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Agri-food System and Climate Change: A Focus on Agroecology and Regenerative Agriculture Approaches

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Sistema agroalimentar e mudanças climáticas: o foco nas abordagens da agroecologia e da agricultura regenerativa

RESUMO

O futuro da segurança alimentar global depende de um sistema agroalimentar (SAG) que está atualmente sob ameaça direta das mudanças climáticas. Esse sistema, fundamental para sustentar a população mundial, enfrenta desafios que colocam em risco tanto sua funcionalidade quanto sua sustentabilidade. O SAG, muitas vezes apontado como um dos principais causadores das mudanças climáticas, também se revela altamente vulnerável aos seus impactos. Diante dessa realidade, alternativas sustentáveis e resilientes são, cada vez mais, necessárias. Há uma lacuna de conhecimento quanto às possibilidades de transformar o SAG em consonância com a resiliência climática. Quais aspectos são destacados para entender o papel de abordagens alternativas, agroecologia e agricultura regenerativa (AR), na reconfiguração do sistema agroalimentar (SAG) tendo em conta o desafio das mudanças climáticas? Este trabalho busca responder a essa questão, elucidando os principais aspectos dessas abordagens. Para isso uma revisão sistemática da literatura foi realizada nas bases: Web of Science e Scopus, seguida de uma análise *SWOT* (forças, fraquezas, oportunidades e ameaças). Os aspectos-chave identificados na revisão são: práticas produtivas, atores, benefícios e desafios. Entre as forças, destacam-se as práticas produtivas sustentáveis e a diversidade de atores que promovem essas abordagens. As fraquezas incluem barreiras à implementação e a escassez de evidências concretas sobre sua eficácia na mitigação das mudanças climáticas. Contudo, a necessidade de ampliar a produção de evidências científicas configura uma oportunidade. Já as ameaças estão relacionadas às barreiras políticas para a disseminação da agroecologia e à falta de consenso sobre as técnicas da AR.

PALAVRAS-CHAVE: Mudanças Climáticas. Agricultura Sustentável. Análise *SWOT.*

Agri-food System and Climate Change: A Focus on Agroecology and Regenerative Agriculture Approaches

ABSTRACT

The future of global food security depends on an agri-food system (AFS) that is currently under direct threat from climate change. This system, essential for sustaining the world population, faces challenges that jeopardize both its functionality and sustainability. The AFS, often cited as one of the primary contributors to climate change, is also found to be highly vulnerable to its impacts. In light of this reality, sustainable and resilient alternatives are increasingly necessary. There exists a knowledge gap regarding the possibilities of transforming the AFS in alignment with climate resilience. What aspects are highlighted to understand the role of alternative approaches, agroecology, and regenerative agriculture (RA) in the reconfiguration of the agri-food system (AFS) in the context of the challenges posed by climate change? This paper aims to address this question by elucidating the main aspects of these approaches. A systematic literature review is conducted in the Web of Science and Scopus databases, followed by a SWOT analysis (strengths, weaknesses, opportunities, and threats). The key aspects identified in the review include: productive practices, actors, benefits, and challenges. Among the strengths, sustainable productive practices and the diversity of actors promoting these approaches stand out. The weaknesses include barriers to implementation and the lack of concrete evidence regarding their effectiveness in mitigating climate change. However, the need to expand the production of scientific evidence presents an opportunity. The threats are related to political barriers to the dissemination of agroecology and the lack of consensus on RA techniques.

KEYWORDS: Climate Change, Sustainable Agriculture, SWOT Analysis.

Sistema agroalimentario y cambio climático: el enfoque en las aproximaciones de la agroecología y la agricultura regenerativa

RESUMEN

El futuro de la seguridad alimentaria global depende de un sistema agroalimentario (SAG) que actualmente está bajo amenaza directa por el cambio climático. Este sistema, fundamental para sostener a la población mundial, enfrenta desafíos que ponen en riesgo tanto su funcionalidad como su sostenibilidad. El SAG, frecuentemente señalado como uno de los principales causantes del cambio climático, también resulta ser altamente vulnerable a sus impactos. Ante esta realidad, son cada vez más necesarias alternativas sostenibles y resilientes. Existe una brecha de conocimiento sobre las posibilidades de transformar el SAG en consonancia con la resiliencia climática. ¿Qué aspectos se destacan para entender el papel de las aproximaciones alternativas, la agroecología y la agricultura regenerativa (AR), en la reconfiguración del sistema agroalimentario (SAG) considerando el desafío del cambio climático? Este trabajo busca responder a esta cuestión, elucidando los principales aspectos de estas aproximaciones. Para ello, se realizó una revisión sistemática de la literatura en las bases Web of Science y Scopus, seguida de un análisis FODA (fortalezas, oportunidades, debilidades y amenazas). Los aspectos clave identificados en la revisión son: prácticas productivas, actores, beneficios y desafíos. Entre las fortalezas destacan las prácticas productivas sostenibles y la diversidad de actores que promueven estas aproximaciones. Las debilidades incluyen las barreras para su implementación y la escasez de evidencias concretas sobre su eficacia en la mitigación del cambio climático. Sin embargo, la necesidad de ampliar la producción de evidencias científicas constituye una oportunidad. Las amenazas están relacionadas con las barreras políticas para la difusión de la agroecología y la falta de consenso sobre las técnicas de la AR.

PALABRAS CLAVE: Cambio Climático. Agricultura Sostenible. Análisis FODA.

1 INTRODUCTION

The Global Agri-Food System (AFS) encompasses the interconnected actors and activities involved in value addition, ranging from the primary production of food and non-food products in agriculture, fishing, and forestry, to the storage, transportation, handling, post-harvest, processing, distribution, marketing, and consumption of food (Ericksen, 2008; Popkin et al., 2017). This system plays a crucial role in sustaining societies by providing essential food supplies to the global population, yet it faces complex challenges that are expected to intensify in the coming years. Climate change is one of the greatest threats confronting human societies, necessitating immediate action across all sectors (Rosenzweig et al., 2020). It has emerged as a significant concern due to its impacts on food production and global food security (Bajzelj et al., 2014; Willet et al., 2019; Rosenzweig et al., 2020; Crippa et al., 2021; Zurek et al., 2022).

The global agri-food system is distinguished by its socioeconomic strength, attributed to the high volume of imported and exported agri-food products, as well as the substantial number of stakeholders involved in a complex chain that encompasses various actors, processes, and sectors. The AFS is predominantly represented by a small group of agribusiness companies that maintain close political connections. The current agri-food model generates negative environmental and social impacts and has led to a reduction in the supply of diverse foods for the domestic market while increasing the supply of commodities, particularly grains and biofuels, for the external market (Xavier et al., 2018; Quevedo et al., 2022).

This model, also known as industrial agriculture, relies on practices that include intensive farming, monoculture, irrigation, the application of inorganic fertilizers, pest control, genetic modification of domesticated plants and animals, and the confinement of livestock (Gliessman et al., 2022). These practices not only depend on natural resources such as water, energy, land, and external inputs but also result in climatic impacts that raise questions about their sustainability in the short and medium term (FAO, 2017).

There are three main dimensions through which the agri-food system contributes to greenhouse gas (GHG) emissions. This last dimension includes: (i) agricultural and livestock activities; (ii) land use planning and dynamics; and (iii) pre- and post-production processes. This dimension encompasses stages such as food transportation, processing and manufacturing of inputs, as well as domestic consumption and waste management (Mbow et al., 2020; Tubiello et al., 2021; Zurek, 2022).

Emissions resulting from agricultural practices, reforestation, and other land uses are predominantly composed of greenhouse gases that do not include carbon dioxide (CO_2). Predominantly, methane is generated through enteric fermentation during the digestive processes of ruminant animals and through submerged rice cultivation. Nitrous oxide emissions primarily stem from the application of nitrogenous fertilizers and the management of animal waste, while carbon dioxide emissions are intrinsically linked to deforestation (WRI, 2018; Assad, 2019; Mbow et al., 2020).

The agri-food system is vulnerable to climatic events due to its direct dependence on climate (Soussana, 2014; Zurek et al., 2022). The Sixth Assessment Report (AR6) of the IPCC warns of the negative impacts of climate change on food production and malnutrition among populations (IPCC, 2018, 2021). An increase in global temperature beyond 1.5 °C, which may lead to more frequent and devastating extreme weather events, is projected to transform terrestrial ecosystems and affect agricultural productivity, fishing, aquaculture, and the food supply chain (FAO, 2017). The AR6 also highlights that developing countries, particularly those reliant on agriculture, will be disproportionately affected, with small farmers being especially vulnerable. Clark et al. (2020), in a study on the agri-food system's contribution to global emissions, indicate that the AFS may undermine global climate targets.

Although the AFS is identified as a contributor to climate change, it is also highly vulnerable to its climatic impacts. Agri-food production is affected by extreme events such as prolonged droughts, precipitation changes, heatwaves, frosts, and cyclones, which can lead to reduced crop yields and promote the proliferation of invasive plants and pests. Other consequences of climatic variation include intensified land degradation due to increased soil erosion, particularly in coastal areas, as well as increased soil salinity in irrigated lands in drier climates, which are more prone to desertification in certain arid regions (Mirzabaev et al., 2023).

Concerns arise from the fact that extreme weather events are becoming more intense and frequent, disproportionately affecting different regions of the globe (IPCC, 2021). Climate change has altered the structure of ecosystems, causing phenological variations, changes in population dynamics, and alterations in the life cycles of animals and plants. Combined with land use conversion, these changes are accelerating the decline of native populations, the loss of ecosystem services, and, in extreme cases, global species extinction. Among these losses are local agricultural varieties, heritage breeds, and traditional knowledge associated with agroecosystems. Such impacts are primarily linked to the expansion of industrial agriculture, increasing rural exodus, and the emergence of new climate refugees (Berchin et al., 2019). In light of these consequences, climate change studies have emerged as one of the most challenging global issues for over two decades, particularly concerning the unsustainability of the Global Agri-Food System. In this context, the urgent search for sustainable and resilient alternatives is crucial, revealing knowledge gaps and enabling a better understanding of the transformations necessary within the AFS in alignment with climate resilience.

In light of this, it is imperative to enhance our understanding of the potential for reformulating the agri-food system in alignment with climate resilience. As the cumulative impacts of climate change become increasingly pronounced across various sectors and geographical regions, innovative approaches aimed at delivering more comprehensive solutions are emerging (Altieri et al., 2022). Activities within the global agri-food system (AFS) associated with agricultural production have engendered substantial risks, including the depletion of water resources, air pollution, soil degradation, and a decline in global biodiversity (Bajzelj et al., 2014; FAO, 2017). Within this framework, methodologies that seek to transform agri-food systems in order to achieve favorable environmental, socioeconomic, and public health outcomes have gained considerable prominence (Willett et al., 2019).

Approaches such as agroecology and regenerative agriculture are presented as viable alternatives for transforming the agri-food system by promoting sustainable and resilient practices (Altieri et al., 2022; Willett et al., 2019). However, significant barriers exist to the implementation of alternative agricultural systems (Reganold and Wachter, 2016). The guiding question of this study is: which aspects are highlighted to understand the role of alternative approaches, such as agroecology and regenerative agriculture (RA), in reconfiguring the agri-food system (AFS), considering the challenge posed by climate change? This question aims to clarify the key aspects of these two approaches. The focus on agroecology and regenerative agriculture is justified by the increasing relevance these frameworks have gained regarding the benefits of agricultural practices and climate resilience.

Altieri et al. (2022) perceive agroecology as a promising approach to reconfiguring the global agri-food system in the face of climate change. By prioritizing methods that include crop diversification, water conservation, and animal integration, agroecology not only strengthens the resilience of agricultural systems to climatic variations but also contributes to food security and environmental sustainability on a global scale. On the other hand, regenerative agriculture, as noted by Giller et al. (2021), emerges as a "buzzword" and a fundamental response to the contemporary challenges faced by agriculture. Its recent resurgence is driven by the growing understanding of the need for more sustainable and integrated approaches. In addition to offering solutions to social and economic issues, regenerative agriculture plays a crucial role in mitigating climate change. By focusing on soil health, crop diversification, and reducing chemical input use, this approach not only sequesters atmospheric carbon but also strengthens the resilience of agricultural systems in the face of emerging climatic challenges.

Section 2 addresses the methodology, followed by the presentation and discussion of results in Section 3, and concludes in Section 4.

2 METHODOLOGY

The research method consists of a systematic literature review in the Web of Science and Scopus databases, considering publications from the period of 2018 to 2022.

2.1 Systematic Review

The review of approaches to the transformation of the agri-food system focused on the intersection of three main themes: i) agroecology/regenerative agriculture, ii) agri-food system, and iii) climate change (Figure 1).

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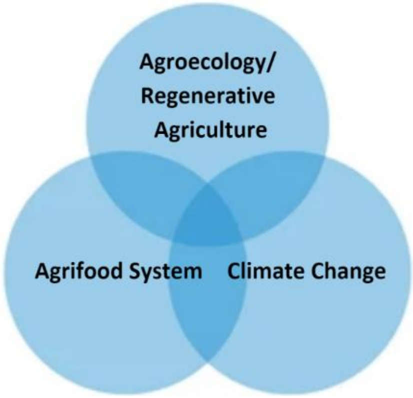
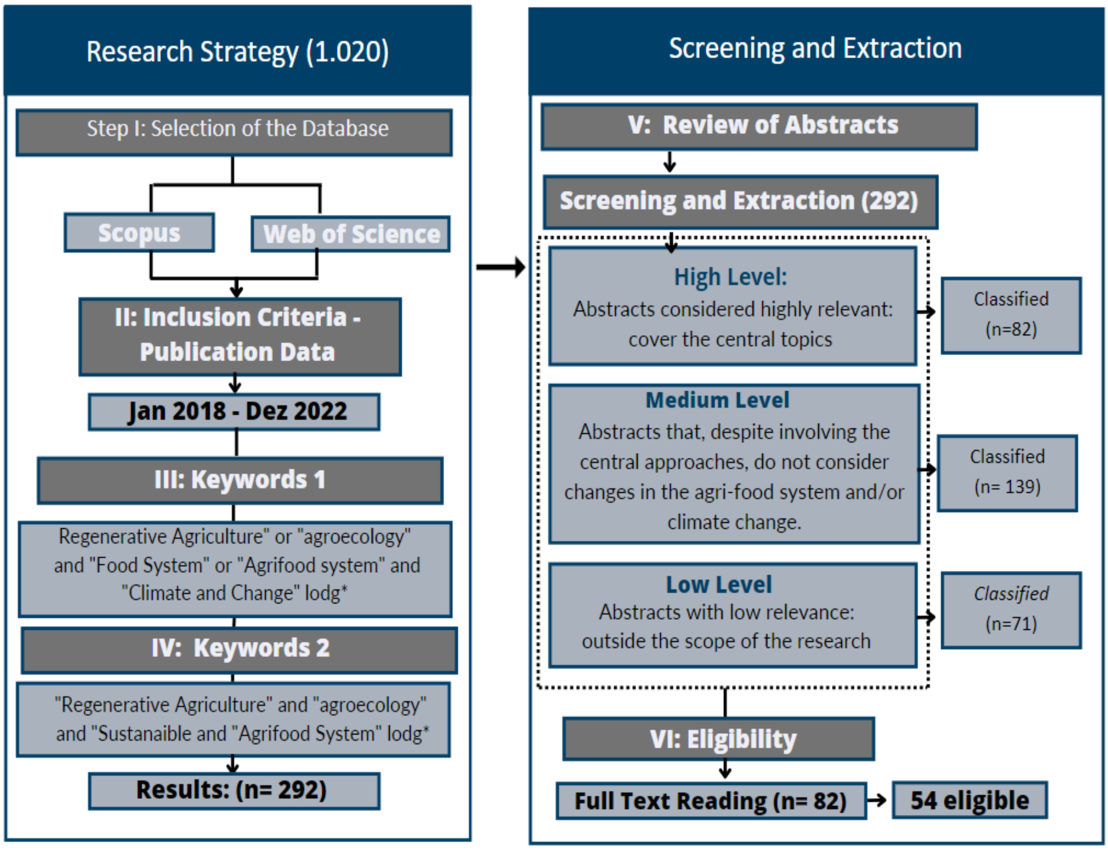
Figure 1 - Thematic Framework of the Systematic Review



Source: Elaborated by the authors, 2024.

The search included scientific articles written in English and Portuguese, concluding in February 2023. Keywords were employed in the SCOPUS and Web of Science databases, as represented in Figure 2.

Figure 2 - Systematic Review and Selection of Articles



Source: Elaborated by the authors, 2024.

We identified 1,020 articles, of which 606 are indexed in the Web of Science and 414 in Scopus. The analysis of 54 of these articles led to the organization of the data into four

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categories: practices, actors, benefits, and challenges. Additionally, a SWOT matrix (strengths, weaknesses, opportunities, and threats) was applied.

2.2 Analysis Categories

The data were organized and discussed based on four analysis categories, as defined in Table 1, and explored in greater detail in Section 3, utilizing the SWOT matrix.

Table 1 – Analysis Categories

Category	Definition
Practices	Consist of a set of principles, standards, and technical recommendations that should be applied from agricultural input production to food transportation and delivery to consumers.
Actors	Include individuals and organizations involved in developing agroecology and regenerative agriculture.
Benefits	Refer to the advantages, gains, or positive outcomes achieved from applying agricultural practices within the context of transitioning to more sustainable and climate-resilient food systems.
Challenges	Refer to obstacles, difficulties, or complex situations requiring effort or resolution to overcome, based on the context of applying each studied approach as a means of transitioning to more sustainable and climate-resilient food systems.

Source: Elaborated by the authors, 2024.

The SWOT analysis considers internal and external factors that may be favorable or unfavorable for achieving a goal (Ghorbani et al., 2015). This analysis examines the influence of both internal and external environments, where strengths and weaknesses originate from the internal environment of the operation, encompassing aspects such as image, structure, availability of tangible and intangible resources, capacity, and productivity. Conversely, opportunities and threats pertain to external factors related to political scenarios, economic volatility, social and technological changes, as well as environmental concerns (Lynch, 2012). This study employs SWOT analysis to evaluate the strengths, weaknesses, opportunities, and threats of agroecology and regenerative agriculture, in light of the need to transform the global agri-food system (AFS) while considering climate change.

3 RECONFIGURATION OF THE AGRO-FOOD SYSTEM FROM THE PERSPECTIVES OF AGROECOLOGY AND REGENERATIVE AGRICULTURE

A critical reassessment of the current paradigm in conventional food production is imperative, necessitating the adoption of sustainable practices that optimize the use of natural resources. This need implies the preservation and regeneration of ecosystems, strengthening the resilience of agricultural areas, mitigating vulnerabilities, and adopting a proactive approach to the challenges posed by climate change. In this context, agroecology and regenerative agriculture emerge as promising alternatives to achieve these objectives. Analysis categories were explored, encompassing implemented practices, involved stakeholders, generated benefits, and encountered challenges. These categories reflect the predominant aspects highlighted in the critical literature review on agroecology and regenerative agriculture, reinforcing the urgency for a transformation in the global agro-food system in response to the demands of climate change.

3.1 Agroecology

Table 2 presents the sources used to support the literature review and the delimitation of the analysis categories, with an emphasis on the agroecological perspective. Various authors have investigated the adoption of agroecological practices as a mechanism to promote the transition of agri-food systems, making them more resilient to climate change (Altieri and Nicholls, 2018; Aguilera et al., 2020; Amoak et al., 2022; Snapp, 2021). It is argued that traditional practices, rooted in agricultural systems, constitute an essential starting point for the implementation of agroecology and the development of new agricultural arrangements.

Table 2 – Analysis Categories and Sources Related to Agroecology

Category	Sources (29)
Practices	Aguilera et al., 2020; Altieri et al., 2022; Altieri e Nicholls, 2018; Amoak et al., 2022; Anderson et al., 2019; Belmin et al., 2023; Clapp e Martin, 2022; Debray et al., 2019; Gliesmann, 2018; Gliessman et al., 2022; Kerr et al., 2023; Knapp e Van Der Heijden, 2018; Kpienbaareh, 2022; Lessmann et al., 2022; Márquez-Barrenechea et al., 2020; Nicholls e Altieri, 2019; Salazar et al., 2020; Snapp et al., 2021; Tittonell et al., 2022; Wezel et al., 2020.
Actors	Aguilera et al., 2020; Amoak et al., 2022; Anderson et al., 2019; Darnhofer et al., 2019; Lal, 2020; Márquez-Barrenechea et al., 2020; Milhorance et al., 2020; Ross et al., 2022; Snapp et al., 2021; Tittonell et al., 2022; Wezel et al., 2020.
Benefits	Amoak et al., 2022; Cardoso et al., 2018; Gliesmann, 2018; Kerr et al., 2023; Knapp e Van Der Heijden, 2018; Kpienbaareh, 2022; Lal, 2020; Lessmann et al., 2022; Márquez-Barrenechea et al., 2020.
Challenges	Altieri, 2022; Anderson e Rivera et al., 2021; Belmin et al., 2023; Gliessman et al., 2022; Knapp, 2018; López-Garcia, 2021; Milhomens et al., 2021; Nicholls e Altieri, 2019; Orion, 2021; Salazar et al., 2020; Snapp et al., 2021; Tittonell et al., 2022; Wezel et al., 2020;

Source: Compiled by the authors, 2024.

Practices: The agroecological approach has emerged as an essential paradigm for mitigating the impacts of climate change on agriculture, highlighting the implementation of diverse and integrative practices. Among these practices, the adoption of polyculture systems and intercropping is particularly notable (Altieri and Nicholls, 2018; Gliessman et al., 2022; Amoak et al., 2022; Anderson et al., 2019; Clapp and Martin, 2022), promoting synergistic interactions among different plant species and strengthening the resilience of agricultural ecosystems. Additionally, agroforestry management strategies (Debray et al., 2019; Altieri and Nicholls, 2018; Gliessman et al., 2022; Wezel et al., 2020) integrate trees, crops, and animals into cohesive productive units, contributing to the diversification and resilience of agricultural systems. These practices also play a crucial role in protecting soil against erosion and enhancing its water retention capacity, critical aspects for adapting to climate change.

Actors: The transition to agroecological practices involves a dynamic interaction among various actors, uniting scientific and traditional knowledge in a holistic dialogue. Authors such as Lal (2020), Snapp (2021), Nicholls and Altieri (2019), and Gliessman et al. (2022) emphasize the importance of this participatory approach, which transcends agricultural scale and encompasses the socioeconomic and environmental aspects of the agri-food system. The involvement of multiple actors, including small farmers, traditional communities, and agroecology advocates, is fundamental to addressing climate challenges and promoting resilient adaptation. Kerr et al. (2023) underline the necessity of a participatory approach that enables farmers to adapt their practices to climate change and share knowledge about effective coping strategies.

Benefits: The adoption of agroecological practices offers a range of benefits for both agricultural systems and the environment. The promotion of biodiversity, resilience of agricultural ecosystems, reduction of dependency on external inputs, and improvement of soil and water resource health are considered some of the main benefits provided by agroecological systems (Gliessman et al., 2022; Nicholls and Altieri, 2019; Amoak et al., 2022; Knapp and Van der Heijden, 2018). These practices, which include crop diversification and the integration of trees and animals, create favorable conditions for the proliferation of beneficial soil organisms and for the natural control of pests and diseases (Altieri and Nicholls, 2018; Debray et al., 2019).

Challenges: The transition to agroecology-based agricultural systems faces several challenges, particularly in light of climate change and the need for a rapid and effective transition (Salazar et al., 2020; Kerr et al., 2023). Among the primary challenges are the resistance from groups tied to the conventional agricultural model, political barriers that hinder the implementation of public policies favorable to agroecology, and inequalities in access to resources, such as land and financing, which limit the adoption of agroecological practices, especially for small farmers and marginalized communities (Dale, 2020). Furthermore, the lack of understanding and a consensual definition of agroecological practices may lead to confusion and undermine their potential as a viable alternative in the face of climate challenges. Based on the analysis categories, the following SWOT Matrix was constructed (Figure 3):

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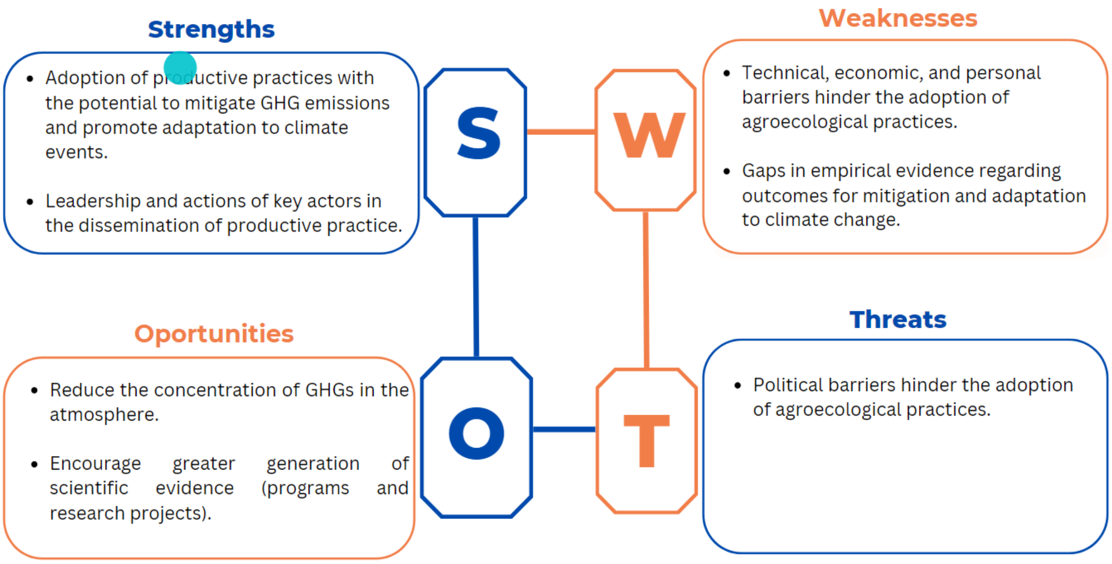
Figure 3 - SWOT Matrix of the Agroecological Approach for the Transformation of the Agro-Food System with a Focus on Climate Change



Source: Elaborated by the authors, 2024.

The analysis of the SWOT Matrix highlights the strengths of the agroecological approach in mitigating greenhouse gas emissions and promoting adaptation to extreme weather events. Agroecological practices provide an effective response to climate challenges, enhancing the resilience of agricultural systems and ensuring long-term sustainability. However, some weaknesses are identified, such as technical and economic barriers to the adoption of these practices and the lack of clear empirical evidence regarding their benefits in terms of climate mitigation and adaptation. Opportunities include favorable public policies, the strengthening of cooperative networks among involved actors, and investments in research and development of technologies tailored to local conditions and climate challenges. On the other hand, threats encompass resistance from groups tied to the conventional agricultural model, the lack of consistent political support, and competition for scarce resources in an increasingly intense climate change context.

3.2 Regenerative Agriculture

Regenerative agriculture (RA) has been discussed in recent articles as an approach with the potential to strengthen modern agri-food systems, guiding them toward climate resilience and sustainability (Gosnell et al., 2019; Gordon et al., 2022; Soto et al., 2020; Tittonell, 2022). Table 3 synthesizes the sources that underpin the analysis categories, considering regenerative agriculture.

Table 3 – Analytical Categories and Sources Related to Regenerative Agriculture

Category	Sources (25)
Practices	Al-Kaisi e Lal, 2020; Anderson e Rivera et al., 2021; Corbeels et al., 2018; Duncan et al., 2020; Fassler et al., 2021; Gibbons, 2020; Giller et al., 2021; Gliessman, 2018; Gordon et al., 2022; Gosnell et al., 2019; Vrska, 2019; LaCanne e Lundgren, 2018; Lal, 2020; Loring, 2022; Soto et al., 2021; McGuire et al., 2020; McLennon et al., 2021; Mitchell et al., 2019; Newton et al., 2020; Nicholls, 2019; Ranganathan et al., 2020; Schreefel et al., 2020; Soto et al., 2020; Tittonel et al., 2022.
Actors	Corbeels et al., 2018; Giller et al., 2021; Gosnell et al., 2019; Vrska, 2019; LaCanne e Lundgren, 2018; Lal, 2020; Soto et al., 2021; McLennon et al., 2021; Newton et al., 2020; Ranganathan et al., 2020; Romero et al., 2020; Schreefel et al., 2020; Tittonel et al., 2022.
Benefits	Gosnell et al., 2019; Vrska, 2019; LaCanne e Lundgren, 2018; McLennon et al., 2021; Ranganathan et al., 2020; Schreefel et al., 2020; Soto et al., 2020.
Challenges	Al-Kaisi e Lal, 2020; Fassler et al., 2021; Giller et al., 2021; Gordon et al., 2022; Gosnell et al., 2019; McGuire et al., 2020; Mitchell et al., 2019; Newton et al., 2020; Ranganathan et al., 2020; Schreefel et al., 2020; Tittonell et al., 2022.

Source: Compiled by the authors.

Practices: Among the identified practices, notable mentions include the use of cover crops, crop rotation, and the combination of crop rotation with livestock grazing (Gibbons, 2020; Ranganathan et al., 2020; Anderson and Riviera, 2021; Duncan et al., 2020; Giller et al., 2021; McLennon et al., 2021; Schreefel et al., 2020; Loring, 2022). Cover crops are implemented to protect the soil after the harvest of the main crop, improving water retention and providing resilience against extreme weather events, such as droughts and floods. Additionally, these crops contribute to soil recarbonization (Gibbons, 2020; Anderson and Riviera, 2021; Duncan et al., 2020; Giller et al., 2021; Loring, 2022). Such soil conservation and restoration practices are fundamental for adapting to and mitigating climate change, promoting soil resilience and atmospheric carbon capture.

Crop rotation, which involves planting three or more species over several years, combined with alternating livestock grazing, is an effective strategy for enhancing soil biodiversity, promoting the health of plants and animals, and reducing dependence on external inputs, such as fertilizers and pesticides (Gibbons, 2020; Anderson and Riviera, 2021; Duncan et al., 2020; Giller et al., 2021; Loring, 2022). These practices not only strengthen the resilience of agricultural systems but also contribute to the long-term sustainability of agriculture, generating significant environmental benefits.

Actors: The category of actors is crucial for mapping the agents involved in Regenerative Agriculture (RA). The main identified actors include farmers, agri-food corporations, governments, and civil society. RA has attracted the attention of policymakers, farmers, researchers, consumers, and agri-food companies, both local and multinational, encompassing agricultural operations, financial institutions, chemical input companies, and food processors

(Gosnell et al., 2019; Al-Kaisi and Lal, 2020; Newton et al., 2020; Schreefel et al., 2020; Tittonell et al., 2022). Interest in RA extends across public, private, and non-profit sectors.

In the public sector, governments at both international and local levels have explored RA as part of their climate action plans (Newton et al., 2020). The Intergovernmental Panel on Climate Change (IPCC, 2018) recognized RA as a sustainable land-use management practice, highlighting its effectiveness in building resilience in agroecosystems. Locally, municipal governments in the USA have also investigated the potential of RA to achieve sustainability goals (Newton et al., 2020).

In the private sector, large agri-food companies have adopted RA practices, such as the Regenerative Organic Alliance, which has established a certification program for regenerative agriculture, and General Mills, which has committed to promoting RA on over 400,000 hectares by 2030 (Newton et al., 2020). Furthermore, many companies frequently integrate RA into their corporate sustainability programs, reflecting the growing interest and importance attributed to this approach (Ranganathan et al., 2020; Newton et al., 2020; Tittonell, 2022).

Benefits: Regenerative Agriculture (RA) offers a range of significant benefits, promoting sustainability and addressing the challenges posed by climate change. Its acceptance across various sectors—political, private, and non-profit—results in increasing support and adoption of these practices at different levels of society. This dynamic can create a favorable environment for widespread dissemination and implementation, culminating in substantial environmental, economic, and social benefits.

RA promotes the restoration of degraded ecosystems, increases the resilience of agricultural systems in the face of adverse climatic conditions, and enhances soil carbon sequestration, contributing to the reduction of greenhouse gas emissions (Gibbons, 2020; Anderson and Riviera, 2021; Duncan et al., 2020). These factors provide farmers with the opportunity to adopt regenerative practices, access markets, and implement innovations that elevate the resilience of their agricultural systems.

Challenges: Regenerative Agriculture (RA) faces various challenges in the context of climate change and the transition from conventional agricultural systems. Increasingly uncertain climatic conditions, such as extreme weather events and intense seasonal variations, can negatively impact regenerative agricultural practices (Fassler et al., 2021; Gordon et al., 2022; McGuire et al., 2020). Water scarcity, driven by changes in precipitation patterns and increased evaporation due to global warming, represents a significant challenge for RA (Giller et al., 2021; Mitchell, 2019; Schreefel et al., 2020).

Moreover, the transition from conventional agricultural systems to regenerative practices encounters obstacles, such as institutional and cultural resistance, lack of knowledge and practical experience, and issues related to access to resources, such as land, financing, and appropriate technology (Giller et al., 2021; McGuire et al., 2020; Schreefel et al., 2020). The complexity of ecological interactions in regenerative agricultural systems necessitates more holistic and integrated management approaches, which may be more challenging than in simplified conventional systems (Fassler et al., 2021; Soto et al., 2021; McLennon et al., 2021).

These challenges underscore the need for public policies and support programs that encourage and facilitate the transition to RA, addressing the practical and structural barriers

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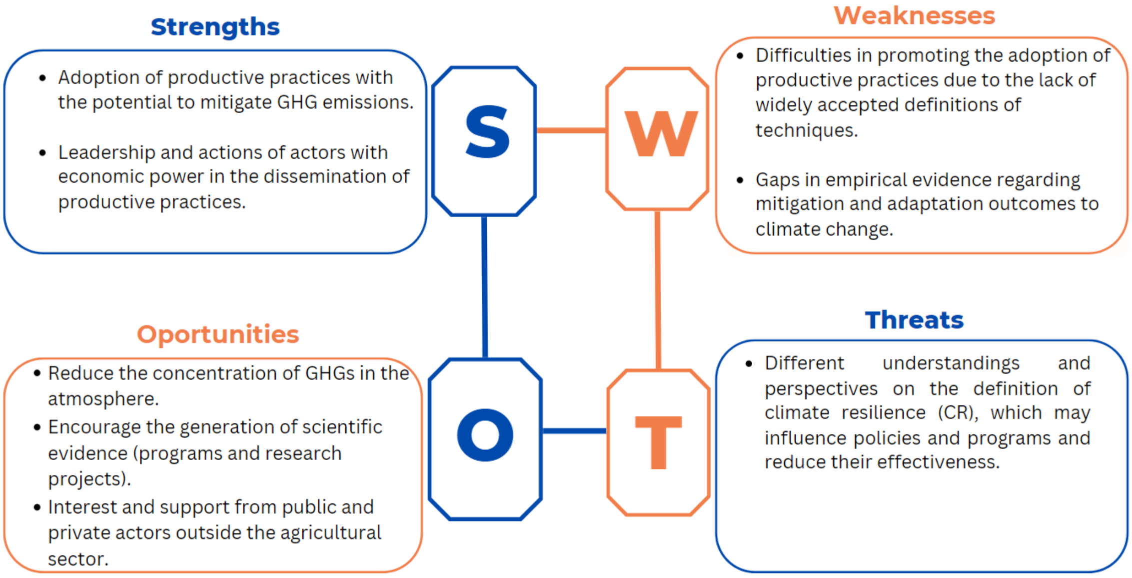
faced by farmers. Based on the analysis categories, the following SWOT Matrix has been developed (Figure 4):

Figure 4 – SWOT Matrix of Regenerative Agriculture for Transforming the Agri-Food System with a Focus on Climate Change



Source: Elaborated by the authors, 2024.

The application of SWOT analysis (Figure 4) reveals that regenerative agriculture possesses notable strengths, including the promotion of practices that align with the reduction of greenhouse gas emissions, as well as the involvement of economically prominent stakeholders, who may assume a pivotal role in the dissemination of such practices. Nevertheless, the weaknesses are characterized by the absence of a clear definition and the inconsistent implementation of techniques, which may impede adoption by agricultural producers.

Conversely, the opportunities associated with regenerative agriculture are fueled by an increasing recognition of its benefits, the establishment of supportive public policies, and a rising consumer demand for sustainable products. However, the threats confronting regenerative agriculture include the lack of a shared understanding of the term "regenerative agriculture" and the absence of a broadly accepted definition, which could undermine its viability as an effective alternative in the context of climate change mitigation.

4 CONCLUSION

The increasing vulnerability of the agri-food system to climate change necessitates a critical and comprehensive reassessment of the strategies currently employed to ensure food security in the context of a growing population. This article underscores the urgency of a profound understanding of the fundamental aspects surrounding the implementation of alternative approaches, such as agroecology and Regenerative Agriculture (RA), in transforming the global agri-food system (AFS).

Through a meticulous analysis of productive practices, the key stakeholders involved, and the emerging benefits and challenges, this study aims to contribute to the academic discourse by highlighting the potential of these approaches to mitigate greenhouse gas emissions and enhance local climate resilience. However, the lack of robust evidence demonstrating concrete results in mitigating climate change represents a significant vulnerability, necessitating further investigations.

Moreover, while agroecological and regenerative approaches appear promising for optimizing agricultural production and addressing climate challenges, the resistance from proponents of conventional agricultural models, along with the absence of consistent political support, poses substantial barriers to their dissemination. In the specific case of RA, the conceptual ambiguity surrounding its definition may compromise its effectiveness and, consequently, its long-term impact.

Therefore, it is imperative that future research not only deepens the evaluation of specific practices that foster climate resilience but also investigates the sociopolitical dimensions influencing the adoption of these approaches. Additionally, the results related to greenhouse gas emissions reduction must be highlighted, ensuring that implementations occur equitably and justly within agri-food systems.

In summary, the severity of the challenges posed by climate change renders the urgent development and implementation of innovative policies and sustainable practices essential. Only in this manner will it be possible not only to mitigate the adverse effects of climate change but also to secure a resilient and sustainable agricultural future capable of addressing the global food crisis.

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