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THESIS

Presented by

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Theme

The Potential of agroforestry as a climate change adaptation and mitigation strategy. Case of the Tlemcen region

Defended on 23 June 2024 before the jury composed of :

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Dedication

First and foremost, I would want to dedicate this thesis to the Almighty God and then to my family, Nguruve Karemba, for their unwavering support.

Declaration

In this thesis, "The Potential of Agroforestry as a Climate Change Adaptation and Mitigation Strategy for Smallholder Farmers : The Case of the Tlemcen Zone-Algeria," I certify (signed) that this work is entirely original. It is the result of my work from the time I started applying for masters.

I hereby certify that I have not submitted this document to any other organisation in hopes of receiving a certificate, diploma, or academic degree. I followed scholarly ethical principles while I prepared, gathered, analysed, and completed this thesis. All academic work has been properly recognised with footnotes and references. I attest that every source I used for this work was correctly mentioned and referenced. Additionally, I have tried my hardest not to plagiarise.

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List of Abbreviations

AFOLU Agriculture, Forestry and Other Land-use

AFP Agroforestry Practices

AFS Agroforestry Systems

ASALs Arid and Semi-Arid Lands

CBD Convention on Biological Diversity

CDM Clean Development Mechanism

CH4 methane

CO2 Carbon Dioxide

FAO Food and Agriculture Organization

GIS Geographic Information System

ICRAF International Council for Research in Agroforestry

ICT Information and Communication Technology

IPBES Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services

IPCC Intergovernmental Panel on Climate Change

N2O Nitrous oxide

SDGs Sustainable Development Goals

UN United Nations

UNFCC The United Framework Convention on Climate Change

USAID United States Agency for International Development

Abstract

Climate change poses a significant threat to global agriculture, particularly affecting smallholder farmers in developing countries who rely heavily on crop productivity for their livelihoods. Agroforestry, which integrates trees, crops, and/or livestock on the same land, is emerging as a promising strategy for climate change adaptation and mitigation. This thesis investigates the role of agroforestry as a strategy for climate change adaptation and mitigation, with a specific focus on smallholder farmers in the Tlemcen area. This research employs the Diffusion of Innovations Theory to analyze the adoption and dissemination of agroforestry practices. The study revealed a significant engagement of young to middle-aged, well-educated men in agroforestry, highlighting a dynamic and innovative agricultural workforce. Predominant agroforestry systems identified include silvopastoral (32%), intercropping (26%), and windbreaks (14%), indicating strategic land use to enhance soil fertility, crop yields, and mitigate environmental challenges like soil erosion and wind damage. Market demand (30%) and climate suitability (20%) are primary considerations in tree selection, highlighting the farmers' strategic approach to maximizing economic viability and resilience, with fruit trees being the predominant choice among 50% of the farmers. Financial stability (40%) and diversification of production (30%) are perceived as the most significant benefits of agroforestry, crucial for mitigating risks and enhancing food security. Effective tree management practices, including irrigation (40%), fertilization (30%), thinning (30%), and pest and disease control (30%), were crucial for maintaining tree health and productivity. The adoption of agroforestry practices was driven by both economic (60%), environmental incentives (50%), and socio-cultural factors (40%). The findings provide insights into how agroforestry can be a viable climate-smart agricultural approach, fostering sustainable development and enhancing food security for smallholder farmers in the Tlemcen area. To enhance the adoption and effectiveness of agroforestry as a climate change adaptation and mitigation strategy in Tlemcen Wilaya, the following recommendations are proposed: enhance access to financial incentives, such as subsidies and low-interest loans, to support farmers in establishing and maintaining agroforestry systems; develop supportive policies that promote agroforestry adoption and integrate it into national climate change strategies.

Summary

This study aimed to assess the potential of agroforestry as a climate change adaptation and mitigation strategy for smallholder farmers in the Tlemcen zone. The study was guided by three specific objectives: to identify the agroforestry practices used by farmers, identify the motivating factors for agroforestry systems adoption among farmers in Tlemcen, and propose possible recommendations to improve agroforestry systems as a climate change adaptation and mitigation tool. To achieve these objectives, a purposive sampling tool was used to sample (40) farmers from Ain Fezza and Beni Snous because of their involvement in agroforestry practices. This was complemented by field data collections and observations. The data were collected via a questionnaire, an in-depth interview guide, and observation. The analysis of the data included the application of descriptive statistics.

Résumé

Cette étude visait à évaluer le potentiel de l'agroforesterieen tant que stratégied'adaptation et d'atténuation du changementclimatique pour les petits exploitantsagricoles de la zone de Tlemcen. L'étude a étéguidée par trois objectifsspécifiques : identifier les pratiques agroforestièresutilisées par les agriculteurs, identifier les facteursmotivantl'adoption des systèmesagroforestiers par les agriculteurs de Tlemcen, et proposer des recommandations possibles pour améliorer les systèmesagroforestiersen tant qu'outild'adaptation et d'atténuation du changementclimatique. Pour atteindrecesobjectifs, un outild'échantillonnagetéléologique a étéutilisé pour échantillonner (40) agriculteursd'Ain Fezza et de Beni Snous en raison de leur implication dans les pratiques agroforestières. Cela a étécomplété par des collectes de données et des observations sur le terrain. Les données ontétérecueillies au moyen d'un questionnaire, d'un guide d'entrevueapprofondi et d'observations. L'analyse des données comprenaitl'application de statistiques descriptives

ملخص

تهدف هذه الدراسة إلى تقييم إمكانات الحراجة الزراعية كاستراتيجية للتكيف مع تغير المناخ والتخفيف من آثاره للمزارعين أصحاب الحيازات الصغيرة في منطقة تلمسان. واسترشدت الدراسة بثلاثة أهداف محددة: تحديد ممارسات الحراجة الزراعية التي

توصيات واقتراح تلمسان، في المزارعين بين الزراعية الحراجة نظم لاعتماد المحفزة العوامل وتحديد المزارعون، يستخدمها أداة استخدام تم الأهداف، هذه ولتحقيق .آثاره من والتخفيف المناخ تغير مع للتكيف كأداة الزراعية الحراجة نظم لتحسين ممكنة ذلك واستكمل .الزراعية الحراجة ممارسات في مشاركتهم بسبب سنوس وبني فزة عين من مزارعا (40) من عينات لأخذ هادفة البيانات تحليل تضمن .وملاحظة متعمق مقابلة ودليل استبيان خلال من البيانات جمع تم .والملاحظات الميدانية البيانات بجمع الوصفي الإحصاء تطبيق

INTRODUCTION

Background

Climate change is one of the most pressing global challenges of our time, and its impacts on agriculture are increasingly felt by smallholder farmers in developing countries (IPCC, 2014; Tengberg et al., 2019). Most studies report that the source of livelihood affected mainly by climate change is agriculture, particularly crop productivity (Aniah et al., 2019; Ighodaro et al., 2020; Adeagbo et al., 2021). This negatively affects rural households that largely depend on agriculture. The number of hungry people worldwide is expected to increase by 20% by 2050 due to the adverse effects of climate change on agricultural production and rural household lives (Hossain et al., 2019). Smallholder farmers, who often depend on agriculture for their livelihoods, remain the most vulnerable to the adverse effects of climate change.

The profound changes taking place today in the world on the climate plan and the preservation of our biodiversity and the negative impacts on the preservation of natural resources and the maintenance of land productivity, challenge us at the highest level and project us into major challenges that we must face. Faced with challenges that call into question the viability of production systems, the agriculture and forestry sectors must currently find solutions to adopt sustainable development strategies to face social, economic, and environmental challenges. These issues encourage us to consider new sustainable modes of exploitation.

Faced with the need for sustainable production, agroforestry, the association of trees with crops, appears as a solution to respond to environmental policies but also for farmers wishing to make their production systems more resilient (Morsli, 2019). Agroforestry, one of the alternatives, opens new prospects for the future of rural areas in Algeria, especially in mountain areas. Agroforestry systems provide many benefits, they improve land productivity and income, protect crops, livestock, soils and waterways, stimulate biodiversity, contribute to carbon capture and beautify landscapes (Akinnifesi and al., 2010); Studies show that agroforestry is one of the main sustainable management practices in many parts of Africa, with a significant impact on food security through increased productivity (Gudeta et al. 2009; Pretty et al. 2011; Pinho et al. 2012; Minang et al. 2014).

According to the World Agroforestry Center (ICRAF), agroforestry is a land-use system that integrates trees, crops and/or livestock on the same land, simultaneously or sequentially, in a way that generates environmental, economic and social benefits. Agroforestry is a system that requires low input cost with less maintenance while generating a higher recycling rate, which is preferable for low-income farmers with more profitability (Jezeer et al., 2018). In general, agroforestry exists around the world in various forms such as silvopastoral systems, silvopastoral systems, agrosilvopastoral systems, multi-purpose trees, riparian buffer zones, fallow improvement (Mosquera-Losada et al., 2009).

However, the potential of agroforestry as a climate change adaptation and mitigation strategy among smallholder farmers is not yet well understood, particularly concerning the type of agroforestry practices and what motivates farmers to adopt it as a green technology (van Noordwijk et al., 2014).

Therefore, assessing the potential of agroforestry as a climate change adaptation and mitigation strategy among farmers, especially in mountainous areas becomes a necessity. This study falls within this framework, it contributes to filling this knowledge gap by identifying and evaluating agroforestry practices among farmers and the factors which influence the adoption of agroforestry as a green technology. Our work aims to assess opportunities and potential for the development of agroforestry in the Tlemcen region: identification of agroforestry practices used in the region, identification of factors that influence the adoption of SAF, and study of the opportunity for the development of agroforestry. The results of this research can inform decisions to improve the effectiveness of agroforestry as a climate change adaptation and mitigation strategy among farmers, thereby improving their resilience and livelihoods in the face of change. climatic.

The methodology is based on the identification of agroforestry practices (field prospecting, surveys, etc.), the identification of factors that influence the adoption of agroforestry, and the evaluation of the potential of agroforestry as a strategy. adaptation and mitigation of climate change among farmers in the Tlemcen area.

This work will be structured around the following four chapters:

- The first chapter is a bibliographical study that presents the work problem by giving an idea about agroforestry and climate change.

- The second chapter sets out the very detailed methodology which was followed to carry out this work.

- The third chapter gives a general presentation of the study area “the region of Béni Snous and Ain Feza”.

- The fourth chapter presents the results and discussion

Problem Statement

Climate change poses significant challenges to the agricultural sector, particularly in developing countries where smallholder farmers depend on agriculture for their livelihoods (IPCC, 2014; Tengberg et al., 2019). Changes in temperature and precipitation patterns, coupled with extreme weather events, lead to lower agricultural yields, reduced food security, and increased vulnerability of smallholder farmers (FAO, 2016). As a result, there is a growing interest in identifying and implementing climate change adaptation and mitigation strategies that can build smallholder farmers' resilience and improve their livelihoods. Agroforestry has been identified as a promising approach for climate change adaptation and mitigation in the agricultural sector (Akinnifesi et al., 2010; Locatelli et al., 2015). Agroforestry is a land use management system that combines trees, crops, and/or livestock on the same plot of land (Nair, 2013). Agroforestry practices can provide a range of ecosystem services, including carbon sequestration, biodiversity conservation, soil conservation, and improved water management (Jose, 2009). Carbon sequestration through agroforestry practices has proven to be an effective strategy for mitigating climate change

Despite the potential of agroforestry as a climate change adaptation and mitigation strategy, there is a lack of empirical evidence on the effectiveness of agroforestry practices among smallholder farmers, particularly concerning its adoption as a green technology (Van Noordwijk et al., 2014). In addition, its adoption has been limited in many smallholder farming communities, due to factors such as limited access to knowledge, resources, and markets (Franzel et al., 2004). The extent to which smallholder farmers adopt agroforestry practices, the factors that influence their adoption, and the amount of carbon sequestered through these practices are not well understood. In addition, there is a need to identify barriers and opportunities for the adoption of green technologies in agroforestry among smallholder farmers. Therefore, the issue addressed by this research is the lack of empirical evidence on the potential of agroforestry as a climate change adaptation and mitigation strategy among smallholder farmers, especially concerning the adoption of green technologies and carbon sequestration in Algeria. This research aims to fill this knowledge gap by identifying and assessing agroforestry practices among smallholder farmers and the factors that influence the adoption of agroforestry as a green technology. The results of this research can inform policy recommendations to improve the effectiveness of agroforestry as a climate change adaptation and mitigation strategy among smallholder farmers, thereby improving their resilience and livelihoods to climate change.

Objectives

Assessing the Potential of Agroforestry as a Climate Change Adaptation and Mitigation Strategy for Smallholder Farmers: The Case of the Tlemcen Zone-Algeria

Methodology

❑ Choice of study areas; two zones are chosen at the level of the Tlemcen zone. The area

of Ain Fezza and the area of Beni Snous

Assess the potential of agroforestry as a climate change adaptation and mitigation strategy among smallholder farmers.

❑ Identification of agroforestry practices

❑ Identify the factors that influence the adoption of green technologies in agroforestry.

❑ Propose recommendations on how agroforestry can be improved as a climate change

adaptation and mitigation strategy

Research question

➢ How can agroforestry be used as an effective climate change adaptation and mitigation strategy among smallholder farmers, with a particular focus on what influences its adoption as a green technology in Algeria?

Justification of the Study

This research topic is important for several reasons. First, it addresses a critical need for empirical evidence on the potential of agroforestry as a climate change adaptation and mitigation strategy among smallholder farmers, particularly in developing countries. This is important because smallholder farmers are among the most vulnerable to the impacts of climate change and their livelihoods depend on agriculture. By identifying the factors that influence the adoption of agroforestry practices and green technologies, this research can provide insight into how smallholder farmers can improve their resilience to climate change. Secondly, this research can inform policy recommendations to improve the effectiveness of agroforestry as a climate change adaptation and mitigation strategy among smallholder farmers. By identifying barriers and opportunities for the adoption of agroforestry practices and green technologies, policymakers can develop targeted interventions to promote the adoption of these practices and technologies. Finally, this research can contribute to the academic literature on agroforestry, climate change, and sustainable agriculture. By generating new knowledge about the potential of agroforestry as a climate change adaptation and mitigation strategy, this research can contribute to the broader academic discourse on sustainable agriculture and rural development.

CHAPTER ONE

LITERATURE REVIEW

1.1 Introduction

The literature review chapter aims to synthesize existing theoretical and empirical studies that provide the foundational background for understanding agroforestry as an adaptation and mitigation strategy for climate change. This chapter critically examines and reviews relevant works on various aspects of agroforestry in the context of climate change adaptation and mitigation.

1.2 Discussions of Agroforestry Systems on Global Climate

The United Nations Framework Convention on Climate Change (UNFCCC) and other leading global environmental and scientific organisations emphasize the increasing importance of integrating and putting into practice sustainable land management methods, which prominently feature agroforestry systems (AFS) (Bélanger and Pilling, 2019; Watson et al. (2019). AFS has gained significant acknowledgement from international bodies such as the FAO, the Convention on Biological Diversity (CBD), and the World Bank (Buttoud, 2013).

The Figure below provides a summary of key Conventions and reports that have highlighted the significance of Agroforestry Systems (AFS) on a global scale. The Kyoto Protocol marked the initial international agreement to recognise AFS's role in mitigating climate change. Subsequently, there has been growing global attention towards utilising AFS for enhancing carbon sequestration (Zomer et al. (2016). However, incorporating AFS into the Clean Development Mechanism (CDM) of the Kyoto Protocol faced obstacles due to inconsistent protocols for estimating carbon sinks and concerns related to land rights (Atangana et al. (2014).

REDD+ (Reduced Emissions from Deforestation and Forest Degradation) refocused attention on Agroforestry Systems (AFS) in 2007, leading many countries to significantly enhance their national planning by recognizing the critical role of agriculture, forestry, and other land-use (AFOLU) sectors in both adapting to and mitigating climate change (Noordwijk, 2020). Nine of the seventeen Sustainable Development Goals (SDGs) have been identified as benefiting from AFS, including SDGs 15 (life on land), 13 (climate action), 12 (responsible production and consumption), 2 (zero hunger), 1 (no poverty), 3 (good health and well-being), 8 (decent work and economic growth), 5 (gender equality), and 10 (reduce inequalities) (Noordwijk et al., 2018).

AFS is a significant climate mitigation strategy that benefits developing and underdeveloped regions by fostering policy alignment across technologies, landscapes, rights, and markets (Van Noordwijk et al., 2019). They also facilitate the localisation of SDGs, particularly targeting SDGs 2.4, 13.2, and

15.3, promoting the restoration of multifunctional landscapes, climate adaptation and mitigation efforts, meeting reforestation targets aligned with initiatives like the Bonn Challenge and the UN Decade on Restoration (2021–2030), and enhancing food and water security Fagan et al. (2020); Borah et al. (2018).

1.3 Key Agreements and Reports on Agroforestry

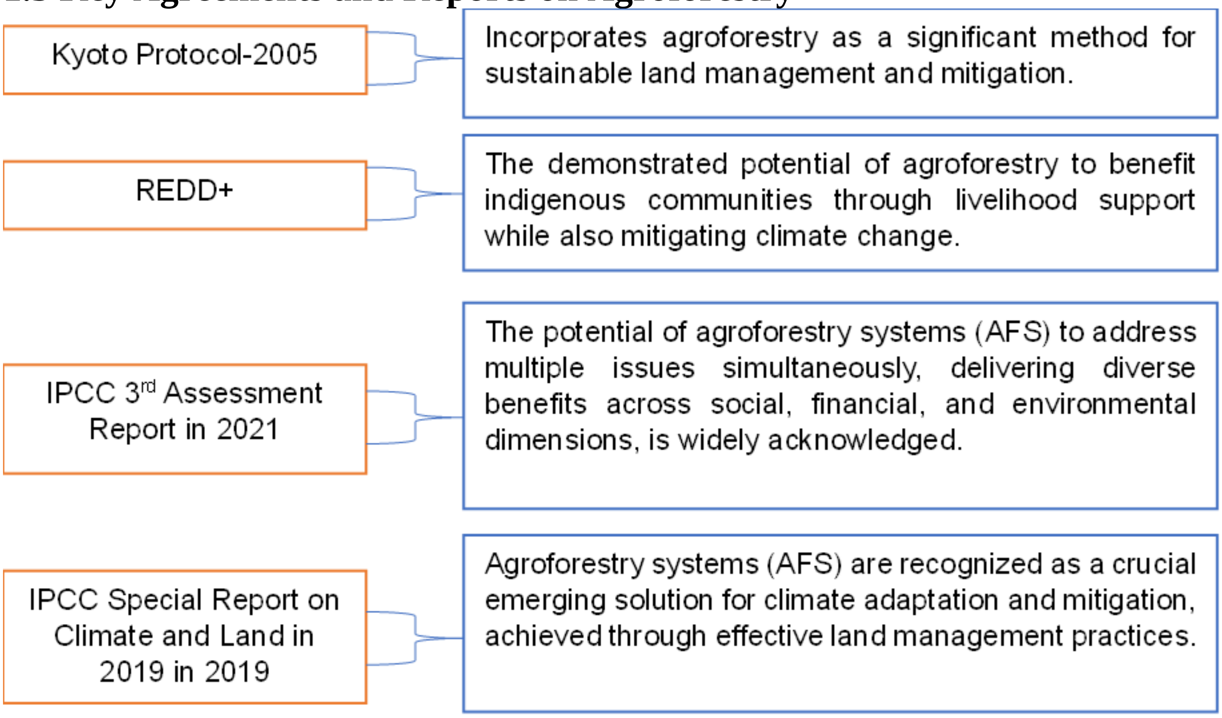

Figure 1.1: Key agreements and Reports on Agroforestry **(Source:** Shukla et al. (2019); Yasin et al. (2019); McCarthy (2001))

1.4 Agroforestry Practices

Agroforestry encompasses various sustainable land-use systems, including tree intercropping, home gardens, shaded perennial cash crops, silvopasture, windbreaks, and tree woodlots (Nair, 2014). These practices offer numerous benefits such as erosion reduction, enhanced water quality, and wildlife habitat provision (Bentrup and Leininger 2002). In the Lohardaga District of India, agroforestry represents a longstanding traditional practice that meets local needs while preserving the microclimate and aesthetic appeal of the area (Singh, 2019). Each of these findings underscores the versatility and effectiveness of agroforestry in sustainable land management.

Again, the diversity of agroforestry practices highlighted by Nair (2014) showcases the range of options available to farmers and land managers seeking to integrate trees into their agricultural systems. This integration not only helps in improving soil health and preventing erosion, as noted by

Bentrup et al. (2002) but also supports biodiversity and ecosystem resilience through the creation of wildlife habitats. Moreover, the case of Lohardaga District in India, as described by Singh *et al.* (2019), illustrates how agroforestry can serve as a time-tested solution that aligns with local cultural and environmental values, contributing to both community livelihoods and landscape preservation.

Aside from the above, several researchers presented on agroforestry practices, such as incorporating trees into agricultural landscapes, have been recognized as effective strategies for mitigating climate change Stavi (2012); Amrutha et al. (2023); Sana and Mandal 2020; Newaj et al. (2013). These practices contribute to climate change adaptation and mitigation by sequestering carbon in biomass and soils, reducing greenhouse gas emissions, and improving soil health. The potential of agroforestry in this context is particularly significant in developing nations like India, where it can address multiple challenges including population growth, water scarcity, declining soil fertility, and biodiversity loss (Amrutha, 2023; Sana, 2020). Additionally, agroforestry systems create favourable conditions for crop, forage, and livestock production, enhancing resilience to changing temperature and moisture patterns (Newaj, 2013).

1.5 Factors Influencing the Adoption of Agroforestry

According to Mwase et al. (2015), agroforestry adoption is influenced by various socioeconomic, biophysical, and farmer-specific dimensions. Research indicates that access to credit, extension services, and proximity to markets play crucial roles in agroforestry adoption rates (Oloyede, 2017), alongside factors like education levels, decision-making autonomy, and household size (Oino and Mugure 2013). Additionally, studies highlight the significance of environmental considerations and specific regional challenges, such as those in arid and semi-arid areas where factors like education, household size, credit access, and training become particularly influential Kinyili et al. (2020).

Keil et al. (2005) found that farmers categorized as poor or very poor had lower rates of adoption, likely due to the extended time required to realize benefits from agroforestry technologies such as improved fallows. This extended establishment phase necessitates that farmers have alternative means of survival during this period.

The age of household heads is a critical factor influencing the adoption of agroforestry practices. In Western Uganda, younger household heads are more inclined to adopt agroforestry technologies compared to older farmers (Thangata, 1996). This trend may be attributed to the willingness of younger households to take risks, which makes them more open to adopting agroforestry innovations. These findings align with prior research (Adesina and Chianu 2002) indicating that adoption tends to decrease with increasing age. Age also plays a significant role in the sustained use of agroforestry technologies, as older farmers are less likely to continue with the technology compared to younger ones (Ajayi and Kwesiga 2003).

Opio (2001) discovered that the lack of secure land tenure adversely impacts the establishment of agroforestry practices. Specifically, in the Katete District of Zambia, female farmers faced challenges in participating in the establishment of Sesbania sesban fallows due to insecure land tenure. Similarly, Ajayi and Kwesiga (2003) synthesized evidence indicating that farm size positively correlates with farmers' decisions to plant and sustain improved fallows, although this association is not gender-specific. In many African societies, most small-scale farmers operate under customary land tenure systems where land is inherited through ancestry. This arrangement means that families are limited to using land inherited from their ancestors, and as family sizes grow, each successive generation receives smaller land portions due to land fragmentation.

1.6 Climate Change Adaptation and Mitigation Strategy

Agroforestry not only mitigates climate impacts but also aligns with local contexts and priorities, maximizing its overall benefits for communities and ecosystems alike. Agroforestry is increasingly recognized as a crucial strategy for addressing the challenges of climate change, providing a spectrum of benefits that contribute to both adaptation and mitigation efforts (Newaj, 2013; Amrutha et al., 2023). This integrated approach not only modifies microclimates, conserves biodiversity, and enhances soil health (Newaj, 2013) but also delivers a diverse array of products essential for livelihoods, including food, fuel, and timber, which are particularly valuable in the context of climate uncertainty (Amrutha *et al*, 2023).

Moreover, agroforestry plays a pivotal role in building resilience among smallholder farmers, helping them cope with climate-related risks while simultaneously sequestering carbon from the atmosphere Lasco et al. (2014). Despite these advantages, there are potential tradeoffs to consider at both farm and landscape scales, underscoring the need for careful planning and management (Lasco *et al.* 2014). To optimize the effectiveness of agroforestry as a climate adaptation and mitigation strategy, systems should be designed to incorporate mixed species, mixed-age stands, and diverse economic, social, and cultural values (Butarbutar, 2012).

According to (IPCC, 2019), agroforestry offers a wide range of benefits, playing a critical role in climate change mitigation and helping farmers adapt to unpredictable and extreme weather conditions. By integrating trees into agricultural landscapes, agroforestry enhances ecosystem services such as regulating water and sediment flow, cycling carbon and nutrients in soils, and providing habitat for biodiversity. These practices contribute to increased soil fertility, reduced soil erosion, and natural pest and flood control (IPCC, 2019). Furthermore, agroforestry supports farmers by boosting farm productivity and decreasing reliance on external inputs like conventional fertilizers and chemical pest management, thereby leading to higher income generation (IPCC, 2019).

The concept of carbon sequestration involves the long-term storage of atmospheric CO2 and carbon capture (Newaj et al., 2012). This process aims to mitigate global climate change by reducing the amount of carbon dioxide in the atmosphere (Newaj et al., 2012). Agroforestry plays a crucial role in climate change adaptation due to its multifaceted benefits (Newaj et al., 2012). It enhances microclimates, mitigates soil erosion, improves soil fertility, reduces carbon emissions, and increases carbon sequestration (Newaj et al., 2012). Integrating trees with agricultural systems, agroforestry not only provides environmental benefits but also contributes to sustainable land management practices that support climate resilience and mitigation efforts.

Similarly, the integration of trees into land-use systems serves a dual purpose, as confirmed by Garnett et al. (2016), which includes sustainable intensification of cultivation and diversification to enhance crop management. This approach not only supports increased agricultural productivity but also promotes resilience and sustainability.

Additionally, the Food and Agriculture Organization (Appanah, 2016) highlights that planting trees and protecting forests across Africa can be an effective measure to mitigate the impacts of climate change globally. By combining agroforestry practices with forest conservation efforts, regions can enhance carbon sequestration, conserve biodiversity, and promote climate resilience in agricultural landscapes.

1.7 Farmers' Awareness and Knowledge about Agroforestry Practices

It is interesting to note the findings of Tokede et al. (2020) regarding farmers' knowledge and awareness of agroforestry, which directly influences their willingness to adopt such practices. The low levels of knowledge and awareness among farmers highlighted in these studies underscore important considerations for promoting agroforestry and conservation consciousness within agricultural communities.

According to Karshieet al., (2017) study conducted in Taraba State, Nigeria, it was discovered that extension agents, forestry departments, and mass media played pivotal roles as the primary sources of awareness regarding agricultural and environmental practices. This study also revealed a noteworthy correlation between the level of awareness and the degree of participation among individuals.

According to Tokede, *et al.* (2020) report on agroforestry in Akinyele Local Government Area, Oyo State, there is a prevalent issue of low knowledge and inadequate attitudes towards agroforestry among local farmers. This finding highlights a critical need for enhanced education and awareness initiatives to promote the adoption of sustainable agricultural practices in the region.

Aside from the above, Constantine et al. (2020) findings in Tanzania, revealed a significant barrier hindering the adoption of agroecological practices, including agroforestry, among smallholder farmers is the lack of adequate knowledge and awareness about these sustainable farming methods. This key finding highlights the critical need for targeted education and capacity-building efforts to promote the adoption of agroecological practices in the country.

1.8 Cause of Climate Change

Climate change, as defined by the Intergovernmental Panel on Climate Change (IPCC), refers to any alterations in climate patterns over time, whether caused by natural variability or human activities. According to the IPCC (2014), climate change specifically relates to changes in climate that are directly or indirectly linked to human activity, impacting the composition of the global atmosphere alongside natural climatic variations observed over comparable periods. These definitions recognize the significant influence of human activities on atmospheric composition, which is the primary driver of climate change. Future consequences of climate change include increased occurrences of extreme weather events, glacier melting, rising sea levels, shifts in rainfall patterns, and heightened heat stress (Dore, 2005).

According to the 4th Assessment Report by the Intergovernmental Panel on Climate Change (IPCC, 2007), there is clear and unequivocal evidence attributing global warming after 1950 to human activities. The report highlights the increase in anthropogenic greenhouse gas concentrations, such as carbon dioxide (CO_2), nitrous oxide (N_2O), and methane (CH_4), with CO_2 being the primary driver of global warming through the greenhouse effect, leading to unintended environmental consequences. It is projected that a twofold increase in atmospheric carbon dioxide levels could result in a temperature rise of 2-4 degrees Celsius by the year 2100. Additionally, other anticipated environmental impacts include increased evaporation, changes in atmospheric circulation, heavier summer rainfall, stronger winds, and increased risk of flooding (UNFCCC, 2007).

1.9 Theoretical Framework

Several theoretical frameworks and concepts can be relevant to provide a comprehensive understanding and analysis. However, the most appropriate theory that can be applied to this study is the Diffusion of Innovations Theory propounded by (Rogers 2003).

1.9.1 Diffusion of Innovations Theory

The Diffusion of Innovations Theory provides a valuable lens for understanding the adoption and spread of agroforestry practices in the context of climate change adaptation and mitigation in the Tlemcen area. This theory, developed by Everett Rogers, outlines key factors that influence the rate and extent of adoption of innovations within a community or region.

1.9.1.1 Innovation Characteristics

The theory highlights how specific characteristics of the innovation (in this case, agroforestry) influence its adoption. Factors such as perceived relative advantage (e.g., increased resilience to climate change, enhanced ecosystem services), compatibility with existing practices and values, complexity, trialability, and observability play roles in determining the rate of adoption (Rogers, 2003). For instance, if agroforestry practices align well with traditional agricultural methods and offer tangible benefits like improved soil fertility and diversified income sources, they are more likely to be adopted by farmers in Tlemcen.

1.9.1.2 Communication Channels

The theory emphasizes the importance of communication channels in spreading innovations. Effective communication strategies, such as farmer-to-farmer networks, extension services, workshops, and demonstration plots, can facilitate the dissemination of knowledge and experience about agroforestry benefits and practices (Rogers, 2003). Understanding and leveraging these communication channels can accelerate the adoption of agroforestry as a climate change adaptation strategy in Tlemcen.

1.9.1.3 Social System Factors

The Diffusion of Innovations Theory underscores the influence of social systems on adoption processes. Factors such as social networks, norms, leadership, and opinion leaders within the community significantly impact the diffusion of agroforestry practices (Rogers, 2003). Strong community support, leadership endorsement, and collective action can promote the widespread adoption of agroforestry as a climate-smart agriculture approach in Tlemcen.

1.9.1.4 Time and Adaptation

The theory acknowledges that adoption is a gradual process that involves learning, experimentation, and adaptation. Farmers in Tlemcen may initially be hesitant to adopt agroforestry due to perceived risks or uncertainties. However, with time and successful demonstrations, early adopters can pave the way for broader adoption across the community (Rogers, 2003) as illustrated in the figure below.

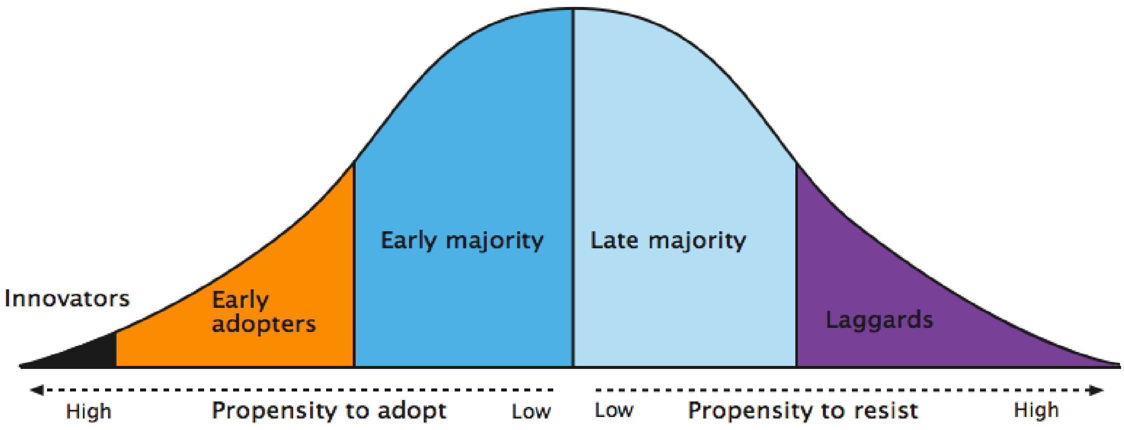

Figure 1.2: Time and Adaptation **(Source:** Robinson, (2009))

According to Rogers (2003), the innovation-decision process is a cognitive activity involving information-seeking and processing, driven by an individual's desire to reduce uncertainty regarding the benefits and drawbacks of an innovation (p. 172). Rogers (2003) outlines five sequential steps in this process: (1) acquiring knowledge about the innovation, (2) being persuaded of its merits, (3) making a decision to adopt or reject the innovation, (4) implementing the innovation into practice, and (5) confirming the decision through evaluation and reinforcement. These stages typically occur in a linear, time-ordered progression.

1.10 Conceptual Framework

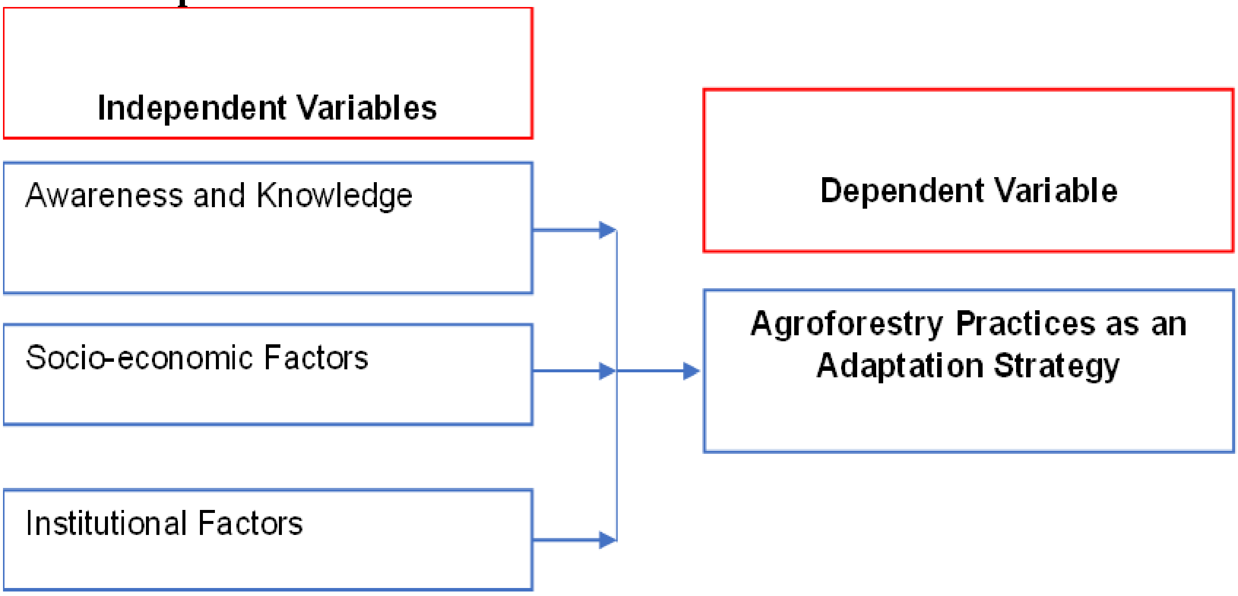

Figure 1.3: Conceptual Framework **(Source:** Admire, (2024))

The proposed conceptual framework, shown above, consists of three independent variables; Awareness and Knowledge of Agroforestry, Socio-economic factors, and Institutional factors with the dependent variable as Agroforestry Practices as an Adaptation Strategy.

1.10.1 Awareness and Knowledge of Agroforestry

Higher levels of awareness and knowledge about agroforestry practices positively influence the adoption of agroforestry as an adaptation strategy. Increased awareness helps farmers understand the benefits of agroforestry in mitigating climate change impacts (e.g., soil erosion control, carbon sequestration, microclimate regulation).

1.10.2 Socio-economic Factors

Favorable socio-economic conditions, such as higher education levels, household income, and farm size, contribute to increased adoption of agroforestry practices. Farmers with better socio-economic status may have more resources (e.g., land, capital) and the capacity to implement agroforestry systems effectively.

1.10.3 Institutional Factors

Supportive institutional frameworks and policies play a crucial role in facilitating the adoption of agroforestry practices. Access to extension services, financial incentives, and technical assistance from institutions encourages farmers to integrate agroforestry into their farming systems.

1.10.4 Interrelationships

These variables indicate that a combination of increased awareness and knowledge, favourable socio-economic conditions, and supportive institutional factors can collectively contribute to the successful adoption and implementation of agroforestry practices as an adaptation strategy to climate change. These factors interact to create an enabling environment that promotes the uptake of agroforestry among farmers in the study area, ultimately enhancing resilience and sustainability in agricultural systems.

CHAPTER TWO

RESEARCH METHODOLOGY

MATERIALS AND METHOD

2.1 Selection of Study Area

Using stratified random sample processes combined with purposive sampling techniques, the study was conducted in three stages (Kothari, 2004). The farmers Ain Fezza and Ben Snous were selected, as well as the sample of responders, using a combination of objective, purposive, and stratified random sampling techniques. Because it had the most agroforestry activity, the Tlemcen Wilaya was purposefully chosen in the initial stage out of all the wilayas in Algeria. There are twenty (20) administrative districts in Tlemcen Wilaya. Two districts were deliberately chosen from among the twenty district administrations in Tlemcen Wilaya after a reconnaissance survey.

2.2 Sampling Techniques.

The number of districts to be studied for the study was determined by taking into account the availability of different agroforestry practices, the representativeness of the agroforestry practices in the district, the availability of financial resources, human resources, and time. A proportionate representative farmer selection of the two districts that were chosen was finally identified by Kothari (2004) as part of the third stage, which states that "a stratified technique is generally applied to obtain a representative sample if the population from which a sample is to be drawn does not constitute a homogeneous group." However, in the third stage, purposive sampling was employed in the selection of the respondents for the study. In each of the districts, (20) farmers practicing agroforestry were purposively selected to ensure a true reflection of the data richness. As a result, hundred (100) farmers were selected from both districts.

Table 3.1: Sample size for each of the zones

Districts Selected	**Number of people interviewed**
Ben Snous	20
Ain Fezza	20

2.3 Types of Data and Data Collection Tools

2.3.1 Primary Data.

Key formants forming the base for the primary data were the selected farmers and some key personnel with stakes in agroforestry. These were carefully chosen to provide a broad perspective of the research area's agroforestry practices. The interview schedule and questionnaires employed were divided into four parts. The first part of the questionnaire sought information about the demographic characteristics of the respondents such as age, gender, educational background, household size, years of experience in agroforestry, and marital status. The second part sought information on the agroforestry techniques practiced by the respondents and the type of trees utilized under each of the agroforestry practices. The third part sought information on the factors and drivers that influenced the respondents to practice agroforestry as well as the perceived benefits of practicing agroforestry. The last part of the questionnaire sought information on the possible recommendations to improve agroforestry practices as well as the significant contribution of agroforestry to climate change adaptation and mitigation efforts. The information in the questionnaires was prepared in the English language, translated into French but was most often interpreted in Arabic (a language understood and spoken by the respondents) during the interview. This facilitated clear communication and comprehension between the respondents, thereby enhancing the quality and accuracy of the data collected. In some instances, joint interviews were conducted to maximize participation and alleviate the burden on individual farmers.

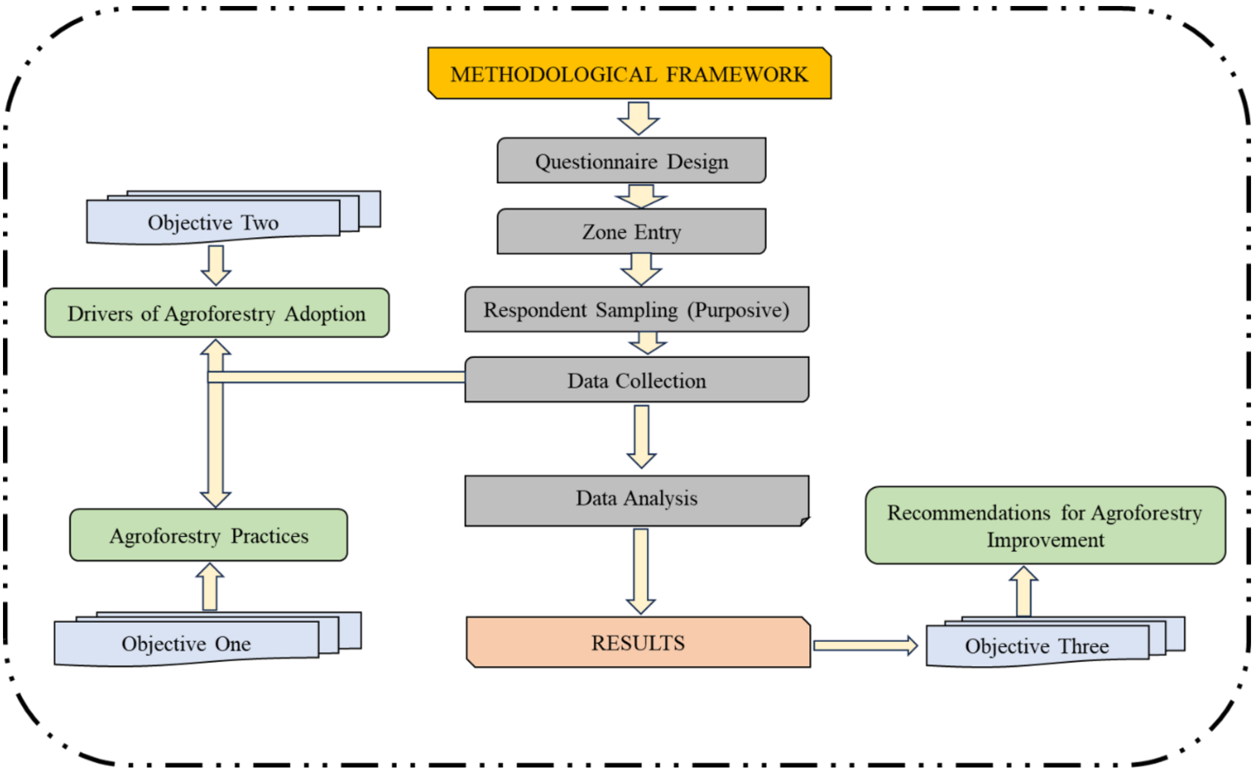

Figure 2.1 Methodological framework for the study

2.3.2 Personal observation

In order to conduct this study, the researcher observed agroforestry practices (AFP) on farms in the study locations and documented his observations. According to Castle et al. (2022), this enabled the researcher to explain current agroforestry practices and contrast reported data with actual occurrences in the study area. The general state of their farming practices, the identification of various agricultural practices used, their contribution to the rural farm income in the study area, their components, such as tree crop components and tree crop animal components, and the kinds of trees and shrubs used in their farms were all directly observed by researchers in a few household farm fields. For the project, secondary data on the value and effects of agroforestry techniques were also gathered and used.

2.4 Data Analysis.

Quantitative data were gathered through interviews, field observations, and household surveys. MiniTab, ArcGIS, and Microsoft Excel version 21 were then utilised to process the data. Approaches to descriptive and inferential data analysis were used. Both the primary motivations behind the decision to choose agroforestry and the demographic features of the farmers sampled are described using descriptive statistics. The mean, percentage, and frequency were obtained in Excel using descriptive statistics.

CHAPTER THREE:

PRESENTATION OF THE STUDY AREA

3.1 Introduction

This chapter deals with the presentation of the study area that includes the geographical, rainfall, slope, soil, and temperature of the two study areas, Ain Fezza and Beni Snous. It also includes materials and methods used in the study that as selection of study area, sampling techniques, types of data, data collection tools, personal observation, and data analysis.

3.1.1 Geographical Representation of Study Area

The Béni Snous region in western Algeria is renowned for its ethnobotanical potential, traditional water and soil conservation techniques, and linguistic accommodation studies. The Chamaerops humilis plant, native to the area, is used for therapeutic purposes, with various parts such as the heart of the stipe, fruits, roots, and leaves serving different medicinal functions. Additionally, Beni Snous boasts innovative traditional water and soil conservation methods, with 78% of these systems still functional and valued, contributing to the region's hydro-agricultural and cultural heritage. Furthermore, research on linguistic accommodation in Beni Snous has revealed how rural speakers modify their speech when interacting with urban areas, particularly with regard to gender markers, showcasing a blend of native and urban linguistic influences. The Béni Snous region is part of the Montes de Tlemcen, located southwest of Tlemcen, 35 kilometers away and extends 40 km to the Moroccan border. This mountainous region with fabulous landscapes is known for its mysterious and magical valley of Oued El Khemis which extends over 40 km, surrounded by douars and typically Berber villages, namely Tagga, Beni Achir, Zahra, Keddara, Tassa, Fahs, Oules Moussa, Ouled Arbi… The daïra of Béni Snous covers an area of 55,543 ha for a population of 21,646 inhabitants (2008). Its geographical coordinates are: Latitude 34° 45′ 7.83″ and 34° 30’ 33” north and Longitude 1° 21’ 5.47” and 1° 41′ 21″ west. It is limited to the north by the communes of Sidi Medjahed and Bouhlou, to the west by the commune of Béni Boussaid, to the east by the communes of Ain Ghoraba and Sebdou and finally to the south by the communes of El Bouihi and Sidi Djilali. Moreso, The Ain Fezza commune, selected as the study area, is situated 12 kilometers from the capital of the wilaya of Tlemcen and covers an expanse of 18,300 hectares. It derives its name from the local spring called “Ain Sakhra,” which translates to “springing water.” It is positioned between western longitudes 0.63° to 0° and northern latitudes 33.27° to 33.63°. This territory is confined to the West by the municipalities of Tlemcen and Chetouane; to the East by the commune of Ouled Mimoun, and to the South by the commune of Oued Lakhdar (formerly known as Oued Chouly).

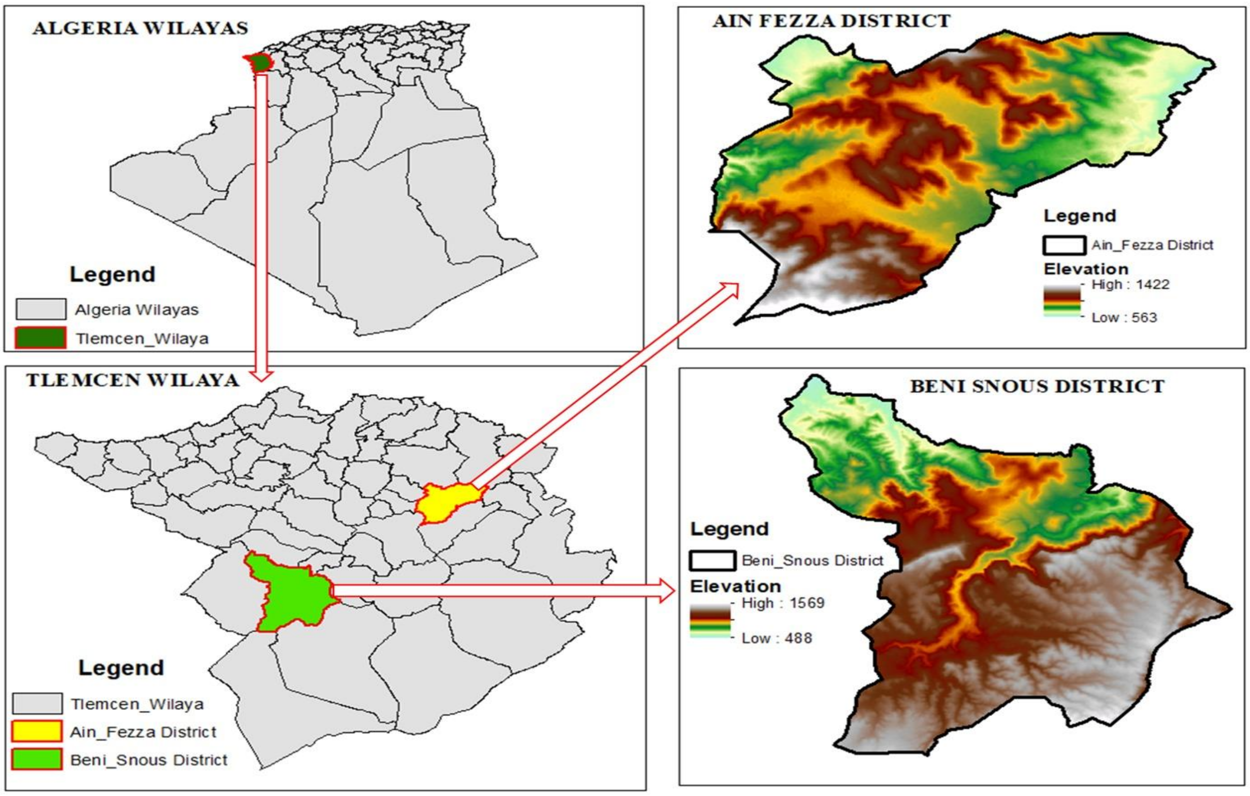

Figure 3.1: Shows the map of the study area and their elevation (Source: Admire, 2024)

3.1.2 Rainfall

3.1.2.1 Rainfall Characterization and Trend for Ain Fezza

The average monthly rainfall of Ain Fezza is displayed in the first chart, demonstrating a seasonal trend. There is a dry summer season based on the highest rainfall of 46 mm in January, 49 mm in October, and 59 mm in November. The lowest rainfall is recorded in July (3 mm) and June (8 mm). The average yearly rainfall from 2000 to 2022 is shown in the second chart. The trend line, which exhibits some oscillations, indicates a slight decline in the average annual rainfall over the period. The trend is not significantly predictive, as seen by the very low R^2 value (0.0013). The information points to a yearly rainfall pattern that is largely consistent but is gradually diminishing, with notable annual fluctuation. This analysis highlights the seasonal and interannual variability in Ain Fezza's rainfall patterns.

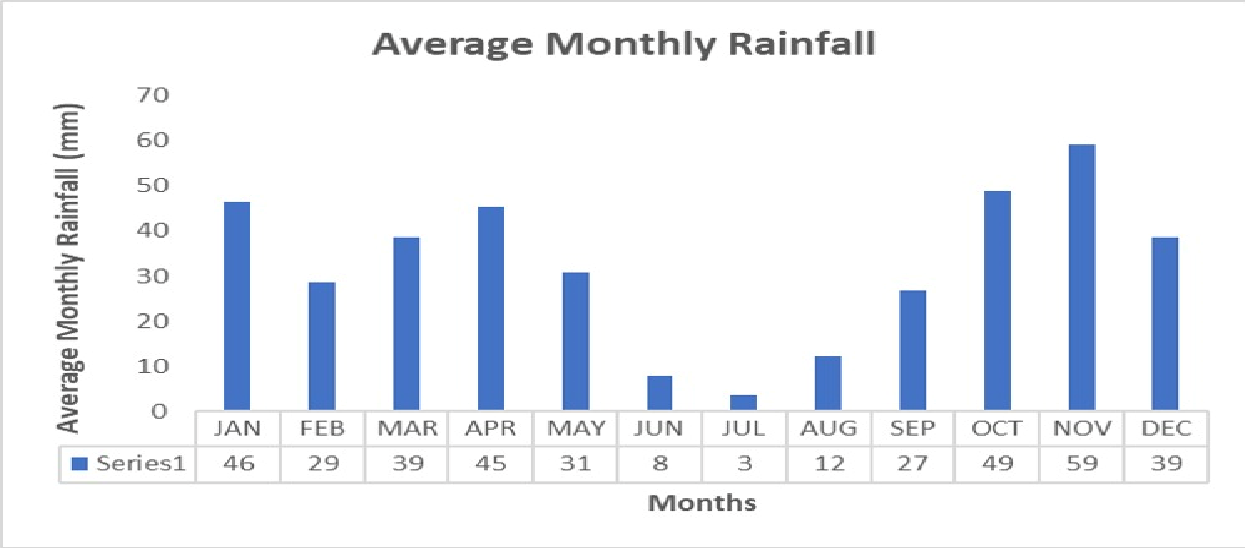

Figure 3.2 Average monthly rainfall pattern for Ain Fezza

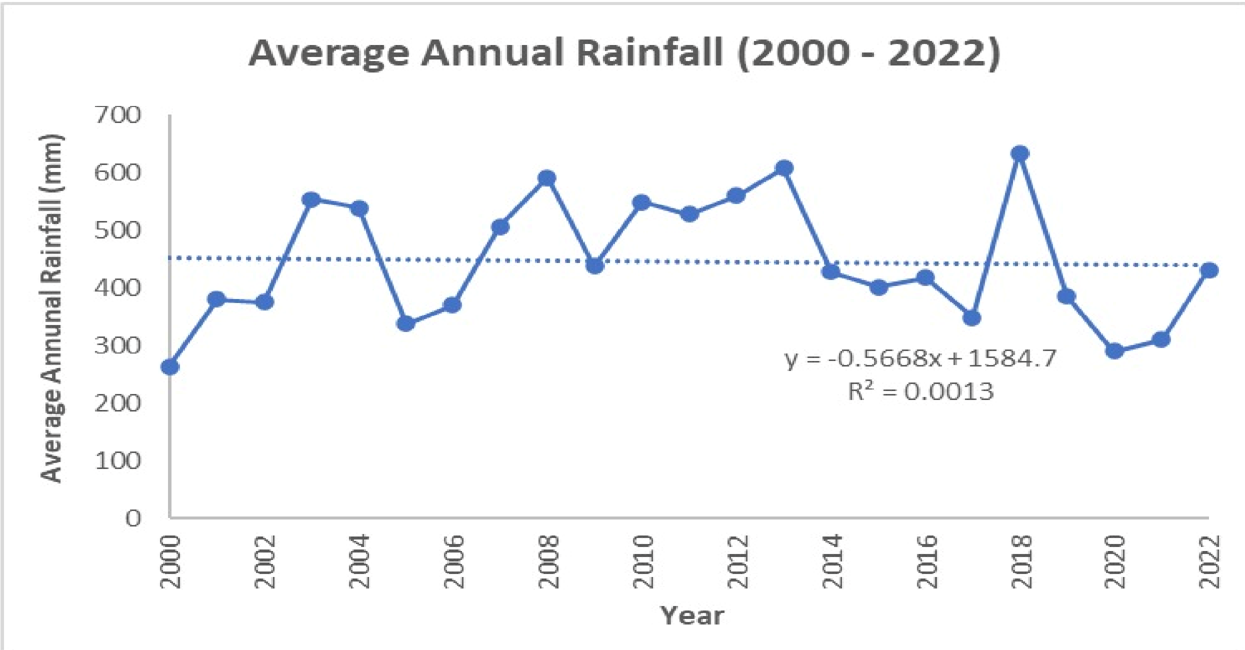

Figure 3.3 Average annual rainfall trend for Ain Fezza

3.1.2.2. Rainfall Characterization and Trend for Beni Snous

Two charts depicting the rainfall data at Beni Snous demonstrate notable seasonal and yearly variability. The average monthly rainfall chart shows a clear trend, with July (3 mm) and June (8 mm) having the lowest rainfall and November (69 mm) and January (57 mm) having the highest rainfall. This points to a Mediterranean climate characterized by dry summers and rainy winters. Regression line data from 2000 to 2022 indicates a decreasing trend in the average annual rainfall, with a slope of -4.7019 mm/year. The weak association indicated by the R2 value of 0.0892 suggests that annual variability is influenced by additional factors. The general trend indicates a slow decline in yearly rainfall, except for occasional extremes like the maxima in 2008 and 2018. This might have a big impact on the region's water supplies and farming methods.

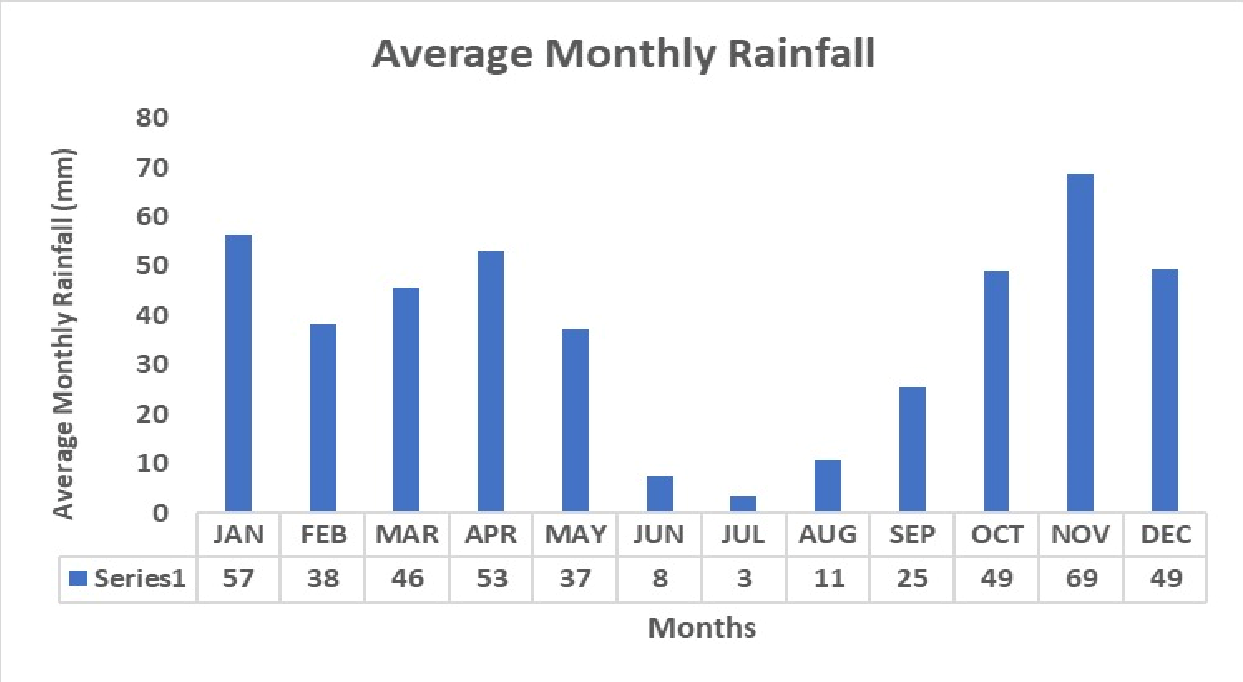

Figure 3.4 Average monthly rainfall pattern for Beni Snous

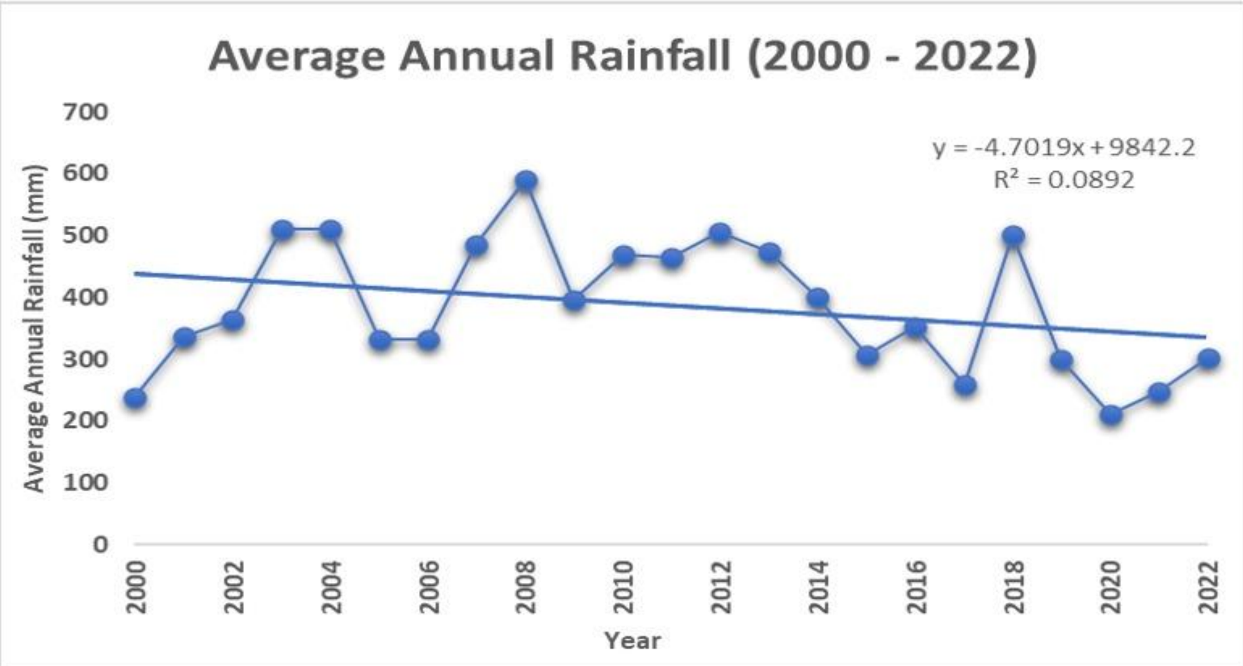

Figure 3.5 Average annual rainfall for Beni Snous

3.1.3 Slope

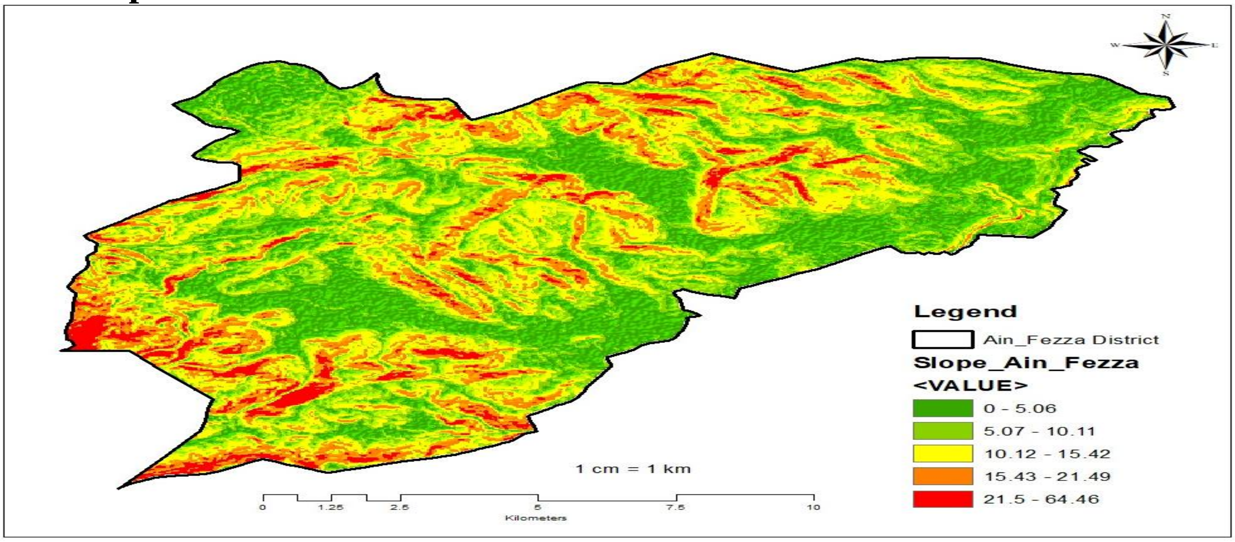

Figure 3.6 Slope characteristics of Ain Fezza

The distribution of slope gradients in the Ain Fezza District is shown on the map, which is divided into five classes with degrees ranging from 0 to 64.46. The topography is primarily level or moderately sloping, with the regions highlighted in green denoting slopes ranging from 0 to 5.06 degrees. The yellow and light orange sections indicate locations that are spread throughout the district and have modest slopes; their respective slopes range from 10.12 to 15.42 degrees and 15.43 to 21.49 degrees. The steepest parts of the district are indicated by the red patches, which are mainly located in ridges and elevated places and show slopes ranging from 21.5 to 64.46 degrees. This distribution indicates that although the district contains a sizable amount of land that is flat or slightly slopes, there are also sizable regions of more difficult topography, which may have an impact on infrastructure development, agriculture, and land use.

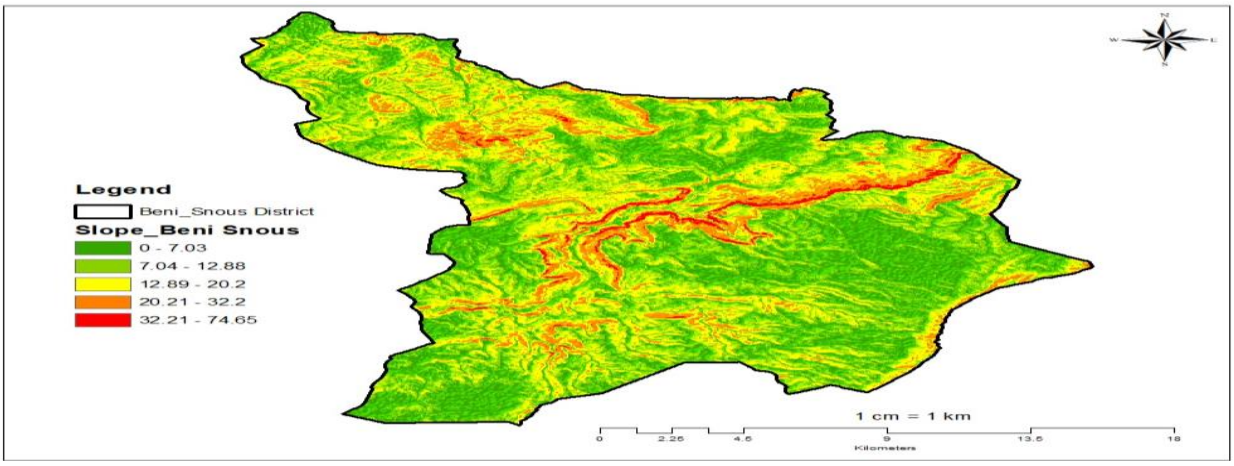

Figure 3.7 Slope characteristics of Beni Snous

The Beni Snous District's slope distribution is shown in the accompanying chart, which is divided into five slope classes. The color-coding of the slope values shows the flattest regions (0–7.03) as green, and the steepest slopes (32.21-24.65) as red. The green and yellow zones, which represent mild to moderate slopes (0–20.2 degrees) that are common in the center and southern regions of the area, encompass the majority of the district. These regions are probably appropriate for the development of infrastructure, agriculture, and human settlement. On the other hand, the orange and red colors represent the more steeply sloping terrain in the northern and eastern regions, which suggests that these areas are not as suitable for such operations and that there is a greater chance of erosion or landslides. Planning land use, evaluating agricultural potential, and putting erosion control measures in place in the area all depend on this thorough slope analysis.

3.1.4 Soil

Three primary soil types are identified on the FAO Soil Map of Ain Fezza: Sandy Clay Loam, Loam, and Clay Loam. The majority of the land is covered in loam (green), which has a balanced texture and high drainage qualities, making it ideal for agriculture. Much of the northwest of the area is covered in clay loam, or dark grey soil, which is noted for its high fertility but poor drainage.

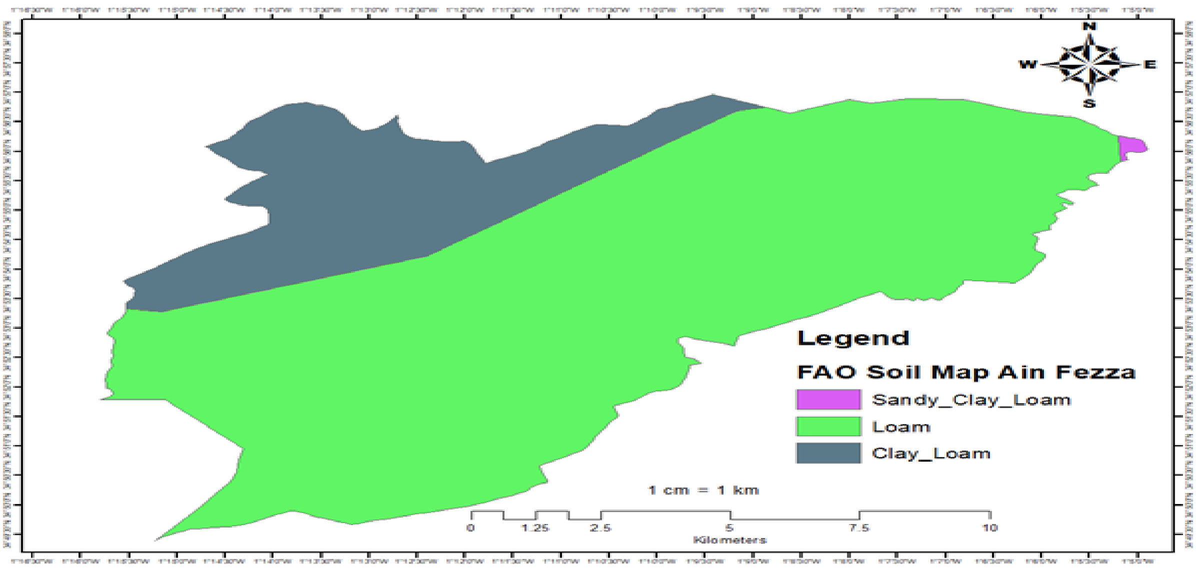

Figure 3.8 Soil-type characterization for Ain Fezza

A minor soil type called sandy clay loam (purple) is found in a small area in the northeast and offers a compromise between the fertility of clay soils and the draining qualities of sandy soils. Ain Fezza's agricultural techniques must be carefully managed to account for the different soil types and seasonal variations in water availability due to the region's unique soil composition and seasonal rainfall patterns, as indicated by the previous charts. The predominance of loamy soils indicates the possibility of varied crop cultivation; yet, the fluctuations in yearly precipitation would need the implementation of irrigation techniques to alleviate dry spells.

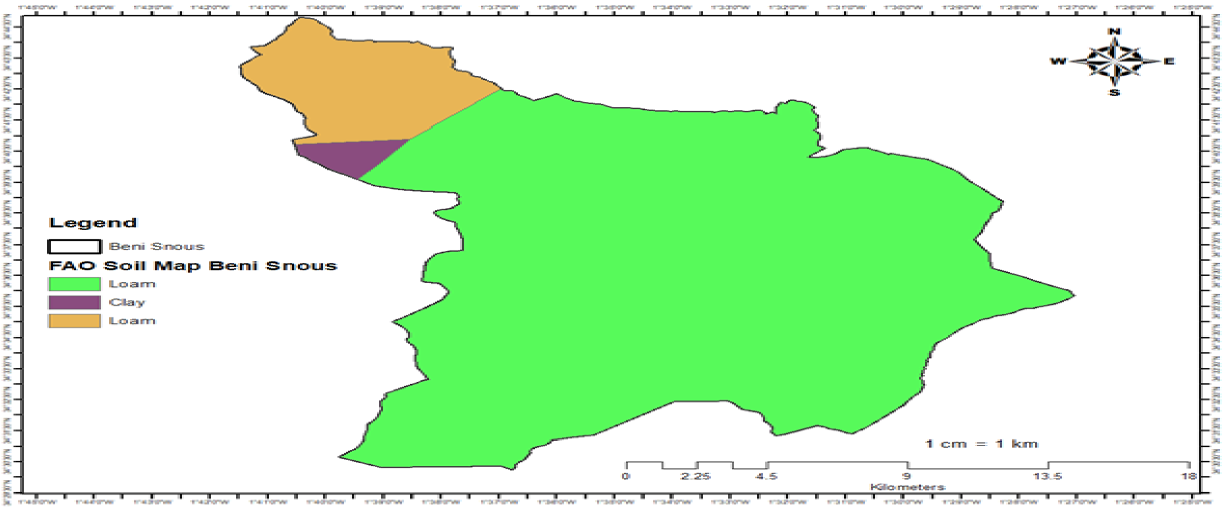

Figure 3.9 Soil-type characterization for Beni Snous

The distribution of soil types in the area is depicted on the FAO Soil Map of Beni Snous, with the majority of the territory being covered by the dominant presence of loam (green). Because of its excellent drainage and capacity to retain nutrients, this loamy soil—which is renowned for having a balanced texture and fertility—is appropriate for a range of agricultural techniques. There's a smaller area in the northwest called Clay (purple), which is very productive but has poor drainage, so it's best suited for crops that can withstand higher temperatures. Brown clay loam, which combines the qualities of both clay and loam and gives intermediate fertility and drainage, is another type of soil found in the northwest. Beni Snous's diversified soil composition indicates that, although the region's vast majority of loamy soils make it suitable for a wide range of agricultural pursuits, sections with clay and clay loam soils necessitate certain management techniques in order to mitigate any drainage problems. For Beni Snous to have the highest possible agricultural output and sustainability, soil management must be integrated with rainfall patterns.

3.1.5 Temperature

3.1.5.1 Ain Fezza

The average monthly temperature is shown in the first chart, which clearly shows a seasonal pattern. January's temperature is 5.67°C, and it rises progressively through the spring until reaching its highest points in July and August (29.9°C and 29.6°C, respectively). Then, it drops during the autumn and reaches 9.76°C in December. This pattern is characteristic of a temperate environment with distinct warm and cold seasons.

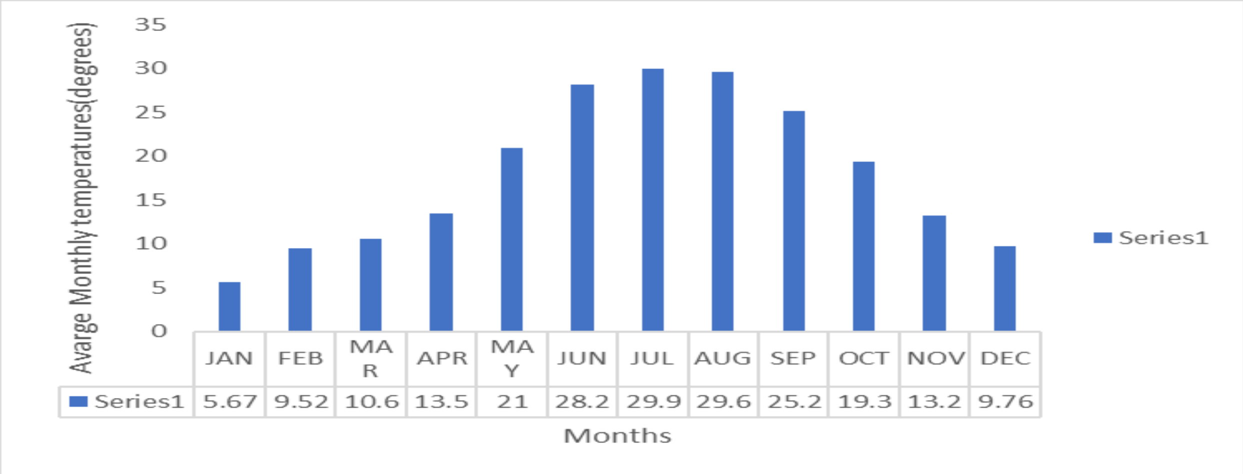

Figure 3.10 Average monthly temperature for Ain Fezza

The summer months are markedly warmer than the winter months. The average yearly temperatures from 2000 to 2022 are shown in the second chart, which also includes a linear trend line. Although there is significant annual variability in the data, the overall trend during the 22 years reveals a progressive increase in average temperatures, as suggested by the trend line's slope (0.0274) and R2 value (0.0844). Notably, the most recent years have seen the greatest temperatures, with a notable peak in 2022. This steady rise in annual temperatures is consistent with evidence of a worldwide warming trend, suggesting that there is long-term climate change. These charts show both the long-term warming trend and the anticipated seasonal variations, pointing to possible effects on regional climate patterns and ecosystems.

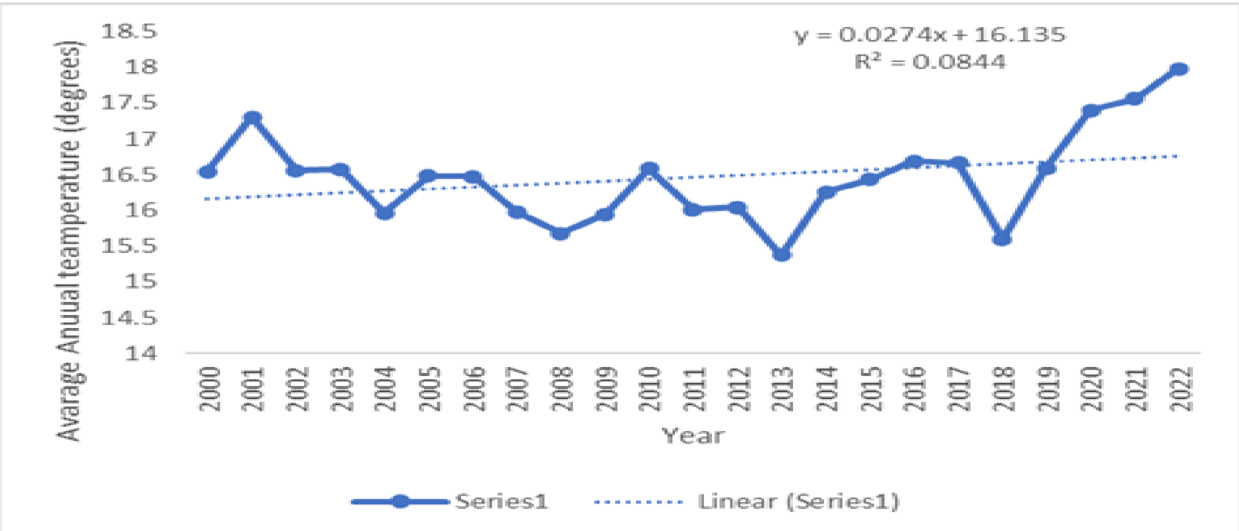

Figure 3.11 Average annual temperature for Ain Fezza

3.1.5.2 Beni Snous

Beni Snous's temperature data shows both long-term and seasonal patterns. The average monthly temperature chart reveals a distinct seasonal trend, with July (28.3°C) and August (27.6°C) being the hottest months and January being the lowest (5.01°C). This suggests a normal temperate climate with cool winters and pleasant summers. The regression line with a slope of 0.036°C annually shows a modest increase trend in the average annual temperature chart from 2000 to 2022. The years and rising temperatures appear to have a modest but discernible link, as indicated by the R2 value of 0.122. The average annual temperature has been gradually rising, reflecting a larger trend of global warming. This could have a big impact on Beni Snous's agriculture, ecosystem stability, and local climatic patterns.

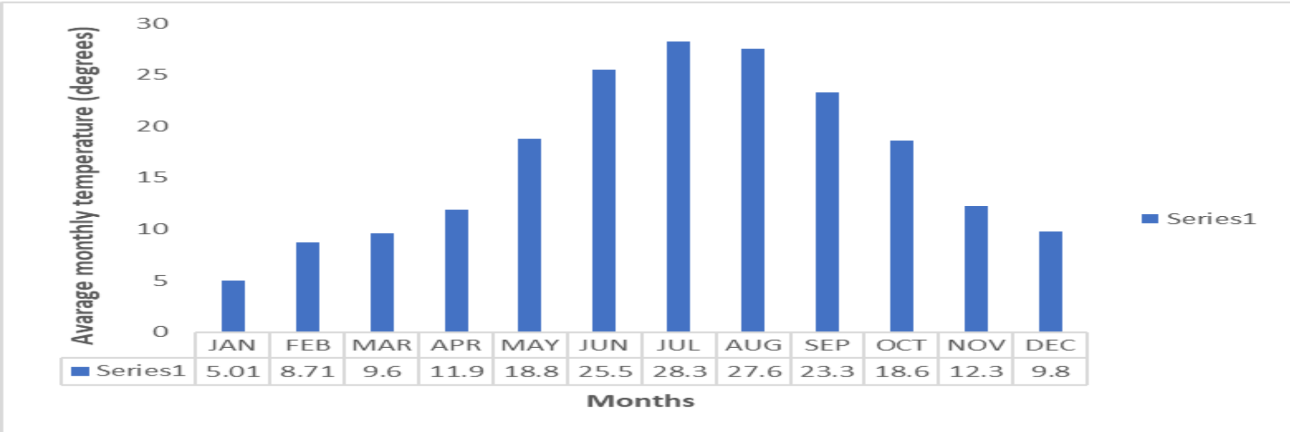

Figure 3.12 Average monthly temperature pattern for Beni Snous

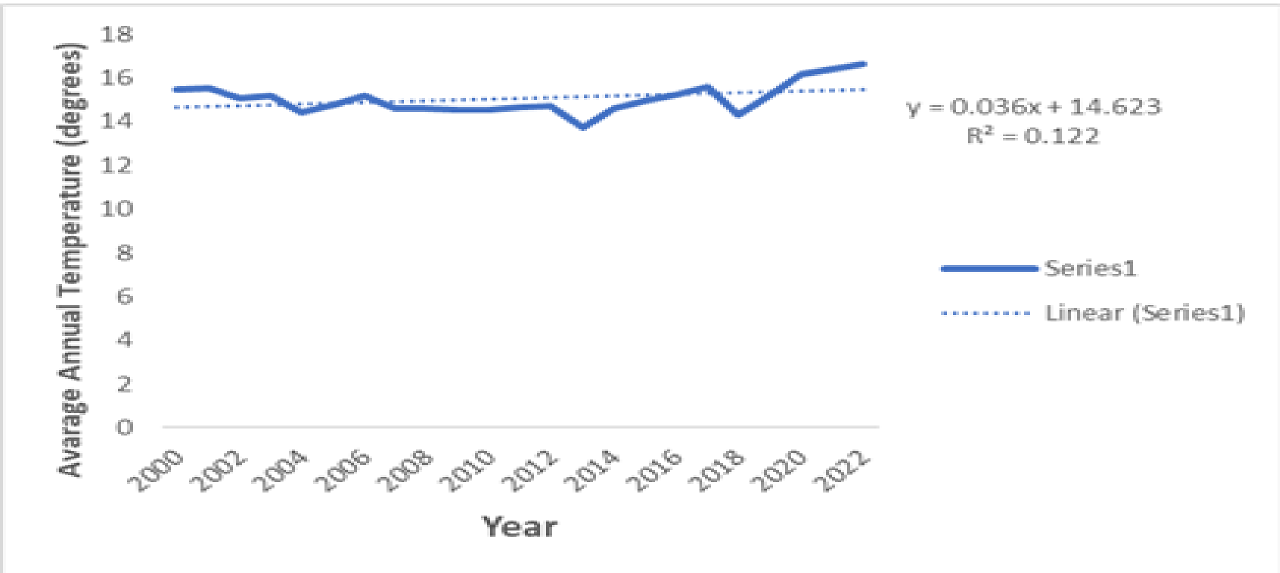

Figure 3.13 Average annual temperature trend for Beni Snous

CHAPTER FOUR

RESULTS AND DISCUSSIONS

4.1 Introduction

This chapter presents the study's findings and provides a detailed discussion on the various aspects of agroforestry practices among farmers. The analysis encompasses several key dimensions, including the demographic characteristics of the respondents, the types of agroforestry practices they employ, the specific types of trees integrated into these practices, and the motivations driving the adoption of agroforestry. Furthermore, the chapter explores the contributions of agroforestry to climate change mitigation and adaptation. The chapter is structured as follows: first, the demographic profile of the respondents is outlined to provide context for the subsequent findings. Next, the different agroforestry practices adopted by the farmers are examined, followed by an analysis of the tree species utilized in these systems. The motivations behind adopting agroforestry practices are then discussed, highlighting economic and environmental factors. Finally, the chapter delves into the role of agroforestry in addressing climate change, including its mitigation potential and contributions to resilience and adaptation strategies.

4.2 Demographic characteristics of the respondents

Table 4.1: Demographic characteristics of the respondents (Source: Admire, 2024)

VARIABLE	FREQUENCY	PERCENTAGE
Gender		
Male	35	87,5%
Female	5	12,5%
Age Group		
< 18	0	0%
18 – 24	0	0%
25 – 34	2	5%
35 – 44	9	22,5%
45 – 49	11	27,5%
50 +	18	45%
Educational Background		
Formal education	40	100%

Years in Agroforestry		
< 1	5	12,5%
1 – 5	25	62,5%
6 – 10	10	25%
10+	0	0

The aim of selecting the socioeconomic characteristics of the farmers studied in this study was to gain a general understanding of who the respondents are and how these characteristics could influence the adoption of agroforestry practices in the study area. Table 4.1 illustrates that males comprised the majority of farmers 87,5%, while females constituted only 12,5% in Ain Fezza and Beni Snous. This gender disparity exists despite the fact that females are typically the primary carers in most farm households. The socioeconomic characteristics of the farmers sampled were analysed using data from the study sites, and the socioeconomic characteristics of the respondents for each study area are also briefly described. This finding aligns with studies conducted by Tega & Bojago (2022), which also observed a higher involvement of men in agroforestry than women. However, more women are involved in agroforestry at Beni Snous than in Ain Fezza. These women mostly engage in irrigation of the farm crops, weed control, and also harvesting of fruits when ready. Despite the small number of women in the practice, their role cannot be overlooked. The age distribution of the respondents reveals that 62,5% of the farmers are over 50 years old. This suggests that middle-aged adults are the primary drivers of agroforestry activities, implying that most of the farmers have had some form of active public engagement before venturing into agroforestry whereas those under 25 are not actively engaged. This is consistent with the findings of Deepa et al (2022) who found 51 years on average as the age of farmers practicing agroforestry. In terms of education, it was found that all participants had formal education (100%). This indicates the presence of a well-educated workforce within the study areas. This finding is consistent with studies by Owooh (2013), which emphasized a higher percentage of educated farmers involved in agroforestry. This implies that the respondents were literate, therefore the ability of the majority of the farmers to read is expected to have a positive influence on their willingness and capacity towards adopting agroforestry practices, (USAID, 2010). Furthermore, certain individuals have experience in agroforestry, but agroforestry is a relatively new practice for other respondents.

4.3 Agroforestry systems practiced by the respondents

Figure 4.1 depicts the various agroforestry systems practiced by farmers in Ain Fezza and Beni Snous.

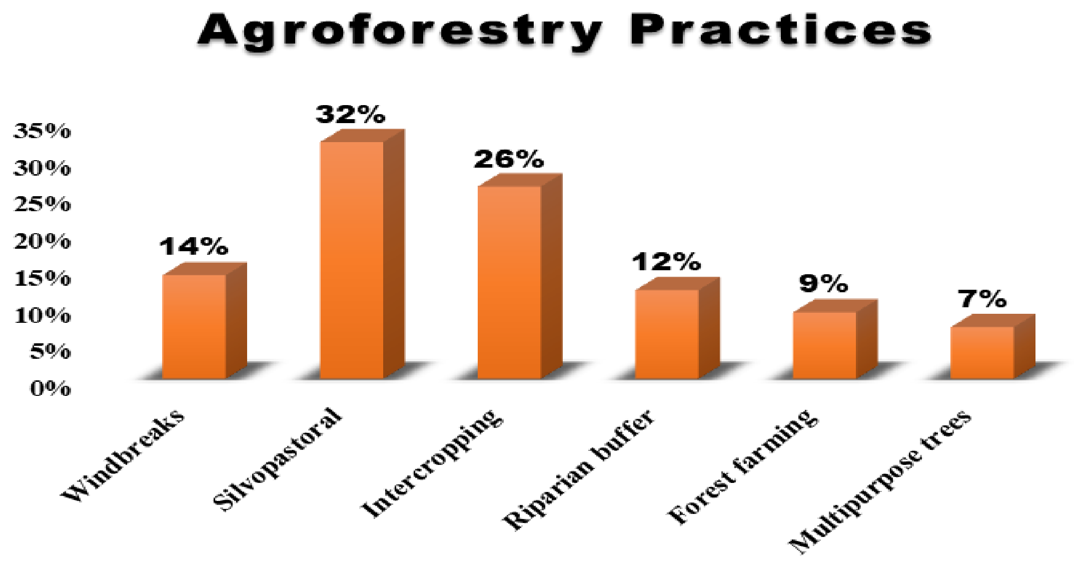

Figure 4.1 Type of Agroforestry systems practiced by the respondents (Source: Admire, 2024)

4.3.1 Silvopastoral

32% of the respondents widely practice silvopastoral systems – which involve a combination of forestry and livestock grazing. The majority opted for this system of agroforestry because this method allows for dual use of the land, providing both tree products (such as timber, fuelwood, or fruit) and pasture for livestock. The benefits of this system include improved soil fertility through organic matter from tree litter, enhanced biodiversity, and better water retention in the soil. Trees offer shade and shelter for livestock, which can reduce heat stress and increase productivity.

Photo 4.1 Pictures of silvopastoral systems practiced by the farmers (Source: Admire and Morsli, April 2024)

4.3.2 Intercropping

26% of the respondents practice intercropping – which involves planting rows of trees or shrubs with annual crops in the alleys between them. This system's ability to enhance biodiversity and improve crop yields by creating a microclimate that reduces wind speed and provides shade is what influenced the decision of the farmers practicing the system.

Photo 4.2 Intercropping systems practiced by the farmers (Source: Admire and Morsli, April 2024)

4.3.3 Windbreak

14% of the respondents practice windbreak systems – strips of trees or shrubs planted to protect agricultural fields from wind. Reasons such as windbreaks' ability to help prevent soil erosion, retain soil moisture, and protect crops from wind damage influenced the decision of the farmers practicing this system. The location of the farmers practicing this system is prone to strong winds and wind erosion, thus, buttressing the prevalence of this system.

Photo 4.3 Windbreak systems practiced by the farmers (Source: Admire and Morsli, May 2024)

4.3.4 Riparian Buffers

Photo 4.4 Riparian buffer systems practiced by the farmers (Source: Admire and Morsli, May 2024)

Riparian buffers, which are permanent plantings of grasses, shrubs, and trees placed between agricultural land and water resources to prevent runoff and non-point source pollution, stabilize stream banks, and preserve water quality, are used by 12% of the respondents. The respondents prioritize this system because of its crucial role in maintaining the health of aquatic ecosystems by trapping sediment, nutrients, and pollutants before they enter water bodies. However, the low adoption is a result of the perception that riparian forest buffers are used for conservation at the expense of production which is consistent with studies conducted by Trozzo et al. (2014).

4.3.5 Forest Farming

Forest farming, a method that involves cultivating high-value crops under a forest canopy, is practiced by 9% of the respondents. The ability of the forest farming system to allow for the integration of economically valuable crops into forest ecosystems, providing an additional source of income while maintaining ecological balance influenced the decision of the adopters.

Photo 4.5 Sample pictures of forestry farming systems practiced by the farmers (Source: Admire and Morsli, May 2024)

4.3.6 Multipurpose

On the other hand, the practice of cultivating multipurpose trees, which offer various benefits such as food, fodder, and timber, is the least common among the respondents, with only 7% of individuals engaging in this method. Multipurpose Trees are woody perennials which are deliberately kept or grown in a land use system to produce multipurpose products and benefits. According to Mulugeta et al., (2011); Diriba et al., (2011); Negash et al., (2012); Girmay et al., (2015), multipurpose trees have a greater impact on a farmers' well-being than exotic species because they have one or more secondary roles, such as: family food (fruits/nuts/leaf), firewood, wood/timber for construction and soil and water conservation

Photo 4.6 Sample pictures of multipurpose trees practiced by the farmers (Source: Admire and Morsli, April 2024)

The diverse range of agroforestry practices observed in Ain Fezza and Beni Snous suggests a strategic approach by farmers to maximize land use efficiency and resilience. The preference for systems that combine trees with agricultural or pastoral activities indicates an understanding of the multifunctional benefits of agroforestry. These systems not only enhance productivity and sustainability but also offer socio-economic advantages, such as diversified income streams and improved food security.

4.4: Criteria used by the farmers to select trees for agroforestry systems

The results from Figure 4.2 indicate the factors that motivate the farmers (respondents) to choose a particular tree or species in their agroforestry practice. Market demand is the primary consideration in plant selection accounting for 30% responses. The predominance of market demand as the primary factor indicates a strong emphasis on economic viability. Farmers prioritize plants with high market value to ensure profitability. This aligns with the broader trend in agriculture where market forces dictate crop choices to maximize income. Climate suitability accounted for 20% of the responses underscoring the importance of selecting plants that are well-adapted to the local environmental conditions. This reduces the risk of crop failure and ensures more stable yields.

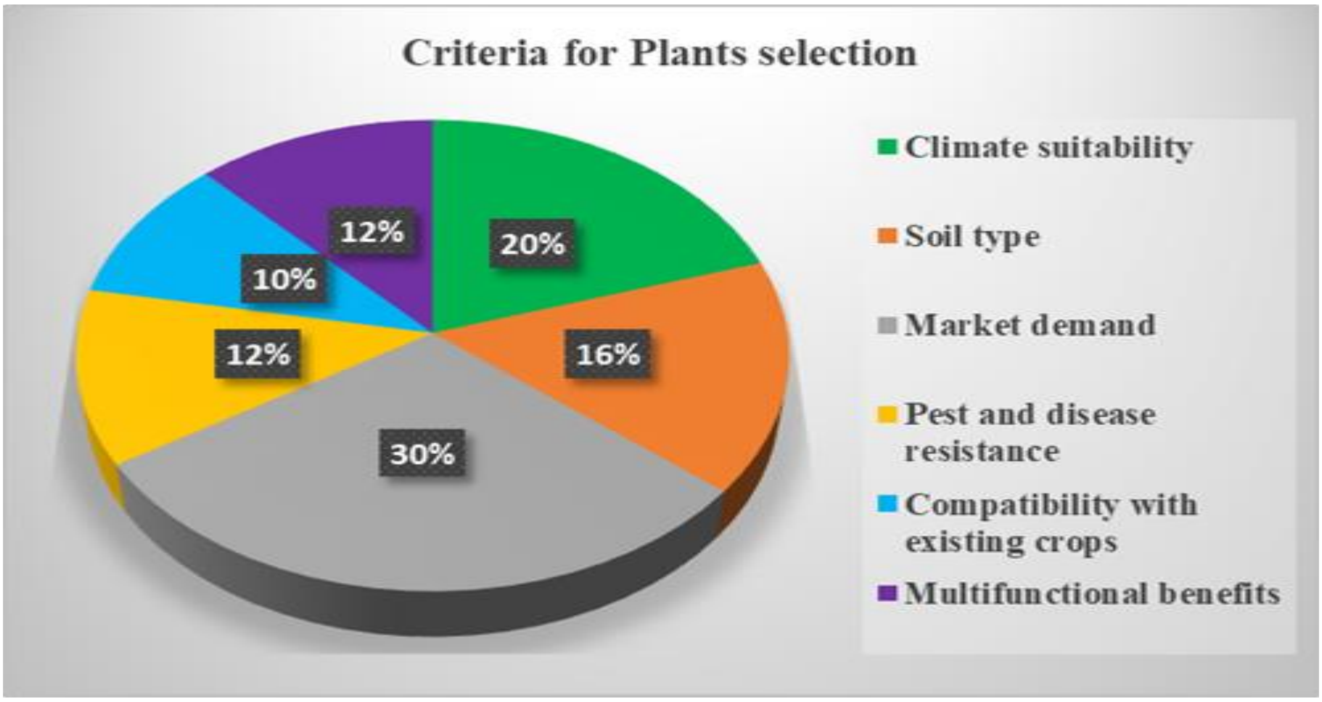

Figure 4.2: Criteria for tree selection (Source: Admire, 2024)

16% of the farmers prioritized local soil compatibility as a selection criterion highlighting the importance of maintaining soil health. Crops that are well-suited to the soil can enhance productivity and reduce the need for soil amendments, thus, the choice of compatible soil. Pest and disease resistance accounted for 12% of the responses highlighting its crucial for maintaining crop health and reducing losses. The ability of resistant tree varieties to lower the need for chemical inputs promotes more sustainable and environmentally friendly farming practices emphasizing the choice of the farmers. 10% of the farmers prioritize compatibility with existing crops as an important factor that reflects an integrated approach where the interplay between different crops is considered. This is to ensure that new plants do not negatively impact existing crops, promoting harmonious coexistence. On the other hand, Multifunctional benefits 12% such as soil fertility improvement, erosion control, and biodiversity conservation as well as other benefits they can derive from the plant variety are recognized, underscoring the holistic benefits of diverse trees chosen by the farmers.

4.5 Trees used by the farmers in their agroforestry practices

Figure 4.3 depicts the types of trees employed by the farmers in their agroforestry systems. 50% of the farmers prioritize fruit tree varieties in their agroforestry practices. The strong preference for fruit trees is likely driven by their direct market value and the potential for consistent yields, which contribute to local food security and income generation. The outcome is in line with research by Davis et al. (2019) and Omotayo & Aremu (2020), who suggested that fruit trees are essential for the economy and, in some situations, for the diet.

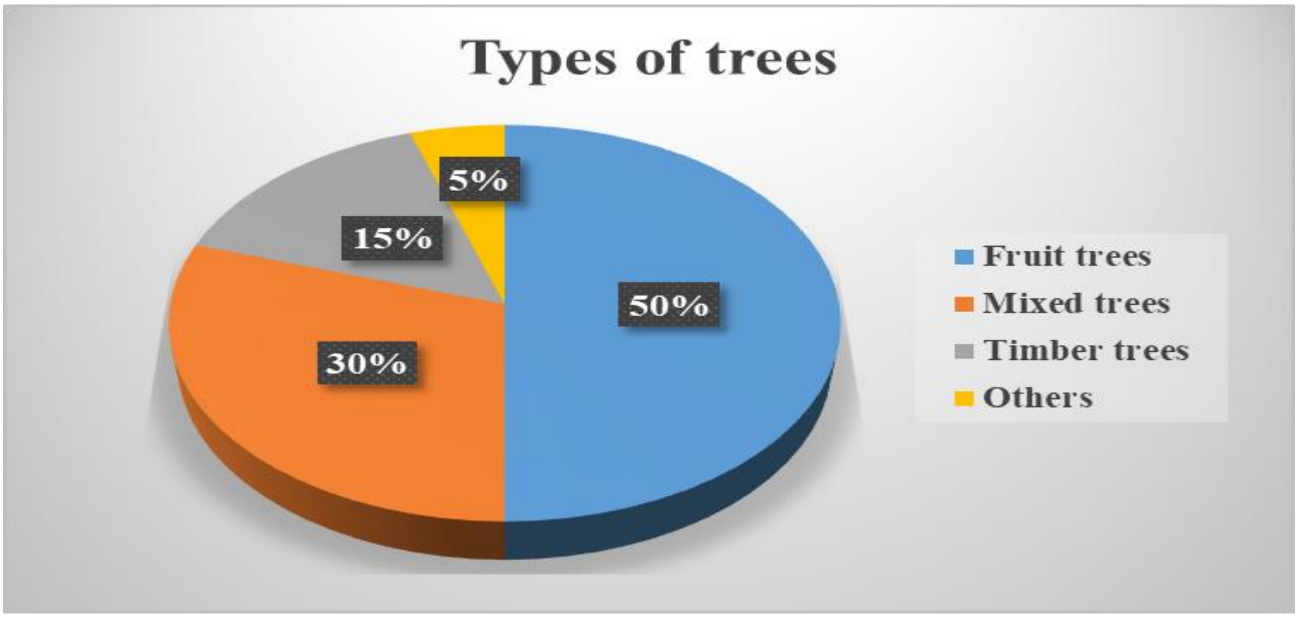

Figure: 4.3 Categories of trees utilized by the farmers in their agroforestry systems (Source: Admire, 2024)

Timber trees comprised 15% of the tree varieties utilized by the farmers. The substantial presence of timber trees indicates a secondary focus on wood production, which supports construction, fuel, and other uses. This diversifies income sources and supports rural livelihoods. The "mixed" category, which includes various types of trees planted together, accounts for 30% of the trees, indicating an interest in diversifying the landscape and the benefits of mixed agroforestry systems, such as enhanced resilience and ecosystem services. Finally, the "Others" category, which represents 5% of the trees, could include ornamental, medicinal, or other non-conventional trees that provide additional benefits or fulfill specific needs. Taken together, these charts suggest that agroforestry practices in these regions are driven by a combination of economic, ecological, and practical considerations. The focus on market demand, climate suitability, and soil type for tree selection, along with the prevalence of fruit and timber trees, demonstrates a strategic approach aimed at maximizing both profitability and sustainability.

4.6: Benefits of Agroforestry as perceived by the respondents

The survey results on the perceived advantages of agroforestry reflected in Figure 4.3 provide a comprehensive view of how respondents value different aspects of this practice. Financial stability emerged as the most commonly recognized benefit, cited by 40% of respondents. This high percentage underscores the significant role that agroforestry can play in providing consistent and reliable income for farmers, likely due to the diversified sources of revenue it offers through multiple types of crops and products. This result is in line with research by Jahan et al. (2022) and Kiyani et al. (2017), who found that, in comparison to non-agroforestry, adopters of agroforestry methods saw an increase in their income. Following closely, 30% of respondents see the diversification of production as a key advantage. This reflects an appreciation for the way agroforestry can reduce risks associated with farming by not relying on a single crop, thus enhancing food security and market opportunities. The results align with the principles of agroforestry, which offer several advantages such diversified agriculture income via wood and nontimber forest products production (Brown et al. 2018; Duffy et al. 2021).

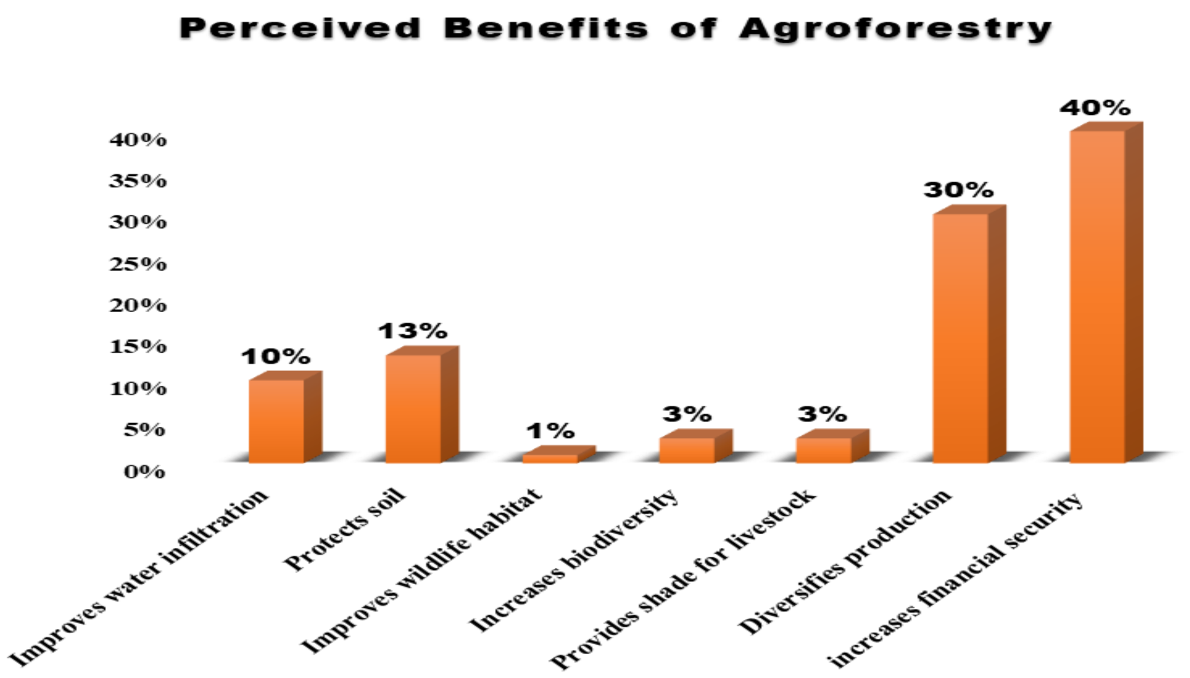

Figure 4.3 Perceived benefits of agroforestry (Source: Admire, 2024)

Soil protection is recognized by 13% of respondents, indicating a less understanding of some of the ecological benefits of agroforestry. By integrating trees with crops and livestock, agroforestry systems can significantly reduce soil erosion, improve soil fertility, and enhance overall soil health. This is consistent with studies by Kassie (2018) and Tega & Bojago (2023 he believed that planting a variety of leguminous trees in agricultural fields improves yields without requiring the use of chemical fertilizers by fixing nitrogen in the soil.). Improving water infiltration is acknowledged by 10% of respondents. This benefit, while less dominant, points to the role of agroforestry in enhancing water infiltration and reducing runoff, which can lead to cleaner water sources and better water conservation. This is in line with research by Fanish & Priya (2013), who suggested that by lowering the unproductive components of the water balance, agroforestry systems have the potential to increase water use efficiency. Enhancing wildlife habitat and providing shade for livestock are each identified by only 3% of respondents. These benefits are crucial for biodiversity and animal welfare, suggesting that these aspects of agroforestry may not be widely recognized or may be undervalued among the respondents. The least acknowledged benefit is the increase in biodiversity, with only 1% of respondents noting this advantage. This low recognition is concerning, given that biodiversity is a critical component of resilient and sustainable ecosystems. These outcomes indicate that while agroforestry is widely recognized for its economic and production-related benefits, its ecological benefits, such as biodiversity and habitat improvement, are less frequently acknowledged. This could suggest a gap in awareness or appreciation of the broader environmental impacts of agroforestry among the respondents.

4.7: Agronomic techniques and practices employed by the respondents

Figure 4.4 shows the distribution of various techniques employed in agroforestry, with irrigation being the most commonly used, accounting for 40% of the total. This demonstrates a heavy reliance on water management to support agroforestry practices. Crop rotation is the second most frequently utilized technique, accounting for 29% of the total, emphasizing its importance in maintaining soil fertility and reducing pest and disease cycles. Organic mulching is used by 16% of respondents, indicating less preference for this method, which aids in soil moisture retention and weed suppression. Intercropping, used by 10% of respondents, suggests some recognition of its benefits in maximizing land use efficiency and crop diversity. Terracing and contour farming, used by only 5% of respondents, indicate that they may be less applicable or less familiar to the respondents, despite their potential to prevent soil erosion and manage water runoff.

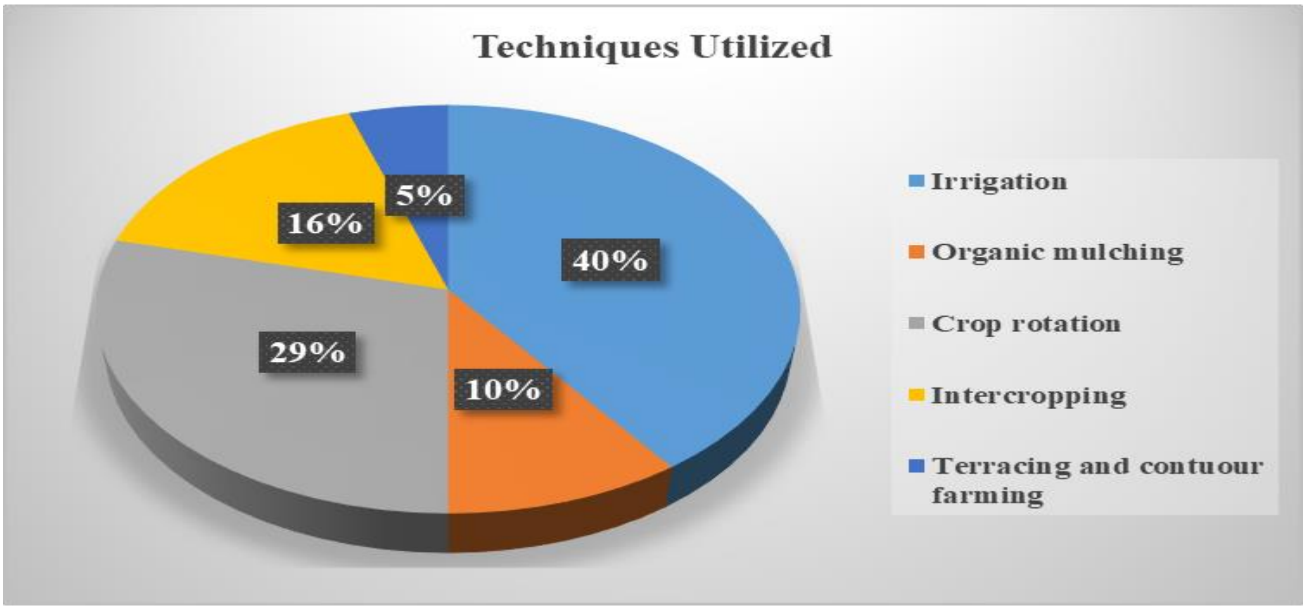

Figure 4.4: Techniques and practices employed in the agroforestry systems (Source: Admire, 2024)

These results show a diverse array of practices within agroforestry, with a strong emphasis on irrigation and crop rotation, while other techniques like intercropping and terracing are less commonly implemented. This distribution may point to varying levels of knowledge, resource availability, or suitability of these techniques to different agricultural contexts.

4.8: Outputs derived from the agroforestry systems

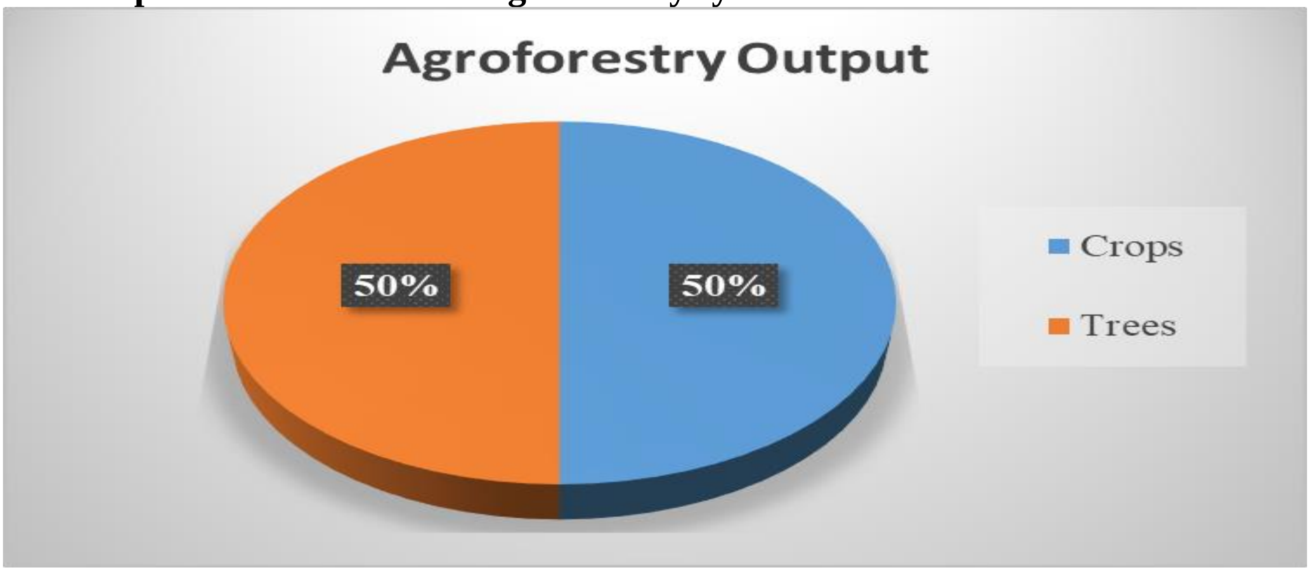

Figure 4.5: Categorization of agroforestry outputs (Source: Admire, 2024)

Figure 4.6 offers an overview of the products generated by agroforestry practices, showcasing the wide range of outputs that these systems produce. Fruits are the largest segment, accounting for 35% of the outputs, suggesting that fruit production is a primary focus and significant benefit of agroforestry, likely due to its high market demand and nutritional value. Nuts come in second, representing 30% of the outputs, reflecting their economic importance and the role they play in diversifying income streams for farmers. Timber and fuelwood make up 13% of the outputs, highlighting the dual-purpose use of trees in agroforestry for both construction materials and energy sources, which are essential for many rural communities.

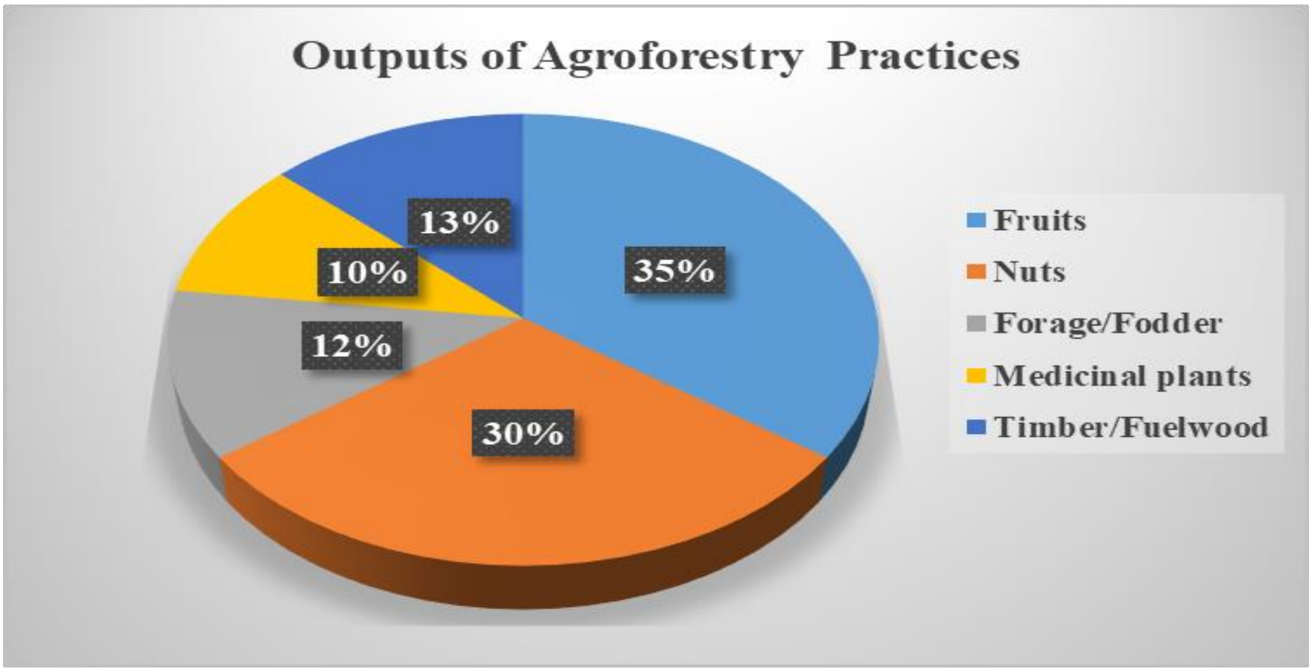

Figure 4.6: Expected outputs of practiced agroforestry systems (Source: Admire, 2024)

Forage and fodder account for 12% of the outputs, emphasizing their importance in supporting livestock production and integrated farming systems. Medicinal plants are the smallest segment, comprising just 10% of the outputs, indicating a niche yet valuable output, potentially contributing to both traditional and modern medicinal markets. This distribution of outputs reveals a well-balanced approach in agroforestry practices, where food production (fruits and nuts) is prioritized, but there is also significant emphasis on sustainable resource use (timber/fuelwood) and livestock support (forage/fodder), as well as the cultivation of plants with medicinal properties. This diversity in outputs not only supports food security and income diversification but also promotes ecological sustainability and resilience in farming systems.

4.9: On-farm tree management practices employed by respondents

Figure 4.7 depicts the tree management practices used on the farms of the respondents. With 40%of the respondents, irrigation is the most often used technique, demonstrating its critical role in preserving tree health and productivity, particularly in regions where water availability is a limiting factor. 5% of mulching are provided, highlighting its significance for weed reduction, temperature regulation, and soil moisture retention. The 30 % that pest and disease control is used reflect the necessity of shielding trees from biotic stresses that could have a major negative influence on production and quality.

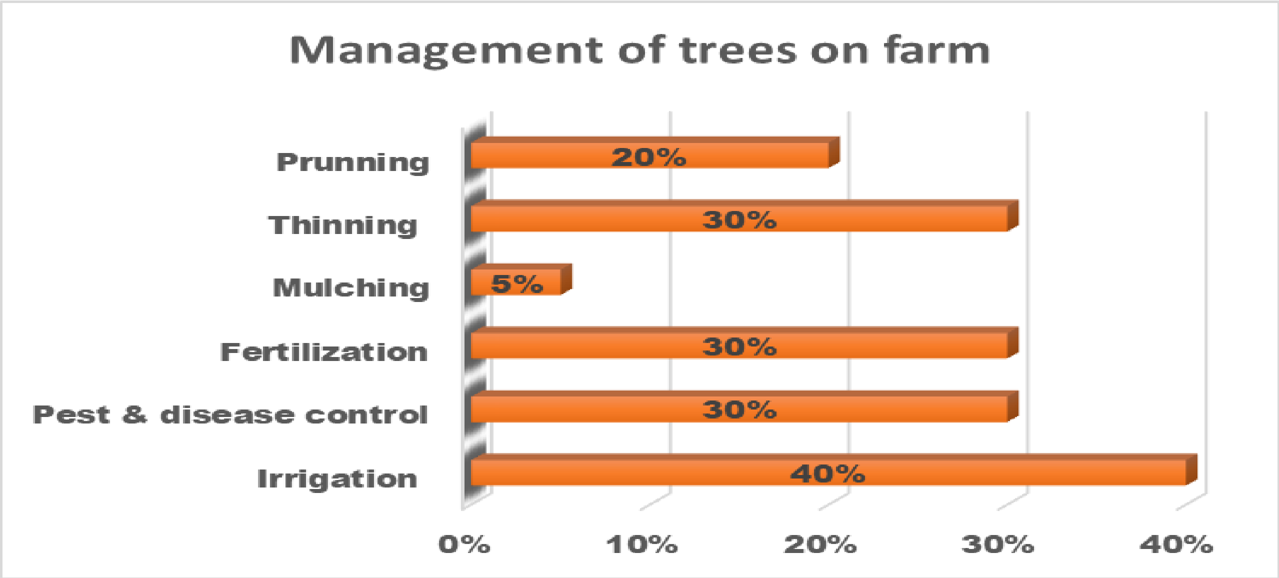

Figure 4.7: Management practices of the trees used in agroforestry systems (Source: Admire, 2024)

With 20% examples, pruning highlights its function in reshaping tree structure, eliminating unhealthy or dead branches, and encouraging robust development. Thinning is prioritized 40% is a crucial technique for controlling tree density and guaranteeing ideal growth circumstances by lowering resource competition. Fertilization is 40% prioritized by the farmers. This implies that although nutrition management is crucial, it may not be as necessary or commonly used as other activities. The distribution of management methods shows that maintaining soil health and the tree structure is prioritized, with less frequent but no less important attention paid to optimizing tree density and nutrient availability. Additionally, efforts to control pests and diseases are prioritized. The chart (Figure 4.7) presents an all-encompassing strategy for managing trees, giving priority to important elements that affect the productivity and health of trees on farms.

4.10: Motivation for Agroforestry Adoption among farmers

The findings allowed us to pinpoint the main variables influencing farmers' choices to engage in agroforestry. Researchers have spent the last few decades studying how farmers' decisions to embrace environmentally friendly practices like agroforestry are shaped by their behavioural choices. Three categories of behavioural factors influencing farmers' decision-making were proposed by Dessart et al. (2019) in their review of these studies: dispositional factors, which are connected to the characteristics and values of farmers; social factors, which include social interactions with other people and social norms and motives; and cognitive factors, which are connected to farmers' assessments of the relative costs, benefits, and risks associated with a specific sustainable practice. Our research shows that all three categories of factors and, crucially, their simultaneous action had an impact on farmers' agroforestry practices.

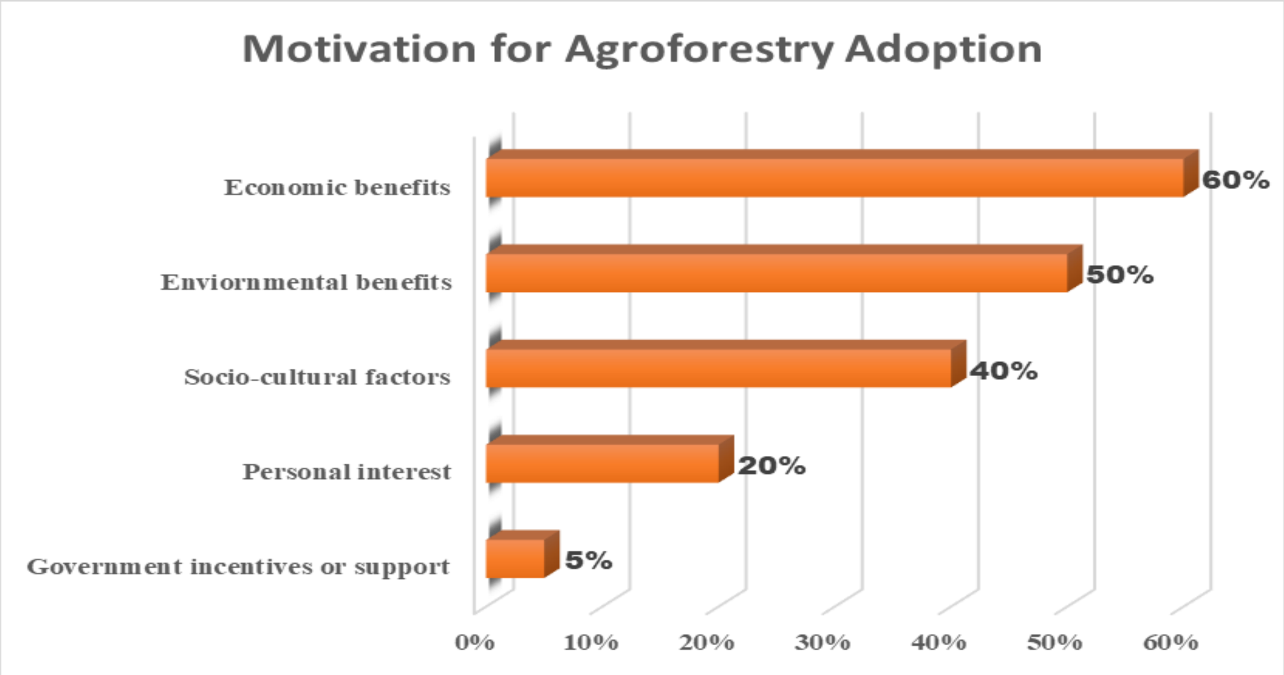

Figure 4.8: Motivating factors for agroforestry adoption (Source: Admire, 2024)

Economic benefits and environmental benefits the primary motivation to practice agroforestry as indicated in the Figure 4.7. The presence of trees can improve soil fertility by fixing nitrogen, increasing organic matter, and reducing erosion. This, in turn, leads to better crop yields. Enhanced yields mean more produce for farmers to sell, directly boosting their income. The agroforestry systems enable farmers to diversify their income sources by producing a variety of products. This underscores the majority prioritizing as a motivator for adopting agroforestry. this is consistent with the findings of Dawson et al. (2013) which opined that agroforestry supports food and nutrition through the direct provision of food and raises farmers' incomeIt also aligns with the conclusions of Bojago et al. (2022), who highlighted the substantial economic benefits of agroforestry systems by increasing yields and yield-producing various goods from limited areas of land.

While 60% of economic benefits are a significant motivator for agroforestry adoption, environmental benefits also play a crucial role, with 50% of farmers explicitly citing these benefits as their primary motivation. These farmers emphasize various aspects of environmental sustainability, improving soil fertility, recycling organic matter, and furthering animal welfare. This motivation aligns with the findings of Schaffer et al. (2024), who reported that 11 out of 13 farmers they studied cited environmental sustainability as a key reason for practicing agroforestry.

In addition to economic and environmental factors, socio-cultural considerations also play a significant role in motivating farmers to adopt agroforestry practices. 40% of respondents identified these socio-cultural influences as their primary motivation, highlighting the importance of social influences, cultural legacy, and community practices in shaping agricultural decisions. Among these considerations, the desire to utilize traditional knowledge to restore and maintain past agroforestry landscapes emerges as a prominent theme. This factor is more importance in the Beni snous as compared as Ain fezza.

While economic, environmental, and socio-cultural factors are primary drivers of agroforestry adoption, personal interests also significantly influence farmers' decisions, with 20% of respondents citing personal motivations as their primary driver. These motivations underscore the importance of individual preferences and values in the adoption process. For some of these farmers, lifestyle preferences served as motivation, seeking farming methods that foster a closer connection to nature and greater harmony with the environment. Additionally, the aesthetic appeal of agroforestry landscapes was a significant factor, drawing farmers to the visual beauty of diverse systems characterized by a mosaic of trees, crops, and livestock. The aesthetic appeal of agroforestry landscapes in Beni snous is different as compared to the one in Ain fezza. These personal interests, whether rooted in lifestyle, aesthetics, or health consciousness, contribute to the holistic adoption of agroforestry practices.

However, only 5% of the respondents cited government support or incentives as a motivator for agroforestry adoption. This highlights potential gaps in government initiatives or the need for more robust support mechanisms to encourage agroforestry practices.

4.11 Contribution of Agroforestry to Climate change mitigation and adaptation

Agroforestry has emerged as a vital tool to address the challenges of climate resilience, marrying agriculture and forestry to produce synergetic effects. These effects stretch across several dimensions—soil health, water conservation, carbon sequestration, biodiversity preservation, and microclimate regulation- and bolster climate resilience. The results highlight the multifaceted benefits of agroforestry, emphasizing its significant role in climate change mitigation and adaptation.

38% of farmers highlighted that agroforestry enhances resilience to extreme weather events. This is consistent with recent research that shows farmers' susceptibility is decreased and their adaptive capacity is increased as a result of the overall socioeconomic benefits of agroforestry (Quandt, 2020;

Chemura et al., 2021). This helps farmers adapt to extreme events caused by climate change. For instance, farmers in Kenya have demonstrated how planting drought-tolerant tree species can boost their resilience to drought (Quandt et al., 2017; Quandt, 2020). The results are in line with multiple studies that found smallholder farmers depend on agroforestry trees to generate revenue from the sale of tree products in addition to fruit, firewood, fodder, timber, and medicine for domestic use when faced with unpredictable weather patterns and extreme weather events. (Papa et al. 2020; Quandt et al. 2017; Quandt, 2020; Paudel et al. 2019; Reppin et al. 2020)

Additionally, 25% of farmers pointed out that it helps prevent soil erosion. This is because the trees and shrubs in agroforestry systems stabilize the soil with their extensive root networks as well as leaf litter from trees provides ground cover, protecting soil from erosion caused by rain impact and surface runoff. This is consistent with the findings of Osman (2013) who emphasized that in agroforestry settings, tree roots improve soil structure and decrease soil erosion. The shedding of leaves, bark, and other organic material from the trees adds nutrient-rich organic matter to the soil. This improves soil fertility, making it a healthier medium for crops to grow. The finding is also consistent with several studies that have shown that, compared to conventional agricultural systems, agroforestry can improve soil quality by as much as 40% (Nair, 2011), and the trees in these systems can also act as a buffer against soil salinity, a growing concern under changing climatic conditions (Dagar et al. 2016).

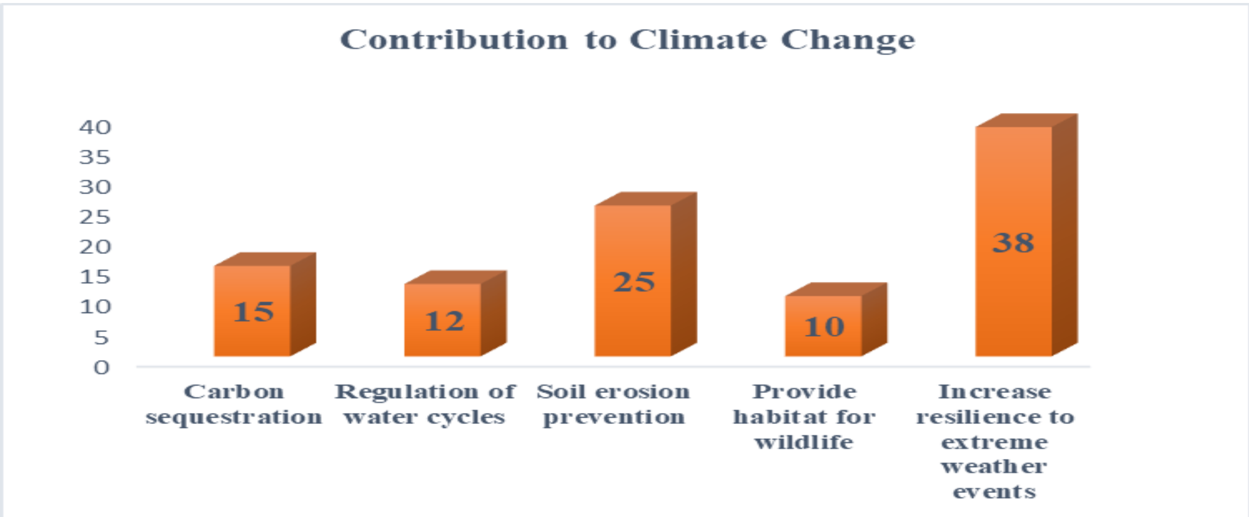

Figure 4.9: contribution to climate change (Source: Admire, 2024)

15% of the farmers recognized the potential of agroforestry for carbon sequestration, reflecting its importance in mitigating climate change. Carbon sequestration is perhaps one of the most talked-about benefits of agroforestry. With the increasing levels of atmospheric carbon dioxide, strategies for carbon capture and storage are paramount. This is consistent with studies by Ramachandran and his colleagues who highlighted that trees in agroforestry systems act as carbon sinks, capturing carbon dioxide from the atmosphere and storing it in their biomass and the soil (Ramachandran et al., 2009). This not only contributes to mitigating climate change but also enriches the soil. According to (Waldén et al. 2020), it is estimated that agroforestry systems could sequester up to 30% more carbon than monoculture agricultural systems. This not only contributes to mitigating climate change but also enriches the soil. According to Walden and his colleagues, it is estimated that agroforestry systems could sequester up to 30% more carbon than monoculture agricultural systems (Waldén et al., 2020; Morsli and al., 2005).

Furthermore, 12% of farmers mentioned that agroforestry contributes to the regulation of water cycles, highlighting agroforestry's role in water management. Trees act as natural reservoirs, absorbing water during periods of excess rainfall and releasing it during dry spells. This has been shown to significantly mitigate the risks associated with both flooding and droughts. Trees also play a role in maintaining groundwater levels. A study in the Sahel region demonstrated that agroforestry systems could enhance local water tables by as much as 15 meters compared to traditional agricultural systems (Takimoto et al. 2009).

10% of the farmers emphasized agroforestry's importance in providing habitats for wildlife, thus promoting biodiversity. By incorporating trees into agricultural landscapes, habitats are created for various types of flora and fauna. This is particularly important as habitat loss is one of the key drivers of biodiversity decline (Mantyka-Pingle et al. 2012). This is consistent with the findings of Harman & Uphoff (2019) who opined that the integration of multiple plant species both crops and trees provide opportunities for symbiotic relationships like pollination and pest control, which can be instrumental in improving crop yields.

Taken together, these dimensions position agroforestry as a cornerstone for enhancing climate resilience. The amalgamation of trees with traditional farming practices offers a multi-faceted approach to counter the vulnerabilities associated with climate change. Whether it's through improved soil quality, efficient water management, enhanced carbon sequestration, rich biodiversity, or regulated microclimates, agroforestry stands as a robust strategy to build resilient and sustainable agricultural landscapes.

CONCLUSIONS AND RECOMMENDATIONS

5.1 General Conclusion

This study comprehensively examined the potential of agroforestry as a climate change adaptation and mitigation strategy for smallholder farmers in the Tlemcen region. The research focused on three primary objectives: identifying the agroforestry practices used by farmers, understanding the motivating factors for adopting these systems, and proposing recommendations to enhance agroforestry as a tool for climate resilience. Data were meticulously gathered from 100 farmers in Ain Fezza and Beni Snous through structured questionnaires, detailed interviews, and field observations, and analyzed using descriptive statistics.

The findings revealed a dynamic and educated workforce predominantly composed of young to middle-aged men, with silvopastoral systems, intercropping systems, and windbreaks being the most prevalent agroforestry practices. These practices were strategically chosen to optimize land use, enhance soil fertility, and improve crop yields while addressing environmental challenges such as soil erosion and wind damage. The selection of tree species was primarily influenced by market demand, climate compatibility, and soil suitability, with fruit trees being the most common. Financial stability and production diversification emerged as the primary benefits perceived by farmers, supported by effective irrigation and crop rotation techniques. Tree management practices, including irrigation, mulching, and pest and disease control, were crucial for maintaining tree health and productivity. Motivations for adopting agroforestry were driven by a combination of economic and environmental benefits. Economic incentives included improved soil fertility, increased crop yields, and diversified income sources, while environmental motivations focused on soil erosion control, carbon sequestration, and microclimate regulation. These findings align with existing literature on the behavioural factors influencing farmers' decisions to adopt sustainable practices.

The study highlighted the importance of awareness and knowledge about agroforestry, favorable socio-economic conditions, and supportive institutional frameworks in promoting the adoption of agroforestry practices. Increased awareness and education about the benefits of agroforestry, coupled with access to extension services, financial incentives, and technical assistance, were identified as critical factors in encouraging farmers to integrate agroforestry into their farming systems.

The diagnosis shows that these areas have great potential for the development of agroforestry. A significant proportion of operators expressed interest in the carry-out agroforestry projects. Analyses and surveys show that the prospects for Development of the ' agroforestry are very large in these areas studied. But we must keep bearing in mind that any association must take into consideration the edaphic and species characteristics. Also, the development of ' agroforestry must be done based on systems that have been referenced (research /development). Therefore, even though the number of agroforestry systems AF is vast, it will be necessary to be cautious when it comes to putting associations that have never been studied. Route availability training and extension are necessary for the promotion of l' agroforestry. Since we need to draw inspiration from systems that have worked well and use of high-value-added species.

5.2.1 Agroforestry Practices

Following the descriptive analysis of the data collected on the field, the demographic profile of the farmers revealed a significant involvement of young to middle-aged, well-educated men in agroforestry, indicating a dynamic and innovative workforce. Silvopastoral was the prominent agroforestry system practiced (32%), followed by alley cropping (26%), and windbreaks (14%) suggesting a strategic approach to optimizing land use, enhancing soil fertility, and improving crop yields while mitigating environmental challenges like soil erosion and wind damage. About 30% of the trees planted were selected based on market demand, 20% based on climate compatibility, and 16% on soil suitability highlighting a practical approach focused on economic viability and sustainability. Based on this selection criterion, fruit trees were the dominant trees planted. Financial stability and diversification of production were the prominent perceived benefits of practicing agroforestry as they accounted for 40% and 30% respectively. Irrigation and crop rotation were the dominant farming practices undertaken on the farms owing to their effectiveness in ensuring water and soil management. Tree management practices such as irrigation, mulching pest and disease control were the domineering tree agronomic practices employed by the farmers to ensure the overall health and productivity of the tree varieties planted.

5.1.2. Motivation for Agroforestry Adoption

The top motive for 50% of farmers to pursue agroforestry was economic benefits, according to our survey, which also highlighted other important aspects. 60% were motivated by environmental benefits, emphasizing sustainability initiatives. For 40% of respondents, sociocultural factors were very important, placing a strong emphasis on customs and traditional knowledge. 20% of farmers were motivated by personal interests, such as aesthetic appeal and lifestyle choices. There may be a need for more robust incentives as only 5% of respondents named government funding as a motivator.

5.1.3. Contributions to Knowledge

This study is important because it offers empirical proof of agroforestry's potential to help smallholder farmers in poor nations adapt to and mitigate the effects of climate change. Agroforestry can help smallholder farmers, who are extremely susceptible to climate change, become more resilient. In addition to providing insights into successful policy interventions to support these activities, the study highlights factors influencing the adoption of agroforestry practices. Furthermore, it contributes to the larger conversation on sustainable rural development by enhancing the body of knowledge in the academic literature on agroforestry, climate change, and sustainable agriculture.

5.2 Recommendations

5.2.1 Government

- ✓ Establish more robust financial incentives, including subsidies and grants, to encourage the adoption of agroforestry practices. These should be accessible and substantial enough to motivate farmers to invest in long-term agroforestry systems.
- ✓ Provide low-interest loans specifically for agroforestry projects, enabling farmers to invest in necessary infrastructure, such as irrigation systems and pest control measures.
- ✓ Develop and implement a national strategy for agroforestry that includes clear guidelines, objectives, and support mechanisms for smallholder farmers.
- ✓ Strengthen land tenure policies to ensure that farmers have secure and long-term rights to their land, encouraging investment in sustainable practices like agroforestry.
- ✓ Expand agricultural extension services to provide training and technical support on agroforestry practices, focusing on young and middle-aged farmers who have shown a propensity for innovation.
- ✓ Allocate funds for research into agroforestry practices suited to local conditions, including the study of climate-compatible and market-demand-driven tree species.

5.2.2 Forestry Commission

- ✓ Offer advisory services on the selection of tree species based on market demand, climate compatibility, and soil suitability. Provide guidelines on best practices for tree management, including irrigation, mulching, and pest control.
- ✓ Establish demonstration farms to showcase successful agroforestry practices and technologies, providing practical learning opportunities for farmers.
- ✓ Implement systems to monitor and evaluate the performance of agroforestry projects, helping to identify best practices and areas needing improvement. This data should be made available to farmers to guide their practices.

- ✓ Supply high-quality seedlings and other necessary inputs at subsidized rates to ensure farmers have access to the resources needed for successful agroforestry implementation.

5.2.3 Academic Institutions

- ✓ Integrate agroforestry into agricultural science and environmental studies curricula, ensuring that students are educated on its benefits and practices from an early stage.
- ✓ Conduct applied research focused on the local adaptation of agroforestry practices, addressing specific challenges faced by farmers in the Tlemcen zone.
- ✓ Partner with governmental and non-governmental organizations to conduct field trials and studies, providing empirical data and case studies that can inform policy and practice.
- ✓ Develop and offer training programs and workshops for farmers, focusing on the latest agroforestry techniques and innovations. These should include practical, hands-on learning experiences.

5.2.4 Farmers

- ✓ Implement integrated farming systems that combine agroforestry with other sustainable agricultural practices such as crop rotation and organic farming to enhance soil fertility and productivity.
- ✓ Select a diverse range of tree species based on economic viability, climate compatibility, and soil suitability to ensure resilience and profitability.
- ✓ Participate in local farmer groups and cooperatives to share knowledge and experiences regarding agroforestry practices. Collective action can also improve bargaining power and access to resources.
- ✓ Engage in joint ventures for large-scale agroforestry projects, which can provide economies of scale and shared investment in necessary infrastructure.
- ✓ Practice sustainable water and soil management techniques, such as effective irrigation systems and mulching, to maintain the health and productivity of agroforestry systems.
- ✓ Stay informed about and apply the latest pest and disease control measures to protect tree health and ensure high yields.

5.3 Recommendations for further research

- ✓ Investigate the role of education and extension services in promoting agroforestry. Study how knowledge transfer and training programs can be optimized to increase farmer awareness and adoption of agroforestry practices. Evaluate the impact of educational interventions on farmer behavior and outcomes.

- ✓ Analyze the effectiveness of current policies and institutional frameworks in promoting agroforestry. Identify barriers to adoption and propose policy interventions that can facilitate the widespread implementation of agroforestry practices. Study successful case studies from other regions to derive best practices that can be applied locally.
- ✓ Explore the application of advanced technologies such as machine learning, artificial intelligence, and remote sensing in agroforestry. Develop and test decision-support systems that provide real-time recommendations to farmers. Assess how these technologies can be tailored to the needs of resource-poor settings to improve planning, monitoring, and management of agroforestry systems.
- ✓ Study the interactions between tree species and agricultural crops under various climatic conditions.
- ✓ Examine the economic viability of various agroforestry systems, identifying the most profitable tree-crop combinations. Analyze market trends and demand for agroforestry products to provide farmers with insights that can enhance their income and economic stability.
- ✓ Conduct comprehensive research on the social impacts of agroforestry, particularly focusing on how it influences community dynamics, cultural practices, and social cohesion.

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ANNEX 1

DATA COLLECTION ON THE POTENTIAL OF AGROFORESTRY AS AN ADAPTATION AND MITIGATION STRATEGY OF CLIMATE CHANGE

» Consent

I am a master's student from the Abou Bekr Belkaid University in Algeria. I am currently doing this study to obtain data from farmers, and this will be added to other responses to better understand the role agroforestry plays in adapting and mitigating climate change. This study will help us to track the progress towards achieving the goals and objectives of designing proactive mitigation and adaptation measures to ensure resilience building to climate change in Tlemcen. Please be assured that every response given in this survey is going to be used solely for academic purposes and reported with a high degree of anonymity and confidentiality.

Please do you consent to participate in this discussion?

a. Yes ( )   b. No ( )

Name of Respondent (Optional)……………………………………………………………………………….

PART 1: DEMOGRAPHIC DATA

---

1. Gender of Respondent

a. Male ( )   **b.** Female ( )

2. **Age of Respondent**

a. Under 18 ( ) **b.**18-24 ( ) **c.** 25-34 ( ) **d**. 35-44 ( ) **e.** 45-54 ( ) f. 55-64 ( ) **g.** 65+ ( )

3. How many people live in your household?

…………………………………………………………………

4. Educational Background

a. No Formal Education ( ) **b.** Basic School ( ) **c.** Senior High School ( ) **d.** Tertiary ( )

5. Occupation:

……………………………………………………………………………………………………

6. Farm Size

………………………………………………………………………………………………………

7. Marital status (optional)……………………………………………………………………………………

PART 2: AGROFORESTRY PRACTICES

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8. What types of trees or shrubs do you currently have on your farm?

a) Fruit trees
b) Timber trees
c) Nut trees
d) Shrubs for erosion control
e) Other (please specify: ________)

9. Are these trees or shrubs integrated with your crops? If so, how?

a) Yes, as shade for crops

b) Yes, for windbreaks

c) Yes, as living fences

d) No, they are separate from crops

10. How long have you been practicing agroforestry on your farm?

a) Less than 1 year

b) 1-5 years

c) 6-10 years

d) More than 10 years

11. Could you describe the specific agroforestry practices you implement? (e.g., alley cropping, windbreaks, silvopasture)

a) Alley cropping

b) Windbreaks

c) Silvopasture

d) Forest farming e)

Other (please specify: ________)

12. What are the main objectives you aim to achieve through agroforestry on your farm?

a) Soil conservation

b) Diversification of income sources

c) Climate change mitigation

d) Biodiversity conservation

e) Other (please specify: ________)

13. Have you observed any benefits or drawbacks associated with your agroforestry practices?

a) Yes, benefits only

b) Yes, drawbacks only

c) Both benefits and drawbacks

d) No, neither benefits nor drawbacks

PART 3: FACTORS INFLUENCING THE ADOPTION OF AGROFORESTRY

14. What motivated you to start practicing agroforestry on your farm?

a) Economic benefits

b) Environmental sustainability

c) Social and cultural factors

d) Government incentives or support

e) Other (please specify: ________)

15. Have you encountered any barriers or challenges in adopting agroforestry practices?

a) Yes

b) No

16. If Yes, what kind of barriers or challenges?..

……………………………………………………………………………………………………
……

17. How do you perceive the economic benefits of agroforestry compared to conventional farming methods?

a) Much higher

b) Slightly higher

c) About the same

d) Slightly lower

e) Much lower

18. Do you believe agroforestry contributes to environmental sustainability? If so, in what ways?

a) Yes, through soil conservation

b) Yes, through biodiversity conservation

c) Yes, through carbon sequestration

d) No, it does not contribute to environmental sustainability

19. Are there any social or cultural factors that influence your decision to adopt agroforestry practices?

a) Yes

b) No

20. If Yes, what kind of social or cultural factors influenced your decision?...

……
……

21. Have you received any support or incentives from government agencies, NGOs, or other organizations to implement agroforestry on your farm?

a) Yes

b) No

22. If Yes, what kind of support or incentives?..

**……
……**

23. Do you think there is enough awareness and information available about agroforestry in your community?

a) Yes

b) No

PART 4: CLIMATE ADAPTATION AND MITIGATION

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24. Are you aware of climate change?

a) Yes

b) No

25. In what ways do you believe agroforestry practices contribute to climate change adaptation and mitigation?

a) Carbon sequestration

b) Regulation of water cycles

c) Soil erosion prevention

d) Providing habitat for wildlife

e) Increasing resilience to extreme weather events

f) Other (please specify: ________)

26. Any other relevant information or suggestions for promoting agroforestry?

……

……

……

………………

Thank you for participating in this survey. Your input is valuable for understanding and addressing the impacts of flooding in our community.

List of trees used by the farmers in Beni Snous and Ain Fezza

Pistacia atlantica

Ceratonia siliqua

Juglans regia L

Cupressus sempervirens

Castanea sativa

Corylus avellana

Prunus cerasus

Malus domestica

Prunus armeniaca

Prunus domestica

Prunus persica

Carya illinoinensis

Diospyros kaki

Ziziphus jujuba

Pistacia vera

Pistacia terebinthus

Casuarina equisetifolia

Ficus carica

Opuntia ficus-indica

Olea europaea

Vitis vinifera

Prunus dulcis

Cydonia oblonga

Citrus sinensis

Citrus limonum