, pests like moths and olive flies have contributed to agricultural challenges. According to the farmers, the populations of pathogens and insects are heavily influenced by temperature and humidity levels, and any variations in these factors can disrupt their population dynamics. This means that changes in climate conditions can directly impact the abundance and behavior of these harmful organisms, exacerbating crop damage.

Furthermore, the consequences of these agricultural issues extend beyond the immediate crop losses. Dairy farmers have reported declining milk production from their cows, likely due to the effects of diseases and pests on the animals' health and nutrition. Additionally, local farmers indicate that the aquatic ecosystem has been affected, with reduced fish reproduction, disrupted migration patterns, and decreased harvests, adversely affecting the fishing industry and related sectors.

Crop rotation

Based on interviews conducted with farmers in the study area, a new strategy emerged following the introduction of wheat and barley crops into the cropping system. As a result, previously cultivated crops like lentils and broad beans were abandoned. Consequently, the traditional crop rotation patterns of wheat–lentil–fallow, broad bean–barley–fallow, and so on have been replaced by rotations solely focused on wheat and barley. Despite this change, other farming practices have remained unchanged compared to the previous situation.

Sowing date

The rainy season in Morocco spans from November to March, with the highest amount of rainfall occurring in December, which accounts for half of the total annual precipitation (Balaghi et al. 2011). As stated by local farmers, sowing conducted after December poses a disadvantage for rainfed crops. Recently, local farmers have noticed a noticeable shift in sowing dates compared to the past. They explained that traditionally, sowing would commence with the onset of significant rains, typically in October or November. However, the farmers have now observed that early sowing, before the arrival of the initial rains, enables them to capitalize on the rainy season and enhance crop yields fully.

Conversion of cereals into olive

The study area was recognized as susceptible to climate change's effects while possessing significant agricultural potential (Balaghi et al. 2011). Based on interviews with local farmers, it was determined that the cultivation of olive trees was deemed a crucial sector in this region and necessitated actions to adapt to climate change. The farmers disclosed that a specific initiative had been undertaken in the study area: integrating climate change into implementing the Green Morocco plan. This initiative involved converting cereal crops into olive tree plantations, covering an initial area of 2000 ha in the rural communes of Sfassif and Al Kansera in 2011, with a future objective of expanding to 8000 ha. The Provincial Directorate of Agriculture in Khemisset was responsible for identifying the beneficiaries of this project. The proposed measures aim to enhance the resilience of agricultural practices in the region to withstand the impacts of climate change. Specifically, two priority measures for adapting to climate change in the study area are supplementary irrigation and rainwater collection.

Discussion

A total of 120 local farmers participated in the study through semi-structured surveys. The farmers were selected from eleven sites, and their responses were analyzed. Most of the farmers interviewed were male (108), with only 12 being female. Furthermore, a significant portion of the surveyed farmers (55%) owned multiple plots, equal to or less than two. However, there may be more farmers who own more than five plots.

Additionally, it is typical for farms in the area to be divided into several smaller parcels. Every local farmer surveyed has witnessed climate variations and comprehends climate change as partially attributed to human-induced pollution. These farmers detect climate change by noting reduced rainfall, more frequent occurrences of strong winds, rising temperatures, intensified droughts, and the depletion of water sources. This upward trend in temperature will lead to higher potential evapotranspiration rates and augmented water loss from oceans and reservoirs. As a result, there will be a reduced amount of water accessible for human and animal consumption and irrigation purposes. The negative impact of this situation will primarily affect economies that heavily rely on natural resources (Romero et al. 2011). To elaborate further, the effects of climate change, such as increased precipitation, lead to a higher outflow of water. However, simultaneously, the rising temperatures contribute to a decrease in the overall water flow (Kim 2012).

The findings derived from interviews conducted in the field indicate that all the surveyed farmers have noticed local climate changes. These changes have affected their agricultural practices, which are highly dependent on the climate conditions specific to the study area. The observations related to climate change are extensively discussed throughout all stages of the study, ranging from the initial presentation of the research to the conclusions of the maintenance activities. Various climate risks have been identified based on these discussions, including rising temperatures, increased variability at the beginning of the agricultural season, a shorter rainy season, strong winds, and drought. Over the past two decades, farmers' most commonly mentioned perceptions have been the decline in precipitation, droughts, and the prevalence of excessive heat. Both natural factors and socio-cultural factors of human origin influence these perceptions. Among the farmers' responses regarding climate change, four key aspects stand out: droughts, water scarcity, excessive heat, and decreased cereal yields. These four perceptions account for more than half of the responses received from the farmers, reflecting their understanding and experiences of climate change.

The annual precipitation is gradually declining but becoming more concentrated over time. This phenomenon can be observed in the study area, leading to a higher drought occurrence in recent decades. In rainfed agriculture, rainfall distribution plays a crucial role in determining the success of crop production. Rainfed agriculture refers to cultivating crops without additional irrigation, relying solely on natural rainfall for water supply (Schilling et al. 2012). While soil conditions are essential for crop growth, the availability and timing of rain have a more direct and significant impact on agricultural productivity (Al et al. 2008). According to this investigation conducted among farmers, it has been observed that there has been a more variable distribution of rainfall throughout the year. This variability refers to irregular patterns in the timing and intensity of rainfall events.

Instead of having consistent and evenly distributed precipitation throughout the year, farmers are experiencing concentrated periods of heavy rainfall and prolonged periods without rain. So, these results indicate a significant perception of the increase in extreme rains. The farmers surveyed pointed out that about 30 years ago, when the rains started in October, it was rare to observe 5 to 10 days without rain. Today, after the late start of the rains toward the end of November, rain stops in May and April are not only noted but can reach 20 days. In other words, the seasons are less pronounced, and defining a typical climatic day per season is no longer possible. Analysis of these results indicates a strong farmer awareness of the increase in pockets of drought over the last 20 years, especially between two periods (1980–1985) and (1990–1995). One significant consequence of this irregular distribution of showers is increased rainfall intensity during concentrated periods.

When the rains arrive, they have much higher power than before. This sudden and heavy downpour can lead to various problems for farmers and the surrounding environment. One of the primary concerns is the rise in the number of floods. Excessive rainfall overwhelms the capacity of the soil to absorb water, leading to waterlogging and subsequent flooding in low-lying areas. These floods can cause extensive damage to crops, livestock, infrastructure, and even human settlements.

Furthermore, the irregular distribution of rainfall also contributes to increased erosion. When heavy rain falls over a limited period, the soil becomes more susceptible to decay. The force of the rainfall can wash away the topsoil, which is rich in nutrients necessary for plant growth. This erosion not only diminishes the fertility of the land but also leads to sedimentation in rivers and other bodies of water, affecting aquatic ecosystems and water quality. In addition, the survey indicates that farmers are experiencing a rise in consecutive rainy days. Instead of intermittent rainfall events spreading over time, there is more continuous rainfall for multiple days. This extended period of rain poses challenges for farmers as it becomes difficult to carry out necessary agricultural activities such as planting, harvesting, and soil preparation. It also increases the risk of waterlogging and crop diseases, further impacting agricultural productivity.

Conversely, there is also an increase in the number of days without consecutive rains. This means that farmers have to endure longer dry spells between rainfall events. The prolonged absence of rain negatively affects crop growth and reduces water availability for irrigation. It can lead to drought-like conditions, forcing farmers to rely on alternative water sources and irrigation methods, which may only sometimes be feasible or cost-effective (Salhi et al. 2019). So, these results indicate a significant perception of the increase in extreme rains. The farmers surveyed pointed out that about 30 years ago, when the rains started in October, it was rare to observe 5 to 10 days without rain. Today, after the late start of the rains toward the end of November, rain stops in May and April are not only noted but can reach 20 days. In other words, the seasons are less pronounced, and defining a typical climatic day per season is no longer possible. Analysis of these results indicates a strong farmer awareness of the increase in pockets of drought over the last 20 years, especially between two periods (1980–1985) and (1990–1995).

In the study area, farmers have noticed and expressed concerns about the increasing intensity and prolonged duration of heat. They observe that extreme temperatures have risen, particularly during the hottest days of summer (June, July, and August). The heat intensity during these months has become more severe than in previous years. Similarly, the coldest winter days (December, January, and February) have also worsened in severity. Interestingly, the farmers interviewed have varying perceptions regarding winter. Some farmers feel that winters have become less challenging over the past two decades, while others perceive them as more complex. This opinion discrepancy may be due to regional differences, individual experiences, or specific farming practices. However, the farmers acknowledge that changes in climatic conditions, including both extreme heat and cold, have become more noticeable (Mertz et al. 2009). The presence of infections in crops and plants within natural ecosystems is another concern raised by farmers. They highlight the potential for plants to act as asymptomatic carriers of diseases, which may emerge as illnesses when subjected to environmental stress caused by warmer temperatures. The stress experienced by the host plant plays a crucial role in the decline of many forest species (Chaachouay et al. 2020c; Nazir et al. 2018). Some farmers attribute the observed changes in rainfall patterns to natural phenomena, suggesting that these climatic variations are part of a natural cycle. However, a few respondents also point out the lack of environmental management as a potential factor contributing to the changes in rainfall. This implies that human activities, such as deforestation or land degradation, affect the local climate and precipitation patterns (Chaachouay et al. 2019; Oldeman 1992).

The consequences of climate change on crops are complex and multifaceted, with variations depending on factors such as rain delays/breaks, decreases in rainfall, and the degree of insolation occurrence (Snaibi et al. 2021). However, it is essential to note that the susceptibility of agricultural output to climate change is not solely determined by the physiological response of plants but also by the ability of socioeconomic systems to adapt to changing conditions and yield variations (Malla 2008). One of the general consequences of climate change on crops is lower yields, both in plant and animal production. Changes in temperature and precipitation patterns can disrupt the delicate balance required for optimal crop growth and development (Ali et al. 2017). Excessive heat, droughts, or erratic rainfall can negatively impact crop yields, reducing harvests and lowering productivity (Li et al. 2019). Livestock can also be affected by changes in temperature and availability of water and forage, resulting in decreased productivity and potentially affecting the availability of animal-based food products (Chaachouay et al. 2022a, b; Snaibi 2020). Another consequence is the challenge posed by traditional risk management mechanisms. Climate change introduces new uncertainties and risks to agricultural systems, making it more difficult for farmers to predict and manage potential losses. Conventional practices that have worked in the past may become less effective or obsolete in changing climatic conditions. This can lead to increased vulnerability and difficulties in coping with the impacts of climate change.

Climate change and increased levels of CO_2 have significant impacts on livestock systems, affecting various aspects such as feed availability, cost, and direct effects on animal health, growth, and reproduction (Rochdane et al. 2012; Sejian et al. 2015). The research conducted by Nardone et al. (2010) in 2010 highlights these effects. One of the critical ways climate change affects livestock systems is through its impact on feed availability. Temperature and precipitation patterns can alter the growth and productivity of forage and feed-grain crops. Extreme weather events such as droughts, floods, and heat waves can reduce the overall availability of feed, making it more challenging for livestock farmers to meet the dietary needs of their animals.

Additionally, climate change can influence the cost of feed. Changes in weather patterns and the availability of crops can lead to fluctuations in market prices for feed-grain crops and forage crops. Livestock farmers often rely on purchasing feed from the market, and price variations can affect their overall production costs and profitability (Kmoch et al. 2018; Nemes 2009). Climate change can also directly affect animal health, growth, and reproduction. Higher temperatures can lead to heat stress in livestock, impacting their well-being and productivity. Heat stress can reduce feed intake, decrease weight gain, and impair reproductive performance, ultimately affecting the overall output of livestock systems (Nardone et al. 2010).

Moreover, the impacts of climate change on grasslands can have immediate consequences for animals grazing on these pastures (Nassif 2008; Olesen and Bindi 2002; Snaibi 2020). Temperature and precipitation patterns can influence the quality and quantity of grass available for grazing. Warmer months can significantly impact livestock output in regions such as Europe due to reduced forage availability and quality. Interestingly, climate change can positively affect livestock systems in colder areas during the winter (Olesen and Bindi 2002). Warmer temperatures can reduce animal feed needs, increase survivability, and decrease energy expenditures. These factors can benefit livestock in colder areas and help mitigate some of the negative impacts of climate change. In addition to the effects above, climate change also influences the turnover and losses of nutrients from animal manure in various settings, such as homes, storage facilities, and farms. Balaghi et al. (2011) emphasized that climate change can affect animal manure's decomposition and nutrient cycling processes, impacting nutrient availability for crop production. This, in turn, can lead to less productive livestock and farming systems, affecting the livelihoods of rural people and farmers who depend on these systems for their income and food security.

The combined effects of climate change on livestock systems have far-reaching consequences, impacting various aspects such as feed availability, cost, direct impacts on animals, and nutrient turnover. These effects can increase vulnerability among the poorest populations, mainly rural communities. As a result, people may contemplate leaving their villages and seeking alternative livelihoods due to the reduced productivity of livestock and farming systems (Freier et al. 2014). The collective dynamics of these changes further exacerbate the challenges rural communities face, particularly those with limited resources and options. One of the critical impacts of climate change on livestock systems is the availability and quality of feed. Changes in temperature, precipitation patterns, and extreme weather events can affect the growth of natural forage and cultivated feed crops. Droughts, floods, and shifts in rainfall patterns can reduce pasture productivity, leading to a scarcity of grazing land and a decrease in the nutritional value of available forage (Giridhar and Samireddypalle 2015; Parish and Funnell 1999). This scarcity can result in increased competition for feed resources among livestock, ultimately affecting their health, growth rates, and overall productivity.

Additionally, climate change can influence the cost of feed. Reduced availability of locally produced feed can lead to increased dependence on external sources, which may result in higher prices for purchasing and transporting feed. This can pose a significant financial burden for small-scale livestock farmers who may need help affording the necessary feed to sustain their animals. The increased feed cost can further erode the profitability of livestock systems, exacerbating poverty and food insecurity among the most vulnerable populations. Direct impacts on animals are another concern. Livestock are sensitive to changes in temperature, humidity, and other climatic factors. Heat stress, for example, can negatively affect animal health, reproduction, and productivity. Higher temperatures can lead to reduced feed intake, decreased milk production in dairy animals, and impaired growth in young animals. Livestock may also be more susceptible to diseases and parasites, which can further undermine their welfare and productivity (Van Praag et al. 2022). Climate change also affects nutrient turnover in livestock systems. Changes in precipitation patterns and temperatures can influence soil moisture levels, nutrient availability, and microbial activity. These changes can impact nutrient cycling and alter the composition and quality of forage, potentially affecting animal nutrition. Reduced nutrient availability and imbalances in feed quality can lead to suboptimal growth, reduced reproductive performance, and increased susceptibility to diseases (Kmoch et al. 2018).

The combined effects of these climate change impacts on livestock systems can significantly increase the vulnerability of the poorest populations, particularly in rural areas (Chaachouay and Zidane 2023; Moinina et al. 2018). Livestock and farming systems often serve as a primary source of income and livelihood for these communities. Reduced productivity and increased costs can threaten the economic viability of these systems, pushing farmers into poverty and exacerbating existing inequalities. As a result, rural populations may contemplate leaving their villages and seeking alternative livelihoods. The reduced profitability of livestock systems, coupled with limited opportunities for diversification, may lead individuals to migrate to urban areas for employment and better economic prospects. This rural exodus can have profound social, cultural, and economic consequences, disrupting traditional farming practices, community cohesion, and local economies. The collective dynamics of these changes further compound the challenges rural communities face, particularly those with limited resources and options. As more people migrate from rural areas, the remaining population may face increased pressure on limited resources, including land, water, and social infrastructure. This can further hinder the resilience and adaptive capacity of rural communities, making it even more challenging for them to cope with the impacts of climate change.

Adaptation to climate change and variability is a crucial process for communities to cope with the impacts of changing climatic conditions. This adaptation typically occurs in two stages, as Sexton and Harris (2015) outlined. The first stage involves local people perceiving and recognizing the existence of climate change and acknowledging its effects on their environment and livelihoods. The second stage requires them to develop and implement specific adaptation strategies to mitigate the adverse impacts and take advantage of potential positive outcomes. In agriculture, several agronomic adaptation strategies have been developed to address the challenges posed by climate change (Kmoch et al. 2018; Snaibi 2020). These strategies aim to minimize the adverse effects on agricultural production and maximize the potential benefits. Some standard methods include animal husbandry, good farming practices, trade, crafts, beekeeping, fertilizer use, and other adaptations.

Among these strategies, animal husbandry has been considered particularly effective for Zemmour farmers due to the agroecological conditions favoring this agricultural activity in the study area. Animal husbandry involves the rearing and managing of livestock, such as cattle, sheep, or goats. Livestock can provide multiple benefits to farmers, including a diversified income source, access to animal products (meat, milk, eggs), and additional support for agricultural systems through manure as organic fertilizer (Smith et al. 2013). In addition to animal husbandry, farmers in the study area have also chosen to adopt new crop varieties that exhibit resistance to drought and the prevalent pests in the region. Common wheat varieties, which serve as a staple food crop for the local population, have been a primary focus of these adaptation efforts. Conventional and biotechnological procedures have been utilized to develop heat- and drought-tolerant crop varieties (Ashraf 2010). Crop breeding plays a crucial role in this process, as it involves selecting and breeding plant varieties with desired traits that can withstand changing climatic conditions (Chapman et al. 2016). This can include improved heat tolerance, water-use efficiency, pest resistance, or faster maturation. By using breeding techniques, researchers and farmers can develop crop varieties that are better suited to the local environment, enabling them to thrive despite the challenges posed by climate change. Adopting new crop varieties and developing heat- and drought-tolerant crops are examples of adaptive responses to climate change in the agricultural sector. These strategies help farmers reduce their vulnerability to climate-related risks, ensure food security, and maintain their livelihoods in changing environmental conditions.

Soil organic matter is crucial in developing and maintaining soil fertility (Dick and Gregorich 2004). It significantly influences the soil's various physical, chemical, and biological properties (Fageria 2012; Usharani et al. 2019). Good agricultural practices emphasize preserving soil fertility through fertilization, spreading, and weed control. One aspect of maintaining soil fertility is crop rotation. Crop rotation involves alternating different crops in a specific sequence within a farming system (Reckling et al. 2016). This practice helps improve soil health, reduce pest and disease pressure, and optimize nutrient utilization. In the given scenario, introducing wheat and barley crops into the crop system led to abandoning other crops like lentils and beans. As a result, the crop rotation pattern changed to combinations such as wheat–lentil–fallow, bean–barley–fallow, and so on. However, the other cropping practices remained consistent in their respective positions within the rotation sequence. Altering land distribution is another strategy to stabilize productivity and enhance soil fertility. By redistributing the land allocated to different crops, farmers can optimize their productivity and reduce the impact of interannual output variability. For instance, crops with high variability in annual yields could be replaced with crops with lower productivity but more predictable yields. This approach helps farmers mitigate the risks associated with fluctuating output and maintain a more stable agricultural production system.

Furthermore, crop substitution can be a suitable method for conserving soil moisture. Certain crops have higher water requirements, while others are more adapted to drought conditions and can better retain soil moisture. By replacing crops that demand significant amounts of water with more drought-tolerant alternatives, farmers can conserve soil moisture levels and ensure more efficient water utilization in their agricultural practices (Nissen and Wander 2003).

Soil organic matter is essential in developing and maintaining soil fertility, influencing physical, chemical, and biological soil qualities (Dick and Gregorich 2004). Good agricultural practices include maintaining soil fertility through fertilizer or spreading and weed control (Watson et al. 2002). Crop rotation occurred after introducing wheat and barley crops into the crop system and abandoning others, such as lentils and beans. Thus, processes of wheat–lentil–fallow, bean–barley–fallow, etc., with the previous situation, other cropping practices have remained the same in the last position. Alterations in land distribution may also be utilized to stabilize productivity. In this instance, crops with significant interannual output variability may be replaced with crops with lower productivity but more predictable yields. Additionally, crop substitution may be adequate for conserving soil moisture.

The study area was determined to be vulnerable to climate change's effects while possessing significant agricultural potential. One particular sector identified as a priority in this region was the cultivation of olive trees. Recognizing the potential impacts of climate change on this sector, it was deemed necessary to implement specific adaptation measures. The implications of climate change on the agriculture industry are complex and can vary. On the one hand, climate change can bring about positive impacts that offer new possibilities for agricultural practices. For instance, it may result in longer growing seasons, increased availability of water resources, or improved conditions for specific crops. These positive effects can create opportunities for agricultural growth and development.

On the other hand, climate change can also lead to adverse effects on agriculture, resulting in increased expenses. These adverse effects may include extreme weather events like droughts, floods, heat waves, or storms, which can damage crops, disrupt production, and impact the overall productivity and profitability of the agricultural sector. Additionally, temperature and precipitation pattern changes can affect the suitability of specific crops in a particular region. Given the equivocal nature of climate change impacts on agriculture, it becomes crucial to design and implement adaptation strategies that maximize opportunities while minimizing the costs associated with climate change. Specifically, in the case of the olive tree sector in the identified region, adaptation actions should be taken to ensure its sustainability and growth in the face of changing climatic conditions.

Conclusions

Climate change is not only recognized by scientists but also perceived by farmers, with variations observed among different levels of prosperity and age groups. A recent investigation in the Khemisset region revealed that farmers understand the primary climate risks associated with rainfed agriculture. Based on the survey responses, it is evident that climate variability has led to significant fluctuations in annual precipitation, resulting in a considerable decrease in overall quantity. Additionally, farmers have noted a rise in temperatures and droughts similar to those experienced in 1980 and 2015. Moreover, the local farmer population in Zemmour demonstrates a keen awareness of the changes in their environment. The findings of this study aim to provide scientific support for the specialization of agricultural production in the Khemisset region and guide the implementation of necessary farming activities. Despite farmers' awareness of climatic variations, only a tiny proportion have taken measures to adjust their agricultural practices in response to the impacts of climate change. Around 40% of farmers have adapted their methods accordingly. Therefore, the focus should not solely be on finding the right solutions to address climate change but, more importantly, on supporting and fostering ongoing adaptive capacities among farmers.

Consequently, this research sheds light on how farmers adapt to climate change's effects. Furthermore, it emphasizes the significance of adaptation among farmers, particularly in the Khemisset region, regarding climate change. Access to reliable climatic data specific to the area is crucial for evaluating climate impacts and developing effective adaptation strategies. Lastly, supporting adaptation to climate change necessitates long-term collaboration between researchers, stakeholders, and decision-makers. This collaboration is vital for generating general and localized knowledge, providing agricultural expertise, and establishing a sustained relationship of trust between researchers and stakeholders.

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Declarations

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