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From sustainable agriculture to sustainable agrifood systems: A comparative review of alternative models

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Review

From Sustainable Agriculture to Sustainable Agrifood Systems: A Comparative Review of Alternative Models

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Abstract: This paper reviews, compares, and critically evaluates two broad groups of sustainable agriculture models: "sustainable agriculture" and "sustainable agrifood systems". The "sustainable agriculture" models—comprising organic farming, regenerative agriculture, climate-smart agriculture, carbon-capture agriculture, and nature-based solutions—focus primarily on improving ecological sustainability through farm-level practices. These models emphasize reducing external, industrial inputs, enhancing biodiversity, and promoting climate resilience, relying on technological and market-based solutions to address environmental concerns. On the other hand, the "sustainable agrifood systems" models—agroecology, alternative food networks, and permaculture—offer more ambitious visions of systemic transformation. These approaches not only seek to implement environmentally sound practices but also aim to reconfigure the broader food system by challenging corporate power, promoting local governance, fostering food sovereignty, and prioritizing social justice. Grounded in grassroots movements, these models emphasize social justice and economic viability in addition to ecological sustainability. This paper's contribution lies in its comparative analysis of the wide array of sustainable alternatives, highlighting both their strengths and limitations. Adopting an agrarian political economy perspective, it critiques the former camp for limited engagement with structural issues inherent in capitalist agriculture and the latter camp for underplaying the importance of industrial agriculture for national development in the Global South.

Keywords: sustainability; industrial agriculture; agroecology; climate-smart agriculture; alternative food networks; organic farming

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1. Introduction

The current industrial agrifood system is widely recognized as being ecologically unsustainable, socially inequitable, and economically unjust [1–3]. It relies heavily on monoculture, high levels of synthetic chemical inputs, intensive energy and resource use, and globalized supply chains, all of which contribute to soil degradation, loss of biodiversity, water pollution, and greenhouse gas emissions [4–6]. This system often prioritizes short-term productivity and profitability over long-term ecological health, resulting in declining soil fertility, increased vulnerability to climate change, and the erosion of smallholder farming practices [7]. Economically, the industrial agri-food system tends to concentrate power in the hands of a few multinational agribusiness corporations, marginalizing small-scale farmers and entrenching global inequalities in food production and distribution [8,9]. Socially, it perpetuates injustices, including land dispossession, poor labor conditions, and the erosion of local food cultures and traditional knowledge [10,11].

In response to these systemic issues, various alternative practices and models have emerged, each proposing different approaches to address the flaws of the industrial agrifood system and to achieve greater ecological, economic, and social sustainability [12,13]. Recent global initiatives like the UN Sustainable Development Goals (SDGs) and the Paris Climate Agreement have also emphasized the need for transforming food systems to address climate change, food security, and environmental degradation [1]. These alternatives include those that propose more sustainable agricultural practices—often grouped under the umbrella of "sustainable agriculture"—such as organic farming, nature-based solutions, climate-smart agriculture, carbon-capture agriculture, and regenerative agriculture [14–17], as well as those that advocate for the transformation of the agrifood system—grouped under "sustainable agrifood systems"—such as agroecology, permaculture, and alternative food networks [18–20]. The presence of this diverse array of concepts, each with its own emphasis, historical origins, and ideological inclinations, has rendered both "sustainable agriculture" and "sustainable agrifood systems" vague and ambiguous. This article seeks to clarify these competing models and concepts through a comparative review.

Although these diverse alternatives share some common goals, they diverge in their emphasis on various dimensions of sustainability, as well as in their relationships to modern science, markets, and agrarian capitalism. Previous literature reviews on sustainable agriculture and agrifood systems sought to provide thorough examinations of relevant research literature and illustrate the variety in the components, goals, and approaches to sustainable alternatives in these models [12,13,21–23]. However, these reviews did not focus on comparing the competing models of sustainable alternatives, nor did they critically evaluate these models or assess the transformative potential and feasibility of their respective visions of sustainability against each other. To fill this gap, this paper will clarify, compare, and critically evaluate these competing conceptions of sustainable agrifood alternatives, examining their varying emphases on ecological, economic, and social sustainability, as well as their differing ideological relationships with the industrial agrifood system. Drawing on relevant academic literature and policy debates, this review aims to clarify how these concepts interact, where they converge, and where they diverge. Due to the extensive nature of this comparative review, it will not explore the varied conceptions and practices within each model in detail, nor can it offer detailed reviews of the implementations of these models in the real world. The aim here is to provide a comparative overview that outlines the main approaches in sustainable agrifood alternatives.

2. Competing Conceptions of Sustainable Alternatives

This section reviews the various alternative agricultural practices as well as agrifood systems that have been proposed as remedies to the current industrial agriculture and globalized agrifood system. These alternative models arose from different scientific, economic, and social frameworks, each offering unique approaches to addressing the shortcomings of the dominant industrial agrifood system. Some focus on farming techniques and practices that can either reduce external inputs or mitigate the impacts of climate change; others go beyond agricultural practices to seek transformations in distributive networks and consumption behaviors; still, others advocate for systemic changes in the agrifood system through reforming land distribution, global trade, and agrarian politics. These diverse perspectives reflect not only differences in how sustainability is envisioned but also varying views on the role of technology, markets, and social equity in transforming food systems. This review examines and critically compares these alternative models, highlighting their strengths, limitations, and implications for sustainable agriculture globally. This paper begins with five models that focus on farm-level agricultural practices, which are grouped under "sustainable agriculture", and then discusses three models that extend beyond the farm level and propose more systemic transformations, which are grouped under "sustainable agrifood systems".

2.1. Sustainable Agriculture

Organic farming, proposed in the early 20th century by Rudolf Steiner, is a holistic farming system that avoids synthetic inputs and genetically modified organisms while promoting ecosystem integrity [24]. Organic agriculture can contribute to sustainability by minimizing environmental impacts, preserving soil and water quality, reducing nonrenewable resource use, and increasing carbon sequestration [24,25]. Organic agriculture has been formalized into certification standards, particularly in the Global North, often focusing on inputs—prioritizing the avoidance of synthetic fertilizers, pesticides, and genetically modified organisms (GMOs)—rather than system changes. Among all the models of sustainable alternatives, organic agriculture is the most widely practiced and most mature [26,27]. However, this wide application has led to increased co-optation by agribusinesses and thus, "conventionalization" of organic farming [28,29]. While organic farming has shown benefits, including higher biodiversity, improved soil quality, and enhanced profitability [30], it also faces challenges in raising productivity, increasing affordability, and reducing per-unit greenhouse gas emissions [27,31–33].

Regenerative agriculture (RA) is an evolving approach to farming that aims to enhance ecosystem services, improve soil health, and promote sustainability [34,35]. The concept originated in the 1950s but has gained significant attention recently. RA focuses on soil conservation, biodiversity, and ecological resilience and seeks ecosystem restoration through practices like no-till farming, cover cropping, and rotational grazing [34–36]. While there is no standardized definition, RA generally involves practices such as cover cropping, livestock integration, and reduced tillage [37,38]. It aims to regenerate agricultural resources and promote soil health, carbon sequestration, and biodiversity [16,35,39]. While offering strong ecological benefits, RA is often seen as more accessible to wealthier farmers, limiting its broader transformative potential. Its recent resurgence can be linked to climate change concerns and the need for carbon sequestration strategies by corporations [36,38].

Climate-Smart Agriculture (CSA) was first proposed in 2009 as an approach to address food security and climate change challenges in agriculture, aiming to achieve three goals: boosting productivity, enhancing resilience, and mitigating greenhouse gas emissions [40,41]. The concept has evolved through stakeholder interactions and debates on sustainable agriculture [40]. CSA embraces a technocratic approach, focusing on increasing productivity, adaptation, and mitigation of climate impacts through modern technologies and markets [42]. While CSA provides space for holistic approaches, it has been criticized for its apolitical framework, its narrow focus on technical fixes, its top-down approach, and its alignment with corporate-led models of agriculture [43]. Unlike other sustainable practices discussed here, CSA lacks a specific set of criteria, allowing any practice that offers incremental improvements toward the three sustainability goals to be labeled as CSA [43,44]. As a result of this vagueness in definition, the application of CSA varied widely in practice across settings [45], and conventional producers have often co-opted this label to green-wash their continuation of business-as-usual [46,47].

Carbon-capture agriculture, also known as carbon farming, aims to sequester atmospheric CO_2 in soil and biomass to mitigate climate change while enhancing agricultural productivity [48,49]. This concept has evolved from early proposals of soil carbon sequestration to more comprehensive approaches integrating various practices. Key practices include no-till farming, cover cropping, agroforestry, crop residue retention, and applying organic amendments like manure, compost, and biochar [17]. While results may vary depending on factors such as climate and soil conditions, carbon farming can increase crop yields, improve soil quality, and reduce water requirements; it also offers potential for negative emissions when combined with bioenergy and carbon capture systems [48–50]. Limitations include the need for widespread adoption and the time required for soil carbon pools to stabilize [51]. In addition, while this approach has been championed for its climate mitigation potential, its reliance on market-driven mechanisms such as carbon offsetting has raised concerns about its long-term viability and equity, especially for small-scale farmers [47].

Nature-based agriculture, also known as "nature-based solutions" (NBSs) in agriculture, encompasses approaches that draw from natural processes to enhance ecosystem functions and sustainability [52]. It focuses on water conservation, habitat restoration, and biodiversity promotion, aiming to improve agricultural productivity and ecosystem services. NBSs include practices like soil and landscape management, which address environmental challenges and can lead to increased crop yields, reduced pesticide use, and improved carbon sequestration [53,54]. These solutions, when applied in agriculture, also offer potential benefits in related sectors, such as tourism [55]. However, NBS implementation requires collaboration across multiple disciplines and stakeholder involvement [56]. Despite its promise, critics argue that NBSs are susceptible to co-optation by agribusinesses and international organizations, allowing them to continue unsustainable practices under the guise of ecological benefits. This has led to concerns that, similar to CSA, NBSs may serve as superficial greenwashing efforts without leading to substantial systemic changes in agriculture [57]. Ensuring the wider adoption of NBSs, especially in developing countries, will require the development of supportive policies and frameworks [53,54].

Summary: The five models of sustainable agriculture—organic farming, RA, CSA, carbon-capture agriculture, and NBS—are aligned in their emphasis on ecological sustainability, seeking to improve soil health, biodiversity, water management, and carbon sequestration. They address the environmental consequences of industrial agriculture and promote climate resilience through distinct strategies. Organic farming, RA and NBS focus on avoiding synthetic inputs and restoring soil health, while CSA and carbon-capture agriculture rely on technology and innovation to boost productivity and capture carbon.

A shared limitation of these models is their emphasis on technical solutions at the farm level, focusing on specific practices such as no-till farming, cover cropping, and agroforestry. While these are valuable, they primarily function within the existing agrifood system and yield incremental improvements in sustainability without tackling broader structural issues. These models are criticized for not addressing the power dynamics and inequalities inherent in the global agrifood system and sidestepping the socio-political dimensions of sustainability, such as land reform, equitable access to resources, and the redistribution of power. Particularly, CSA, carbon-capture agriculture, and NBS are often co-opted by agribusinesses and international organizations as instruments of greenwashing, allowing them to claim sustainability without enacting meaningful change [43,57].

Additionally, these approaches tend to benefit wealthier farmers who can afford the necessary technologies, leaving behind smallholders and marginalized communities [28,47]. Shorter supply chains, fairer trade practices, and food sovereignty are often sidelined in favor of market mechanisms that perpetuate the status quo. As such, while these models offer valuable tools for promoting sustainability, they require a broader systemic change that addresses the political-economic structures of the global agrifood system if they are to achieve true sustainability [58].

2.2. Sustainable Agrifood Systems

The limitations of these models of "sustainable agriculture" make it clear that sustainability cannot be achieved through farm-level practices alone. The focus on technocratic solutions and incremental improvements in ecological sustainability overlooks the broader structural inequalities and power dynamics that define the global agrifood system. To truly address the root causes of unsustainability, we need to shift from thinking about "sustainable agriculture" as isolated practices toward a more holistic view of "sustainable agrifood systems". Three such models have been proposed and practiced.

Alternative Food Networks (AFNs) are initiatives that challenge the conventional industrial food system and aim to create more sustainable, equitable, and localized food systems by reconfiguring the relationships between food producers, consumers, and markets [59,60]. AFNs include initiatives such as farmers' markets, community-supported agriculture, food co-operatives, fair trade systems, and urban agriculture. These networks challenge the dominant, industrial agrifood system by focusing on localization, shorter supply chains, and ethical food production while promoting environmental sustainability, social justice, and consumer-producer transparency [61,62]. These diverse forms and practices of AFNs have different degrees of "alterity": the weaker ones focus on providing "alternative foods" for urban consumers who want alternatives to the poor quality of industrial food, while stronger ones create "alternative distributive networks"—the localized short supply chains through which the food passes through—that build new social ties and increase sustainability in distribution and consumption [60].

While AFNs also promote sustainable agricultural practices such as organic farming and regenerative agriculture to produce “alternative foods”, they go beyond these farm-level technical fixes and aim to reconfigure the relationships within the food system and foster deeper systemic changes that can challenge the political economy of industrial agriculture. A key approach through which AFNs go beyond the farm-level focus of “sustainable agriculture” is addressing the power imbalances that characterize the industrial agrifood system. AFNs advocate for the re-localization of food systems, where smallholders, local communities, and consumers have greater control over how food is produced, distributed, and consumed [62]. This stands in stark contrast to sustainable agriculture models that are often co-opted by financial corporations and agribusinesses, which continue to dominate global food production. By decentralizing power and promoting community-driven food systems, AFNs aim to dismantle the corporate concentration of power in the food supply chain and empower marginalized communities—especially smallholder farmers, Indigenous groups, and women—by promoting local control over land and resources, equitable access to markets, and fair labor practices [61].

AFNs have been successful in creating niche markets for local, organic, and fair-trade products, but they are sometimes criticized for being elitist and inaccessible to lower-income communities [61]. While AFNs offer potential benefits in terms of sustainability and social justice, they face limitations including increased labor intensity for both farmers and consumers, challenges in scaling up, and tensions between social and environmental goals [63,64]. The sustainability promise of AFNs is subject to debate, with concerns about the sufficiency of impact and potential counter-effects [20].

Permaculture, developed by Bill Mollison and David Holmgren in the 1970s, is a design philosophy and a holistic approach to the sustainable design of human settlements and agricultural systems, focusing on creating self-sustaining ecosystems that mimic natural processes [65,66]. It advocates for small-scale, diversified farming systems that integrate plant, animal, and human components in a closed-loop system [15]. Permaculture extends beyond agriculture to incorporate the sustainable design of human habitats and communities, addressing energy use, waste management, and sustainable living. Permaculture principles draw from scientific ecology, Indigenous knowledge, and creative design and advocate working with nature, not against it, by applying perennial polycultures, water conservation techniques, and landscape heterogeneity [65,67]. As a movement, permaculture also challenges conventional agricultural knowledge systems by promoting farmer-led innovation and experimentation and addressing food justice, land rights, and food sovereignty issues by empowering smallholder farmers and local communities [68,69]. Although permaculture has gained popularity in the Global North and has spread globally, adapting to diverse contexts and scales [70], it has faced criticism for being idealistic and disconnected from the socio-economic realities of food production, especially in the Global South [67].

In contrast to the prevailing industrial agrifood system characterized by monoculture, reliance on industrial inputs, and profit-driven production, permaculture emphasizes ecological design, diversity, and self-reliance and advocates for closed-loop systems where waste is recycled into the system, reducing environmental harm and resource depletion [67,71]. Permaculture explicitly challenges the corporate concentration and centralized control in the industrial agrifood system by encouraging farmer-led innovation, knowledge sharing, and collaborative governance [68,70].

Agroecology, one of the central pillars of food sovereignty movements, is often framed as a transformative solution to the corporate-led industrial food system. Defined as both a scientific approach and a social movement, agroecology focuses on sustainable farming practices, such as diversified cropping systems, agroforestry, soil health and fertility management, integrated pest management, seed sovereignty, and farmer-to-farmer knowledge sharing, that integrate ecological principles with local farmer knowledge [7]. It integrates ecological principles with traditional farming practices to promote sustainability across environmental, social, and economic dimensions. Agroecology also emphasizes food sovereignty and is closely aligned with grassroots movements in the Global South, where it is seen as a tool for resisting the corporate dominance of agriculture [18].

Agroecology, as a movement, places smallholders at the center of its vision for food sovereignty—the right of people to control their own food systems, including land, seeds, and markets [58]. By promoting farmer-led innovation, community-based agriculture, and local food systems, agroecology aims to decentralize control over food production and empower small-scale farmers and marginalized communities [19]. The use of local seeds, indigenous knowledge, and farmer-to-farmer networks reduces farmers' dependency on multinational corporations and enhances their autonomy. This democratization of the food system challenges the top-down, profit-driven logic of industrial agriculture.

Similar to AFNs, agroecology also critiques the industrial agrifood system's emphasis on globalized supply chains and market-driven production and calls for a fundamental transformation of the agrifood system, emphasizing local markets, short supply chains, and collective control over food systems. This promotes fairer pricing for farmers, reduces the environmental footprint of food production, and fosters stronger, more resilient local economies [72].

As a movement advocating for smallholders' food sovereignty, agroecology has garnered strong support in the Global South. Cuba is widely considered to have had the largest-scale implementation of agroecology, where it improved food security, increased staple crop production, and enhanced forest cover [73,74]. Similar positive outcomes were observed in Ethiopia, where agroecological practices improved food security indicators and farmers' livelihoods [75], and in India and Uruguay, where women's empowerment has been a notable benefit [76,77].

Summary: The similarities between permaculture and agroecology are obvious (some even consider permaculture a form of agroecology [3]): both frameworks are deeply committed to sustainability, resilience, and ecological integrity in agricultural systems and pursue these goals through integrating sustainable farming practices and social movements that empower smallholder farmers and re-localize agrifood supply chains. The key differences between them lie in their strategic approaches—with agroecology adopting a more politically engaged, systemic change model, and permaculture emphasizing localized, design-based solutions. Furthermore, while permaculture often operates outside formal political structures and focuses on local, grassroots initiatives and individual or community-led solutions to sustainability challenges, agroecology is deeply embedded in political activism and calls for systemic change at both national and international levels, advocating for land redistribution, policy reforms, and social justice as integral to creating sustainable food systems.

AFNs, on the other hand, differ from permaculture and agroecology in that their primary focus is on reconfiguring market relationships and supply chains. AFNs address issues like consumer–producer transparency, fair trade, and localization of food markets, which differentiates them from the more farm-focused approaches of permaculture and agroecology. AFNs have, therefore, been criticized for being overly consumer-focused and neglecting the production side [64].

Overall, all three approaches recognize that the environmental, social, and economic crises in agriculture are symptoms of deeper systemic issues, such as the concentration of corporate power, land inequities, and the exploitation of labor. Rather than viewing sustainability as simply a matter of tweaking farming techniques, these models confront the political–economic structures that govern the distribution of resources, decision-making power, and market access within the food system. In doing so, they advocate systemic transformations that not only promote ecological health but also ensure social justice, food sovereignty, and economic equity for all actors in the food chain—especially smallholders, farm workers, and marginalized communities.

3. Comparing the Approaches to Sustainability

This section compares how the models we have reviewed approach the various goals of sustainability. Sustainability in the agrifood system is a complex and multi-dimensional concept that seeks to balance the needs of food production and consumption with environmental conservation, economic viability, and social equity [78]. The following is an analysis of sustainability in three interconnected dimensions: ecological, economic, and social sustainability.

3.1. Ecological Sustainability

Ecological sustainability in agriculture emphasizes preserving natural resources and reducing environmental impacts. It is evaluated here in four aspects. First, **soil health**, which is crucial for nutrient cycling, water retention, and carbon sequestration, ultimately boosting productivity and resilience [79]. Another important factor is **biodiversity**, which promotes ecological balance and enhances pest control, pollination, and resilience against extreme weather [80]. Third, to mitigate environmental degradation, sustainable systems aim to **reduce external inputs** (both materials and energy), emphasizing low or no-input systems to maintain natural processes [81]. Lastly, **climate resilience** is increasingly vital as agricultural systems face climate change impacts [82]. Practices like agroforestry, water conservation, and cultivating resilient crops help ecosystems recover from disturbances. All eight models of sustainable alternatives aim to address these four key goals of ecological sustainability, but their approaches and scope of implementation differ slightly.

In terms of soil health, organic farming aims to build soil fertility through the use of organic amendments like compost and manure, while eliminating synthetic fertilizers and pesticides that harm soil structure and biodiversity [83]. RA, NBS, agroecology, and permaculture focus on regenerative practices such as no-till farming, cover cropping, perennial polycultures, and rotational grazing to enhance soil organic matter, improve soil structure, and prevent erosion. For CSA and carbon-capture agriculture, soil health is an important outcome but is not the central focus of the models. The practices they advocate for carbon capture or climate resilience are nearly identical to those advocated by the other models and thus, lead to improved soil health [41]. AFNs show the least direct concern with soil health, but the localized food systems and quality food production they promote also need to adopt agroecological and organic methods, which contribute to soil health.

Modern agriculture has become both energy-intensive and heavily reliant on external, industrial inputs [84]. A primary aim of most sustainable agriculture practices is to reduce external energy input and reduce or eliminate synthetic chemical use to benefit the environment and human health. Organic farming is highly stringent in banning synthetic chemicals and focusing on organic fertilizers and biological pest control. This practice, however, can inadvertently increase the energy consumption caused by transporting organic inputs from afar [85]. RA, NBS, and agroecology all aim to minimize chemical inputs by promoting natural pest control and nutrient cycling, though some external inputs may be allowed depending on the system. Permaculture goes further by fostering self-sufficient ecosystems that eliminate the need for external inputs entirely. CSA and AFNs often support farms using low-input practices, particularly organic and agroecological methods, though the reduction in chemical inputs is not always a formal requirement. Unlike AFNs, however, both CSA and carbon-capture agriculture also advocate the use of new technologies to reduce energy use and carbon emissions [84] without explicitly rejecting synthetic fertilizers.

Agroecology, permaculture, and NBS place the strongest emphasis on biodiversity, promoting polycultures, agroforestry, and intercropping to mimic natural ecosystems and enhance ecosystem services [15,53,58]. Organic farming and RA also encourage diversified cropping and habitat creation, though their focus is more on individual farms. AFNs indirectly support biodiversity by fostering small-scale, local farms that frequently adopt agroecological or organic methods, enhancing biodiversity at the community level. For climate-smart and carbon-capture agriculture, biodiversity is an expected outcome but not the central focus of the models [42].

When it comes to climate resilience, CSA addresses it most directly by incorporating adaptation and mitigation strategies, such as drought-resistant crops and efficient water management, to ensure productivity during climate shocks. RA and agroecology enhance resilience through diversified farming systems, soil health improvements, and agroforestry, buffering farms against climate variability. Permaculture contributes to resilience by creating self-sustaining, closed-loop systems that conserve water and energy. Carbon-capture agriculture focuses on carbon sequestration but also indirectly enhances resilience by improving soil structure and water retention. NBSs use landscape restoration and reforestation to strengthen resilience in both agricultural and natural systems. AFNs support climate resilience by fostering localized food systems that reduce dependency on long, vulnerable supply chains.

3.2. Economic Sustainability

Economic sustainability in agriculture involves ensuring that farmers can maintain livelihoods, support local economies, and adapt to market fluctuations, all while operating in environmentally and socially responsible ways [86]. This is evaluated here in three aspects [87]. First, **economic viability** is essential for all stakeholders, requiring fair wages for workers, stable income for farmers, and reduced dependency on costly inputs. Second, **resilience to market fluctuations** can be enhanced through shorter supply chains, local markets, and stronger social relationships, which offer farmers more stable prices by connecting them directly with consumers. Last, **local food economies** also play a crucial role, as they reduce reliance on globalized supply chains, minimize transportation costs, and create market opportunities for smallholders. Local systems strengthen ties between producers and consumers, fostering food security, reducing environmental impacts, and supporting rural development.

When it comes to economic viability, the eight models vary in their approaches, particularly in how they support smallholder producers. Agroecology and permaculture prioritize the economic well-being of smallholders by reducing dependency on costly external inputs through self-sustaining practices. Organic farming and RA share a similar approach, eliminating synthetic inputs, though it can pose higher costs for certification, making it more accessible to mid-size and larger producers [27]. CSA and carbon-capture agriculture show little concern for the differentiation among producers or their differences in resource endowment, but their approaches are often more aligned with large-scale operations or government programs and harder for smallholders to access the benefits [47]. NBSs, while focusing on ecosystem services and providing long-term economic benefits, often require external funding or state support for implementation [56]. AFNs, through models like community-supported agriculture and farmers' markets, directly link producers and consumers, offering smallholders greater control over pricing and more stable income streams, though these networks can be labor-intensive and limited in scale [63].

In terms of resilience to market fluctuations, agroecology, permaculture, and RA offer strong protection for smallholders by promoting diversified farming systems and reducing reliance on global commodity markets and external inputs. These models enable farmers to generate multiple income streams, making them less vulnerable to market price volatility [37,74]. AFNs also provide resilience by connecting producers directly with consumers, ensuring fair prices and reducing dependence on intermediaries. Organic farming offers some protection through premium pricing for certified products, but organic producers still face exposure to the global market's volatility, and the certification process can be costly, particularly for smallholders [88]. Climate-smart and carbon-capture agriculture, while helping farmers adapt to climate risks, are more closely tied to global markets and state-led programs, which can leave farmers susceptible to changes in international trade and policy. NBSs focus on building long-term resilience through ecosystem services, which can provide stability but often rely on external funding or market-based mechanisms like carbon credits, which may fluctuate [52].

Finally, when it comes to supporting local food economies, AFNs are the most explicitly focused on fostering direct, local connections between producers and consumers [60]. Agroecology, permaculture, and RA also emphasize the importance of local economies by promoting small-scale, diversified farming systems that are better integrated into local communities and less reliant on global supply chains. Organic farming, while encouraging local production in some contexts, often operates within both local and global markets, depending on certification and consumer demand [28,89]. For CSA and carbon-capture agriculture, their goals of climate mitigation and adaptation often align with broader international policies and markets, making them less oriented toward supporting local economies [41]. NBSs, while centered on ecosystem restoration, can support local economies by generating employment in environmental management, but they typically require external funding and are often implemented through larger-scale projects that may not always prioritize local food systems [90].

Overall, agroecology, permaculture, and AFNs are the most committed to strengthening local food economies, offering more immediate benefits to smallholders, and greater market resilience through diversification. However, these models often face challenges related to scalability and market access. On the other hand, CSA, carbon-capture agriculture, and NBSs tend to operate within broader, often global frameworks, relying more on external markets, policies, and institutional support, and have been criticized for reinforcing globalized supply chains and corporate dominance [43,47].

3.3. Social Sustainability

Social sustainability in agriculture focuses on creating equitable food systems that promote community well-being, preserve traditional knowledge, and ensure food justice [91]. First, addressing **food justice and equity** is essential, particularly for smallholder farmers, women, and Indigenous communities often marginalized in agricultural development [92]. Second, social sustainability also involves the preservation and integration of Indigenous and **traditional knowledge** [93]. Third, **community engagement** is another critical aspect, where participatory approaches empower communities to take ownership of their food systems [56,94]. Finally, stronger **producer–consumer relationships** build trust and transparency, support small-scale farmers, and ensure food production meets local needs.

The eight models vary significantly in their concern with food justice and equity. Agroecology and AFNs place food justice at the core of their frameworks, explicitly addressing issues like equitable access to land, resources, and markets for marginalized communities [95]. These models challenge corporate control over food systems and advocate for the redistribution of resources and power. Permaculture focuses more on self-reliance and sustainability rather than directly confronting systemic inequities. RA and organic farming promote fairness through sustainable farming practices but tend to focus more on environmental goals, leaving food justice as a secondary consideration. CSA and carbon-capture agriculture lack an explicit focus on equity, and critics argue that they may reinforce existing power structures by aligning with large-scale, corporate-driven models [43,47]. NBSs typically prioritize ecological outcomes over direct engagement with issues of food justice.

With regard to traditional knowledge, agroecology explicitly values the traditional agricultural knowledge of smallholders and Indigenous communities, promoting seed sovereignty, local biodiversity, and centuries-old ecological practices that are tailored to local environments [93]. Permaculture similarly draws on Indigenous knowledge systems, emphasizing working with natural ecosystems to create self-sustaining food systems [68,69]. RA incorporates some elements of traditional farming, though it tends to focus more on modern, scientifically validated approaches [36]. Organic farming is more driven by certification standards and does not prioritize the inclusion of local or Indigenous knowledge. AFNs support the use of traditional farming methods indirectly by promoting localized, small-scale farms, which often rely on traditional practices [96]. CSA and carbon-capture agriculture, in contrast, tend to focus on modern technological solutions and market mechanisms rather than traditional knowledge. NBSs may incorporate traditional ecological practices in the context of landscape restoration, but traditional knowledge is typically a secondary concern [53].

Agroecology and AFNs place a strong emphasis on participatory approaches, fostering active involvement of farmers, consumers, and local communities in decision-making processes. Permaculture also supports community engagement, though its focus is more on creating self-sustaining, localized systems that encourage communal participation in ecological design and land management. RA can promote community involvement through collective landscape management and farmer collaboration, but it tends to prioritize technical solutions over community-driven decision-making [16]. Organic farming typically engages communities around consumer awareness and certification but is less participatory in terms of decision-making at the farm or community level [97]. CSA and carbon-capture agriculture, on the other hand, tend to be more top-down, with a focus on technological solutions and policy frameworks rather than grassroots community engagement. NBSs can involve community participation in large-scale restoration projects, but they are often externally funded and managed, making direct, long-term community engagement less central [56].

Finally, producer–consumer relationships are central to several of these models, often overlapping with the emphasis on community engagement. AFNs, in particular, are designed to create direct, transparent connections between producers and consumers. Agroecology also supports close producer–consumer ties by promoting local food systems that are embedded in the community, though its primary focus is on farmer empowerment and ecological sustainability. Permaculture similarly encourages direct relationships through local, self-sustaining systems where consumers are often active participants in the design and maintenance of food production. In contrast, the rest of the models are less concerned with creating strong producer–consumer connections.

Social sustainability is the most contested area among these models. Agroecology and AFNs stand out for their strong emphasis on community-driven processes, participatory approaches, and direct producer–consumer relationships [18,62]. These models integrate traditional knowledge and engage deeply with issues of food justice and equity, aiming to address structural inequalities within the food system [18,61,67]. In contrast, CSA, carbon-capture agriculture, and nature-based solutions take more top-down, market-oriented approaches, focusing on modern, science-driven methods and broader environmental and economic goals, often sidelining community engagement and direct producer–consumer connections [43,47,57].

3.4. Summary

Table 1 summarizes the above comparative analysis of the eight sustainable alternatives across the three dimensions of sustainability. It is clear that the three models of "sustainable agrifood systems"—agroecology, permaculture, and AFNs—offer more ambitious and comprehensive approaches to sustainability than the five models of "sustainable agriculture", namely, organic farming, regenerative agriculture, CSA, NBSs, and carbon-capture agriculture. The agrifood system models address all aspects of ecological, economic, and social sustainability and seek to transform the food system beyond farm-level practices, offering more holistic and systemic change. In contrast, while the sustainable agriculture models contribute to ecological sustainability and offer some economic benefits, they tend to focus more on technological solutions and market mechanisms, often sidelining issues of social justice and community empowerment. Furthermore, while these sustainable agriculture models all proclaim to pursue social, economic and environmental sustainability in their rhetorics, their practical applications often reveal a different side. NBSs, for example, are often promoted by fossil-fuel companies and focus on nature-based carbon offsetting mechanisms such as tree planting, which help these corporations to buy carbon credits and continue their carbon emission.

Table 1. Comparison of sustainable agrifood alternatives: contributions to sustainability.

		Sustainable Agriculture					*Sustainable Agrifood Systems*		
		Organic Farming	**Regenerative Agriculture**	**CSA**	**Carbon-Capture Agriculture**	**NBS**	**AFN**	**Permaculture**	**Agroecology**
Ecological sustainability	Soil health	++	+++	++	++	+++	+	+++	+++
	Biodiversity	++	++	+	+	+++	++	+++	+++
	External input reduction	++	++	+	+	++	+	+++	++
	Climate resilience	+	++	++	++	++	+	+++	+++
Economic sustainability	Economic viability	++	++	+	+	+	+++	+++	+++
	Market resilience	+	++	+	+	++	+++	+++	+++
	Local food economies	+	++	+	+	+	+++	++	++
Social sustainability	Food justice and equity	++	+	+	+	+	+++	++	+++
	Traditional knowledge	++	++	+	+	++	++	+++	+++
	Community engagement	++	+	+	+	+	+++	+++	+++
	Producer-consumer relationship	+	+	+	+	+	+++	+++	+++

The number of '+' signs in each cell indicates each approach's level of emphasis on a given aspect of sustainability.

4. Evaluating Potentials

This section evaluates the transformative potential of the various sustainable agrifood alternatives by assessing both their ambitions for change and their feasibility. These two dimensions—ambition and feasibility—together determine the effectiveness of each model in creating a sustainable alternative and its capacity to gain support from key stakeholders, including governments, corporations, and civil society.

4.1. Ambition vs. Feasibility

As shown in the comparative analysis above, the transformative ambitions of the various sustainable agrifood alternatives differ significantly across ecological, economic, and social dimensions. In summary, the three "sustainable agrifood system" models offer more ambitious visions for systemic change, addressing all three aspects of sustainability, while the "sustainable agriculture" models tend to focus more on specific ecological or economic goals. Specifically, agroecology offers the most radical and comprehensive vision, aiming for systemic change by addressing ecological resilience, social justice, and food sovereignty. It challenges the corporate-dominated food system and seeks to empower marginalized communities, particularly in the Global South. Permaculture emphasizes local ecological and social transformation by fostering self-sufficiency and minimal waste, aiming to create resilient, localized food systems. AFNs focus on transforming social and economic relationships within the food system; while their ecological ambitions vary, they emphasize social justice and economic fairness.

On the other hand, regenerative agriculture and nature-based agriculture both focus primarily on ecological transformation, while operating within existing market structures. Even though regenerative agriculture shares commonalities with agroecology in terms of their ecological approaches, there are stark differences in their views on the social dimensions of sustainability: while agroecology sees sustainability "first and foremost as a political issue", regenerative agriculture downplays the social dimension [98]. Organic farming focuses mostly on ecological sustainability with very limited concerns with economic and social goals. CSA and carbon-capture agriculture both take a technocratic approach, emphasizing productivity, resilience, and climate mitigation, but their ambitions for systemic change are limited to incremental improvements.

Greater ambitions, however, often encounter stronger resistance from vested interests, require more resources and collective efforts, and demand higher levels of political support, all of which limit their feasibility [99–102]. The feasibility of these approaches depends on how receptive various stakeholders—such as governments, corporations, and civil society—are to their adoption.

Agroecology, while backed by strong grassroots movements, particularly in the Global South, faces significant challenges in scaling up due to resistance from agribusiness and global institutions that prioritize industrialized agriculture [18,102]. Its transformative potential is heavily dependent on widespread land reform and changes in global governance, making it less feasible in the short term [103]. However, agroecology has gained traction in regions such as Latin America, with governments in countries like Cuba and Brazil supporting agroecological policies and food sovereignty movements [58,75].

Permaculture is feasible on a small scale, but its scalability and application to larger, industrialized systems are limited, as it requires significant cultural shifts and increased land access, which are often unavailable to marginalized communities [104]. Other limitations that hinder its widespread adoption include high labor requirements, pest and disease infestations, lack of knowledge about practices, and challenges in translating ideas to mainstream agriculture [68,105].

AFNs are becoming more feasible in urban contexts in the Global North, where there is rising demand for local, organic, and fair-trade food. However, their scalability is constrained by their focus on niche markets, which can be inaccessible to low-income consumers and small-scale farmers in the Global South [61,63]. The labor-intensive nature of both producing and consuming food in AFNs poses challenges to their long-term viability [106]. Other limitations that AFNs face in terms of feasibility include restricted access to land for food production, low public engagement, and dependence on volunteer labor [107].

RA has garnered attention from mainstream agribusinesses due to its integration of carbon sequestration and potential for profitability through soil regeneration [98]. Its compatibility with market mechanisms and suitability for large-scale farm adoption make it more feasible, especially in regions where environmental degradation threatens agricultural productivity [37].

Organic farming has achieved considerable feasibility due to established certification systems and growing consumer demand, particularly in the Global North [108]. Government subsidies and institutional support have made it an appealing option for farmers. However, the high cost of certification and market barriers limit its accessibility for smallholders, especially in the Global South [89].

CSA has been widely embraced by governments, development agencies, and the private sector due to its market-driven approach, which promises increased productivity while addressing climate change. Its focus on technological solutions and public–private partnerships has made it one of the most preferred models in policy-making circles [43]. The support that CSA has received from the corporate sector, however, often comes at the cost of deeper structural changes, as CSA tends to reinforce the status quo in global food markets rather than challenging them [43]. On the other hand, the adoption of CSA by smallholders in the Global South is heavily constrained by structural inequalities in political, economic and social domains [44,45,109,110]. Due to the tremendous heterogeneity of small-scale farms and their dependence on cash income, unless CSA practices are tailored to the specificities of each site and can generate immediate tangible returns, the adoption will be low [22].

NBSs have also become increasingly attractive to governments and corporations aiming to meet climate goals, making them more feasible within policy frameworks that support environmental management and green jobs [111]. Similarly, the feasibility of carbon-capture agriculture is also increasing due to the rise of carbon markets and international interest in climate mitigation. The feasibility of both NBSs and carbon-capture agriculture, however, heavily depends on favorable external conditions, such as external funding and partnerships with international organizations in the case of NBSs and market-driven mechanisms such as robust carbon pricing systems [112]. Neither condition is readily available to smallholders in the Global South, limiting the feasibility of these alternatives [113].

Summarizing the discussion above, Table 2 presents a comparison of the eight models in terms of both their transformative ambitions and the support they have garnered from various stakeholders.

Table 2. Comparing sustainable agrifood alternatives: transformative ambitions and governmental/societal support.

	Stakeholder Support			*Transformative Ambition*	
	Government and International Organizations	**Businesses**	**Smallholders and Grassroots Communities**	**Target of Transformation**	**Level of Ambition**
Sustainable agriculture					
Organic agriculture	+++	+++	+	Farming inputs	+
RA	+	++	-	Farm-level eco-system	++
CSA	+++	+++	+	Farming practices	+
Carbon-capture agriculture	++	++	-	Carbon capture and emissions	+
NBS	++	++	-	Farm-level eco-system	++
Sustainable agrifood systems					
AFN	+	+	+++	Production and distribution networks	+++
Permaculture	-	-	++	Local ecological and economic system	+++
Agroecology	+	-	+++	The whole agrifood system	++++

The number of '+' signs in each cell indicates the strength of an approach in that given aspect. A '-' sign indicates absence of support.

4.2. Policy Support Across the Globe

The feasibility and transformative potential of these sustainable alternatives depend on the level of policy support they receive from international organizations and national governments. This section briefly reviews the extent to which these models have garnered support at both the international and national levels.

At the global level, several initiatives and frameworks have promoted sustainable agricultural practices in response to growing concerns about climate change, food security, and environmental degradation. Key among these are the Sustainable Development Goals (SDGs), the Paris Climate Agreement, and initiatives led by organizations such as the Food and Agriculture Organization (FAO) and the United Nations Environment Programme (UNEP). These frameworks encourage countries to adopt sustainable agricultural practices, though the specific models and approaches vary across regions.

The SDGs adopted by all UN member states in 2015 provide a global framework for addressing major social, economic, and environmental challenges. Goal 2 (Zero Hunger) calls for promoting sustainable food production systems and resilient agricultural practices that increase productivity while maintaining ecosystems. In this context, CSA has been widely endorsed as a strategy to improve agricultural resilience and reduce emissions, supported by international organizations like the FAO and the World Bank [114,115]. CSA is particularly emphasized in developing regions, such as Sub-Saharan Africa and Southeast Asia, where food production is highly vulnerable to climate change [41]. Additionally, the World Bank has sponsored low-carbon agriculture projects, such as Brazil's Sustainable Production in Areas Previously Converted to Agricultural Use Project, which restored degraded pastureland through regenerative practices, promoting low-carbon technologies and benefiting thousands of small and medium-sized producers [116]. The Paris Climate Agreement (2015), which commits countries to reducing greenhouse gas emissions and limiting global warming to below 2 °C, also added momentum to the adoption of sustainable practices, such as CSA and carbon-capture agriculture [1].

At the regional level, the European Union's Common Agricultural Policy (CAP) has been a global leader in supporting sustainable agricultural practices, particularly organic farming. CAP subsidies incentivize organic practices, biodiversity conservation, and environmentally friendly farming techniques [117]. The EU's Farm to Fork Strategy, part of the European Green Deal, aims to make food systems more sustainable by increasing organic farming to 25% of agricultural land by 2030 [118].

In North America, government policies and initiatives, such as research and education programs [119], subsidies, tax incentives, and regulations [120], have also played a significant role in promoting sustainable agricultural practices. The USDA's Sustainable Agriculture Research Education Program and the National Organics Program are key initiatives in the United States [121]. Canada has implemented various strategies, including research, diffusion, training, market development, and safety net programs to facilitate the transition to sustainable farming [119]. RA is also becoming more popular, especially in the private sector, with increasing interest from corporations and environmental groups. Major corporations like General Mills, Walmart, and Danone are making significant investments in regenerative agriculture practices [122].

In Latin America, agroecology has garnered considerable support, not just as an ecological framework but as a social movement tied to food sovereignty and rural development. Brazil, Cuba, and Mexico have implemented policies supporting agroecology. Cuba, in particular, transitioned to agroecological practices after the collapse of trade with the Soviet Union in the 1990s, and today, agroecology is institutionalized with widespread government support [58,74]. Brazil's National Policy for Agroecology and Organic Production (PNAPO) has historically backed agroecological initiatives, although recent political shifts have weakened this support [18].

In Africa, many governments, with the support of international organizations, have embraced CSA to boost productivity and climate resilience [23,109]. The African Union's Comprehensive Africa Agriculture Development Programme (CAADP) promotes CSA practices like conservation agriculture, agroforestry, and sustainable land management [43].

In Asia, national governments have adopted a range of policies reflecting diverse approaches to sustainable agriculture, depending on their specific political, economic, and environmental contexts. China's approach to promoting sustainable agriculture reflects a balance between state-driven initiatives and market-based reforms. Since the 1980s, the Chinese government has experimented with various strategies, including Chinese Ecological Agriculture, Green Food, and organic agriculture, each aimed at reducing the environmental degradation caused by the overuse of chemical inputs in the countryside [123]. While agroecology and permaculture are not prominent in Chinese policy [124], the government has promoted "eco-farming", which shares some principles with organic and sustainable farming practices. Driven by the broader national goals of sustainability and modernization, the government has also pushed for CSA to enhance the resilience of its agriculture sector against climate change [125]. State-led approaches like these, however, tended to focus more on technological solutions and efficiency improvements than on the broader social and political changes advocated by agroecology [126]. Although the state has provided the institutional frameworks necessary to encourage more sustainable agricultural practices, it relied on market mechanisms to incentivize farmers, which not only made it highly difficult for smallholders to shift to sustainable practices [127] but also created pressure on organic producers to conventionalize their operations [128]. Despite substantial state support for sustainable agriculture, the push for sustainable agrifood systems like AFNs largely originated from grassroots efforts led by civil society [64,126].

Southeast Asia presents a mixed picture when it comes to the state's role in supporting alternative food systems. In countries like Vietnam and Thailand, governments have promoted the adoption of organic farming as part of broader efforts to support rural development and agricultural exports. Thailand's Organic Agriculture Development Strategy (2017–2021) seeks to increase organic farming acreage and export organic products, showing strong state support for this model [129]. However, critics argue that the emphasis on exports may replicate the same global trade dynamics that undermine local food systems, rather than addressing social and economic sustainability at the grassroots level [130]. In Vietnam, which is highly vulnerable to climate change, particularly in the critical agricultural region of the Mekong Delta, the government has shown interest in supporting climate-smart agriculture as part of its climate adaptation strategy. The government's endorsement of CSA aligns with its efforts to modernize agriculture while addressing environmental challenges such as rising sea levels, salinity intrusion, and drought [131]. CSA initiatives in Vietnam have attracted international funding and partnerships, including from the World Bank and the FAO. In the Philippines, movements for agroecology and food sovereignty, backed by civil society organizations and smallholder farmers, have gained momentum [132], as has climate-smart agriculture [45]. However, state support has been inconsistent, with policies often favoring industrial agriculture and export-oriented crops such as rice, sugar, and bananas [133]. Despite this, the government has promoted organic farming through the Organic Agriculture Act of 2010, which provides a legal framework for organic certification and support to organic farmers [134].

Overall, global initiatives like the SDGs and the Paris Agreement have played a pivotal role in shaping policy frameworks for sustainable agriculture. Regional responses, however, vary widely, reflecting different priorities and market conditions. While CSA and organic farming receive broad international backing, agroecology is primarily supported in regions like Latin America, where it aligns with social movements advocating for food sovereignty. Countries in Asia have shown varying degrees of support for alternative food systems, but the dominant focus tends to be on organic farming and CSA, with relatively less emphasis on agroecology or permaculture. Governments in the region often prioritize models that align with national goals of modernization, food security, and export competitiveness, sometimes at the expense of deeper social and economic transformation. Globally, most government and corporate support is directed toward sustainable agricultural practices like CSA, organic farming, RA, NBS, and carbon-capture agriculture. In contrast, more transformative models of sustainable agrifood systems, which face greater challenges in terms of feasibility and scalability, are predominantly driven by grassroots movements within civil society.

In conclusion, agroecology's grassroots movements have garnered significant support in the Global South but face challenges in scaling due to corporate resistance. In contrast, CSA, regenerative agriculture, NBS, and carbon-capture agriculture have gained broader feasibility within existing systems by aligning with market-driven solutions and public–private partnerships, though they often lack the capacity to challenge entrenched power structures. Permaculture and AFNs hold promise at smaller scales, but both require significant cultural and institutional shifts to expand.

5. Sustainable Alternatives in the Global South: Critical Reflections from the Perspective of Agrarian Political Economy

Agrarian political economy offers a critical framework for analyzing sustainable agrifood alternatives by focusing on the structural factors that shape agricultural systems and practices, such as class relations, the role of agriculture in national economies, and the influence of global capitalism on rural production [135]. This approach highlights how different classes of agricultural producers—ranging from subsistence peasants to capitalist enterprises—engage with sustainable agriculture models in distinct ways. Additionally, it underscores the importance of agriculture in broader industrialization and capital accumulation processes, particularly in the Global South, where rural economies are deeply intertwined with urban food demands and national development objectives.

5.1. Class Differentiation and Support for Sustainable Alternatives

Agrarian political economy adopts a class-analytic approach that forefronts class differentiation among agricultural producers, which influences their responses to various sustainable agriculture models and their capacity for adoption [136]. Agricultural producers are not a homogenous group; instead, they range from capitalist enterprises to petty-commodity producers to subsistence peasants, each with different resources, objectives, and relationships to markets and labor. These differences shape how each group engages with sustainability initiatives.

Large-scale capitalist farms, prioritizing profit maximization, generally favor market-driven sustainability models like organic farming or CSA [28,46]. These farms often have the capital and technical expertise to adopt new technologies or obtain certifications, allowing them to access premium markets and carbon trading schemes. At the same time, these models can reinforce the dominance of large-scale producers and promote "green capitalism", which does little to address deeper social inequities within the industrial food system [137].

In contrast, petty-commodity producers, such as smallholder family farmers, face greater challenges in adopting sustainability models. Agroecology and AFNs theoretically align with their socio-economic realities by lowering input costs and connecting them to local markets. However, smallholders often lack access to markets, technical knowledge, and secure land tenure, making it difficult for them to fully participate in these systems. The agroecology discourse tends to romanticize smallholder agriculture while overlooking the economic aspirations of these farmers, who often seek deeper market integration [138].

Subsistence peasants, particularly in the Global South, are frequently disconnected from markets and lack the resources to engage in certified organic or agroecological programs [129]. These farmers often rely on traditional, low-input farming methods due to economic necessity rather than ecological motivations. For them, access to land, water, and basic inputs is more urgent than participation in high-tech or certification-based sustainability models [139]. This highlights the importance of land reform and broader institutional support, as land rights and resource access are central to ensuring their ability to pursue sustainability [58].

Agrarian political economy sheds light on how different types of producers are integrated into global or local markets and how these market relations shape their approach to sustainable practices. Capitalist enterprises are often tied to global commodity chains, exporting cash crops or high-value organic products. While they often react to pressure from the international community to adopt sustainable practices (e.g., fair trade and organic certifications demanded by consumers), they are far less responsive to social justice and economic equity concerns at the local level [140,141]. On the other hand, smallholders and subsistence farmers rely on local or informal markets, where their engagement with sustainability initiatives is driven primarily by local social and economic concerns, such as preserving local food traditions, using local resources, or addressing household livelihood needs [142]. This underscores the need for policies that address class dynamics and recognize the structural challenges faced by various producer groups.

5.2. Sustainable Alternatives in National Economic Development

Agrarian political economy emphasizes the central role of agriculture in national economic development, especially in the Global South, where agriculture is not only a source of food for urban populations but also generates surplus capital necessary for industrialization [143]. This perspective highlights tensions between the goals of sustainable agriculture and broader national development strategies. Agriculture, in many cases, is expected to increase productivity and provide cheap food for the growing urban populations, often at the expense of ecological and social sustainability [8,135,143]. The dominant models like CSA and regenerative agriculture fit into state-led modernization agendas by promising to enhance productivity while addressing environmental concerns. However, these models tend to rely on external inputs and technologies, which can deepen smallholders' dependency on global markets and agribusiness, limiting their autonomy and capacity to resist corporate pressures [43].

On the other hand, agroecology and AFN movements offer an alternative vision of development, emphasizing local control over food systems, ecological sustainability, and social justice. These movements are particularly influential in regions where smallholder farmers are marginalized by industrialization projects that prioritize large-scale, export-oriented agriculture [18]. However, agroecology's focus on small-scale, low-input systems may limit its capacity to meet national food security needs and industrialization goals [137,144].

Agrarian political economy reminds us that sustainable agrifood alternatives must be evaluated not only for their environmental impact but also for their effects on social equity, class relations, and national development objectives [137,138,144]. As countries in the Global South pursue industrialization, these sustainable alternatives need to be critically examined for their ability to meet urban food demands, generate economic surplus, and contribute to broader processes of social and economic transformation. The success of these models will largely depend on how well they align with national policies on industrialization, land reform, and rural development.

5.3. Summary

In the Global South, the structural and institutional conditions necessary for the widespread adoption of sustainable agriculture—such as robust carbon markets, government support, and consumer demand for organic products—are often underdeveloped [145,146]. Moreover, the agricultural sector in these regions is dominated by smallholder producers who face significant barriers, including financial constraints, limited technical capacity, inadequate infrastructure, and insecure land tenure [147]. For many of these smallholders, the primary goal is not incremental ecological improvements like soil health or biodiversity, but rather a more profound transformation of the inequitable agrifood system. This reality has fueled stronger grassroots support for transformative models like agroecology, which seek to address these deeper social and economic injustices [18,19], and the successes of these grassroots movements in some parts of the Global South are well-documented [74,75,148].

However, the enthusiasm from smallholders for radical agrifood alternatives like agroecology, permaculture and AFNs is often overstated. This becomes evident when considering the internal class differences among smallholders and their varied socioeconomic needs [137,138,144]. Studies of various alternative food initiatives in China, for example, have found that most of these initiatives were driven by urban consumers searching for quality foods, while rural farmers had to prioritize economic viability, which usually meant continuing with productivist agriculture [127,149].

Viewing capitalist agriculture and peasant-based agroecology in a binary manner, where agrarian capitalism is seen as an external, homogeneous force that must be opposed by the agroecology movement [137], risks depriving Global South countries of the chance to develop a productive agricultural sector. Such a sector, which integrates modern scientific advances to improve productivity and sustainability, is crucial for addressing the food consumption and capital-accumulation needs of these developing economies [135,144]. Therefore, given the need in Global South countries to balance the demands for affordable, nutritious food with the livelihoods of small farmers, alternatives such as CSA, which incorporate modern scientific advances and use external inputs more efficiently to increase food supply, may in fact offer more practical solutions. In this regard, China's successful experiences in agrarian transition can provide a template for other countries to emulate.

China first went through a prolonged pursuit of agricultural modernization, relying on Green Revolution technologies, state investment in infrastructure, and labor mobilization to raise agricultural productivity, meet national food security needs, and generate surplus capital and labor to support industrialization [150–152]. Only in the 2000s, when urban demands for quality foods and state fiscal resources for rural development were rising, the shift toward more sustainable practices began. This transition is now progressing on multiple fronts and is driven by both top-down and bottom-up forces [64,123–126,149].

6. Conclusions

This paper has critically examined and compared two broad groups of sustainable agriculture models: "sustainable agriculture" (which includes organic farming, RA, CSA, carbon-capture agriculture, and NBS) and "sustainable agrifood systems" (represented by agroecology, AFNs, and permaculture). The sustainable agriculture models tend to focus on improving ecological sustainability through specific practices at the farm level. These approaches emphasize reducing chemical inputs, enhancing biodiversity, and promoting climate resilience, often relying on technological and market-based solutions to improve productivity and sustainability within the existing framework of industrial agriculture. The abundance of these models, varying just slightly in how they prioritize different farm-level practices, leads to needless confusion. One might contend that models like CSA, RA, NBS, and carbon-capture agriculture should be grouped under a broad category of "sustainable agriculture", encompassing any farm-level practices that both go beyond organic agriculture's narrow focus on input reduction and intend to enhance various facets of ecological sustainability.

The sustainable agrifood system models offer more ambitious visions for systemic transformation, addressing ecological, economic, and social dimensions of sustainability. They not only focus on environmentally sound agricultural practices but also seek to reconfigure the entire agrifood system, challenging corporate control and promoting food sovereignty, local economies, and social justice. These approaches are grounded in grassroots movements and emphasize local governance and participatory, community-driven processes.

The contribution of this paper to the sustainable agriculture literature lies in its comparative framework, which highlights both the strengths and limitations of these models and their approaches to various aspects of sustainability. It underscores the need for a more integrated approach to sustainability, one that addresses not only ecological outcomes but also the socio-political structures that perpetuate inequality and unsustainability in the global food system.

From an agrarian political economy perspective, however, both groups of models are critiqued for their limited engagement with the structural issues inherent in capitalist agriculture. The sustainable agriculture models, while making incremental ecological improvements, are often co-opted by agribusiness and fail to challenge the power imbalances in the food system. On the other hand, the sustainable agrifood system models, though more radical, face significant feasibility challenges, particularly in scaling up and competing with industrial agriculture on a global scale. This paper calls for a more nuanced understanding of how different classes of agricultural producers, particularly smallholders and subsistence farmers, can engage with these sustainable alternatives, and stresses the importance of land reform, resource access, and institutional support in achieving genuine sustainability.

Developments in "precision technologies"—including both biotechnologies (such as genetic modification and alternative proteins) and digital technologies (such as AI, blockchain, and e-commerce)—can have a significant impact on the feasibility and transformative potential of these models of sustainable alternatives and may offer a potential synthesis of these competing models [153,154]. In general, the three "sustainable agrifood systems" models are highly skeptical if not outright opposed to these technological developments, seeing them as controlled by the big capital that already dominates the conventional agrifood system and developed to further enhance that control [155,156]. The obstacles that smallholders in the Global South face in adopting bio- and digital technologies and benefiting from these advances are well-documented: they range from low literacy to poor infrastructure to unaffordability [157]. At the same time, it is also well-known that multinational corporations from the Global North have used technological developments to advance their "grabbing" of natural resources, including genetic materials and control over laboring processes in agriculture [158,159].

While the opposition to these technological developments are well-grounded in historical experiences, models such as agroecology and AFNs that advocate for alternative agrifood systems, however, should not outright dismiss these technologies. On the other hand, the "sustainable agriculture" models also need to go beyond embracing these technologies for the technical improvements they offer at the farm level and consider how the development and deployment of these technologies shape power dynamics and socioeconomic inequalities in agrifood systems. In other words, all models need to explore how these developments can be incorporated into their proposed imaginaries of more sustainable, equitable and just agrifood systems. The key issues here include: How to create participatory development of technologies that prioritize community sustainability goals rather than corporate profits? How to ensure equitable access to technological advances? And, how these technologies can be used to address deficiencies of these models? Although the experiences of successful cases from the Global South are varied, they typically underscore two conclusions that align with the insights from agrarian political economy: first, technology development tailored to smallholders' socioeconomic constraints and cultural orientations have higher rates of adoption and success [160–162]; and second, political reforms that transform state capacity, community relations, and land-rights systems are often preconditions that enable small farmers' wider adoption of sustainability-enhancing technologies [163,164]. In summary, as governments in the Global South balance sustainability goals with the demands of industrialization, a holistic understanding of the potentials and limitations of the alternative models from the perspective of agrarian political economy is essential for crafting inclusive and effective policies.

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