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Sustainability Challenges in Morocco's Agri-Food Sector: Balancing Ecological Constraints, Economic Performance, and Public Policy.

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Abstract

The agri-food sector constitutes a strategic pillar of the Moroccan economy, contributing between 13% and 20% of GDP, employing nearly 40% of the active population, and accounting for approximately 19% of exports, while playing a crucial role in food security. However, this economic significance is accompanied by increasing environmental pressures, notably water stress, soil degradation, and the impacts of climate change. This article analyzes the interplay between economic integration and environmental integration of Morocco's agri-food sector through the lens of sustainability principles, sustainable natural resource management, and the theoretical foundations of incentive theory and externality theory. The analysis shows that national agricultural strategies, particularly the Green Morocco Plan (2008–2020) and the Generation Green strategy (2020–2030), have fostered sector modernization, productivity improvements, and integration into global value chains, notably through the development of agri-food exports. Nevertheless, these dynamics remain unevenly distributed and raise persistent challenges regarding smallholder inclusion, while the gradual adoption of sustainable practices, circular economy approaches, and standardization mechanisms such as ISO 14001 certification remains partial due to institutional and financial constraints. The study emphasizes the need for enhanced coherence between agricultural policies, incentive mechanisms, and environmental requirements to reconcile economic performance, environmental sustainability, and resilience of Morocco's agri-food sector. This work offers an original contribution to the literature by proposing an integrated framework linking economic and environmental integration, mobilizing incentive and externality theories to analyze the dynamics of Morocco's agri-food sector, and providing researchers and policymakers with guidance for designing coherent agricultural policies adapted to resource constraints**.**

Keywords : Agri-food sector, Morocco, economic and environmental integration, sustainability, fiscal incentives, externalities, circular economy.

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Introduction

At the global level, the sustainability of the agri-food sector has become a major strategic concern, driven by the combined effects of population growth, climate change, and the progressive depletion of natural resources (Islam, 2025; Kalachevska et al., 2022). Within this context of growing ecological and economic tensions, Morocco appears particularly exposed to multiple vulnerabilities, making the transition toward a sustainable agri-food model both urgent and unavoidable.

The Moroccan agri-food sector faces a complex interplay between ecological imperatives and economic challenges, rendering its sustainable development essential for ensuring national food security and supporting economic growth (Essalhi & Kartobi, 2024; En-Nia et al., 2025). Morocco is highly vulnerable to climate change, as reflected in declining precipitation levels and an increasing frequency of droughts (Essalhi & Kartobi, 2024; Mangal & Govind, 2025; Kaiss et al., 2025). The year 2023, identified as the driest in at least eight decades, with rainfall below 100 mm and a deficit of nearly 48% compared to the national average, illustrates the severity of this vulnerability and its adverse effects on water resources and agricultural production (Boutagayout et al., 2025). Agriculture, which consumes nearly 80% of freshwater resources, therefore contributes significantly to the intensification of national water stress (Boutagayout et al., 2025; Mangal & Govind, 2025). These environmental pressures are compounded by accelerated ecosystem degradation. Agricultural expansion has contributed to deforestation in regions such as the central Rif, resulting in soil fertility loss and increased erosion (Ennaji et al., 2024; Mazi et al., 2022; Moutaoikil et al., 2024). Similarly, the Loukkos basin, a strategic agricultural area, illustrates the combined impacts of climate change and land-use dynamics on water erosion, with consequences for both agricultural productivity and water quality (Acharki et al., 2022). More broadly, the agricultural sector is a significant contributor to global greenhouse gas emissions and remains a major driver of habitat degradation (Ershadfath et al., 2024). In Morocco, efforts to mitigate these emissions are constrained by the country's high climate vulnerability, reinforcing the need to accelerate the adoption of sustainable agricultural practices (Azzeddine et al., 2024). On the economic front, the agri-food sector is confronted with persistent structural challenges related to competitiveness, production costs, and profitability. Morocco's dependence on food imports—particularly cereals and sugar—heightens its exposure to international market volatility, especially under conditions of water stress (Boutagayout et al., 2025). The negative effects of climate change on agricultural GDP further underscore the urgency of strengthening resilience and economic efficiency within

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the sector (En-Nia et al., 2025). In addition, the rapid increase in solid waste generation, projected to rise substantially by 2030, highlights growing challenges in the sustainable management of agri-food by-products and reinforces the relevance of circular economy approaches (Louzizi et al., 2024). Despite these constraints, the Moroccan agri-food sector occupies a central position in the national economy, playing a key role in employment, exports, and food security. However, this economic importance is accompanied by mounting environmental pressures, revealing a structural tension between economic performance and environmental sustainability. This tension raises critical questions regarding the sector's ability to maintain its economic contribution while reducing its ecological footprint in a context of increasing resource scarcity.

In response to these challenges, agricultural public policies have played a structuring role in shaping the economic integration of the sector. Through the Green Morocco Plan and, more recently, the Generation Green strategy, public authorities have promoted the modernization of agri-food value chains and their integration into international markets. While these strategies have enhanced sectoral competitiveness, they have also generated persistent challenges related to equity, the inclusion of smallholders, and the effective integration of environmental requirements. Against this backdrop, this article addresses the following central question: **How can Moroccan agricultural public policies reconcile the economic integration of the agri-food sector with environmental sustainability requirements in a context of increasing natural resource scarcity?**

This main question is articulated through three research questions:

How does the Moroccan agri-food sector balance its strategic economic role with growing environmental challenges?

How do agricultural public policies and forms of economic integration structure agri-food value chains and influence equity and sustainability outcomes?

How can environmental integration—through circular economy practices, agroecology, and environmental certifications—enhance the resilience of the Moroccan agri-food sector?

To address these questions, the article is structured as follows. The first section presents the conceptual and theoretical framework, drawing on incentive theory, externality theory, and the principles of sustainability and sustainable natural resource management. The second section analyzes the economic integration of the Moroccan agri-food sector through national agricultural strategies and their effects on value chain structuring. The third section examines the environmental integration of the sector, focusing on sustainable practices, circular economy

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approaches, and environmental standardization mechanisms. Finally, the last section discusses the main findings of the study and outlines policy implications and directions for future research.

1. Conceptual and Theoretical Framework

This section establishes the conceptual and theoretical framework of the study. It begins by defining the key concepts essential to understanding the research context, followed by the presentation of the main theoretical approaches mobilized. Together, these elements provide an analytical foundation for examining the role of agricultural public policies, as well as environmental integration, within the Moroccan agri-food sector.

1.1 Key Concepts

This study is grounded in two fundamental concepts: sustainability and sustainable natural resource management. These concepts provide analytical reference points for examining the interactions between agri-food activities and environmental constraints**.**

1.1.1 Sustainability

Sustainability is a central concept that has emerged as a major social movement over the past four decades (Brinkmann, 2021). It is commonly defined as a form of development that meets the needs of the present without compromising the ability of future generations to meet their own needs. Sustainability is a complex concept with multiple applications, which makes its precise definition challenging (Brinkmann, 2021). Nevertheless, it generally refers to a balance between economic, social, and environmental needs to ensure long-term viability (Thompson & Norris, 2021).

Sustainable development is not limited to environmental considerations alone; it also integrates economic and social dimensions (Thompson & Norris, 2021). Adopting a systemic approach to sustainability is therefore essential for analyzing practices and processes within this framework (Thompson & Norris, 2021).

1.1.2 Sustainable Resource Management

Sustainable resource management refers to all practices, strategies, and policies aimed at using, conserving, and regenerating natural resources—such as energy, water, minerals, and other raw materials—in a responsible manner. Its main objective is to meet present needs while preserving the capacity of ecosystems to meet the needs of future generations, reducing environmental impacts, and promoting green economic growth (Wang & Xu, 2024) .The objective is to reconcile economic progress with environmental responsibility (Wang & Xu, 2024).

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1.2 Theoretical Foundations

The following **theoretical framework** provides a structured basis for understanding why public intervention is necessary and how policy measures can influence economic behavior. This study draws on externalities theory to justify corrective action and on incentive theory to explain the effectiveness of policy design under information constraints.

1.2.1 Externalities Theory

In *the Economics of Welfare* (1920), Pigou laid the foundations of externality theory, highlighting that positive or negative effects on third parties, not accounted for by the market, can be corrected by government intervention through instruments such as taxes or subsidies, with the aim of maximizing social welfare. He demonstrates that a fiscal instrument, set at a rate equal to the marginal external cost or marginal external benefit, allows for the internalization of external effects and restores a Pareto-efficient allocation of environmental resources (Schläpfer & Vatn, 2023). In this context, Pigou specifically recommends the implementation of a so-called "Pigouvian tax" as an optimal tool for regulating negative externalities (de Vries & Hanley, 2016). The example of air pollution in Manchester illustrates this approach, showing that taxing polluting activities can reduce the social costs borne by the community and enhance national welfare (de Vries & Hanley, 2016).

(Coase ,1960), for his part, suggests that externality problems can, in theory, be resolved through negotiations among the parties involved, provided that property rights are clearly defined and transaction costs remain low. Within this framework, the efficiency of resource allocation does not depend on the initial allocation of rights, as negotiation can lead to an optimal solution. However, the practical application of this reasoning to environmental policies faces limitations due to the large number of actors involved, the cumulative nature of pollution, and the existence of strategic behaviors such as free-riding or moral hazard, thus justifying public intervention through regulatory mechanisms and pollution pricing.

In the early 1970s, (Baumol and Oates ,1971) showed that pollution could be effectively reduced through a unit tax on pollutant emissions. According to them, such a tax encourages polluters to internalize the cost of their activities and allows for the attainment of an optimal level of pollution. In their later work (Baumol & Oates, 1988), they specify that if the tax is calibrated to achieve the desired reduction in total emissions, it minimizes the overall cost to society, thus combining environmental effectiveness with economic efficiency. This approach highlights the value of economic instruments as an alternative to strict regulations in managing environmental externalities.

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1.2.2 Incentive Theory

Within the framework of incentive theory and public economics, fiscal incentives constitute central instruments of public action, enabling the state to influence the decisions of economic agents by modifying the cost–benefit structures they face. By relying on institutional mechanisms that incorporate financial signals, public authorities aim to align individual behaviors with collective social welfare objectives, particularly in the presence of market failures (d'Aspremont & Gérard-Varet, 2005; Laffont, 2008).

Incentive theory assumes that economic agents are rational and seek to maximize their utility under constraints, responding predictably to the incentive mechanisms designed by the regulator. Within this analytical framework, fiscal policies can be interpreted as mechanisms intended to reveal private information and guide agents' choices toward socially desirable outcomes, despite the existence of information asymmetries between the state and economic actors (Laffont & Martimort, 2002).

In this context, fiscal incentives—such as taxes and subsidies—operate as policy instruments capable of inducing behavioral change by increasing the relative attractiveness of sustainable practices and discouraging undesirable activities. These instruments contribute to both ecological and economic efficiency, foster the adoption of cleaner technologies, and provide flexibility in decision-making (Schanzenbacher, 1995). However, their effectiveness may be constrained by political pressures, their potential use as revenue-generating tools, administrative complexity, and limited acceptance by the public and targeted stakeholders (Schanzenbacher, 1995).

2.Economic Importance of the Agri-Food Sector in Morocco

The agri-food sector occupies a strategic position in the Moroccan economy due to its significant contribution to wealth creation, employment, and exports. It also serves as a key lever for national food security and the overall economic development of the country.

2.1 GDP Contribution

From a macroeconomic perspective, agriculture constitutes a strategic sector of the Moroccan economy, making a significant contribution to gross domestic product (GDP) and employment, particularly in rural areas (El Ghmari et al., 2021). Several studies emphasize that the agricultural sector mobilizes a substantial share of the labor force and plays a central role in national production (Epule et al., 2022). However, agriculture's contribution to GDP exhibits pronounced interannual fluctuations, reflecting the sector's structural dependence on climatic

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conditions, notably rainfall variability, recurrent drought episodes, and the impacts of climate change (Tahiri et al., 2023; En-Nia et al., 2025). This dynamic is embedded within a long-term structural trend characterized by a gradual decline in the share of agricultural value added in GDP, while remaining marked by persistent volatility, as illustrated in Figure 1. In line with this evolution, recent World Bank data indicate that agricultural value added accounted for approximately **10.1% of Morocco's GDP in 2024**. Despite these structural and environmental constraints, the agricultural sector has demonstrated notable resilience, particularly through the development of fruit tree cultivation, whose performance has contributed significantly to the growth dynamics of national GDP (Kara et al., 2025).

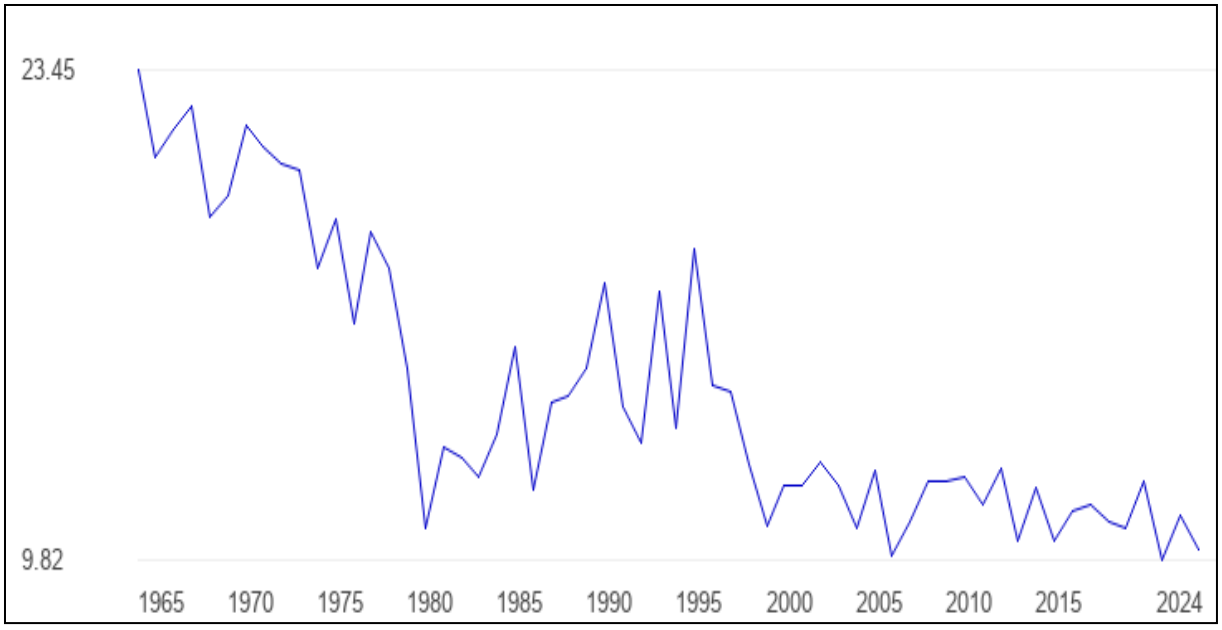

Figure 1. Value added in the agricultural sector (% of GDP), Morocco. *Source: TheGlobalEconomy.com (2025), Data retrieved from the World Bank.*

2.2 Employment and Exports

Agriculture plays a fundamental role by ensuring food supply, providing raw materials, and generating employment opportunities. In Morocco, it remains a key pillar of the economy and rural livelihoods (Babakhouya et al., 2023). However, recent World Bank data reported in Figure 2 indicate that the share of employment in agriculture has gradually declined over time. After reaching 29.59% in 2023, it fell further to 28.00% in 2024 (World Bank , 2024). , reflecting a continued downward trend and a progressive structural transformation of the Moroccan economy.

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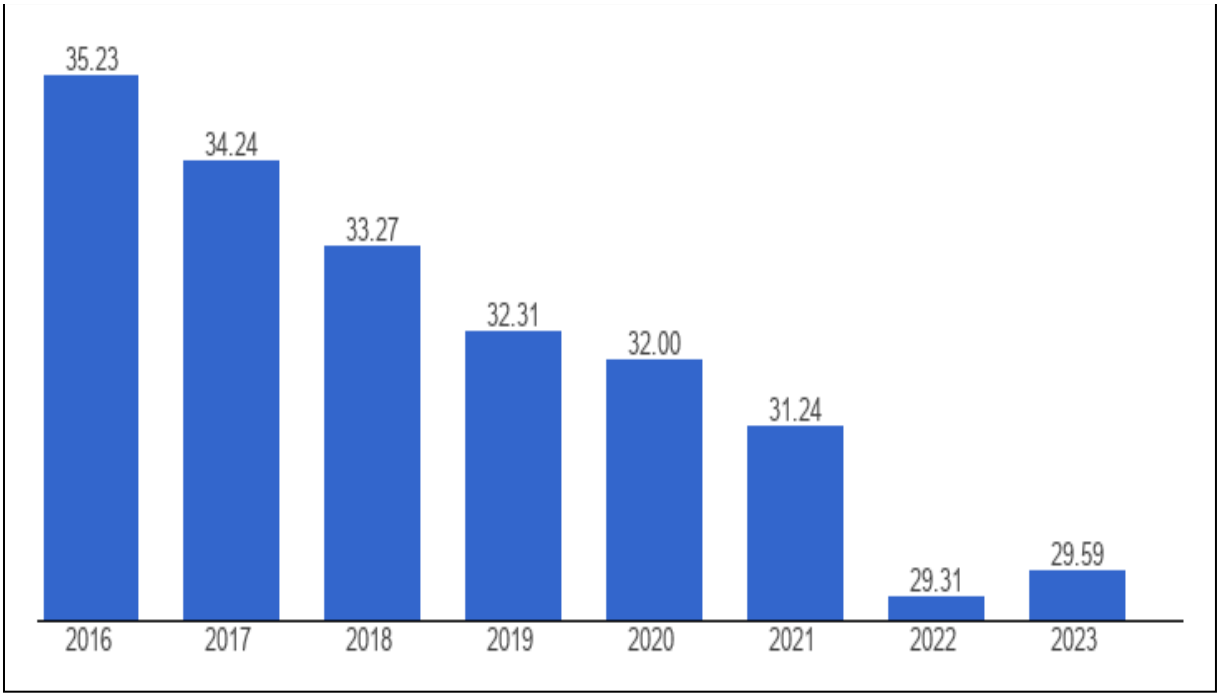

Figure 2 . Employment in agriculture (% of total employment), Morocco. *Source: TheGlobalEconomy.com (2025), Data retrieved from the World Bank.*

Beyond its role in employment, the agricultural and agri-food sector also plays a significant role in Morocco's external trade, accounting for approximately **19% of total national exports in 2023**, which underscores its strategic importance in the country's economic and trade structure (World Bank , 2024).

3.Environmental Challenges in Morocco's Agri-Food Sector:

Morocco is facing environmental challenges of increasing magnitude, amplified by the effects of climate change, demographic pressure, and a development model that is highly intensive in natural resource consumption. These closely interconnected issues jeopardize water security, agricultural productivity, ecosystem balance, as well as the country's economic sustainability. Among the major challenges identified are water stress, soil degradation, and the increase in greenhouse gas (GHG) emissions, which directly affect key sectors such as agriculture, energy, and public health.

3.1 Water stress and resource pressure

Water stress represents one of the most critical environmental challenges for Morocco. The country is classified among those subjected to a high level of water stress according to several international reports, with renewable water resources estimated at approximately 22 billion m^3

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in 2023 (World Bank, 2023). This situation has significantly deteriorated in recent years, particularly due to the impact of extreme climatic events. The year 2023 was thus marked as the driest in at least eighty years, recording precipitation levels below 100 mm, representing a decrease of approximately 48% compared to the national average (Boutagayout et al., 2025). Persistent rainfall deficits, combined with rising demand driven by urbanization, industrial development, and the intensification of agricultural irrigation, have further exacerbated water scarcity. Hydrological modeling studies indicate that river basins such as the Bouregreg are becoming increasingly vulnerable to reductions in ecological flows, which are essential for sustaining aquatic ecosystems (Brouziyne et al., 2022). This situation is further aggravated by inefficient water governance, particularly the overexploitation of groundwater aquifers (Bzioui, 2011). Moreover, major infrastructure projects such as the "Water Highway," which plans the annual transfer of 860 million m³ of water from the humid northern regions to the arid south, could be compromised by climate projections forecasting a decline in precipitation in the source areas (Moçayd et al., 2020).

3.2 Soil Degradation

Soil degradation also constitutes a major threat to the country's food security and environmental resilience. Water erosion remains the main degradation process, particularly in mountainous areas such as the High Atlas, where intense rainfall affects slopes that are often devoid of vegetation cover (Jazouli et al., 2019).

This issue is particularly evident in the upper Oum Er-Rbia basin, whose mountainous relief, hydrographic network, and dam system are shown in Figure 3. This loss of soil leads to a decline in agricultural fertility and promotes the sedimentation of dams, reducing their storage capacity and affecting both hydroelectric power generation and drinking water supply (El Boukhari et al ., 2019). In arid and semi-arid regions, notably the southern argan forests and oases, the overexploitation of pastoral resources, deforestation, and unsustainable agricultural practices accelerate desertification processes (Kirchhoff et al., 2020; Mokhtar et al., 2019). A study conducted in the upper Oum Er Rbia basin, based on satellite imagery and the RUSLE model, highlighted a significant increase in soil loss resulting from the combined effects of climate change and land-use dynamics (Jazouli et al., 2019).

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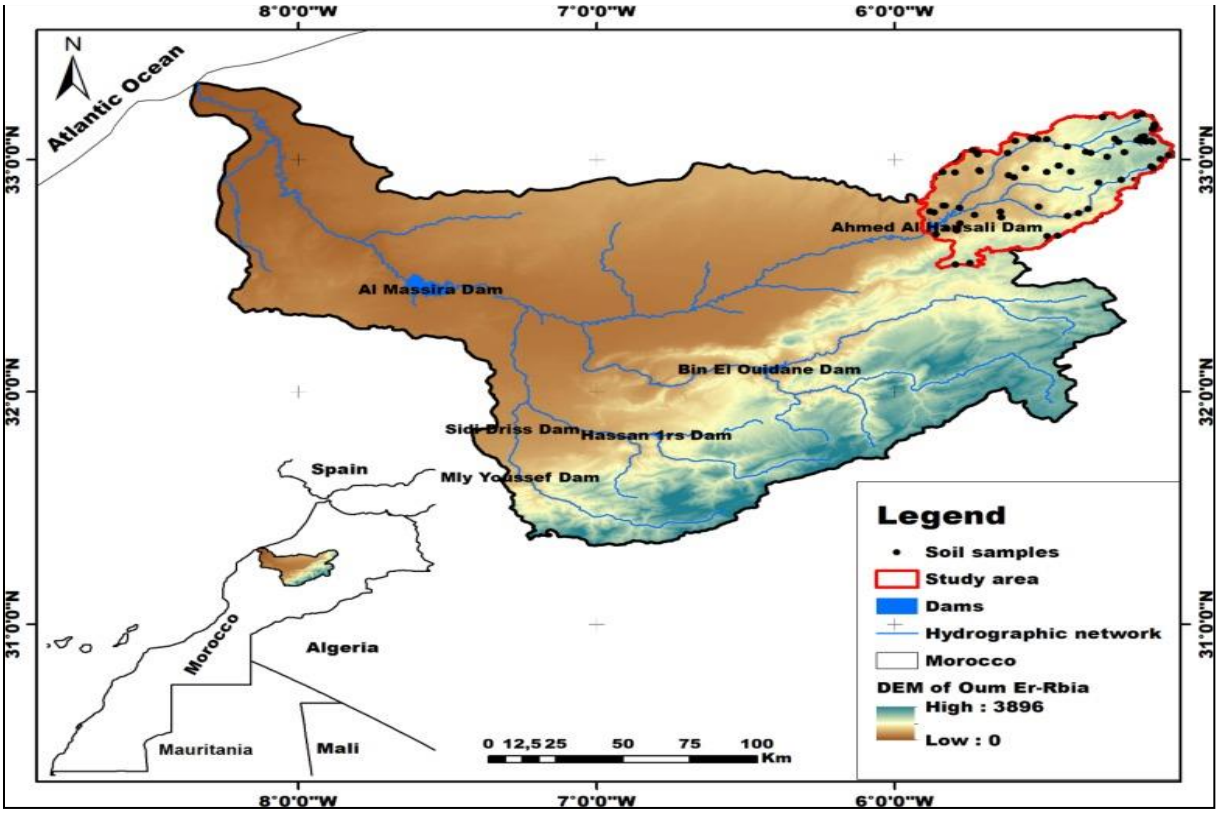

Figure 3. Location map of the Oum Er-Rbia basin (Morocco*). Source: (Faouzi et al. 2023).*

3.3 Greenhouse Gas Emissions

Although Morocco is not among the major historical per capita emitters of greenhouse gases, its GHG emissions have been gradually increasing. This trend is mainly attributable to the country's persistent and largely unchanged reliance on fossil fuels, particularly in the energy and transport sectors (Bouyghrissi et al., 2021). In recent years, fossil fuels have continued to dominate Morocco's final energy consumption, thereby contributing to the sustained rise in carbon dioxide concentrations (Bouyghrissi et al., 2021).In response to this situation, Morocco has committed to achieve a 13% reduction in GHG emissions by 2030 compared to the business-as-usual scenario, with a target that could reach 32% subject to adequate international support (Taj & Belmir, 2021). Figure 4 illustrates Morocco's projected emissions trajectory to 2030 and contextualizes its unconditional and conditional Nationally Determined Contribution (NDC) targets, as well as current policies, against pathways compatible with the Paris Agreement. It indicates that Morocco's overall climate action is rated as "Almost sufficient", meaning that while its current commitments are broadly consistent with limiting global warming to below 2°C, they remain insufficient to fully achieve the 1.5°C objective without additional domestic efforts and sustained international support (Climate Action Tracker,

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2023).To this end, the country has made significant investments in renewable energy, particularly solar energy, exemplified by the Ouarzazate complex, and wind energy, while promoting the transition toward more sustainable transport systems (Bouyghrissi et al., 2021; Laaroussi & Bouayad, 2021). However, several structural constraints continue to hinder this transition, notably the limited adoption of electric vehicles due to their high costs, insufficient charging infrastructure, and still underdeveloped incentive policies (Nasreddin et al., 2023). An analysis of the decoupling between economic growth and GHG emissions reveals that, despite the long-term relationship between GDP and emissions, significant progress can be achieved through the implementation of a sustainable energy strategy (Azzeddine et al., 2024).

4.Economic Integration of the Agri-Food Sector in Morocco

The economic integration of the agri-food sector in Morocco constitutes a strategic lever for national development, both in terms of economic growth and food security, as well as social inclusion. It is based on the organization of the agri-food value chain, the various forms of integration—vertical, horizontal, and institutional—and the structuring role of public policies in the modernization and regulation of the sector. An analysis of these dimensions highlights a process of progressive yet uneven transformation, characterized by notable performance in certain export-oriented value chains, while also revealing persistent constraints related to the fragmentation of the productive fabric, environmental pressures, and unequal access to markets.

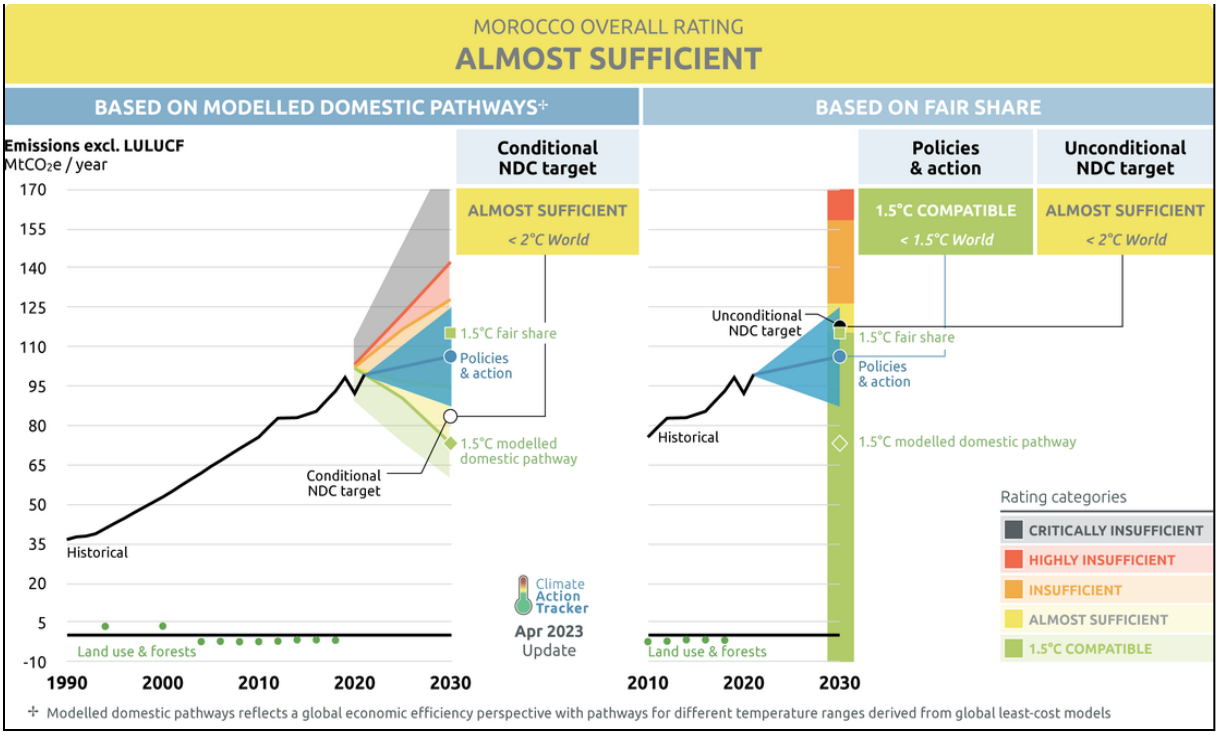

Figure 4 . Morocco's projected emissions trajectory and NDC targets to 2030. *Source: (Climate Action Tracker, 2023).*

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4.1 The Agri-Food Value Chain .

The Moroccan agri-food value chain brings together a diverse range of actors, from small family farms to large commercial operations, including agricultural cooperatives, processing industries, national and international distributors, as well as logistical intermediaries. Although some studies highlight the key economic role of certain agricultural sectors with strong backward and forward linkages and high labor intensity, the Moroccan agri-food value chain is particularly well-developed in the fruit and vegetable sectors destined for export to the European Union, notably through the Euro-Mediterranean Association Agreements (Mekki et al., 2015). For example, The Souss-Massa region is a major center for horticultural production and export in Morocco, with a large number of producers and exporters involved in the fruit and vegetable supply chain (Ait Hou et al., 2015). However, within this value chain, the fruit and vegetable supply chain segment remains vulnerable, particularly in terms of coordination among actors, which may limit traceability and the consistent quality of products (Saidi *et al.,* 2022).

4.2 Vertical Integration

Vertical integration mainly develops in agri-food sectors oriented toward exports. It relies on contractual arrangements linking producers to agri-food companies or exporters, ensuring technical support, access to inputs (seeds, fertilizers), and commercial outlets at pre-determined prices. This organizational model helps reduce the risks borne by farmers and improves production predictability. Several studies show that contractual integration enhances the competitiveness of horticultural farms and encourages the adoption of good agricultural practices as well as private certifications such as GlobalG.A.P. (Codron et al., 2014). The expansion of buyer-driven agri-food value chains, characterized by a high concentration of power downstream and increasingly stringent standards, tends to create asymmetric relationships between buyers and producers, which may reinforce the dependence of small producers (Ait Hou, 2013).

4.3 Horizontal Integration

Horizontal integration primarily takes place through the structuring of agricultural cooperatives, which allow producers to pool production resources, strengthen their bargaining power, and access technical, financial, and commercial services. In this context, the public program “MOURAFAKA” has contributed to the creation and strengthening of numerous cooperatives, improving their economic viability and organizational capacity (Ibourk & Aynaoui, 2023). However, these structures still face significant constraints, particularly in terms of governance,

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professional management, and capitalization, which continue to limit their effectiveness and sustainable anchoring in value chains (Ibourk & Aynaoui, 2023). Strengthening horizontal integration could also involve territorial or sectoral groupings that promote collective projects for irrigation, local processing, and joint marketing.

4.4 Institutional Integration and the Role of Public Policy

Institutional integration, closely linked to the role of public policies, constitutes a central element in the structuring of the Moroccan agri-food sector. It relies on coordination between various public and private actors, notably the relevant ministries (Agriculture, Trade, Environment), specialized agencies such as the Agricultural Development Agency (ADA), chambers of commerce, professional organizations, and international partners. This coordination aims to align strategic objectives, harmonize incentive mechanisms, and improve the regulation of value chains. The Green Morocco Plan (PMV), launched in 2008, illustrates this logic of institutional integration by combining public investments, targeted subsidies, training programs, and the development of hydraulic and logistical infrastructures (Faysse, 2015; Ruck & Hatimy, 2025). While this plan enabled productivity gains in certain sectors, its evaluation also highlights regional and social imbalances, with benefits concentrated in favor of large-scale farms (Faysse, 2015).

Building on this, the “Generation Green 2020–2030” strategy aims to strengthen institutional integration by addressing identified limitations, emphasizing the inclusion of small farms, climate resilience, and the sustainability of natural resources (de Souza et al., 2025). Figure 5 provides a comparative overview of the two strategies, highlighting their main objectives, policy instruments, and priority areas, such as productivity modernization, inclusivity, environmental integration, and support for cooperatives (de Souza et al., 2025). In this context, public policies supporting agricultural digitalization, traceability, and technological innovation also fit into this dynamic, improving actor coordination and the efficiency of agri-food supply chains (Babakhouya et al., 2023; Bhilat et al., 2023).

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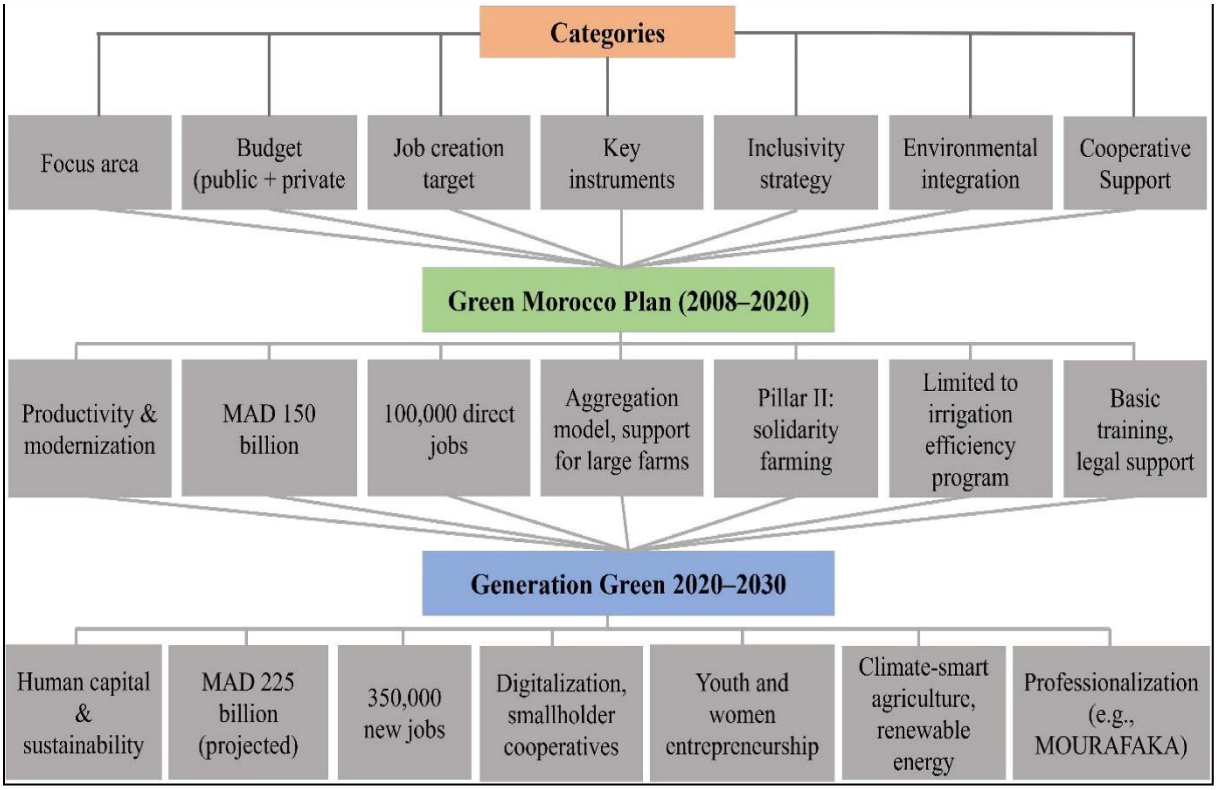

Figure 5. Green Morocco Plan (2008–2020) and Generation Green (2020–2030): A Comparative Synthesis. *Source: (de Souza et al., 2025).*

The following figure provides a conceptual synthesis of the Moroccan agri-food value chain and the main forms of economic integration shaping its organization. It offers a visual overview of how the different stages of the agri-food system—from input supply and agricultural production to processing, distribution, and final markets—are structured through horizontal, vertical, and institutional integration mechanisms

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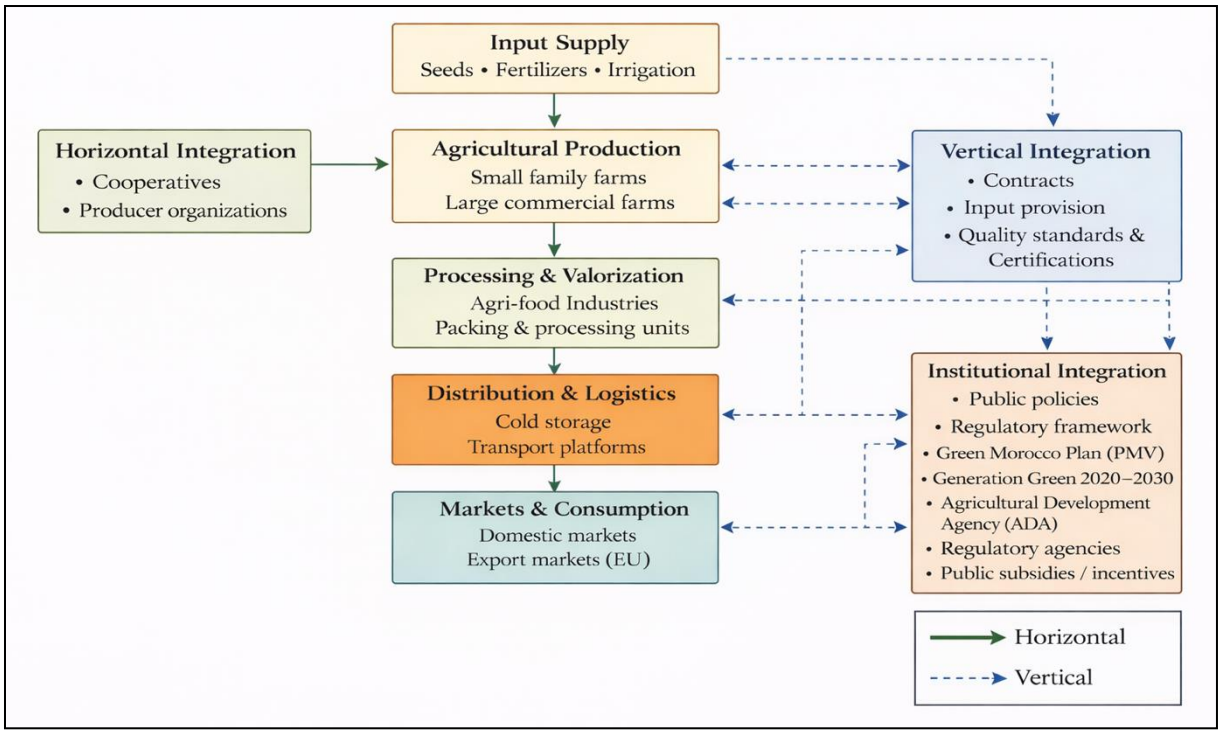

Figure 6. Agro-food value chain and economic integration mechanisms in Morocco. ***Source: Authors' elaboration.***

The economic integration of the agri-food sector cannot be dissociated from environmental and social challenges. Integration policies must therefore incorporate sustainable resource management approaches, such as agroecology and the circular economy, to ensure the long-term viability of the sector (Souza et al., 2025).

5.Environmental Integration of the Agri-Food Sector in Morocco

The Moroccan agri-food sector, facing increasing pressures from climate change, water scarcity, and soil degradation, is gradually moving toward environmental integration based on the principles of sustainability and the circular economy. This approach relies on complementary pillars, including sustainable natural resource management, the development of agroecological practices, and the adoption of environmental standards, aiming to reduce environmental pressures while enhancing the sector's resilience and sustainability.

5.1 Circular economy and sustainable management of natural resources

In a context of increasing water stress linked to semi-arid to arid climatic conditions, Morocco faces a structural scarcity of its water resources, particularly impacting the agri-food sector (Ortega-Pozo et al., 2022). To address these constraints, the circular economy is progressively emerging as a central pillar of environmental integration, in contrast to the traditional linear model based on the "take–produce–dispose" principle, which leads to excessive consumption

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of natural resources (El Ouadi, 2023). In the Moroccan context, this transition involves the valorization of wastewater as well as agricultural and industrial waste, the optimization of material and energy flows, and the adoption of concrete practices such as drip irrigation and the use of renewable energy, in order to limit waste and secure resources (El Ouadi, 2023). This approach also aligns with the principles of the 3Rs (reduce, reuse, and recycle) promoted by Moroccan national strategies, including the valorization of solid waste, sludge, organic residues, and wastewater (Dahchour et al., 2021).

In this context, the reuse of treated wastewater for agricultural irrigation constitutes a key component of water resource circularity, although its use remains marginal, representing less than 1 % of irrigation volumes (Ortega-Pozo et al., 2022). Several studies nevertheless highlight the significant potential of this practice (Benlemlih et al., 2024) to relieve pressure on overexploited aquifers, provided that regulatory frameworks are strengthened and advanced treatment technologies are adopted to ensure sanitary and environmental safety (Ortega-Pozo et al., 2022). More broadly, these interventions contribute to an integrated approach to the water–energy–food–climate nexus, where the recovery of water and nutrients helps strengthen the resilience of agri-food systems to the impacts of climate change (El Ouadi, 2023), while supporting the Sustainable Development Goals within the framework of the national plan for sustainability and circularity (Dahchour et al., 2021).

5.2 Agroecological practices and sustainable agricultural systems

Environmentally friendly agricultural practices in the Moroccan agri-food sector are based on the adoption of more sustainable production systems, capable of reducing pressure on natural resources while ensuring food security. In this regard, the integration of legumes, such as chickpea and lentil, into crop rotations with wheat constitutes an effective strategy to reduce the environmental footprint of agricultural systems, notably through lower water consumption and reduced use of chemical inputs, while maintaining satisfactory production levels in arid and Mediterranean zones (Lago-Olveira et al., 2024). Furthermore, the development of agroecological practices, such as agroforestry, crop diversification, the use of organic fertilizers, and cereal–legume rotations, contributes to improving soil fertility and strengthening the resilience of agroecosystems, particularly within small Moroccan farms, where local knowledge plays a central role (Irhza et al., 2023). In a context marked by severe water scarcity in Morocco and more broadly in the MENA region, agroecology appears as a relevant transition framework, based not only on technical practices but also on the capacity of farming

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communities to self-organize and collectively manage resources, an essential condition for the sustainability and autonomy of agri-food systems (Goetz et al., 2023).

5.3 Environmental certifications and sustainability standards

Environmental certifications, such as the ISO 14001 standard (International Organization for Standardization), play a central role in formalizing good agricultural practices and facilitating access to markets, particularly international ones. They contribute to better structuring environmental management systems and to strengthening transparency and monitoring of agri-food practices. The literature highlights that the adoption of standards such as ISO 14001 is mainly driven by economic factors and market pressure, and that it is associated with improved commercial and marketing performance, particularly through the development of exports (Labella et al., 2024). By contrast, the direct effects on financial profitability remain limited, and the adoption of these certifications continues to be constrained for small structures due to costs and organizational requirements (Labella et al., 2024). Nevertheless, these standards constitute a strategic lever for aligning the Moroccan agri-food sector with international sustainability standards.

The environmental integration of the Moroccan agri-food sector relies on a complementary combination of circular economy principles, agroecological practices, and environmental certification schemes. In the face of structural resource scarcity, particularly water resources, these approaches help reduce environmental pressures while strengthening the resilience of production systems. However, their implementation remains partial and uneven, especially among small-scale farms. Strengthening regulatory frameworks, technical support mechanisms, and public incentives therefore appears essential to ensure an effective and inclusive environmental transition of the sector.

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Conclusion

This literature review provides an integrative reading of academic works addressing the economic and environmental integration of Morocco's agri-food sector, mobilizing the concepts of sustainability, sustainable natural resource management, and the contributions of incentive and externality theories. It contributes to the existing literature by articulating, within a unified analytical framework, the dynamics of agri-food value chain integration with environmental challenges and economic instruments aimed at correcting market failures in a context of severe natural resource constraints. Existing studies highlight the central role of the agri-food sector in the Moroccan economy, particularly in terms of employment, exports, and food security, while also emphasizing its strong vulnerability to environmental pressures, notably water stress, soil degradation, and climate change. The literature indicates that the economic integration of agri-food value chains—through vertical, horizontal, and institutional forms of integration supported by public policies—has fostered productivity gains and improved access to international markets, particularly in horticultural value chains. However, several studies underscore that these dynamics remain unevenly distributed, largely benefiting large-scale, export-oriented farms, while small producers continue to face persistent structural constraints. From an environmental perspective, the reviewed literature points to the gradual emergence of practices based on circular economy principles, agroecology, and environmental certification schemes, reflecting a transition toward more sustainable production systems that remains partial and fragmented. Insights from incentive and externality theories emphasize the critical role of public intervention in correcting market failures, internalizing environmental costs, and steering actors' behavior toward more sustainable practices. In this perspective, the literature converges on the idea that the long-term sustainability of Morocco's agri-food sector depends on a stronger alignment between economic integration strategies and environmental objectives, requiring greater policy coherence, more effective incentive mechanisms, enhanced institutional coordination, and improved inclusion of small producers in sustainability-oriented value chains. Future research based on empirical approaches could complement these findings by more precisely assessing the impacts of public policies and the microeconomic responses of farmers to economic and environmental incentives.

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