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Dual Role of Agriculture in Climate Change: Orchard-Based Systems in Afghanistan

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ABSTRACT

Agriculture plays a dual role in climate change, acting both as a contributor to greenhouse gas emissions and as a sector highly vulnerable to climatic impacts. In Afghanistan, orchard-based horticulture, including pomegranate, apple, apricot, and almond production, is essential for rural livelihoods, food security, and export income. This study analytically examines the dual role of orchard agriculture in the context of climate change. The research is based on a review and analysis of scientific literature, international reports, and studies related to agriculture and climate change. The study evaluates major greenhouse gas emission pathways (CO_2, CH_4, and N_2O), climate-related vulnerabilities such as heat stress, water scarcity, and extreme weather events, as well as adaptation and mitigation strategies suitable for Afghan conditions. The findings indicate that improved orchard management practices, including efficient irrigation, soil conservation, and nutrient management, can reduce greenhouse gas emissions while enhancing resilience, productivity, and income stability. The study confirms that sustainable horticultural systems can contribute to climate change mitigation and adaptation simultaneously.

Keywords: Adaptation, Afghanistan, Climate change, Greenhouse gases, Mitigation, Orchards.

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1. INTRODUCTION

اَلْحَمْدُ للهِ رَبِّ العَالَمِينَ وَالصَّلاَةُ وَالسَّلَامُ عَلى سَيدِالْمُرْسَلِينَ وَعَلَى اَلِهِ وَصَحْبِهِ اَجْمَعِينَ.

Climate change is one of the most significant global challenges affecting agroecosystems (Intergovernmental Panel on Climate Change, IPCC, 2022; Shukla *et al*., 2019). Agriculture is both a major source of greenhouse gas emissions and a sector highly sensitive to climatic variability (Hillel & Rosenzweig, 2013). In Afghanistan, where more than half of the population depends on agriculture, climate-related risks directly threaten livelihoods and food security (FAO, 2021; World Bank, 2020).

Orchard-based horticulture-particularly pomegranate (Kandahar), apple (central highlands), apricot, and almond (northern and central regions)-plays a crucial economic role. These perennial systems represent long-term investments, making them particularly vulnerable to climate shocks. This study analyzes the dual role of orchard agriculture in climate change and proposes integrated responses.

Problem Statement

In Afghanistan, there is limited understanding of this dual role of agriculture both as a contributor to climate change and as a sector affected by it, especially in orchard systems. The lack of context-specific knowledge on emissions, climate impacts, and effective adaptation strategies hinders sustainable agricultural development.

Therefore, this study aims to examine this dual role and identify strategies to improve resilience and reduce environmental impacts in Afghan horticulture.

TheMain Objective of analyze the dual role of agriculture in climate change, with a focus on horticultural systems in Afghanistan, considering both its contribution to greenhouse gas emissions and its potential to enhance resilience through adaptation and mitigation strategies.

Therefore the Specific Objectives is to identify the main pathways of greenhouse gas emissions in orchard systems and examine the role of orchard management practices and to assess the impacts of climate change on the productivity and vulnerability of horticultural crops, and to propose appropriate adaptation and mitigation strategies for decreasing of greenhouse gas emissions from horticultural operations in Afghanistan.

Main Research Question is How does the dual role of agriculture in climate change manifest in Afghanistan’s orchard systems, and what are its implications for production as well as for climate mitigation and adaptation?

Sub-questions is Which management and environmental factors in Afghanistan's orchard systems contribute to increased greenhouse gas emissions? Through what mechanisms does climate change affect the yield and quality of horticultural crops, and which adaptation and mitigation strategies are most effective in the Afghan context?

2. LITERATURE REVIEW

Scientific literature indicates that agriculture has a dual relationship with climate change (IPCC, 2022). It contributes to greenhouse gas emissions while simultaneously being affected by climate variability. According to Hillel and Rosenzweig (2013), agricultural practices such as tillage, fertilizer application, and land-use change significantly increase emissions of CO_2, CH_4, and N_2O.

Reports by the IPCC (2022) estimate that the agriculture, forestry, and land use (AFOLU) sector accounts for approximately 20–25% of global greenhouse gas emissions (Smith et al., 2014).

This highlights the importance of sustainable agricultural management, particularly in developing countries.

Sivakumar and Motha (2007) emphasize that climate change affects agricultural productivity through increased temperatures, altered precipitation patterns, and more frequent extreme events such as droughts and floods. These impacts are particularly severe in arid and semi-arid regions such as Afghanistan (UNDP, 2021).

Anboumozhi *et al*. (2012) note that Asian countries with high dependence on agriculture are especially vulnerable due to limited water resources (FAO, 2020). And weak infrastructure. In horticulture, perennial crops are more sensitive to climate variability than annual crops. For example, reduced winter chilling affects apple flowering, while heat and water stress reduce pomegranate quality (Hillel & Rosenzweig, 2013).

Furthermore, Lal (2018) highlights that orchard systems have significant potential for carbon sequestration, (Zomer *et al*., 2016) suggesting that properly managed horticultural systems can contribute to climate change mitigation.

Climate change poses a serious threat to global food security by affecting crop productivity, food availability, and stability (Burney & Ramanathan, 2014; Godfray *et al*., 2010). These challenges are particularly significant in developing countries where agriculture is highly climate-dependent.

Agricultural intensification and climate change also contribute to biodiversity loss and ecosystem degradation, which in turn affect agricultural sustainability (Tilman *et al*., 2017).

3. METHODOLOGY

This study is analytical and review-based in nature. It is conducted through a comprehensive review of credible international scientific literature, reports from global organizations, and studies related to agriculture and climate change. Data were collected from sources such as the Food and Agriculture Organization (FAO, 2020; 2021), the Intergovernmental Panel on Climate Change (IPCC, 2022), NOAA (2021) and other peer-reviewed scientific publications, and were systematically analyzed.

4. RESULT

4.1 Agriculture as a Source of Greenhouse Gas Emissions

Agricultural systems emit CO_2, CH_4, and N_2O (Smith *et al*., 2014; IPCC, 2022) through soil processes, input use, and residue management.

CO_2 Emissions from Soil Disturbance Tillage, land-use change, and removal of organic residues reduce soil organic carbon (Lal, 2018). In orchard systems, excessive soil disturbance accelerates oxidation and CO_2 release.

Nitrous Oxide (N_2O) from Fertilizers: Nitrogen fertilizer use leads to N_2O emissions (Sivakumar & Motha, 2007) through nitrification and denitrification. Overuse of urea in orchard systems significantly increases emissions.

Methane (CH_4) from Organic Waste: Improper management of organic residues under anaerobic conditions produces methane, especially in poorly aerated soils (FAO, 2020).

4.2 Agriculture as a Victim of Climate Change

Orchard crops are highly sensitive due to their perennial nature.

Temperature Stress: Rising temperatures affect flowering, pollination, and fruit set. Reduced winter chilling leads to lower yields in apple orchards (Mavi & Tupper, 2005; Sivakumar & Hansen, 2007).

Water Scarcity: Declining snowfall and irregular rainfall reduce irrigation water availability. Pomegranate orchards in southern Afghanistan face significant water stress (FAO, 2021; World Bank, 2020).

Extreme Events: Frost, heatwaves, and droughts damage orchard crops. Late spring frost can destroy apricot blossoms, causing severe yield losses (IPCC, 2022; UNDP, 2021).

4.3 Case Analysis: Orchard Crops in Afghanistan

Pomegranate: Sensitive to irregular irrigation, Heat stress reduces fruit quality, increased pest pressure under warming conditions

Apple: Requires winter chilling, Vulnerable to rising temperatures, Yield variability due to climate fluctuations

Apricot and Almond: Early flowering increases frost risk, Water scarcity reduces productivity

These examples demonstrate that climate change affects both yield and quality, impacting farmer income and their export potential (FAOSTAT, 2022; World Bank, 2020).

4.4 Mitigation Strategies in Orchard Systems: Reduced tillage to conserve soil carbon, efficient fertilizer management, Application of organic amendments (compost), Integration of agroforestry and cover crops (Lal, 2018; Smith *et al*., 2014).

4.5 Adaptation Strategies: Use of drought-resistant rootstocks, improved irrigation systems (drip irrigation), Mulching to conserve soil moisture, Crop diversification (FAO, 2020; ICARDA, 2019).

Tables:

Table 1. Climate Change Impacts on Orchard Crops

Crop	Climate Risk	Yield Impact	Economic Effect
Pomegranate	Heat, drought	Reduced fruit quality	Lower export value
Apple	Reduced chilling	Poor flowering	Yield instability
Apricot	Frost	Flower damage	Crop failure
Almond	Water stress	Reduced production	Income loss

Table 2. Mitigation and Adaptation Strategies

Strategy	Type	Benefit
Drip irrigation	Adaptation	Water efficiency
Mulching	Both	Moisture + carbon retention
Reduced tillage	Mitigation	Lower CO_2 emissions
Compost use	Both	Soil fertility + carbon storage
Crop diversification	Adaptation	Risk reduction

5. DISSCUSSION

The findings of this study are consistent with previous research indicating the dual role of agriculture in climate change (Hillel & Rosenzweig, 2013; IPCC, 2022). Agriculture contributes significantly to greenhouse gas emissions while also being highly vulnerable to climate impacts (Smith *et al.*, 2014).

Sivakumar and Motha (2007) emphasize the role of climate variability in reducing agricultural productivity, which is evident in Afghan orchard systems. Reduced chilling in apple orchards and increased water stress in pomegranate production confirm these findings (UNDP, 2021).

Lal (2018) suggests that orchard systems have high carbon sequestration potential. This indicates that orchard agriculture in Afghanistan can serve not only as a vulnerable sector but also as a mitigation opportunity (Zomer *et al.*, 2016).

However, limited infrastructure, weak water management, and lack of access to modern technologies constrain the implementation of climate-smart practices in Afghanistan (FAO, 2021; World Bank, 2020).

These findings are also supported by global studies indicating that climate change threatens food security and agricultural sustainability at multiple levels (Burney & Ramanathan, 2014; Godfray *et al*., 2010). Furthermore, the interaction between climate change and agricultural expansion may lead to biodiversity loss and long-term ecosystem instability (Tilman *et al*., 2017).

6. CONCLUSION

Orchard-based horticulture in Afghanistan clearly demonstrates the dual role of agriculture in climate change. While contributing to greenhouse gas emissions, it is highly vulnerable to climatic variability. The results of this study are consistent with previous literature (Hillel & Rosenzweig, 2013; IPCC, 2022), confirming that sustainable orchard management can simultaneously reduce emissions and enhance resilience. Strengthening institutional capacity, improving water management, and promoting climate-smart agriculture are essential for long-term sustainability (Lal, 2018; FAO, 2020). These findings are aligned with global assessments of land use and climate interactions (Shukla *et al*., 2019).

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