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Adopting Conservation Agriculture Systems in Morocco: A Case Study

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ABSTRACT

This research paper addresses, from an ecogeographic perspective within a localised context, a new concept of nature conservation within modern farming systems: the direct seeding technique based on the principles of the Conservation Agriculture System (CAS). The adoption of CAS aims to increase soil fertility, promote biodiversity, and sustain production, making it one of the most effective adaptation solutions available to address the challenges of climate change. CAS is defined as a farming system based on three key principles: minimal soil disturbance (reduced or zero tillage), maintaining a permanent soil cover (with residues from previous crops), and adopting crop rotation (diversifying crops rather than limiting them to a single type in consecutive seasons). However, there is limited research and a lack of scientific studies on the implementation of conservation agriculture in developing nations such as Morocco, particularly in the Had Kourt region. This study aims to assess the feasibility of CAS compared to traditional agricultural systems by surveying the opinions of farmers who have experience with both systems and comparing the outcomes of their practices based on simple indicators as an initial stage, with further analysis of additional indicators planned through subsequent scientific investigations. The sampling method used in this study is non-discriminatory, as semi-structured interviews were conducted with a group of farmers to gather their opinions on CAS. The adoption of conservation agriculture has been linked to prior knowledge of the system, acquired through training and fieldwork via application platforms, which remain limited in scope.

Keywords: Conservation Agriculture System (CAS); Climate Change; Zero Tillage; Soil Optimization; Biodiversity, Sustain Production

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ARTICLE INFO
Received: 22 March 2025 | Revised: 24 April 2025 | Accepted: 28 April 2025 | Published online: 28 May 2025
DOI: https://doi.org/10.30564/jees.v7i6.9198

CITATION
Brache, O., Laaribya, S., Bouta, A., et al., 2025. Adopting Conservation Agriculture Systems in Morocco: A Case Study. Journal of Environmental & Earth Sciences. 7(6): 73–90. DOI: https://doi.org/10.30564/jees.v7i6.9198

1. Introduction

Thinking about alternatives to adapt to climate change has become an urgent necessity, particularly in light of mounting scientific evidence highlighting the close relationship between climate dynamics and environmental systems. Changes in climate directly affect natural resources such as soil and water, as well as entire ecosystems. According to the Intergovernmental Panel on Climate Change (IPCC, 2022) [1], climate change is disrupting ecological and agricultural systems globally, necessitating immediate adaptive strategies to protect food security, biodiversity, and natural capital.

Research also shows broad consensus that African agriculture, in general, is highly vulnerable to climate change, with no region exempt from its negative impacts. Existing cropping systems will have to evolve, and scientific efforts must focus on identifying context-specific adaptation options for farmers [2].

With the development of scientific research, especially in the field of climate change, all indicators confirm that Morocco, like many countries in North Africa, is particularly exposed to the consequences of climate change. Scientific projections suggest that the country will experience rising temperatures and declining rainfall in the coming decades. Estimates predict a temperature rise of 1.1–1.6 °C by 2030, 2.3–2.9 °C by 2050, and 3.2–4.1 °C by 2080. Rainfall may decrease by 14% by 2030, 13–30% by 2050, and 21–36% by 2080 [3].

Simultaneously, Morocco's population is growing—from 36.82 million in 2024 to a projected 46.16 million by 2050 which will increase pressure on already scarce natural resources, especially arable land and water [4,5].

Morocco's land distribution adds further complexity to its agricultural development. Less than 10% of the country lies in humid or sub-humid areas with over 500 mm of annual rainfall, while 80% is classified as arid or desert with less than 250 mm of annual precipitation [6]. These constraints severely limit water availability for agriculture.

Although wheat typically requires between 270 and 380 mm of water per hectare, precision irrigation methods (e.g., drip irrigation) can optimize its use to between 2731 and 3760 m³ of water per hectare for a yield of 5.9 to 6.64 tons/ha [7]. Still, the agriculture sector consumes about 85% of the total water from dams in an average year [8].

Soil degradation also poses a major challenge. An estimated 50% of the 20 million hectares of catchment areas in Morocco are at risk of erosion, with water erosion affecting over 2 million hectares of agricultural land. In the northern and northwestern agricultural basins, soil erosion rates exceed 5 to 20 t/ha/year and can surpass 50 t/ha/year in areas like the Pre-Rif hills [9,10].

Despite Morocco's export of early fruits and citrus, the country continues to face structural deficits in basic commodities such as grains, sugar, and oilseeds. Cereal self-sufficiency remains between 30–75% due to limited productivity, poor adoption of modern technology, and insufficient technical support [11].

Cereal farming occupies 71% of the country's 8.7 million hectares of arable land but contributes only 19% to agricultural GDP and employment [12]. The cereal chain also contributes to human and animal nutrition, resulting in significant overlap between several agricultural poles. As a result of its importance in Morocco's agriculture industry, this chain has substantial socioeconomic implications.

According to World Bank data, Morocco's average cereal yield rarely exceeds 24 quintals per hectare in favorable seasons (e.g., 2015, 2018, 2021) and may drop below 4 quintals in harsh years (e.g., 2000) [13]. In contrast, Egypt, France, and China produce over 60 quintals/ha, while the U.S. reaches 80 quintals/ha [14].

These indicators confirm that climate and water availability are the primary factors determining Morocco's agricultural outcomes. Therefore, future strategies must prioritize water resource optimization and better management of ecologically fragile zones [15,16].

Conservation Agriculture Systems (CAS) offer a promising solution to these challenges. CAS is based on three core principles: minimal soil disturbance, crop rotation, and permanent soil cover through residues or cover crops [17,18]. These practices have proven effective in reducing soil degradation and are particularly beneficial in regions affected by climatic variability [19,20].

Improper land management, poorly timed farming activities, erosion, and delayed rainfall continue to worsen soil degradation and reduce yields [21]. Given these challenges, adopting conservation agriculture can play a key role in achieving climate adaptation, enhancing productivity, and ensuring sustainability.

Faced with this situation, we are obliged to adopt effective strategies to adapt to the new realities in the short, medium and long term, as well as to find urgent solutions aimed at alleviating the pressures on natural resources natural resources and ensuring their sustainability and renewal.

Internationally, research by the CGIAR Research Program on Maize (MAIZE) in Malawi, Zambia, and Zimbabwe has demonstrated the positive impacts of conservation agriculture on productivity, profitability, and socio-environmental outcomes [22].

Given Morocco's climate vulnerabilities and the potential of conservation agriculture, this study aims to evaluate the level of CAS adoption in the Had Kourt region and to analyze how socioeconomic factors influence its uptake among farmers. It also proposes a tailored strategy to accelerate CAS implementation in this region.

Building on similar research conducted in Rwanda [23], this study offers new insights by applying the methodology in a completely different agroecological and socio-economic context. By identifying key enablers and barriers to CAS adoption, the study contributes to the design of more effective agricultural policies and extension services in Morocco.

Furthermore, the extracted data also recorded the estimated use of CAS technology by study participants, the CAS usage frequency, farmers' perceptions and the individual reasons for its adoption. Other factors considered included economic and social aspects, in order to identify key elements that would help promote conservation agriculture. The data from this study will serve as a baseline for the development of this technology in other parts of the country.

2. Materials and Methods

The method employed in this study is called snowball sampling [24], which is centered on leveraging a known contact to recruit other connections in order to generate a sample that would help meet the goals of the study.

Snowball sampling, a non-probability sampling method often used in qualitative research, requires careful explanation due to its reliance on participant referrals, which can influence the representativeness of the data.

As noted by Naderifar et al. (2017) [25], clearly describing the snowball sampling process is essential for transparency and for understanding the context and validity of the study findings.

A standardized questionnaire was utilized to conduct the initial in-person interviews with three agronomists working in the local agricultural sector. Upon completion of these interviews, each agronomist recommended three lead farmers to participate in the next phase of data collection, resulting in the selection of a total of nine lead farmers. Each of these lead farmers was then tasked with forming a group, referred to as a "cell," composed of ten farmers in total this included the lead farmer themselves and nine additional farmers from their respective communities. This structured referral approach not only expanded the sample size in a systematic way but also facilitated the collection of diverse, community-specific data that reflected local agricultural practices and perspectives.

The topic addressed in this research combines both natural and human factors, which made us deal with a complex phenomenon. Despite the reliance on complex approaches, the study will take a holistic approach in order to harmonize the results of those approaches. Therefore, from the methodological point of view, the research will be a diagnostic study to know the qualifications of the groups that make up the area from the natural and human points of view and its relationship with the performance of the agricultural activity.

Then a statistical field study to monitor farmers' perceptions of climate variability and their methods of coping with it, in addition to the extent of their adoption of the conservation agriculture system in light of the reality of climate change. Likewise, on the other hand to develop solutions to any coercion that contributes to limiting the spread and adoption of the conservation agriculture system.

The aim of this research is to study the area geographically by diagnosing its natural and human resources, especially those that are not well exploited. Furthermore, to identify the constraints that limit agricultural activity in general and in particular the adoption of the conservation agriculture system, as well as monitor the perceptions of farmers about the constraints of climate variability and their means of coping with them. All of this is a reaction and response at the local level, such as changes in behaviors and attitudes toward the exploitation of natural resources in the area.

Serval methods were also used, in particular the statistical, descriptive quantitative and comparative methods, in addition to the use of certain Materials, such as statistical programs (SPSS), MS Excel, ArcGis 10.5, Origin Lab2024, etc., in order to extract the data needed to complete this study, as shown in **Figure 1**.

2.1. Study Area

The study area is situated in the northwestern region of Morocco, geographically located between the Rif frontal hills and the Gharb plain, at approximately 34.615974° N latitude and −5.735979° E longitude (**Figure 2**). It covers a total surface area of 108,000 hectares, of which approximately 90,000 hectares are classified as Utilized Agricultural Area (UAA). Within this agricultural zone, about 5,000 hectares—representing 5% of the total UAA are equipped for irrigation.

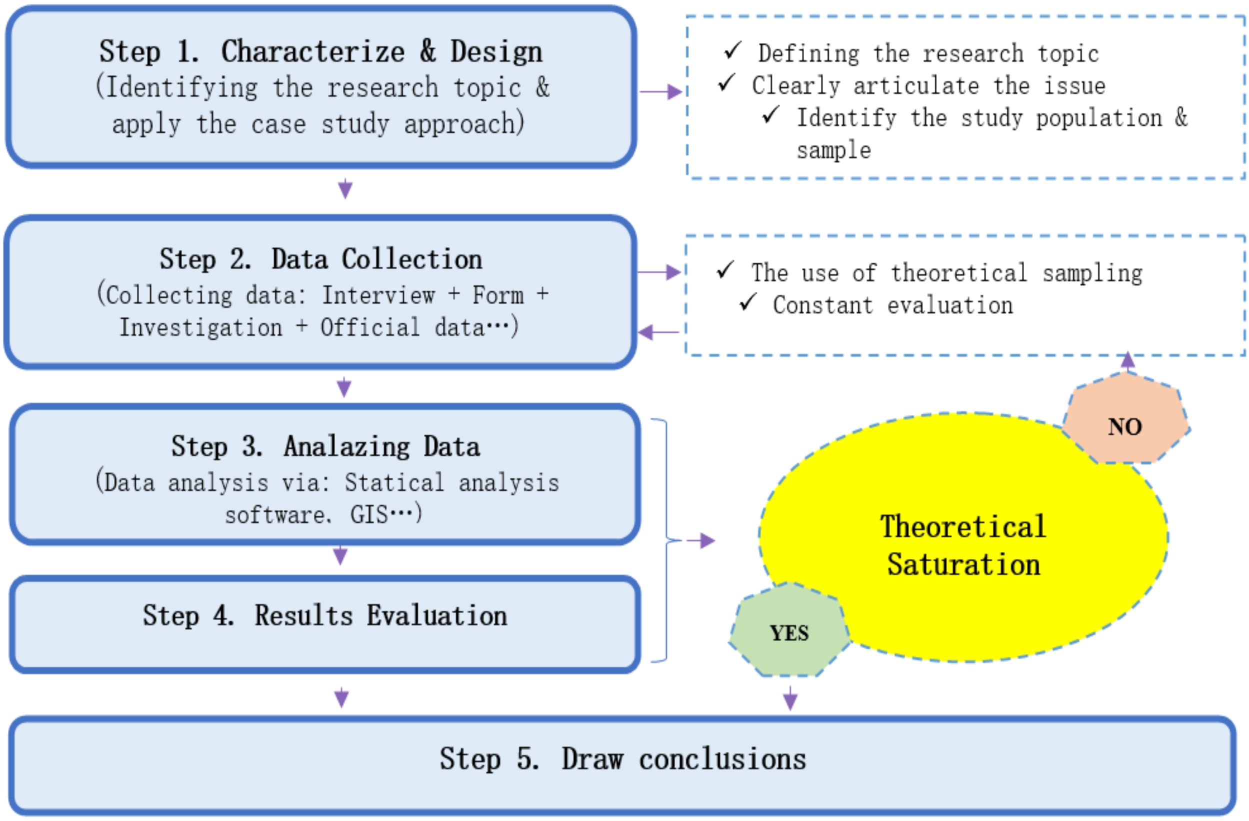

Figure 1. Research methodology plan.

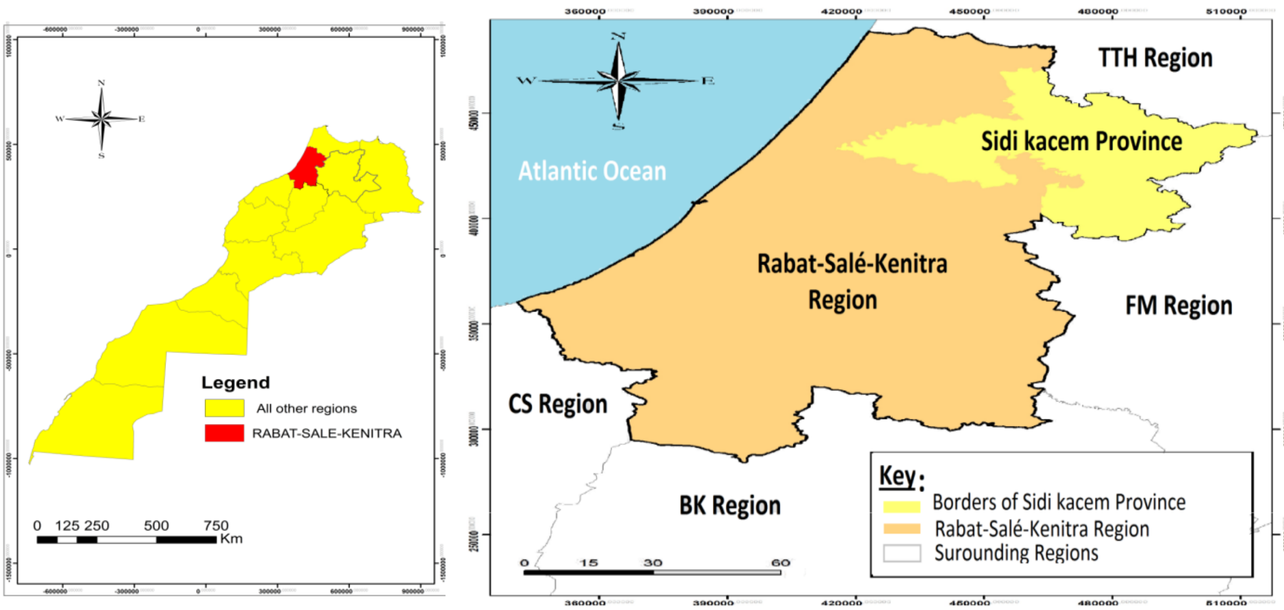

Figure 2. *Cont.*

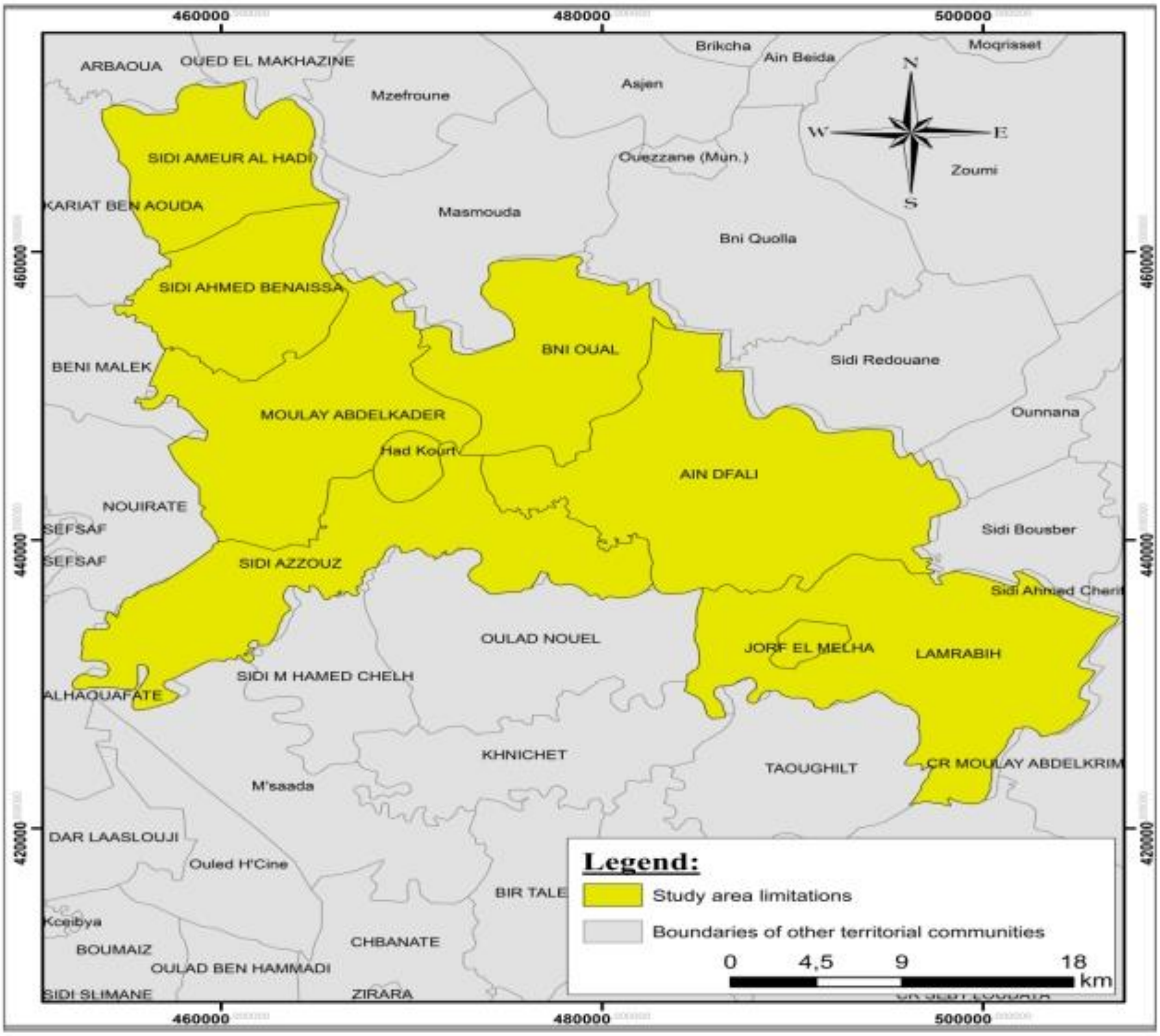

Figure 2. Study area (Had Kourt Territorial Community's).

Topographically, the region can be divided into two distinct agro-climatic zones:

- Hills Zone characterized by undulating terrain with slopes generally less than 15%.
- Plains Zone distinguished by deep, fertile soils that are more favorable for intensive agriculture.

The total population of the area is estimated at 125,000 inhabitants, with a predominantly rural demographic approximately 80% of residents living in rural settings. Among them, around 15,000 individuals are actively engaged in farming, reflecting the region's strong dependence on agriculture as a primary livelihood source [26].

2.2. Climate Data

The overall climate within the study area is characterized by a warm Mediterranean climate throughout the year because of the region's geographic location, which causes temperatures and precipitation to vary according to the months of the year. There are two separate seasonal periods from October to April, while the second is dry and very hot. The amount of precipitation in Had Kourt is more in the winter than in the summer. The climate is categorized as CAS on the Köppen-Geiger climate map [27].

Had Kourt experiences 450 mm of rainfall on average per year, with the highest temperature recorded in the hottest month being 35.6 °C and the lowest temperature recorded in the coldest month being 7.7 °C (**Figure 3**).

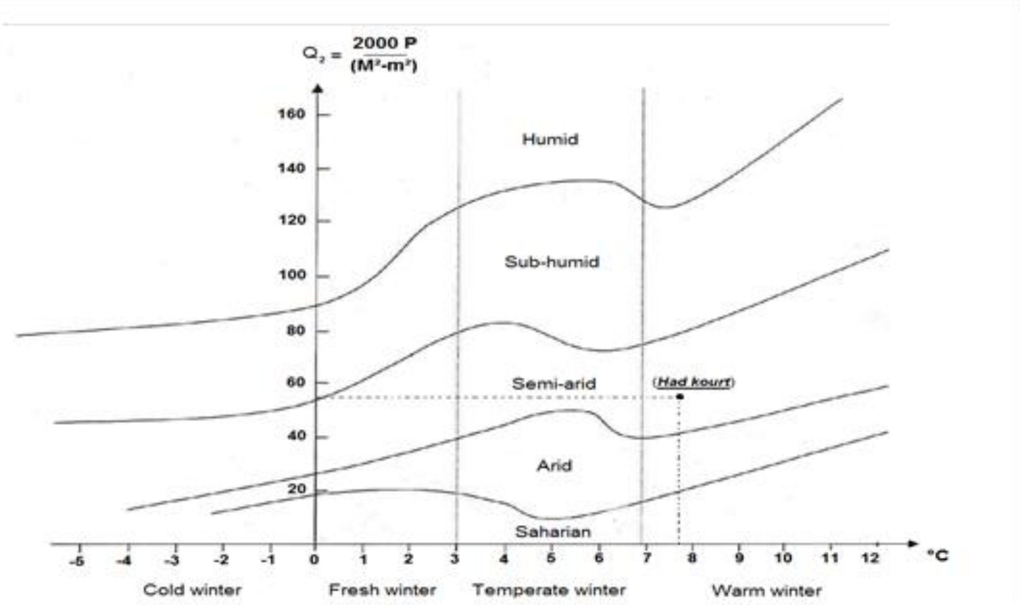

Figure 3. Emberger's Climagram of the study area.

The average annual precipitation between 1990 and 2020 is 450 mm, the average maximum temperature of the hottest month is 35.6 °C, and the average minimum temperature of the coldest month is 7.7 °C, over a 30-year period [28]. The formula for the precipitation quotient (Q_2) in the Emberger model is:

$$Q_2 = \frac{2000 \cdot P}{M^2 - m^2}$$

where:

- ✓ Q_2: Precipitation quotient, used to classify climatic zones.
- ✓ P: Average annual precipitation (in millimeters, mm).
- ✓ M: Average maximum temperature of the hottest month (in Kelvin, °K).
- ✓ m: Average minimum temperature of the coldest month (in Kelvin, °K).
- ✓ 2000: Calibration constant for unit conversion.

Explanation:

- o P (precipitation) is the total amount of rainfall in a year.
- o M and m represent the temperature extremes during the hottest and coldest months, respectively, affecting evaporation and plant growth.
- o Q_2 reflects the balance between precipitation and temperature, helping to classify regions based on their climate and suitability for vegetation.
- o The formula is useful for determining climatic suitability and helps in the classification of regions into phytoclimatic zones based on their precipitation and temperature patterns.

Digital application (**Figure 3**):

$$Q_2 = 54.71$$

The Emberger's Climatogram is a climatogram and system of phytoclimatic belts used in North Africa and Western Europe [29]. There are two major agro-climatic zones in the study region's topography: a plain area with deep and productive soils and a hilly area with an average slope of less than 15%. When it comes to the frequency of terrain units, which are generally monotonous in shape, the basic morphology is rather comparable. The distribution of the research area's terrain is as follows: 45% of the research area is made up of mountainous terrain, with the remaining 20% being plains, 15% being valleys and basins, and hills and plateaus occupying 20% equally [30].

2.3. LULC of Study Area

Global land use/land cover maps produced by Impact Observatory & Esri (2024) (A 10-meter Sentinel-2) were used [31]. These provide information on conservation planning, food security, hydrological modeling, and more. In order to observe and analyze the shape of the land use/land cover distribution in the study area. Using ArcGIS Pro 10.4 software, a map was created (**Figure 4**) that clearly illustrates the shape of the area distribution along the study area, with crops dominating more than 78.80% of the area. While pastures occupy the second place with 12.36%, followed by built area at 7.48%, and forests at 0.92%. The remainder is distributed between water, and bare land, as shown in **Figure 4**.

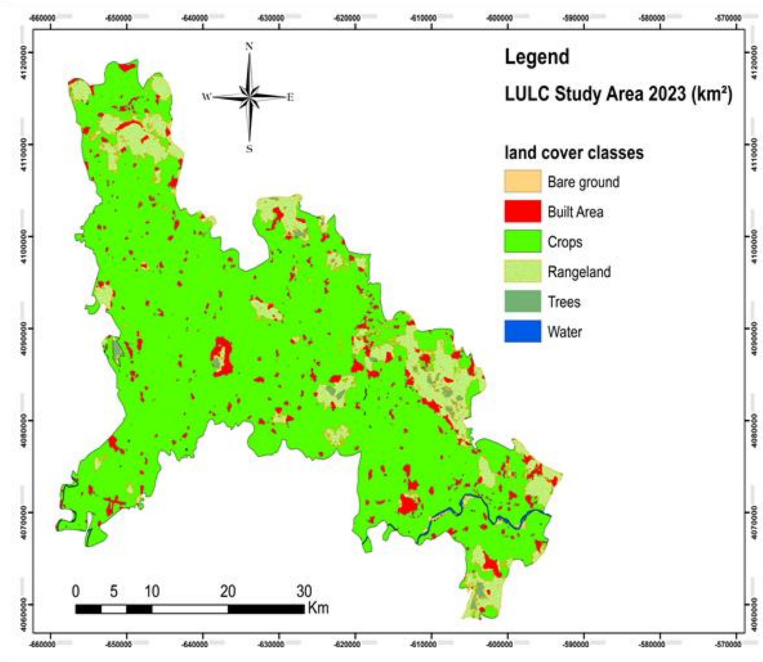

Figure 4. Map LULC (land use land cover) of study area (2023) (0.432km² bare ground; 4.274 km² water; 10.241 trees; 62.713 built area; 136.688 rangeland; 871.164 crops).

Over half of the useful agricultural area (UAA) in the Had Kourt zone is made up of cereal crops, with an average of 45,000 hectares. Durum wheat (7,000 hectares), barley (3,000 ha), and soft wheat (35,000 ha) are the species cultivated. Annual yields differ and are influenced by weather, especially rainfall [32].

2.4. Data Collection

Various local administrations concerned with the supervision of agricultural activities, primarily the Regional Directorate of Agriculture in Sidi Kacem and the Agricultural Advisory Centre in Had Kourt, were contacted in order to collect sufficient and necessary data that would contribute to the study, which led to the identification of Had Kourt as a fertile area to host the research, and then went down to the ground through contact with farmers and questioning their opinions about their experience with the direct planting system according to the principle of conservation agriculture.

Within the period of three years, primary data collection from different areas in the study area began in 2021 from eight regional communities, i.e., Beni Awal; Ain Dfali; Sidi Azzouz; Mili Abdelkader; Sidi Amour El Hadi; Sidi Ahmed Benaissa; Jorf elmalha and Lamrabah.

The data was collected from farmers where a snowball sampling technique was implemented to reach the respondents, based on using a known contact to identify other contacts to form a sample that would contribute to achieving the research objectives. To reach respondents, non-probability sampling was done. Using the snowball strategy [33], additional people who will be regarded as study subjects are found through a known contact (the place was hard to get to and information about the respondents was not readily available).

Official data shows that during the 2020 – 2021 farming season, 208 farmers (1.79% of all farmers) with a total area of 8,700 hectares (19.33% of all the area used for cereals) are implementing direct no-till farming in the study area [34].

The statistical sample was chosen to test the research hypotheses based on the topic's specificity and requirements. Out of 208 farmers actively cultivating cereals using the direct seeding technique, 93 farmers were given the questionnaire. These farmers are engaged in rainfed agriculture, which follows the conserving agricultural pattern. Therefore, the statistical sample is representative of 44.7% of all farmers in the research area who use direct seeding.

A questionnaire was used to conduct in-person interviews with three local sector agronomists. The three agronomists then recommended interviewing 9 additional lead farmers; each leader farmer organized a cell of 10 farmers with 9 other farmers, as seen in **Table 1**.

Table 1. Distribution of respondents.

Sectors (Sub-Districts)	Respondents
Sector agronomists	3
Lead farmers (A leader from each TC)	9
TC1 Jorf elmalha	9
TC2 Ain dfali	9
TC3 Bni oual	9
TC4 Sidi azouz	9
TC5 Moulay abdelkader	9
TC6 Sidi aamer elhadi	9
TC7 Sidi ahmed ben aissa	9
TC8 Had kourt (centre)	9
TC9 Lamrabih	9
Total	93

Note. *3 Agronomists Recommended 9 Lead Farmers; 1 Leader from Each Territorial Community; Each Leader Farmer Organized a Cell of 10 Farmers With 9 Other Farmers.*

Respondents were chosen using a self-selecting process, which meant that the pre-identified group consisted of farmers who either practiced CA themselves or had received instruction in it.

This study used a semi-structured questionnaire with five sections that included statements that needed differential ranking and identical questions composed of both multiple-choice and open-ended questions. The agricultural techniques and knowledge, economic considerations, institutional factors, financial assistance, and demographic and sociocultural features are all represented by the five sections.

The questionnaire was initially administered to a small group of 10 farmers who were identified using data provided by a local branch of a government institution in charge of agricultural counselling and statistical data collection in the region.

Since the main objective was to collect views, thoughts, and opinions rather than the relative number of responses, the sample was diverse. The sections of the questionnaire were formed according to the requirements of the study with the utmost accuracy and objectivity, as shown in **Table 2**.

Table 2. Sections composing the questionnaire structure and information needs.

N°	Sections	Information Needed
1	Demographic characteristics and sociocultural issues	Biographical information, Land ownership, control over how the land is used, individual choice, dynamics of farmer groups, Cultural norms.
2	Farming Practices and CA knowledge	Practices now in use (Such as how they prepare their land, whether they mulch and rotate their crops, and if they use traditional or contemporary market-oriented methods for subsistence) Knowledge of CAS, how often it is practiced, how much land is set aside for CAS, and how the community views CAS advantages and limitations at the agricultural level, prerequisites for broader CAS adoption.
3	Economic factors	The amount of money invested in CA and the degree of adoption (rating statements that could impact their adoption of this technology, such as relying on loans or even donations, improved yields, market.
4	Institutional factors	Government initiatives and CAS-related extended services.
5	Financial support	Availability of assistance or other outside funding.
6	Additional information	Recommendations.

Note. *Each Branch Consists of a Set of Questions That Feed into the Same Angle of Analysis.*

The first section dealt with demographic characteristics and socio-cultural issues by collecting personal data (personal data: age, gender, marital status, educational level, etc.). The second section included open-ended questions about acquired agricultural practices and community perceptions towards the CAS system compared to the traditional agricultural system. This section also asked farmers to describe how respondents understand the CAS system and their requirements that would facilitate wider adoption of the CAS system after overcoming obstacles, followed by a third section that dealt with economic factors arranged by the respondents. Then the fourth section on institutional factors asked for information on government programs and extension services provided to farmers, while the fifth section included information on available financial support and its sources.

At the end of the questionnaire, respondents were asked to add suggestions or recommendations that would contribute to enhancing the adoption of conservation agriculture in their region.

3. Results

3.1. Demographics, Sociocultural Traits, and Social Factors

According to Pearson's chi-square, the adoption of conservation agriculture as the primary variable and other sociocultural and economic elements in the community under study are either correlated or independent.

There is a statistically significant connection between the primary variable and the auxiliary variable whenever the statistical significance value is less than 0.05.

When the Cramer's V value is greater than 0.7, it shows a strong correlation; when it is between 0.2 and 0.3, it suggests a moderate correlation; and when it is less than 0.2, it indicates a weak correlation.

In our case, as shown in **Table 3** [35], we distinguish between independent variables and correlated variables in their relationship with the main variable related to the adoption of the CAS, so that educational level, annual income, additional income, low cost of CAS, Commitment to the CAS, duration of commitment to the CAS, and application of the three pillars of the CAS are all independent variables that are not correlated with the main variable of CAS adoption.

Table 3. Factors that control the acceptance of the adoption of CAS by farmers (The Chi-Square Test of Independence) [35].

Factors	Chi-square of Pearson	Cramer's V	Signification
Farmer's age (Q2)	0.000	0.537	significant
School level (Q3)	0.245	0.201	insignificant
Annual income (Q4)	0.896	0.110	insignificant
Additional income (Q5)	0.741	0.138	insignificant
CAS costs less (Q6)	0.987	0.072	insignificant
Environmental awareness (Q7)	0.000	0.806	significant
Farmer's effect (Q9)	0.000	0.752	significant
Prior knowledge of CAS (Q10)	0.000	0.562	significant
Commitment to CAS (Q11)	0.312	0.196	insignificant
CAS commitment Duration (Q12)	0.697	0.144	insignificant
CAS achieves higher yields (Q13)	0.000	1.000	significant
Applying the 3 pillars of CAS (Q14)	0.449	0.169	insignificant
CAS improves soil quality (Q15)	0.000	0.860	significant
CAS more pronounced in dry (Q16)	0.000	0.863	significant
Government aid & CAS adoption (Q17)	0.000	0.502	significant

Note. *Correlation is Significant at the 0.05 Level (Two Tailed).*

However, we observe that there is a correlation between the main variable of adopting the CAS and a set of variables as shown in the table, starting with the variable of farmers' age (with a moderate correlation), farmers' awareness of environmental issues (with a strong correlation), farmers' influence on each other (with a strong correlation), prior knowledge of the CAS (with a moderate correlation), the advantage of the CAS in terms of yield and production (with a strong correlation), improving soil quality (with a strong correlation), achieving outstanding results during dry seasons (with a strong correlation), in addition to government assistance (with a moderate correlation).

The categorisation of items Q2 (Farmer's age), Q10 (Prior knowledge of CAS) and Q17 (Government aid & CAS adoption) as showing moderate correlation was based on their values being close to or slightly above this range, leading to their inclusion in the 'moderate' category from the point of view of practical interpretation.

While a Cramér's V value of 0.5 technically falls into the "relatively strong" range in many guidelines, its classification as "moderate" in some studies is justified when the value is only slightly above the moderate threshold, especially in the absence of a clear-cut boundary or when using a conservative interpretation. A value of 0.5 lies just above the moderate range and within the relatively strong category, which many practitioners loosely refer to as "moderate to strong" depending on context. This supports a justification for calling 0.5 a moderate correlation, particularly when aiming for conservative or nuanced interpretation [36].

3.2. Agricultural Practices and Conservation Agriculture Knowledge

With regard to agricultural practices, most respondents practice agriculture as their main activity, mixing agricultural and livestock production, and 87% of respondents practice agriculture to cover their subsistence needs and sell the surplus to meet other needs for basic materials. Family members constitute the main source of tillage engaged in agricultural activity, with a decrease and shortage in the availability of foreign tillage. 13% of respondents in the sample are engaged in agricultural activities as a secondary activity in addition to their primary activity.

This section shows the extent to which respondents understand the principles and practices of conservation agriculture as well as their understanding of the idea. By enumerating the advantages and benefits of the direct farming method [37], these farmers supplied us with information about their farming practices, estimates of crop yields employing CAS (**Figure 5**) [38], and their concerns and goals as farmers. In addition to outlining their needs and requirements, they emphasized the primary challenges they encounter at the farm level.

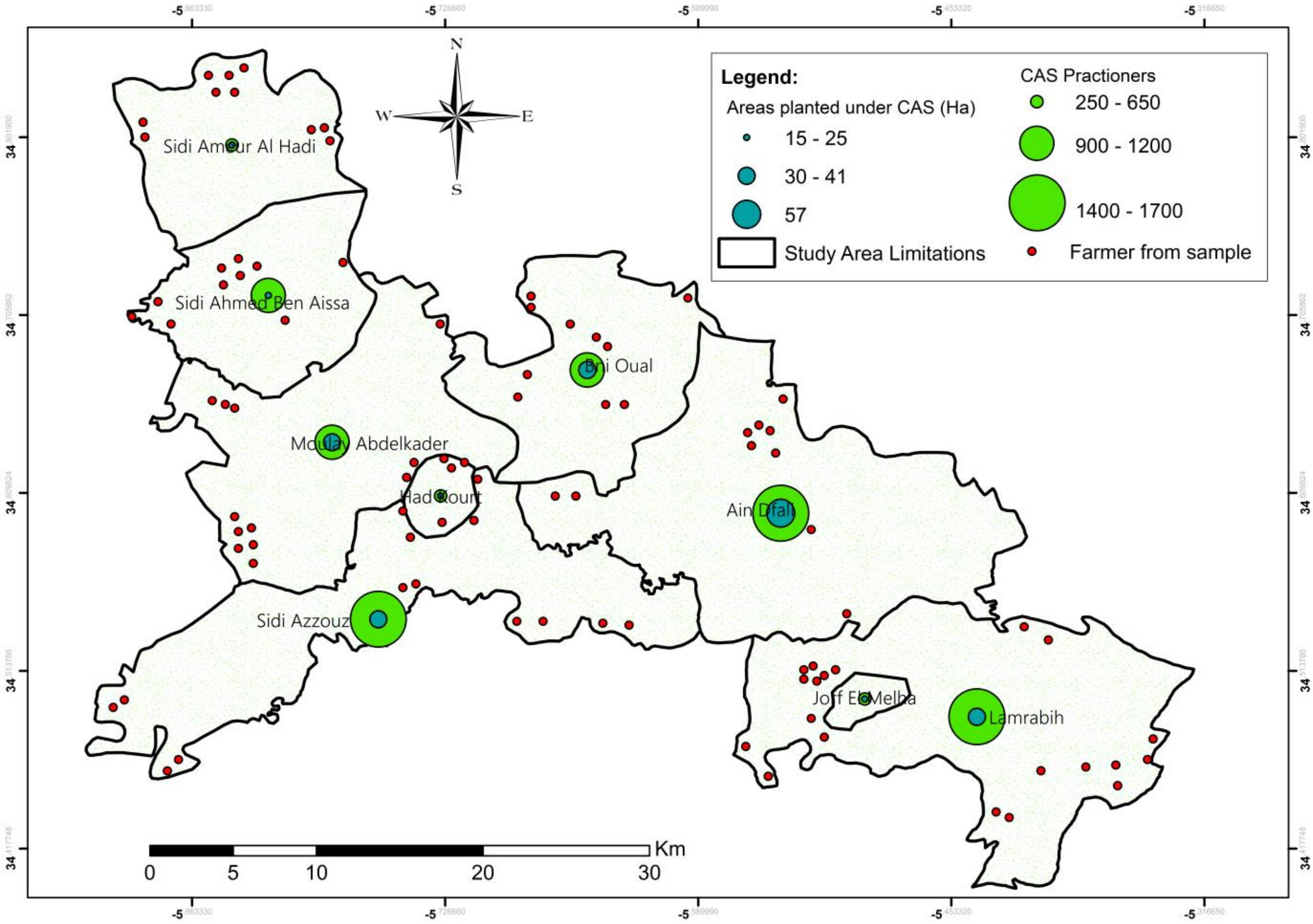

Figure 5. Geographical distribution of CAS practitioners, including sampled CAS farmers and the total area (in Hectares) cultivated under CAS within the study area (Ain Dfali: 1700 ha; Sidi Azzouz: 1500 ha; Moulayabdelkader: 1200 ha; Lamrabih: 1400 ha; Sidi Ahmed Ben Aissa: 900 ha; Bni Oual: 1000 ha; Sidi Ahmed Elhadi: 600 ha; Had Kourt: 200 ha).

In addition, this section assessed respondents' knowledge of acceptable agricultural practices for CAS adoption. It was discovered that only 32% of respondents were aware of the three CAS pillars, but they could only implement two of them as needed, namely crop rotation and minimum tillage. Conversely, 17% of respondents were unsure if they were aware of the three CAS pillars, and 51% of respondents were not familiar with them at all. However, it was the capabilities they learned as a result of the training and learning they received through dedicated government programs that ultimately contributed significantly to their adoption of CAS.

Most farmers in this region rely on growing cereals of all kinds (soft wheat, durum wheat, barley, etc.) as a primary agriculture. Most farmers in this region rely on cereal cultivation as their main crop, along with other types of crops, such as legumes and oil crops, as alternatives to the main crop in order to fulfill the requirement of agricultural rotation (one of the most important pillars of the conservation agriculture system).

In the conventional farming system, farmers plough their land at least twice before planting, deep ploughing once and shallow ploughing one to two times **(Figure 6**, Bottom part), which leads to loosening the soil, and then sowing or planting.

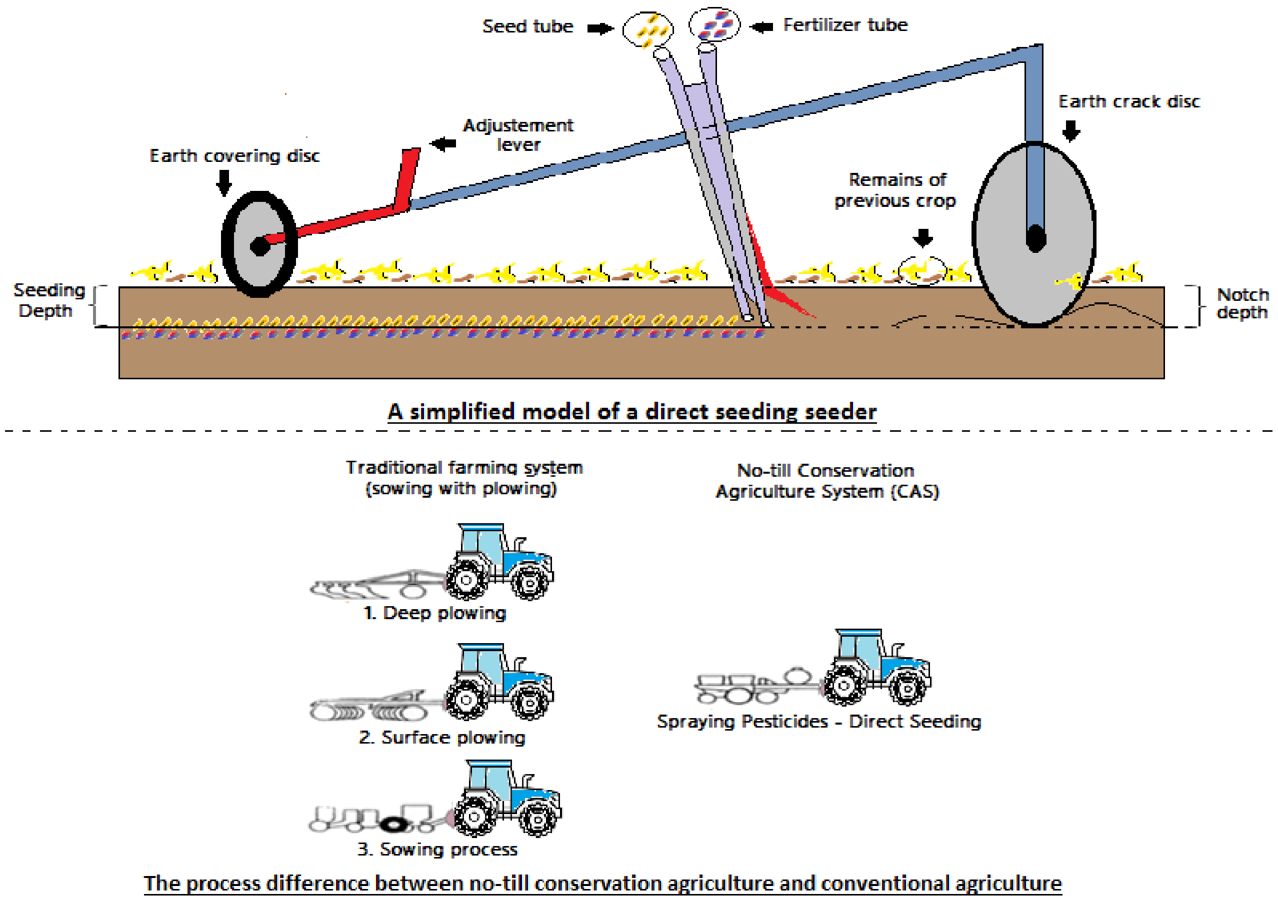

Figure 6. A simplified model of a direct seeding, and the process difference between no-till conservation agriculture and conventional agriculture in Morocco (Created by the Author Using Notes and Instruction Manuals).

As for the conservation agriculture system, it adopts the technique of direct sowing without ploughing, meaning placing the seeds directly into the ground with minimal disturbance of the soil without ploughing, by cutting the ground with special seeders (disk seeders or spiked seeders) that perform three operations simultaneously: cutting the ground, placing the seed and covering it (**Figure 6**, Top part).

3.3. Financial Aspects and Economic Factors

This section examines who relies on self-financing and who relies on external financing in various forms (interest-bearing loans, interest-free loans from relatives and acquaintances, direct support...) to finance their agricultural activities.

According to the results of the questionnaire, 89% of the respondents said that the cost of producing one hectare of cereals (soft wheat) is about $250 per season using a traditional farming system, while 97% of those who adopt the conservation farming system do not exceed $150 per hectare per season.

From a zero net profit that hardly covers production costs to a medium and comparatively large return, the net profit of growing one hectare of soft wheat varies from farmer to farmer (**Figure 7**).

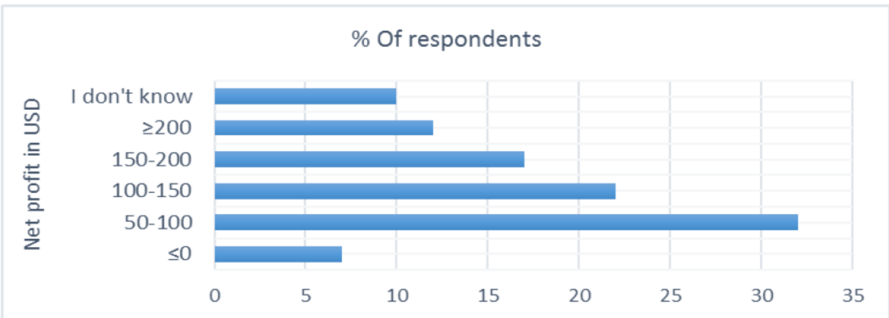

Figure 7. Net profit of growing one hectare of soft wheat (in USD) Invested into CA farming (n = 93).

According to **Figure 8**, the expectation of making a profit through increased crop yields was the main motivator for adopting conservation agriculture.

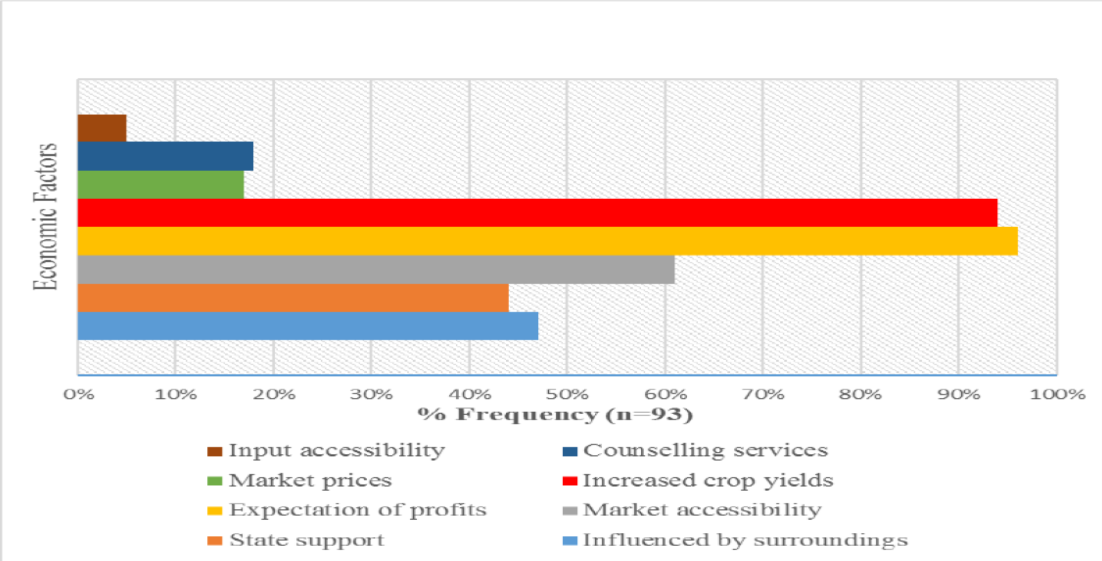

Figure 8. A look at the distribution of the answers pertaining to the economic aspects of CA adoption.

According to the survey results, the primary motivation for adopting conservation agriculture reported by over 90% of respondents is the expectation of increased profitability through higher crop yields. In contrast, factors such as access to inputs and raw materials, government support, market prices, and agricultural extension services were cited by fewer than 20% of respondents. Meanwhile, government support and the farmer's perceived influence on their environment or alignment with market ideologies were mentioned by approximately 44% to 62% of participants.

Participants in this study estimated the expenses they allocated to practicing CAS, and expressed a range of needs that would influence their decision to adopt CAS.

Farmers were given the opportunity to choose more than one economic motive in order to accurately represent the complexity of their real-life circumstances and the various factors that influence their decision-making. Allowing multiple selections ensured that the data captured a broader and more realistic picture of the economic considerations affecting their adoption of agricultural practices, rather than limiting their responses to a single, potentially insufficient option. This methodological choice aimed to enhance the depth and reliability of the findings by acknowledging the multifaceted nature of farmers' economic motivations.

All participants in this study purchased seeds, fertilizers, pesticides and other agricultural materials with self-financing. They all stated that the high prices of some agricultural materials sometimes force them to reduce the amounts or completely dispense with some materials, which would reflect negatively on the yield and quality of the product, and they expressed their dissatisfaction with the price set by the market for their products when they are offered for sale.

The respondents also expressed the needs of their households, which often intersect with essential needs such as nutrition, children's schooling and medical care, which are paid for whenever necessary by selling part of the crop.

3.4. Institutional Factors

Table 4 highlights factors related to institutions interested in CA, information related to government programs, partners involved in promoting the adoption of CA in the study area, and available extension services.

This section presents a breakdown of farmers' responses regarding institutional factors that encourage the adoption of Conservation Agriculture (CSA). It highlights the role of institutions involved in CSA promotion, the dissemination of information about government programs, key partners in CSA initiatives within the study area, and the availability of extension services. **Table 4** provides a detailed overview of these institutional factors. According to the results, more than 85% to 90% of farmers acknowledged the significant role of the government in promoting CSA adoption, particularly through programs that encourage CSA practices and through efforts to raise awareness about their importance.

As shown in **Figure 9**, farmers outlined key recommendations to support the broader adoption of Conservation Agriculture (CSA).

Table 4. Distribution of the answers related to institutions regarding conservation agriculture adoption.

Institutions Related Factors	% Frequency (n = 93)
Government communication on conservation agriculture	85
Conventional practices promote the adoption of conservation agriculture	00
Conducive political environment	55
Government organisations promoting conservation agriculture	85
NGOs promoting conservation agriculture (Partners)	15
Government programs on conservation agriculture	90

Note. *In Addition to the Efforts Made by Government Organizations. There Are Other Partners Such as the National Institute for Agricultural Research (INRA-ICARDA) and the National Agricultural Institutes, as well as Other NGO Partners, Most Notably the Al Moutmir Initiative Sponsored by the Office Cherif du Phosphate (OCP). There is Also TOURBA Program (Carbon Farming), Run by the Mohammed VI Polytechnic University (UM6P), as Actors and Contributors to the Implementation of the Government Program that Aims to Cover One Million Hectares of Cereals with Direct Sowing Under the Conservation Agriculture System by 2030.*

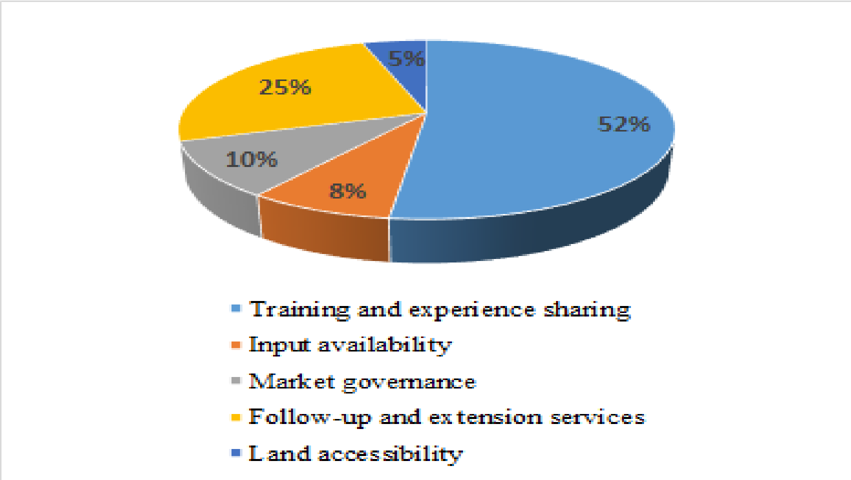

Figure 9. Farmer recommendations to promote the adoption of conservation agriculture system (n = 93).

The majority (52%) emphasized the need for training and practical experience, while 25% highlighted the importance of ongoing extension services. Additionally, 10% pointed to improved market governance, 8% stressed input availability, and 5% called for better access to land. These suggestions reflect the multifaceted challenges farmers face and indicate priority areas for targeted support to advance sustainable agriculture.

3.5. Constraints Highlighted

In this part of the study, farmers clearly expressed some of the obstacles that make it difficult for them to adopt the conservation agriculture system and even prevent other farmers from joining them in adopting this new type of modern agricultural technology. This especially refers to the increasing need for framing and guidance to keep pace with the trend towards adopting the conservation agriculture system instead of the traditional agricultural system, followed by the lack of equipment, i.e., the direct sowing. This remains very expensive for the average farmer, in addition to the issues associated with the high prices of other agricultural goods and inputs, despite the efforts made.

According to research results, 45% of the farmers surveyed did not find any difficulty in applying the conservation agriculture system, while 30% found it very difficult to apply this system. In general, 55% of the respondents confirmed that they had prior knowledge of the direct planting technique according to the principle of conservation agriculture, and 30% of them indicated that increasing the yield was the main reason for adopting the conservation agriculture system, while 25% felt that working with the principle of conservation agriculture contributes to improving soil fertility and health. To accelerate the adoption of CAS in the region, most respondents proposed providing adequate training, support, and follow-up, as well as offering tools—providing a direct seeding machine (seeders).

Generally, agricultural activities in the region are widely considered to be one of the main sectors advancing growth since they rely on people and natural resources as well as modern technologies that assist them, such as the application of modern agricultural techniques and enabling mechanisms. This activity is still impacted by several qualitative, quantitative, and technical elements in order to ensure higher output and promote local population stability.

4. Discussion

Based on the observed data related to the adoption of the conservation agriculture system (CAS) in the study area (Had Kourt), and taking into account the increasing number of farmers joining the ranks of conservation agriculture practitioners, promising opportunities emerge for wider adoption of CAS. By adopting effective strategies to develop and improve this system, in order to overcome the obstacles and difficulties associated with respecting the application of the three pillars of the CAS (no-till farming, agricultural cycle, preserving the remnants of previous agriculture), since each region has its own characteristics and contexts, there is an urgent need to understand the questions and investigate them.

A total of 208 farmers in the study area have already adopted the Conservation Agriculture System (CAS), positioning the region among the leading areas in Morocco in terms of CAS adoption. This notable number highlights the region's strong commitment to sustainable and climate-resilient farming practices. Compared to other regions, the adoption rate here reflects a higher level of awareness and willingness among farmers to shift from conventional to conservation based agriculture. The success is largely driven by effective outreach programs, institutional support, and visible benefits such as improved soil fertility and crop yields. The presence of this many adopters also creates a positive ripple effect, encouraging other neighboring farmers to follow suit. As a result, the region stands as a model for sustainable agricultural development, reinforcing the importance of Conservation Agriculture in addressing both environmental and economic challenges.

The results of this study prove the feasibility of adopting a CAS in areas such as Had Kourt in northwest of Morocco. Like other agricultural regions in Morocco, Had Kourt is increasingly vulnerable to adverse climatic conditions linked to climate change, such as poor and erratic rainfall, successive droughts and their increasing severity, as well as localized inequalities and their consequences.

The actual and main reasons that prompted the farmers participating in the study to adopt the CAS are the information and guidance provided by the Ministry of Agriculture through agricultural advisors covering the entire national territory. They provide guidance through direct communication through field visits to farmers' fields and accompany them during a full agricultural cycle, or in the form of training and training courses for farmers in the form of Farmers Field Schools (FFS) [39].

FFS are applied platforms that simulate the reality and conditions in which the farmer works during a full agricultural cycle of direct cultivation.

Training and capacity building have been widely recognized as critical drivers of CAS adoption. For instance, Thierfelder et al. (2015) found that farmers in Southern Africa who received hands on training were significantly more likely to adopt CA practices [40], due to better understanding and confidence in the techniques.

The importance of extension services is also echoed in studies such as Kassie et al. (2013) [41], which showed that continued technical support enhances the likelihood of sustained CAS adoption by helping farmers adapt practices to local conditions.

Regarding market governance and input access, research by Knowler and Bradshaw (2007) highlighted that weak market structures and limited input supply chains often discourage investment in sustainable practices [42], which aligns with the concerns raised by 10% and 8% of farmers in the current study.

Land accessibility as a limiting factor has been emphasized in North African contexts by Kassam et al. (2009) [43], particularly for smallholders who often lack secure land tenure a barrier mirrored in the present findings.

According to the findings of the study, an important category of farmers still faces some difficulties and complexities in understanding the principle of conservation agriculture in its holistic meaning, which is not only limited to raising yields and improving production, but also to preserving natural resources and the sustainability of production. The same results also showed that providing farmers with the opportunity to learn and open the way for them to learn and rub shoulders with each other's experiences effectively contributes to the assimilation of this system and its optimal application.

The agricultural system in northwest Morocco is characterized by a variety of production chains, primarily annual cereals, along with fruit trees and livestock. Although an important group of farmers in northwest of Morocco have adopted the CAS in cereal production, there are a large number of farmers who are still clinging to the traditional farming system and are not interested in the CAS as an alternative despite the efforts made in this regard. This group of farmers who refuse to abandon the traditional agricultural system that relies on the principle of ploughing as an agricultural necessity can be limited to the age group between 50 and 70 years, and whose educational level does not exceed the primary stage, with some very few exceptions.

It is also impossible to ignore some signs of poverty suffered by a group of farmers who have small holdings that are not sufficiently exploited to meet their basic needs, forcing them to work for well-off farmers who own large holdings, in order to generate additional income and fill the shortage.

Considering these factors, it is clear that there are significant financial difficulties facing small-scale farmers in particular, which should be addressed by taking the necessary measures to encourage this group to adopt conservation agriculture. Namely, this could be done by working to strengthen government support and incentive programs directed at this group, thus enhancing the chances of adopting CAS in the region by small-scale farmers, who account for 71% of the total number of farmers in the region and who own 16% of the total arable area with small holdings, ranging in size from 0 to 5 hectares.

Some farmers are irregular in adopting the conservation agriculture system, so that they mix between the two systems, especially when the conditions for adopting the conservation agriculture system are not available. This is most notable by the absence of the necessary means of production, the most important of which is the direct planting seed machine (seeder), in addition to the succession of drought years and its effects. The urgent need for pastures with the scarcity of livestock, which directly affects another pillar of the CAS, is related to the preservation of the remnants of previous crops to form a cover that protects the soil from rapid evaporation. This directly affects another pillar of the CAS, which is related to preserving the remnants of previous crops to form a cover that protects the soil from rapid evaporation, in addition to turning them into organic fertilizer after their decomposition. Likewise, this means a constant tamping of the soil by the legs of cattle when grazing, thus causing the deterioration of soil health, at the physical, chemical and even biological levels.

The study's findings indicate that social variables play a major role in influencing attitudes, facilitating the gradual transition from traditional to CAS, and improving access to social learning, training, and accompanying. In order to monitor the social elements impacting the field, as well as access and land ownership, particularly for women and adolescents, and to further investigate the role of social networks in the adoption of conservation agriculture in comparable locations, more empirical research is desperately needed.

From an economic perspective, the study clearly expressed the lack and need for more incentives that would contribute to encouraging the adoption of conservation agriculture, such as additional gains and profits through increased productivity and lower cost of production when adopting conservation agriculture. For farmers to be able to benefit from the market, they must improve their collective bargaining power by grouping and organizing into cooperatives, for example, and not fall prey to the exploitation of middlemen, which is a threat to the stability of the farmer and thus the economy of the rural world.

The training courses were a crucial factor in the adoption of the conservation agriculture system because they included practical information, which helped farmers to understand and assimilate more clearly than taking verbal instructions or reading materials through various paper or digital media.

The government and various non-governmental organizations working in the agricultural field should work to promote the adoption of conservation agriculture and invest in the advantages of this system, which can contribute positively to achieving social, economic and environmental development by increasing yields, raising income levels, adapting to climate change, and reducing the impact of soil erosion when exposed to the factors of erosion.

It is worth noting that this study was limited to the use of descriptive data for exploratory analysis without considering causal factors, and additional studies will be needed to support the findings of this study.

5. Conclusions and Suggestions

The data collected from the respondents estimated the number of farmers who have adopted Conservation Agriculture Systems (CAS) on their land, the frequency of adoption, personal reasons for adopting CAS, and the constraints they face. The results indicate that farmers who have adopted CAS save both time and money when cultivating wheat compared to post-till seeding. However, the adoption process of direct seeding to conservation agriculture is complex, requiring additional efforts due to economic and social barriers faced by farmers. Strengthening teamwork and improving monitoring, evaluation, and research and development efforts will be crucial for ensuring the sustainability of this initiative.

The findings from this research provide a solid foundation for scaling up conservation agriculture in the Had Kourt region and beyond. By addressing key factors such as awareness, training, access to finance, and social incentives, the adoption of conservation agriculture can be promoted. Socio-economic challenges, including land ownership and farmer group dynamics, need to be tackled before the planting season to ensure farmers are adequately prepared. Additionally, expanding extension services and increasing the scope of beneficiaries for training courses and hands-on experience will accelerate the adoption of conservation agriculture and facilitate its spread to other regions.

Further research on various aspects such as yield outcomes, production costs, ecological considerations (including soil health), and factors like farmland loyalty, market access, and organization will be vital in making conservation agriculture more appealing and effective in the long run.

Several studies support conservation agriculture. A 2015 study on no-till farming found that while initial costs may be high, long-term savings on inputs like fuel and fertilizers make it economically viable [44]. A 2017 study highlighted the benefits of conservation practices in improving soil health and biodiversity [45]. In 2019, research in Sub-Saharan Africa showed that conservation agriculture enhances soil fertility and climate resilience, especially for small farmers [46]. A 2018 study in Latin America emphasized the role of farmer cooperatives and market access in encouraging conservation practices [47]. Lastly, a 2016 study in the U.S. demonstrated that conservation tillage is economically sustainable due to long-term savings [48].

In case of failure to implement recommendations, it's crucial to analyze the causes whether environmental, economic, or technical. This helps adjust strategies to local conditions. Starting with pilot projects can reduce risks, and involving farmers' feedback ensures that recommendations are practical and more likely to succeed when scaled.

Finally, one of the most important conclusions of the study is the need to redouble the efforts of the government and other partner institutions concerned with the development and promotion of the conservation agriculture system by adopting more material and moral support measures for farmers and encouraging them to replace the traditional farming method with the conservation agriculture system.

Author Contributions

Conceptualization, O.B.; methodology, S.L.; software, O.B.; validation, S.L.; formal analysis, S.L., O.B. and A.B.; investigation, O.B. and A.B.; resources, O.B.; data curation, O.B.; writing—original draft preparation, O.B.; writing—review and editing, O.B., S.L., and B.S.; visualization, O.B.; supervision, S.L.; project administration, O.B. All authors have read and agreed to the published version of the manuscript.

Funding

This research did not receive any external funding. However, after the publication of the article, it is possible to apply for a partial refund of the publication fees as a form of support provided to researchers and to encourage scientific research, through procedures offered by the laboratory and the university.

Informed Consent Statement

Informed and explicit consent was obtained from all participants in the study after fully explaining the nature, objectives, and procedures of the research. Full confidentiality of their data was assured, and the information was used exclusively for scientific research purposes.

Data Availability Statement

This study primarily relies on data available within the scientific references cited in the article, which include the information and findings analyzed and discussed. No new datasets were generated during the course of this research. Therefore, all data supporting the reported results can be traced and verified through the cited sources and references, and there are no ethical or privacy restrictions preventing access to them.

Acknowledgments

The authors are grateful to everyone who assisted in this effort, regardless of the size of their contribution. Special thanks to all farmers in the study area for their help, cooperation, and kindness.

Conflicts of Interest

The authors declare that there is no conflict of interest, and there was no influence on the design of the study; data collection, analysis, or interpretation; manuscript writing; or the decision to publish the results

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