From Crisis to Resilience: Transforming Agrifood Systems for Sustainable Recovery and Food Security in Post-Conflict Syria

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Abstract

Prolonged conflict has profoundly disrupted Syrian agrifood systems, affecting agricultural production, natural resources, value chains, institutions, knowledge systems, and rural livelihoods. As Syria enters a post-conflict recovery phase, rebuilding agriculture represents not only a reconstruction challenge but also an opportunity to transform agrifood systems toward greater resilience, sustainability, and inclusiveness. This review aims to analyze the evolution of Syrian agrifood systems before, during, and after the

conflict period and to identify strategic pathways for sustainable recovery and transformation.

Using a narrative conceptual review approach, this study synthesizes evidence from peer-reviewed literature, international experiences, and agrifood system transformation frameworks related to climate resilience, innovation systems, sustainable resource management, and post-conflict recovery. The analysis highlights that returning to pre-conflict agricultural models may not sufficiently address emerging challenges associated with climate change, water scarcity, economic vulnerability, and institutional recovery.

Based on this synthesis, the review proposes the Syria Sustainable Agrifood Recovery and Transformation Framework (SSARTF) as an integrated conceptual model linking immediate recovery priorities with long-term transformation pathways. The framework identifies seven interconnected pathways: climate-smart agriculture, conservation agriculture and natural resource restoration, water–energy–food nexus integration, circular bioeconomy, digital agriculture, inclusive agripreneurship and value-chain development, and sustainable rural community recovery. The framework is structured across three interconnected levels, recovery drivers, transformation pathways, and long-term outcomes, and is designed to be operationalized through pathway-specific indicators that can support monitoring, evaluation, and adaptive implementation.

The findings suggest that future agrifood recovery strategies should integrate technological innovation, institutional strengthening, environmental sustainability, and inclusive economic development. The SSARTF provides a

foundation for guiding policies, investments, and research agendas aimed at supporting food security, climate adaptation, rural revitalization, and resilient agrifood systems in Syria and other fragile contexts.

Keywords: Agrifood systems transformation, post- conflict recovery, Syria, food security, climate-smart agriculture, conservation agriculture, circular bioeconomy, digital agriculture, sustainable livelihoods, peacebuilding.

من الأزمة إلى الصمود: تحويل النظم الزراعية والغذائية لتحقيق التعافي المستدام والأمن الغذائي في سوريا ما بعد النزاع

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الملخص

أدى النزاع الممتد في سوريا إلى اضطراب عميق في النظم الزراعية والغذائية، مما أثر سلبًا في الإنتاج الزراعي، والموارد الطبيعية، وسلاسل القيمة، والمؤسسات، ونظم المعرفة، وسبل العيش الريفية. ومع دخول سوريا مرحلة التعافي بعد النزاع، فإن إعادة بناء القطاع الزراعي لا تمثل تحديًا لإعادة الإعمار فحسب، بل توفر أيضًا فرصة لتحويل النظم الزراعية والغذائية نحو مزيد من الصمود والاستدامة والشمولية. ويهدف هذا الاستعراض إلى تحليل تطور النظم الزراعية والغذائية السورية قبل النزاع وأثناءه وبعده، وتحديد المسارات الاستراتيجية اللازمة لتحقيق التعافي المستدام والتحول الشامل.

اعتمدت الدراسة منهجية المراجعة السردية المفاهيمية، حيث جرى تجميع وتحليل الأدلة المستمدة من الأدبيات العلمية المحكمة، والخبرات الدولية، وأطر تحويل النظم الزراعية والغذائية ذات الصلة بالقدرة على التكيف مع تغير المناخ، ونظم الابتكار، والإدارة المستدامة للموارد، والتعافي في مرحلة ما بعد النزاع. ويُظهر التحليل أن العودة إلى النماذج الزراعية التي كانت سائدة قبل النزاع قد لا تكون كافية لمواجهة التحديات المستجدة المرتبطة بتغير المناخ، وشح المياه، والهشاشة الاقتصادية، وإعادة بناء المؤسسات.

واستنادًا إلى هذا التحليل، تقترح الدراسة إطار التعافي والتحول المستدام للنظم الزراعية والغذائية في سوريا (SSARTF) بوصفه نموذجًا مفاهيميًا متكاملًا يربط بين أولويات التعافي العاجلة ومسارات التحول طويلة الأمد. ويحدد الإطار سبعة مسارات مترابطة، هي: الزراعة الذكية مناخيًا، والزراعة الحافظة على الموارد واستعادة الموارد الطبيعية، وتكامل ترابط المياه والطاقة والغذاء، والاقتصاد الحيوي الدائري، والزراعة الرقمية، وريادة الأعمال الزراعية الشاملة وتنمية سلاسل القيمة، والتعافي المستدام للمجتمعات الريفية. كما بُني الإطار على ثلاثة مستويات مترابطة تشمل: محركات التعافي، ومسارات التحول، والنتائج طويلة الأجل، مع تصميمه ليُفعَّل من خلال مؤشرات خاصة بكل مسار بما يدعم عمليات المتابعة والتقييم والتنفيذ التكيفي.

وتشير نتائج الدراسة إلى أن استراتيجيات التعافي الزراعي والغذائي المستقبلية ينبغي أن تدمج بين الابتكار التكنولوجي، وتعزيز المؤسسات، والاستدامة البيئية، والتنمية الاقتصادية الشاملة. ويوفر إطار SSARTF أساسًا علميًا يمكن الاستناد إليه في توجيه السياسات والاستثمارات والأجندات البحثية الرامية إلى تعزيز الأمن الغذائي، والتكيف مع تغير المناخ، وإنعاش المجتمعات الريفية، وبناء نظم زراعية وغذائية أكثر صمودًا في سوريا وغيرها من السياقات الهشة.

الكلمات المفتاحية: تحول النظم الزراعية والغذائية، التعافي في مرحلة ما بعد النزاع، سوريا، الأمن الغذائي، الزراعة الذكية مناخيًا، الزراعة المحافظة على الموارد، الاقتصاد الحيوي الدائري، الزراعة الرقمية، سبل العيش المستدامة، بناء السلام.

1. Introduction

Agrifood systems are fundamental drivers of food security, rural livelihoods, economic development, environmental sustainability, and social stability. In recent years, global thinking has shifted from focusing only on agricultural production toward transforming entire agrifood systems, recognizing the interconnected roles of natural resources, value chains, markets, innovation, institutions, and communities in achieving sustainable development (Béné et al., 2019; Barrett et al., 2020; FAO, 2021). Such transformation has become increasingly important as climate change, conflicts, economic shocks, and environmental pressures expose vulnerabilities within conventional agricultural development models and highlight the need for more resilient and adaptive food systems (Tendall et al., 2015; Webb et al., 2020; IPCC, 2023). This transformation is particularly important in fragile and post-conflict recovery contexts, where agriculture is not only a source of food production but also a foundation for livelihood restoration, economic revitalization, and supporting resilient rural recovery processes. Evidence from conflict-affected regions indicates that restoring agricultural systems contributes to household resilience, income generation, market recovery, and broader stabilization processes when linked with inclusive and sustainable development approaches (Brück & d'Errico, 2019; Martin-Shields & Stojetz, 2019; FAO, 2022).

Syria provides a unique and important case for understanding the relationship between agrifood systems, conflict recovery, and sustainable transformation. Before 2011, agriculture represented one of the country's most important economic and social sectors, supporting rural employment, domestic food production, and agricultural value chains (FAO, 2017; World Bank, 2017). Syria also developed considerable agricultural research and technical capacities that supported crop improvement, dryland farming, and natural resource management (ICARDA, 2012). However, even before the conflict, the sector faced structural challenges, including water scarcity, increasing climate variability, pressure on natural resources, and the need for improved resource-use efficiency (Gleick, 2014; Kelley et al., 2015). By 2011, the sector employed an estimated 26% of Syria's economically active population and generated around one quarter of GDP during some pre-conflict years, making it the second-largest contributor to GDP after government services, while underpinning the livelihoods of a rural population that comprised just under half of the national total (FAO, 2017).

The conflict period between 2011 and 2024 resulted in profound disruptions across Syrian agrifood systems. The impacts extended beyond reduced agricultural production and included damage to infrastructure, weakening of agricultural services, disruption of markets and value chains, reduced availability of inputs, degradation of natural resources, and significant losses in human and institutional capacities (FAO, 2017; World Bank, 2023). Rural communities were particularly affected as displacement, economic instability, and reduced livelihood opportunities weakened the connection between people, land, and local production systems, demonstrating the close

relationship between agricultural systems, social resilience, and community stability in fragile environments (Brück & d'Errico, 2019; UNHCR, 2023). These disruptions translated into measurable losses: FAO's nationwide damage and needs assessment estimated more than USD 16 billion in destroyed farming assets and lost crop and livestock production within the first six years of conflict alone, while national food production fell by approximately 40% relative to pre-conflict levels (FAO, 2017). At the whole-economy level the toll was larger still, with cumulative losses estimated at approximately USD 442 billion by 2018 and national GDP having lost roughly 65% of its pre-conflict value, underscoring how deeply agricultural decline was embedded within a broader economic collapse (World Bank, 2017; Alkaddour, 2024).

The post- conflict transition represents a critical turning point for Syria's agricultural future. However, sustainable recovery requires more than restoring pre-conflict production systems. Rebuilding the same structures that existed before the crisis may reproduce previous vulnerabilities, particularly under increasing pressures from climate change, water scarcity, economic uncertainty, and demographic shifts. Instead, the recovery phase provides an opportunity to transform Syrian agrifood systems toward more resilient, inclusive, resource-efficient, and innovation-driven models (Folke, 2016; Barrett et al., 2020; Rockström et al., 2020).

Several emerging approaches in sustainable agriculture, resource management, circular systems, digital innovation, and inclusive rural development provide opportunities to redesign agrifood systems for improved

resilience and adaptability. However, their effectiveness depends on integration within broader transformation strategies that connect technologies, institutions, markets, and communities. (Lipper et al., 2014; Kassam et al., 2019). Agrifood transformation is also connected with rural recovery and sustainable return processes because livelihoods, markets, institutions, and community capacities influence long-term resilience in post-conflict settings. Therefore, agricultural recovery should be considered within broader socioeconomic recovery strategies rather than as an isolated production sector (OECD, 2019; IFAD, 2021; UNHCR, 2023; FAO, 2022).

Although previous studies and assessments have examined specific dimensions of Syrian agriculture, including production losses, food insecurity, climate risks, and humanitarian needs, limited research has addressed agrifood systems as an integrated platform for recovery, transformation, and peacebuilding. Addressing complex post-conflict challenges requires system-based approaches that integrate ecological, economic, institutional, and social dimensions rather than isolated sectoral interventions (Ostrom, 2009; Folke, 2016). There remains a need for a comprehensive framework that connects agricultural recovery with climate resilience, economic development, institutional strengthening, sustainable return, and social stability.

Recent national policy directions also indicate a shift toward transforming Syrian agriculture beyond production recovery. The Syrian Agricultural Strategy 2026–2030 emphasizes rebuilding the agricultural sector through sustainable resource management, food security enhancement, climate adaptation, technological modernization, private-sector engagement,

and improved rural livelihoods (Ministry of Agriculture, 2026). However, translating these strategic priorities into an integrated agrifood system transformation framework requires linking production recovery with innovation systems, environmental sustainability, inclusive value chains, and community resilience.

However, limited integrated conceptual frameworks have specifically linked Syria's agrifood recovery with climate-smart transformation, circular economy, digital innovation, sustainable return, and peacebuilding. Therefore, this review aims to analyze the transformation of Syrian agrifood systems through three interconnected phases: the pre-conflict period before 2011, the conflict period from 2011 to 2024, and the post- conflict recovery and transformation phase. By integrating global evidence with the Syrian context, this article proposes the Syria Sustainable Agrifood Recovery and Transformation Framework (SSARTF) as a strategic pathway for rebuilding resilient agrifood systems that contribute to food security, economic recovery, sustainable rural development, and long-term resilience (Walker et al., 2004; Béné et al., 2019).

2. Methodology

2.1 Review Design and Approach

This study follows a narrative literature review approach combined with strategic framework development to examine the role of agrifood system transformation in supporting recovery, resilience, and sustainable development in post- conflict Syria. A narrative review methodology was

selected because the topic requires integration of evidence across multiple disciplines, including agricultural sciences, climate adaptation, natural resource management, food security, rural livelihoods, institutional development, and peacebuilding.

Unlike systematic reviews that focus on answering narrowly defined research questions through standardized selection and quantitative synthesis of comparable studies, this review aims to develop a broader conceptual understanding of how interconnected agrifood system components can contribute to recovery in a complex post- conflict environment. This approach is particularly suitable for emerging and interdisciplinary topics where evidence is distributed across scientific publications, policy documents, institutional reports, and field-based development experiences.

2.2 Literature Search Strategy and Sources

A structured literature search was conducted using major scientific databases and academic platforms, including Scopus, Web of Science, Google Scholar, ScienceDirect, SpringerLink, and relevant institutional repositories. The search focused on peer-reviewed articles, review papers, policy documents, technical reports, and strategic publications related to agrifood systems, sustainable agriculture, and post- conflict recovery.

Additional grey literature and institutional publications were included from internationally recognized organizations due to their relevance in fragile and recovery contexts. These sources included reports and technical documents from the Food and Agriculture Organization of the United Nations (FAO), International Center for Agricultural Research in the Dry Areas (ICARDA),

CGIAR research programs, the Arab Center for the Studies of Arid Zones and Dry Lands (ACSAD), the World Bank, United Nations agencies, and available publications from Syrian agricultural research institutions and universities.

The inclusion of institutional reports was considered essential because post-conflict agrifood recovery is an applied field where recent evidence, needs assessments, and policy directions are often documented outside traditional academic journals.

2.3 Search Terms and Selection Criteria

The literature search focused mainly on publications from 2010 to 2026, while selected earlier references were included when they provided important historical context related to Syrian agriculture or long-term agricultural development.

The main search terms and combinations included:
"agrifood systems transformation", "post- conflict agriculture", "agricultural recovery", "Syria agriculture", "food security in Syria", "climate-smart agriculture", "conservation agriculture", "dryland farming", "water scarcity", "water–energy–food nexus", "circular bioeconomy", "digital agriculture", "rural livelihoods", "sustainable return", and "peacebuilding".

Sources were selected based on the following criteria:

1. Relevance to agrifood system transformation, agricultural sustainability, or post- conflict recovery;
2. Scientific quality and credibility of the publication source;
3. Applicability to dryland, fragile, or resource-constrained environments;
4. Relevance to Syria or comparable contexts;
5. Contribution to future-oriented recovery and transformation pathways.

2.4 Analytical Framework

The collected literature was analyzed thematically according to three historical and developmental phases of Syrian agrifood systems:

1. The pre-conflict period before 2011, focusing on agricultural capacities, achievements, and structural vulnerabilities;
2. The conflict period from 2011 to 2024, focusing on system disruption, loss of productive assets, institutional challenges, and impacts on rural communities;
3. The post- conflict recovery and transformation phase, focusing on opportunities to rebuild more resilient, sustainable, and inclusive agrifood systems.

The synthesis was organized around key transformation domains identified from literature, including climate-smart agriculture, conservation agriculture, sustainable management of water and natural resources, circular bioeconomy, digital agriculture, innovation systems, inclusive value chains, and rural community recovery. Within each phase and domain, sources were coded thematically according to recurring categories of impact, underlying mechanism, and intervention type, allowing patterns across natural, physical, human, and institutional capital dimensions to be compared systematically rather than summarized narratively in isolation.

Based on this synthesis, the Syria Sustainable Agrifood Recovery and Transformation Framework (SSARTF) was developed as a conceptual model integrating scientific evidence, global recovery lessons, and Syria-specific challenges and opportunities.

2.5 Review Limitations

As a narrative review, this study does not aim to provide a quantitative meta-analysis or exhaustive systematic assessment of all available literature. Instead, it provides an interdisciplinary synthesis designed to identify major trends, knowledge gaps, and strategic pathways for agrifood system transformation. Availability and consistency of data related to Syrian agriculture remain limited due to the prolonged conflict period; therefore, the review prioritizes peer-reviewed evidence and reports from recognized research and international institutions.

3. Global Lessons from Post- conflict Agrifood Recovery

Armed conflicts have long-lasting impacts on agrifood systems that extend beyond immediate declines in agricultural production. Conflict can disrupt the interconnected components that sustain agricultural systems, including natural resources, infrastructure, markets, institutions, knowledge networks, human capital, and rural communities (Brück & d'Errico, 2019; Martin-Shields & Stojetz, 2019). Evidence from different post-conflict and fragile contexts demonstrates that recovery requires rebuilding these multiple system components simultaneously rather than addressing agricultural production alone (FAO, 2021; Barrett et al., 2020). Successful recovery strategies increasingly emphasize agrifood system transformation rather than simply restoring pre-conflict production levels. Experiences from countries recovering from conflict demonstrate that agricultural reconstruction becomes more sustainable when linked with institutional rebuilding, market recovery, innovation systems, and inclusive rural development rather than focusing only

on short-term input replacement (Béné et al., 2019; IFAD, 2021; World Bank, 2020). Agriculture can play a central role in economic recovery and social stabilization in societies affected by prolonged instability. Restoring agricultural livelihoods provides income opportunities, supports local food availability, stimulates rural economies, and contributes to the reintegration of displaced populations (FAO, 2022; UNHCR, 2023). However, recovery approaches focused only on emergency assistance and input distribution often have limited long-term impacts unless they relate to broader investments in value chains, market systems, extension services, and institutional capacities (Barrett et al., 2020; Reardon et al., 2019).

Post-conflict recovery experiences also highlight the importance of rebuilding agricultural knowledge and innovation systems. Research institutions, universities, extension networks, farmer organizations, and private-sector actors are essential for adapting technologies to local conditions and supporting sustainable agricultural transformation. Strengthening agricultural innovation systems enables countries to move from dependency on external assistance toward locally driven and adaptive development pathways (Klerkx et al., 2012; Schut et al., 2016).

Another major lesson is that climate resilience must be integrated into recovery planning from the beginning. Many conflict-affected countries are in regions already facing water scarcity, land degradation, and increasing climate variability. Reconstructing agricultural systems without addressing environmental pressures may recreate previous vulnerabilities and reduce long-term resilience (IPCC, 2023; Folke, 2016). Approaches such as

climate-smart agriculture, conservation agriculture, improved water productivity, and sustainable natural resource management have therefore become central components of modern agricultural recovery and transformation strategies (Lipper et al., 2014; Kassam et al., 2019).

The transition from humanitarian assistance to sustainable development represents another critical challenge in post-conflict recovery. The humanitarian–development–peace nexus emphasizes that food security, livelihood restoration, institutional rebuilding, and social cohesion are interconnected processes rather than separate interventions (OECD, 2019; FAO, 2022). Agricultural recovery can contribute to peacebuilding when it strengthens cooperation among communities, improves access to productive resources, rebuilds local economies, and creates inclusive opportunities for youth, women, and vulnerable groups (Brück & d'Errico, 2019; UNDP, 2022).

These global experiences provide important lessons for Syria's post-conflict recovery phase. Rebuilding Syrian agrifood systems should not aim only to restore the conditions that existed before the conflict but should use the recovery process as an opportunity for transformation toward more resilient and sustainable systems (Tendall et al., 2015; Webb et al., 2020). A future-oriented approach requires integrating climate adaptation, sustainable resource management, agricultural innovation, inclusive value chains, and rural community recovery within a comprehensive agrifood system framework (Béné et al., 2019; Barrett et al., 2020).

4. Evolution of Syrian Agrifood Systems Before 2011: Strengths and Structural Vulnerabilities

Before the onset of the conflict in 2011, Syria had a relatively diversified agrifood system in which agriculture played an important role in food security, rural livelihoods, and national economic activity. The sector combined rainfed cereal-based farming systems, especially wheat and barley, with irrigated production of strategic and high-value crops such as cotton, olives, vegetables, and fruit trees. This diversity reflected Syria's position within the Fertile Crescent and its varied agroecological conditions, ranging from relatively favorable agricultural zones to marginal dryland environments (Mourad & Berndtsson, 2012; Mohammed et al., 2020; Jaradat, 2017). Wheat occupied a particularly strategic position within this system and is substantial share of cultivated land was traditionally sown to wheat, concentrated in the northern governorates, and national seed reserves were generally sufficient to cover consumption and seed-security needs for two to three years (Alkaddour, 2024).

A key pre-conflict strength was the accumulation of agricultural knowledge and research capacity. Syrian national research institutions, universities, and technical agencies worked alongside international research centers, particularly ICARDA, which was historically based near Aleppo and contributed to dryland agriculture, barley and wheat improvement, participatory plant breeding, genetic resources, and farming systems adapted to arid and semi-arid conditions. Participatory barley-breeding work in Syria demonstrated the value of farmer-centered research for marginal environments, where locally adapted varieties and farmer selection criteria were essential for productivity and resilience (Ceccarelli et al., 2001; Ceccarelli & Grando, 2007; Grando & Ceccarelli, 2021). The scale of this

infrastructure was considerable: ICARDA's gene bank near Tel Hadia, south of Aleppo, held more than 135,000 accessions of wheat, barley, lentil, chickpea, and forage species, including what was internationally regarded as the world's most genetically diverse barley collection (ICARDA, 2012).

Syria also had major agrobiodiversity importance. As part of the Fertile Crescent, it is located within a historical center of crop domestication and diversity for cereals and food legumes, including wheat, barley, chickpea, and lentil. Syrian landraces and crop wild relatives represented valuable genetic resources for adaptation to drought, heat, pests, diseases, and low-input farming conditions. However, even before and during the early years of the crisis, studies indicated a decline in the cultivation of traditional landraces, reflecting pressures from market change, seed-system transformation, and insufficient conservation support (Al Darvish et al., 2022; Preece et al., 2017; Jaradat, 2017).

Despite these strengths, the pre-conflict agrifood system also faced structural vulnerabilities. Water scarcity was one of the most important constraints, as agricultural production depended heavily on limited and unevenly distributed water resources. Expansion of irrigated agriculture, inefficient irrigation practices, and pressure on groundwater increased the fragility of production systems, especially in dryland and marginal areas (Mourad & Berndtsson, 2012; Mourad & Berndtsson, 2012a; Gleick, 2014).

Climate variability further exposed these weaknesses. The severe drought affecting Syria and the wider Fertile Crescent between 2006 and 2010 caused major stress to rainfed agriculture, livestock systems, and rural

livelihoods. However, the drought should not be interpreted as a single direct cause of the conflict. Rather, it interacted with pre-existing vulnerabilities, including water mismanagement, rural poverty, agricultural policy weaknesses, and limited livelihood diversification (Kelley et al., 2015; Gleick, 2014; Selby et al., 2017).

In addition, several components of the Syrian agrifood system required deeper modernization before 2011, particularly in relation to market integration, agricultural value-chain development, private-sector participation, water-use efficiency, and the translation of agricultural research outputs into farmer-level innovations. Experiences from dryland agricultural systems have shown that improving productivity alone is insufficient without strengthening innovation systems, farmer participation, institutional linkages, and adaptive capacity (Spielman et al., 2009; Ceccarelli & Grando, 2007; Pretty et al., 2011). Similarly, sustainable intensification approaches emphasize that future agricultural development must simultaneously improve productivity, resource efficiency, ecosystem protection, and livelihood resilience rather than focus exclusively on increasing production (Pretty et al., 2011; Garnett et al., 2013).

Therefore, the pre-conflict Syrian agrifood system should be understood as a system with significant productive capacity, accumulated scientific knowledge, valuable agrobiodiversity resources, and strong human expertise, but also with underlying vulnerabilities linked to natural resource pressure, climate exposure, and the need for stronger institutional and technological transformation. Evidence from fragile and climate-sensitive agricultural regions demonstrates that long-term resilience depends on

integrated approaches combining improved resource governance, climate adaptation, innovation, and inclusive agricultural development (Lipper et al., 2014; Vermeulen et al., 2012).

These strengths and challenges provide important lessons for the current recovery phase. Rebuilding Syrian agriculture should not aim only to restore pre-conflict production systems but should use recovery as an opportunity to develop more resilient, climate-smart, and sustainable agrifood systems. Such transformation requires combining Syria's agricultural heritage, genetic resources, and accumulated technical expertise with modern approaches based on climate adaptation, circular economy principles, efficient resource management, inclusive value chains, and stronger connections between research institutions, farmers, markets, and the private sector (Lipper et al., 2014; Campbell et al., 2018; Barrett et al., 2020).

5. Impact of Conflict on Syrian Agrifood Systems (2011–2024): From Production Decline to System Fragmentation

Using a capital-based food-systems perspective, the conflict period between 2011 and 2024 represented a major disruption phase for Syrian agrifood systems. The impacts extended beyond immediate declines in agricultural production and affected the interconnected foundations required for a functioning food system, including natural resources, infrastructure, markets, institutions, knowledge systems, and rural communities. Contemporary food-system frameworks emphasize that shocks such as conflict, economic instability, and climate stress influence multiple system

components simultaneously rather than affecting production alone (Ericksen, 2008; Tendall et al., 2015; Béné et al., 2019).

5.1 Natural Capital: Pressure on Land, Water, and Agricultural Resources

Natural resources represent the ecological foundation of agricultural resilience, particularly in dryland systems where productivity depends on fragile interactions among soil, water availability, climate conditions, and ecosystem management. During prolonged crises, natural capital can deteriorate as a result of disrupted governance systems, reduced investment in resource management, weakened agricultural services, and limited capacity to implement sustainable land and water practices (Lal, 2015; Verburg et al., 2013).

Water resources represented one of the most vulnerable components of Syria's agrifood system. Conflict-related damage to infrastructure, limited maintenance capacity, energy shortages, and weakened institutional management reduced the reliability of irrigation and water delivery systems. These pressures interacted with long-standing challenges associated with groundwater depletion, inefficient irrigation systems, and increasing climate variability that had already affected Syrian agriculture before 2011 (Gleick, 2014; Kelley et al., 2015; World Bank, 2023). In practice, reduced capacity to maintain canals, pumping stations, and water-control structures shifted a larger share of irrigation toward unregulated private groundwater pumping, accelerating aquifer drawdown in basins that were already operating close to

or beyond their estimated safe yield before the conflict began (Mourad & Berndtsson, 2012a). Field-level assessments corroborate this dynamic in practice, documenting farmers drilling new wells to compensate for unreliable surface supply — a coping response associated with declining regional water tables and the seasonal drying of smaller rivers and reservoirs (Alkaddour, 2024).

Land resources were also affected by reduced agricultural investment, declining access to inputs, disruption of extension services, and changes in farming practices. Evidence from conflict-affected agricultural systems indicates that prolonged instability can accelerate land degradation risks by reducing farmers' ability to maintain soil fertility, implement conservation practices, and invest in sustainable resource management (Baumann & Kuemmerle, 2016; Lal, 2015; FAO, 2023).

5.2 Physical and Economic Capital: Disrupted Infrastructure, Markets, and Value Chains

Agrifood systems depend on interconnected physical and economic networks linking input suppliers, producers, processors, traders, and consumers. Conflict frequently disrupts these relationships by damaging infrastructure, increasing transaction costs, reducing investment, and fragmenting agricultural value chains (Brück & d'Errico, 2019; Barrett et al., 2020). Deliberate destruction of standing crops has been documented as a distinct and recurring conflict-related risk to physical and natural capital alike: between 2017 and 2022, documented incidents exceeded 198 incidents of crops or farmland being set on fire were recorded nationally, with the large majority occurring during the May–June wheat harvest window, when a single

incident can destroy an entire season's yield over a wide area (Alkaddour, 2024).

In Syria, farmers increasingly faced constraints related to access and affordability of agricultural inputs, including quality seeds, fertilizers, fuel, machinery services, and veterinary supplies. These limitations reduced production capacity and increased livelihood vulnerability among rural households dependent on agriculture as their main source of income (FAO, 2022; World Bank, 2023). The cumulative effect on the country's principal food-security crop was severe: national wheat production fell from a pre-conflict average of roughly 4.1 million tonnes to a 29-year low of 1.2 million tonnes in 2018 and to a historic low of 1.05 million tonnes in 2021 under combined drought and input-access constraints (FAO, 2022; World Bank, 2023).

The livestock sector was particularly affected because animal production depends on functioning feed supply systems, veterinary services, grazing access, mobility routes, and market networks. Evidence from fragile dryland systems demonstrates that disruptions to these supporting systems can significantly reduce the adaptive capacity of livestock-dependent communities and increase vulnerability to future shocks (Herrero et al., 2016; Thornton et al., 2009).

The weakening of agricultural markets also reduced opportunities for value addition and rural economic recovery. Fragmented supply chains, limited processing capacity, and reduced private investment restricted the ability of farmers and rural enterprises to shift from primary production toward

more diversified and profitable agrifood activities. Strengthening inclusive value chains is therefore recognized as an essential pathway for improving resilience and rural development after major disruptions (Reardon et al., 2009; Barrett et al., 2020).

5.3 Human Capital: Loss of Knowledge, Skills, and Rural Livelihood Capacity

Human capital represents one of the most important but often underestimated components of agricultural recovery. Prolonged conflicts affect agricultural systems not only through physical destruction but also through population displacement, migration, disruption of education systems, loss of skilled workers, and weakening of knowledge-transfer mechanisms (Justino, 2012; Brück et al., 2019).

In Syria, large-scale displacement and livelihood disruption affected rural communities, agricultural labor availability, and the continuity of farming knowledge systems. Agricultural development depends heavily on accumulated experience, local ecological knowledge, technical skills, and intergenerational knowledge transfer, which can be weakened when farming communities are displaced or fragmented (FAO, 2023; Tengö et al., 2014).

Youth migration and declining rural economic opportunities created additional challenges for long-term agricultural transformation. Evidence from rural development studies indicates that rebuilding infrastructure alone is insufficient unless accompanied by investment in human capacity, agricultural education, entrepreneurship, and innovation systems capable of attracting future generations to agriculture (Spielman et al., 2009; Barrett et al., 2020).

5.4 Institutional Capital: Disruption of Services, Research, and Governance Systems

Effective agrifood systems require institutions capable of providing research, extension, regulation, coordination, market support, and natural resource governance. During prolonged crises, institutional capacity is often weakened through reduced financial resources, fragmentation of services, loss of personnel, and declining ability to maintain long-term development programs (North, 1990; World Bank, 2020). Agricultural research systems, extension networks, seed systems, and veterinary services are essential components of resilience because they facilitate technology transfer, adaptation, and farmer access to improved practices. Weak linkages between research institutions, farmers, and markets reduce the ability of agricultural systems to respond effectively to environmental and economic challenges (Spielman et al., 2009; Klerkx et al., 2012). Nevertheless, Syria's accumulated agricultural expertise, universities, research institutions, and professional human resources represent important assets for future recovery. International experiences show that reconnecting scientific capacity with farmers, private-sector actors, and development organizations is essential for rebuilding adaptive and innovation-oriented agrifood systems (Lipper et al., 2014; Barrett et al., 2020). The fate of ICARDA's own genebank illustrates both the fragility and the resilience of such institutional capital: roughly 83% of its Aleppo holdings were duplicated to the Svalbard Global Seed Vault between 2008 and 2014 as a security measure, and when access to the original collection was lost, ICARDA became the first and, to date, only genebank to withdraw its deposits from Svalbard, using the retrieved seed to

re-establish active genebank operations in Terbol, Lebanon, and Rabat, Morocco (ICARDA, 2019).

5.5 From System Disruption to Transformation Opportunity

The cumulative impacts of conflict demonstrate that Syria's agricultural challenge extends beyond restoring production volumes. Conflict affected the wider agrifood ecosystem, including natural resources, infrastructure, markets, institutions, and human capacities. Therefore, recovery approaches based only on replacing lost assets or returning to previous production models may fail to address future risks associated with climate change, resource scarcity, and socioeconomic transformation (Tendall et al., 2015; Béné et al., 2019).

The post-conflict recovery phase provides an opportunity to rebuild Syrian agriculture through a more resilient and sustainable development pathway. Transformative approaches in agrifood systems emphasize climate adaptation, sustainable resource management, inclusive value chains, innovation, and stronger integration between ecological, economic, and social objectives (Lipper et al., 2014; Campbell et al., 2018; Barrett et al., 2020).

To synthesize the historical evolution of Syrian agrifood systems and highlight the transition from production capacity to disruption and transformation opportunities, Table 1 summarizes the main characteristics, challenges, and priorities across the pre-conflict, conflict, and post-conflict recovery phases.

Table 1. Evolution of Syrian Agrifood Systems Across Historical and Recovery Phases

Dimension	Pre-conflict system (Before 2011)	Conflict disruption (2011–2024)	Transformation needs (Post-conflict)
Production systems	Diverse crop and livestock systems; strong agricultural base	Declining productivity and disrupted farming activities	Climate-resilient and diversified production systems
Natural resources	Irrigated and rainfed agriculture; rich biodiversity resources	Water stress, land degradation, reduced resource management	Sustainable land and water management
Knowledge and innovation	Research capacity, universities, and dryland expertise	Weakening of research-extension linkages and knowledge transfer	Rebuilding agricultural innovation systems
Value chains	Established markets and agro-industrial activities	Fragmented supply chains and reduced investment	Inclusive and competitive agrifood value chains
Institutions	Agricultural services and technical institutions	Reduced service delivery and institutional capacity	Adaptive governance and coordinated institutions

Rural communities	Agriculture-supported rural livelihoods	Displacement and livelihood disruption	Sustainable return and resilient rural economies

6. Syria's Post- conflict Recovery Opportunity: From Reconstruction to Agrifood System Transformation

The post- conflict period represents a critical transition point for Syrian agrifood systems. After more than a decade of conflict-related disruption, recovery efforts face a strategic choice between restoring previous agricultural structures or using reconstruction as an opportunity to address historical vulnerabilities and build more resilient, sustainable, and inclusive systems. International evidence from post-crisis recovery and resilience studies suggests that rebuilding processes are more effective when they combine physical reconstruction with institutional strengthening, risk reduction, and long-term adaptive capacity development rather than simply restoring pre-crisis conditions (Manyena et al., 2011; Tendall et al., 2015; Barrett et al., 2020).

For Syria, agricultural recovery cannot be limited to replacing damaged infrastructure or restoring short-term production capacity. Although rehabilitation of irrigation systems, productive assets, input supply networks, and agricultural infrastructure remains essential, sustainable recovery requires rebuilding the wider agrifood ecosystem, including research and innovation systems, extension services, financial mechanisms, market connections,

institutional capacity, and natural resource governance. Integrated food-system approaches emphasize that agricultural transformation requires coordinated improvements across production, processing, distribution, consumption, and environmental management dimensions (Ericksen, 2008; Béné et al., 2019; Barrett et al., 2020).

6.1 Moving from Agricultural Rehabilitation to Agrifood System Transformation

Emergency agricultural recovery programs in crisis-affected contexts commonly focus on restoring immediate livelihood capacity through the provision of seeds, tools, livestock support, and essential production inputs. While such interventions are necessary to protect food security and prevent further livelihood deterioration, they are insufficient to address deeper structural challenges associated with climate vulnerability, natural resource degradation, weak markets, and limited adaptive capacity (Tendall et al., 2015; Lipper et al., 2014).

The Syrian recovery phase provides an opportunity to move from a production-centered rehabilitation approach toward a comprehensive agrifood system transformation model. Such a transition requires strengthening the full agrifood chain, including sustainable natural resource management, climate-resilient production, processing capacity, market systems, consumption patterns, and circular resource use. Global food-system transformation literature highlights the need for approaches that simultaneously improve food security, economic opportunities, environmental sustainability, and resilience

to future shocks (Garnett et al., 2013; Campbell et al., 2018; Barrett et al., 2020).

6.2 Restoring Agricultural Knowledge, Research, and Innovation Systems

One of Syria's important recovery assets is its accumulated agricultural knowledge and scientific experience. Before the conflict, Syrian universities, agricultural research institutions, and collaborations with international research organizations contributed to dryland farming research, crop improvement, genetic resource conservation, water management, and adaptation strategies for arid and semi-arid environments (Ceccarelli & Grando, 2007; Jaradat, 2017). Reactivating and modernizing agricultural research and innovation systems should therefore represent a central component of recovery. Contemporary agricultural innovation-system approaches demonstrate that successful transformation depends not only on generating technologies but also on strengthening interactions among researchers, farmers, extension providers, private-sector actors, and policymakers (Spielman et al., 2009; Klerkx et al., 2012). In genetic-resource terms, this reactivation could draw directly on the safeguarded ICARDA collections now maintained in Lebanon and Morocco, which retain the great majority of Syria's pre-conflict crop diversity and could supply foundation seed for renewed national multiplication and variety-release programs once distribution channels are restored (ICARDA, 2019).

6.3 Rebuilding Rural Economies and Sustainable Livelihoods

Agrifood transformation is closely linked with rural economic recovery because agriculture provides income, employment opportunities, and connections between households, markets, and natural resources. Evidence from rural transformation studies shows that agricultural development contributes more effectively to poverty reduction and resilience when linked with diversified value chains, rural enterprises, market access, and non-farm economic opportunities (Reardon et al., 2009; Barrett et al., 2020).

For Syria, sustainable recovery requires moving beyond subsistence-oriented agricultural support toward rebuilding competitive and inclusive rural economies. Strengthening agricultural value chains, supporting small and medium rural enterprises, improving processing and storage capacity, enhancing market access, and encouraging responsible private-sector participation can increase income opportunities and improve rural resilience (Reardon et al., 2009; Barrett et al., 2020).

Youth and women represent important actors in future rural transformation. International experience indicates that inclusive access to skills development, entrepreneurship opportunities, financial services, technologies, and productive resources can strengthen participation in agricultural innovation and support more equitable rural development outcomes (Doss et al., 2018; Klerkx et al., 2012).

6.4 Agrifood Systems and Sustainable Return of Displaced Communities

The return and reintegration of displaced populations represent a major dimension of Syria's recovery process. Evidence from post-conflict recovery contexts indicates that sustainable reintegration depends not only on physical

reconstruction but also on restoring livelihoods, access to services, economic opportunities, and community-level resilience (Black & Gent, 2006; Fransen & Kuschminder, 2014).

In rural areas, agriculture can contribute to sustainable return processes by supporting livelihood restoration, rebuilding productive assets, and strengthening local economic opportunities. However, the sustainability of return depends on broader enabling conditions, including access to land, water resources, agricultural services, markets, infrastructure, and financial mechanisms (FAO, 2022; World Bank, 2023).

Agricultural recovery may also contribute to rebuilding cooperation among communities when interventions support inclusive economic opportunities, collective resource management, and locally driven development processes. However, such outcomes require conflict-sensitive approaches that recognize local social dynamics and avoid reinforcing existing inequalities (Brück et al., 2019; Justino, 2012).

6.5 Toward a New Generation of Syrian Agrifood Systems

The future of Syrian agriculture should not be viewed only through the lens of reconstruction but also as an opportunity for transformation. Emerging approaches, including climate-smart agriculture, conservation agriculture, digital innovation, circular bioeconomy systems, and integrated water–energy–food approaches, provide pathways for addressing both historical weaknesses and emerging challenges related to climate change and resource scarcity (Lipper et al., 2014; Muscat et al., 2021; Simpson & Jewitt, 2019).

A transformed Syrian agrifood system would combine the country's agricultural heritage, biodiversity resources, and scientific capacity with

modern approaches focused on resilience, sustainability, inclusiveness, and innovation. Achieving such transformation requires coordinated action among government institutions, universities, research centers, farmers, civil society organizations, private-sector actors, and international partners through integrated governance and innovation systems (Spielman et al., 2009; Barrett et al., 2020).

Based on these principles, this review proposes the Syria Sustainable Agrifood Recovery and Transformation Framework (SSARTF) as a conceptual pathway linking immediate agricultural recovery with long-term sustainability, climate resilience, economic revitalization, and inclusive rural development.

7. Sustainable Agrifood Transformation Pathways in Syria

Transforming Syrian agrifood systems after prolonged conflict requires moving beyond short-term rehabilitation toward integrated transformation pathways that simultaneously address productivity, climate resilience, environmental sustainability, economic recovery, and social inclusion. Global food-system research indicates that resilient agrifood transformation requires coordinated changes across natural resources, technologies, markets, institutions, governance structures, and social systems rather than focusing only on increasing agricultural production (Ericksen, 2008; Tendall et al., 2015; Barrett et al., 2020). Based on Syria's dryland agricultural conditions, accumulated scientific capacity, conflict-related recovery needs, and international evidence from fragile and climate-sensitive regions, seven interconnected pathways are proposed as foundations for building a sustainable and resilient agrifood system: climate-smart agriculture,

conservation agriculture, water–energy–food integration, circular bioeconomy, digital agriculture, inclusive agripreneurship and value-chain development, and institutional innovation.

The proposed SSARTF is consistent with emerging national recovery priorities outlined in the Syrian Agricultural Strategy 2026–2030, particularly regarding sustainable natural resource management, digital transformation, climate-smart agriculture, rural development, value-chain improvement, and strengthening agricultural services. While national strategies define priority intervention areas, SSARTF provides a systems-based conceptual framework that integrates these priorities within broader resilience, innovation, and transformation pathways.

7.1 Climate-Smart Agriculture: Building Resilience under Increasing Climate Risks

Climate change represents a major long-term challenge for global agrifood systems, particularly in arid and semi-arid regions where production depends strongly on rainfall variability, water availability, and ecosystem stability. The Eastern Mediterranean and West Asia region has been identified as highly vulnerable to increasing temperatures, drought risks, and changing precipitation patterns, creating additional challenges for agricultural productivity and rural livelihoods (Kelley et al., 2015; IPCC, 2023).

Climate-smart agriculture (CSA) provides an integrated approach that aims to increase agricultural productivity, strengthen adaptation capacity, and reduce environmental impacts where possible. CSA is particularly relevant for fragile agricultural systems because it combines food security objectives with

resilience building and sustainable resource management (Lipper et al., 2014). Operationally, CSA is commonly organized around three pillars, sustainably increasing productivity and incomes, strengthening resilience and adaptive capacity, and reducing greenhouse gas emissions where feasible, which together provide a practical checklist against which specific interventions can be screened (Lipper et al., 2014).

For Syria, CSA interventions may include drought-tolerant crop varieties, diversified farming systems, improved seed systems, efficient irrigation technologies, climate information services, and improved livestock management practices. Evidence from dryland agriculture demonstrates that locally adapted technologies and farmer-centered innovation processes are essential for improving resilience under water-limited environments (Ceccarelli & Grando, 2007; Lipper et al., 2014).

Rebuilding climate adaptation capacity will require strengthening interactions among researchers, extension services, farmers, and private-sector actors. Agricultural innovation-system research shows that effective transformation depends not only on technologies themselves but also on institutions and networks that enable knowledge exchange and adoption (Spielman et al., 2009; Klerkx et al., 2012).

7.2 Conservation Agriculture and Restoration of Natural Resources

Restoring soil health and improving land management represent critical priorities for sustainable recovery, especially in dryland environments where productivity is limited by water availability, soil degradation, and climate variability. Sustainable soil management is widely recognized as essential for

maintaining productivity, ecosystem functions, and long-term food security (Lal, 2015).

Conservation agriculture (CA), based on minimum soil disturbance, permanent soil cover, and diversified crop rotations, offers an approach for improving resource-use efficiency and agricultural resilience. Research has demonstrated that CA can improve soil structure, reduce erosion, enhance water conservation, and contribute to sustainable intensification when adapted to local agroecological conditions (Kassam et al., 2019; Pittelkow et al., 2015). Mechanistically, the combination of minimum soil disturbance and permanent residue cover increases water infiltration and reduces evaporative loss from the soil surface, effects that are particularly valuable in rainfed systems where a large share of seasonal precipitation would otherwise be lost before reaching the root zone (Pittelkow et al., 2015).

The relevance of CA for Syria is linked to the importance of rainfed farming systems and the need to increase resilience under water-limited conditions. Experiences from dryland systems show that CA performance depends strongly on adaptation to local environments, availability of suitable machinery, farmer knowledge, and supportive extension systems (Pittelkow et al., 2015; Kassam et al., 2019).

Scaling conservation agriculture therefore requires a systems approach that combines technical innovation with farmer training, demonstration platforms, machinery access, knowledge networks, and supportive institutional arrangements (Klerkx et al., 2012).

7.3 Water–Energy–Food Nexus: Managing Scarcity through Integrated Solutions

Water scarcity remains one of the greatest challenges facing agricultural development in arid and semi-arid regions. Because water resources, energy systems, and food production are strongly interconnected, sustainable recovery requires integrated approaches that consider trade-offs and synergies across sectors (Hoff, 2011; Rasul & Sharma, 2016).

The Water–Energy–Food (WEF) nexus approach recognizes that decisions related to irrigation, energy access, and agricultural production influence one another. Integrated planning can therefore improve resource efficiency and reduce unintended consequences from sector-based interventions (Rasul & Sharma, 2016).

For Syria, improving agricultural water productivity will be central to future resilience. Priorities include rehabilitation of irrigation systems, efficient water technologies, improved groundwater governance, climate-resilient planning, and better integration between agricultural and water-management policies (Gleick, 2014; World Bank, 2023). The technical case for modernization is substantial: surface irrigation, still the dominant method across much of Syria's irrigated area, typically achieves application efficiencies on the order of 50–60%, compared with efficiencies above 85–90% achievable with well-maintained drip systems, indicating considerable scope for water savings without expanding the irrigated area itself (Mourad & Berndtsson, 2012a).

Renewable energy, particularly solar-based agricultural energy systems, can contribute to recovery by improving access to energy for irrigation and rural enterprises. However, solar irrigation must be combined with effective water governance because lower pumping costs may increase groundwater extraction if not properly managed (Closas & Rap, 2017).

7.4 Circular Bioeconomy and Green Agricultural Innovation

Circular bioeconomy approaches aim to increase resource efficiency by transforming biological resources, agricultural residues, and organic waste streams into valuable products such as compost, bio-based materials, fertilizers, and alternative feed sources. Such approaches seek to reduce waste generation while creating new economic opportunities within agrifood systems (Muscat et al., 2021; Stegmann et al., 2020). Concrete technical entry points for Syria include composting of crop residues and manure to restore soil organic matter, small-scale anaerobic digestion of livestock waste to generate biogas and digestate fertilizer, and biochar production from pruning and orchard residues, each of which can be implemented at farm or community scale with relatively modest capital investment (Muscat et al., 2021).

For Syria's recovery context, circular agriculture may contribute to reducing dependency on external inputs, improving soil organic matter, supporting rural enterprises, and creating locally available solutions for resource management. Circular food-system studies emphasize that nutrient recycling, biomass utilization, and integrated production systems can strengthen sustainability when designed according to local conditions (Muscat et al., 2021).

Successful circular bioeconomy development requires collaboration among farmers, researchers, entrepreneurs, municipalities, and private-sector actors. Innovation networks and supportive institutions are therefore necessary to transform biological resources and waste streams into sustainable economic opportunities (Stegmann et al., 2020; Klerkx et al., 2012).

7.5 Digital Agriculture and Knowledge Systems

Digital technologies are increasingly influencing agrifood systems by improving information access, resource monitoring, decision-making, and service delivery. Digital agriculture includes tools such as remote sensing, geographic information systems, mobile advisory platforms, artificial intelligence, climate services, and early-warning systems (Wolfert et al., 2017). Earth-observation platforms such as FAO's WaPOR portal, which derives field-scale water productivity and evapotranspiration estimates from freely available satellite imagery across the Near East and North Africa, illustrate the type of climate information service that could be reactivated and localized to support irrigation scheduling, yield monitoring, and drought early warning during Syria's recovery phase (Wolfert et al., 2017).

In Syria's recovery phase, rebuilding agricultural information systems provides an opportunity to modernize extension services and improve evidence-based decision-making. Digital tools can support monitoring of crops, water resources, climate risks, pests, and market information, improving the ability of farmers and institutions to respond to changing conditions (Wolfert et al., 2017; Klerkx et al., 2019).

However, successful digital transformation requires more than technology availability. Inclusive digital agriculture depends on human capacity development, infrastructure, institutional readiness, and equitable access to prevent widening gaps between different groups of farmers (Klerkx et al., 2019).

7.6 Institutional Innovation and Agrifood Governance

Long-term agrifood transformation requires effective institutions capable of coordinating research, extension, markets, natural resource governance, and policy implementation. Institutional weaknesses can limit innovation adoption even when technologies and financial resources are available (North, 1990; Spielman et al., 2009). For Syria, rebuilding agricultural governance systems provides an opportunity to strengthen coordination among public institutions, universities, research organizations, farmers, civil society, and private-sector actors. Innovation-system approaches emphasize that collaboration among diverse actors is essential for adapting technologies and achieving sustainable transformation (Klerkx et al., 2012). Together, these seven interconnected pathways provide the foundation of the proposed Syria Sustainable Agrifood Recovery and Transformation Framework (SSARTF), linking climate resilience, natural resource restoration, technological innovation, institutional renewal, economic recovery, and inclusive rural development.

8. Agrifood Systems, Sustainable Return, and Rural Community Recovery

The transformation of agrifood systems in post- conflict Syria is closely connected with broader processes of sustainable return, rural recovery, and long-term community resilience. Evidence from post-conflict and displacement contexts shows that durable recovery requires more than rebuilding physical infrastructure; it also depends on restoring livelihoods, strengthening institutions, rebuilding social networks, and creating economic opportunities that enable households to regain self-reliance (Black & Gent, 2006; Fransen & Kuschminder, 2014; Brück et al., 2019).

Forced displacement often disrupts the relationship between rural populations and their productive assets, including agricultural land, livestock, local knowledge, markets, and social networks. Therefore, sustainable return should not be understood only as physical relocation to places of origin but as a multidimensional process involving livelihood restoration, access to resources, social reintegration, and institutional support (Black & Gent, 2006; Fransen & Kuschminder, 2014).

8.1 Agrifood Systems as Foundations for Sustainable Return

In rural contexts, agriculture can represent an important pathway for livelihood restoration after displacement because it reconnects households with income generation, food production, natural resources, and local economic systems. However, evidence from fragile contexts indicates that livelihood recovery depends on rebuilding the broader systems that support production rather than restoring agricultural activities alone (Scoones, 1998; Brück et al., 2019).

Agricultural support based only on providing inputs or replacing lost assets may generate short-term benefits but is unlikely to achieve sustainable recovery without addressing structural constraints. Long-term livelihood restoration requires access to land, water resources, extension services, financial mechanisms, markets, infrastructure, and functioning value chains (Scoones, 1998; Barrett et al., 2020).

For Syria, where many rural communities historically depended on crop and livestock production, agrifood recovery may provide an important foundation for voluntary and sustainable return when combined with broader improvements in services, infrastructure, governance, and economic opportunities. International evidence demonstrates that return sustainability depends on the interaction between household capacities, livelihood opportunities, security conditions, and institutional environments (Fransen & Kuschminder, 2014; UNHCR, 2023).

Therefore, agricultural recovery should be integrated within broader area-based recovery strategies rather than implemented as an isolated sectoral intervention. Linking agriculture with housing, water systems, markets, local governance, and social services can strengthen the enabling conditions needed for sustainable reintegration and community recovery (Barrett et al., 2020; Brück et al., 2019).

8.2 Rebuilding Rural Economies through Inclusive Value Chains

Post-conflict economic recovery requires rebuilding not only agricultural production capacity but also the value chains and market systems that connect producers with input suppliers, processors, traders, consumers, and service providers. Agricultural value-chain development can create wider

economic impacts by improving productivity, employment opportunities, market participation, and rural income diversification (Reardon et al., 2009; Barrett et al., 2020).

In recovery contexts, strengthening local agrifood value chains can support rural revitalization by improving market linkages, encouraging entrepreneurship, increasing value addition, and creating opportunities beyond primary production. However, successful value-chain development requires functioning institutions, infrastructure, financial services, and inclusive market access (Reardon et al., 2009; Barrett et al., 2020).

For Syria, rebuilding agricultural markets and supporting locally appropriate value chains—including crops, livestock, food processing, agricultural services, and rural enterprises—can contribute to transitioning from humanitarian assistance toward more sustainable economic recovery pathways. Evidence from rural transformation studies indicates that diversified rural economies are more resilient than systems dependent only on primary agricultural production (Barrett et al., 2020).

Small and medium enterprises, cooperatives, farmer organizations, and responsible private-sector actors can strengthen rural economies by improving access to services, technologies, knowledge, and markets. However, these actors require supportive institutional environments and effective coordination mechanisms to contribute to inclusive development (Spielman et al., 2009; Klerkx et al., 2012).

8.3 Youth and Women as Drivers of Rural Transformation

The sustainability of agrifood transformation depends on enabling youth and women to participate as innovators, entrepreneurs, and decision-makers rather than considering them only as vulnerable groups. Inclusive agricultural development requires reducing barriers related to access to productive resources, finance, knowledge, technologies, and markets (Doss et al., 2018). Youth participation is particularly important for the future of rural economies because demographic change, migration, and limited employment opportunities can reduce the attractiveness of agriculture for younger generations. Creating opportunities through agribusiness, digital agriculture, innovation, and entrepreneurship can support youth engagement in modern agrifood systems (Sumberg & Hunt, 2019; Klerkx et al., 2019).

Women contribute significantly across agrifood systems, including production, processing, household food security, and community resilience. Research shows that improving women's access to resources, technologies, information, and decision-making opportunities can strengthen agricultural productivity and broader development outcomes (Doss et al., 2018). For Syria's recovery phase, inclusive agrifood strategies should therefore prioritize skills development, entrepreneurship support, equitable access to services, and participation of women and youth across agricultural value chains and innovation systems (Doss et al., 2018; Barrett et al., 2020).

8.4 Agrifood Systems, Social Cohesion, and Peacebuilding

The relationship between agriculture and peacebuilding should be understood through the broader humanitarian–development–peace perspective. Agriculture alone cannot resolve conflict drivers, but inclusive livelihood recovery and improved resource governance may contribute to

reducing vulnerability, strengthening cooperation, and creating conditions supportive of social stability (Brück et al., 2019; Justino, 2012).

Natural resources such as land and water can become sources of tension when governance systems are weak, access is unequal, or competition increases. Conversely, participatory resource-management approaches can create opportunities for cooperation when they include transparent decision-making, equitable participation, and locally accepted institutions (Ostrom, 1990; Ratner et al., 2017).

For Syria, rebuilding local agricultural institutions, farmer organizations, water-user associations, and community-based mechanisms may support both economic recovery and social cohesion if implemented through inclusive and conflict-sensitive approaches. International experience highlights that livelihood interventions in fragile contexts must consider social relationships, governance structures, and potential conflict dynamics (Justino, 2012; Ratner et al., 2017).

8.5 From Aid Dependency to Locally Led Agrifood Recovery

A major challenge in prolonged crisis contexts is transitioning from emergency assistance toward sustainable development pathways. The humanitarian–development–peace nexus emphasizes the need to connect immediate support with long-term resilience, institutional strengthening, and locally owned development processes (Howe, 2019).

For Syria, this transition requires moving from short-term agricultural assistance toward locally led recovery models that strengthen capacities,

institutions, innovation systems, and economic opportunities. Farmers, universities, research institutions, civil society organizations, private-sector actors, and public institutions all represent essential components of a renewed agrifood ecosystem (Spielman et al., 2009; Klerkx et al., 2012).

The post- conflict recovery phase therefore provides an opportunity to position agrifood systems as platforms for sustainable return, rural revitalization, and resilience building. Integrating livelihood recovery, innovation, inclusive economic development, and responsible natural-resource governance can contribute to long-term recovery and more sustainable rural development pathways (Tendall et al., 2015; Barrett et al., 2020).

9. Proposed Syria Sustainable Agrifood Recovery and Transformation Framework (SSARTF)

The complexity of Syria's post- conflict recovery requires an integrated approach that moves beyond sector-specific agricultural rehabilitation toward comprehensive agrifood system transformation. Evidence from food-system research demonstrates that agricultural challenges are multidimensional and emerge from interactions among environmental conditions, production systems, markets, institutions, governance structures, and social processes (Ericksen, 2008; Tendall et al., 2015). Therefore, recovery strategies in fragile contexts require approaches capable of linking immediate livelihood restoration with long-term resilience, sustainability, and adaptive capacity (Béné et al., 2019; Barrett et al., 2020).

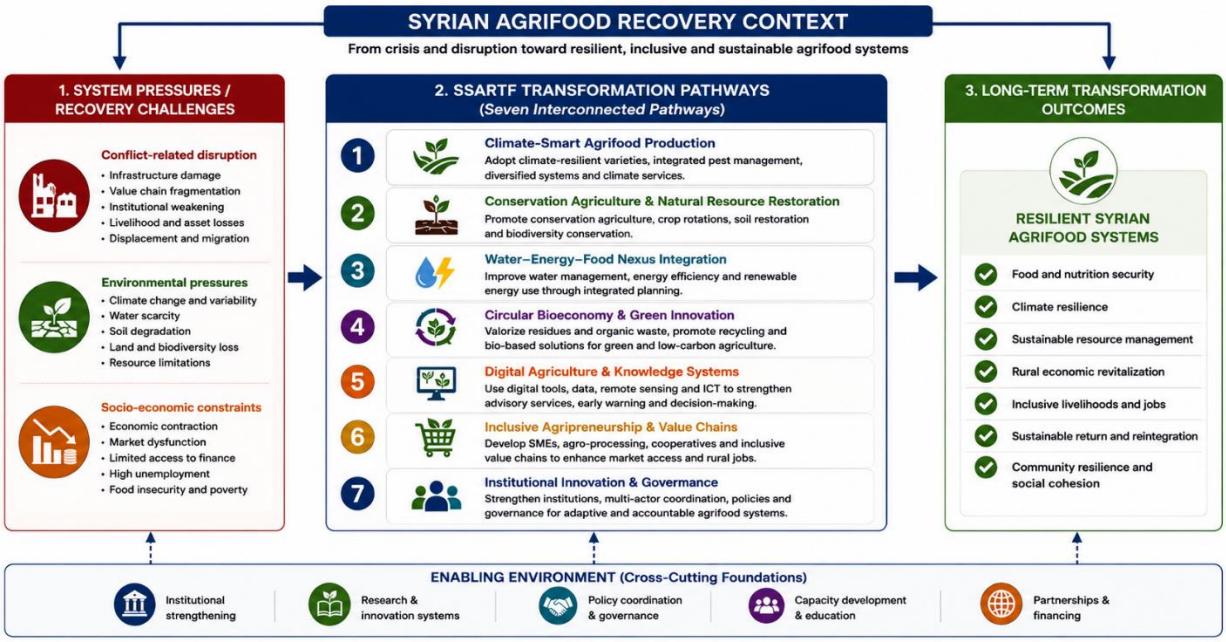
The analysis presented in previous sections indicates that Syrian agrifood systems face interconnected challenges, including pressure on

natural resources, climate vulnerability, disrupted value chains, weakened institutional capacity, reduced livelihood opportunities, and the need for sustainable rural recovery. Addressing such interconnected challenges requires a systems-based framework that considers agrifood systems as complex socio-ecological systems where environmental, economic, technological, and social components interact (Folke, 2006; Tendall et al., 2015).

Based on the synthesis of global evidence, Syria's agricultural context, conflict-related impacts, and identified transformation pathways, this review proposes the **Syria Sustainable Agrifood Recovery and Transformation Framework** (**SSARTF**) (Figure 1). The framework provides a conceptual roadmap for transitioning from a fragmented post-conflict agrifood system toward a more resilient, inclusive, climate-adaptive, and innovation-oriented system.

The SSARTF is based on the principle that sustainable recovery should not aim only to restore pre-conflict production structures but should use the recovery process as an opportunity to address historical vulnerabilities and strengthen future adaptive capacity. This perspective aligns with transformation approaches emphasizing that resilient food systems require changes in technologies, institutions, governance models, resource management, and social inclusion (Lipper et al., 2014; Campbell et al., 2018; Barrett et al., 2020).

Figure 1. Syria Sustainable Agrifood Recovery and Transformation Framework (SSARTF)



9.1 Structure of the SSARTF Framework

The proposed SSARTF consists of three interconnected levels: (1) recovery drivers, (2) transformation pathways, and (3) long-term outcomes. This structure reflects resilience-based approaches, where understanding system vulnerabilities, strengthening adaptive capacities, and achieving sustainable outcomes are interconnected processes (Folke, 2006; Tendall et al., 2015).

9.1.1 Recovery Drivers: Understanding the Starting Point

The first level recognizes that Syria's agrifood recovery begins from a context shaped by interacting environmental, economic, institutional, and social challenges. These include:

- natural resource degradation and climate pressures;
- disruption of agricultural infrastructure and services;
- fragmentation of agricultural value chains;
- reduced livelihood opportunities;
- weakened knowledge and innovation systems;
- institutional and governance challenges.

These drivers represent both constraints and entry points for transformation. Systems-based approaches emphasize that addressing root causes rather than isolated symptoms is necessary for improving long-term resilience and reducing vulnerability to future shocks (Ericksen, 2008; Béné et al., 2019).

9.1.2 Transformation Pathways: The Seven Pillars of SSARTF

The second level represents the core of the framework and includes seven mutually reinforcing transformation pathways.

Pillar 1: Climate-Smart Agrifood Production: Climate-smart agrifood production focuses on improving adaptation capacity while maintaining productivity under increasing climate risks. This pathway includes locally adapted crop varieties, improved seed systems, diversified farming systems, climate information services, efficient resource management, and resilient

livestock systems. Climate-smart agriculture provides an integrated approach connecting productivity, adaptation, and sustainability objectives (Lipper et al., 2014). Progress under this pillar could be tracked through indicators such as the share of cultivated area planted with drought- or heat-tolerant varieties, the proportion of farmers accessing seasonal climate advisories, and trends in cereal yield stability across rainfall-variable seasons.

Pillar 2: Conservation Agriculture and Natural Restoration: This pathway focuses on restoring ecosystem functions through sustainable soil management, conservation agriculture, biodiversity protection, and improved landscape management. These approaches are particularly important in dryland environments where soil health, water availability, and ecosystem resilience strongly influence agricultural sustainability (Lal, 2015; Pittelkow et al., 2015). Relevant monitoring indicators include the area under minimum-tillage or no-till management, changes in topsoil organic carbon content, and the extent of rehabilitated rangeland and degraded land brought back into productive or protective use.

Pillar 3: Water–Energy–Food Systems Integration: The framework emphasizes integrated management of water, energy, and agricultural systems. The Water–Energy–Food nexus approach recognizes that resource systems are interconnected and that coordinated planning can improve efficiency while reducing unintended trade-offs between sectors (Hoff, 2011; Rasul & Sharma, 2016). Indicators relevant to this pillar include irrigation water productivity (output per cubic meter applied), the share of irrigated area converted from surface to pressurized or drip systems, and the volume of groundwater abstraction relative to estimated safe yield by basin.

Pillar 4: Circular Bioeconomy and Green Innovation: Circular bioeconomy approaches aim to improve resource efficiency by converting agricultural residues, organic waste streams, and biological resources into valuable products and economic opportunities. Such approaches can contribute to sustainable production models, reduced resource dependency, and new rural economic activities (Muscat et al., 2021; Stegmann et al., 2020). Suitable indicators include the volume of agricultural residues diverted from open burning to composting or energy use, the number of farm- or community-level biogas or composting units established, and reductions in synthetic fertilizer dependency among participating farms.

Pillar 5: Digital Agriculture and Knowledge Systems: Digital transformation can support evidence-based agricultural recovery through remote sensing, climate information systems, digital extension services, data platforms, and decision-support technologies. However, successful digital transformation requires investment in human capacity, institutional readiness, and inclusive access mechanisms (Wolfert et al., 2017; Klerkx et al., 2019). Tracking progress could draw on indicators such as the share of extension advice delivered through digital or mobile channels, the geographic coverage of remote-sensing-based crop and water monitoring, and the proportion of farmers, disaggregated by gender and age, with active access to digital advisory services.

Pillar 6: Inclusive Agripreneurship and Value Chain Recovery: Agrifood transformation requires strengthening the economic systems connecting farmers with markets, services, and consumers. Inclusive value-chain

development, entrepreneurship, SMEs, and responsible private-sector engagement can improve rural income opportunities and strengthen economic resilience (Reardon et al., 2009; Barrett et al., 2020). Relevant indicators include the number of registered agrifood SMEs and cooperatives, the share of smallholder production sold through formal value chains rather than informal or distress sales, and the volume of private investment mobilized in processing, storage, and logistics infrastructure.

Pillar 7: Institutional Innovation, Sustainable Return, and Community Recovery: This pathway links agrifood transformation with livelihood restoration and community recovery. Sustainable return depends not only on physical reconstruction but also on restoring economic opportunities, access to resources, institutions, and social networks that enable long-term reintegration (Black & Gent, 2006; Fransen & Kuschminder, 2014). Indicators relevant to this pillar include the proportion of returnee households re-establishing agricultural livelihoods within a defined period, the functional status of community-based institutions such as water-user associations and farmer cooperatives, and measures of household food security and asset recovery among returning populations.

9.2 Expected Outcomes of SSARTF

The integration of the seven pathways aims to contribute to five interconnected transformation outcomes:

1. Improved food and nutrition security through resilient and diversified agrifood systems;
2. Rural economic recovery through value-chain development and entrepreneurship;

3. Climate resilience through sustainable natural resource management and adaptation;
4. Sustainable return support through restored livelihood opportunities;
5. Strengthened cooperation and community resilience through inclusive development processes.

These outcomes reflect the understanding that agrifood systems are not only production systems but also complex socio-economic and ecological systems influencing broader development pathways (Ericksen, 2008; Barrett et al., 2020).

The operational logic of the SSARTF framework, including transformation pathways, challenges addressed, strategic actions, expected outcomes, and key stakeholders, is summarized in Table 2.

Table 2. Syria Sustainable Agrifood Recovery and Transformation Framework (SSARTF): Pathways, Strategic Actions, Expected Outcomes, and Key Actors

SSARTF pathway	Challenges addressed	Strategic actions	Transformation outcomes	Main actors
Climate-smart agrifood production	Climate risks; productivity vulnerability	Resilient varieties; improved seeds; climate services;	Adaptation capacity; stable production; food security	Farmers; research institutions; extension services

		diversified systems		
Conservation agriculture & resource restoration	Soil degradation; water limitations	Minimum tillage; rotations; soil restoration; biodiversity protection	Improved soil health; resource efficiency	Farmers; universities ; NGOs
Water–Energy–Food Nexus	Water scarcity; energy constraints	Efficient irrigation; renewable energy; integrated planning	Sustainable resource management	Government; water agencies; private sector
Circular bioeconomy	Waste generation; input dependency	Recycling; composting; bio-based innovations	Resource efficiency; green enterprises	Researchers; SMEs; municipalities
Digital agriculture & knowledge systems	Data gaps; weak advisory systems	GIS; remote sensing; digital extension; early warning	Evidence-based decisions; improved services	Research centers; technology actors
Inclusive agripreneurs	Weak markets;	SMEs; processing; cooperatives;	Income generation; rural	Private sector; farmers;

hip & value chains	unemployment	entrepreneurship	economic recovery	financial actors
Institutional innovation, sustainable return & community recovery	Displacement impacts; livelihood losses	Livelihood restoration; community institutions	Resilient communities; sustainable reintegration	Communities; NGOs; public institutions

9.3 Implementation Considerations

Successful implementation of SSARTF requires coordinated action among multiple actors, including public institutions, universities, agricultural research organizations, farmers, civil society organizations, private-sector actors, and international partners. Innovation-system research demonstrates that agricultural transformation depends on interaction, knowledge exchange, and coordination among diverse actors rather than isolated technological interventions (Spielman et al., 2009; Klerkx et al., 2012).

The framework should not be considered a fixed model but an adaptive roadmap that can be adjusted according to Syria's diverse agroecological conditions, institutional capacities, available resources, and local priorities. Adaptive management approaches are essential because complex food systems continuously evolve under changing environmental, economic, and social conditions (Folke, 2006; Tendall et al., 2015).

Future research should focus on testing and refining SSARTF through field applications, participatory methods, and evidence-based monitoring systems. Such approaches can support learning processes and improve the effectiveness of agrifood transformation strategies over time (Klerkx et al., 2012).

10. Policy and Strategic Recommendations

Future recovery policies should build on existing national strategic directions while strengthening integrated agrifood system approaches that connect productivity improvement, climate resilience, innovation, markets, and inclusive rural transformation. Transforming Syrian agrifood systems from crisis recovery toward long-term resilience requires coordinated actions across policy, research, investment, institutional, and community levels. The proposed Syria Sustainable Agrifood Recovery and Transformation Framework (SSARTF) emphasizes that sustainable recovery cannot depend on isolated agricultural interventions but requires integrated approaches that strengthen adaptive capacity, rebuild institutions, restore productive systems, support innovation, and enhance rural economic opportunities. Food-system transformation literature highlights that sustainable change requires coordinated action across ecological, technological, economic, and governance dimensions (Ericksen, 2008; Tendall et al., 2015; Barrett et al., 2020). Based on the findings of this review and the SSARTF conceptual framework, the following strategic recommendations are proposed for policymakers, research institutions, development actors, private-sector

stakeholders, and rural communities involved in Syria's agrifood recovery and transformation.

10.1 Strengthening National Agrifood Policies and Institutional Capacities

Effective institutions and enabling policy environments are essential foundations for sustainable agrifood transformation because they influence how knowledge, technologies, resources, and services are generated, coordinated, and delivered across agricultural systems (North, 1990; Spielman et al., 2009). For Syria, future agricultural policies should move beyond restoring pre-conflict production structures toward building adaptive systems that integrate food security, climate adaptation, water management, rural development, and economic recovery objectives (Lipper et al., 2014; Barrett et al., 2020). Priority should be given to rebuilding and modernizing agricultural support services, including extension systems, veterinary services, seed systems, agricultural information platforms, and evidence-based planning mechanisms. Strengthening coordination among policymakers, researchers, farmers, and market actors will be essential for creating responsive institutions capable of supporting long-term agrifood transformation (Klerkx et al., 2012).

10.2 Revitalizing Agricultural Research, Universities, and Innovation Systems

Agricultural research and higher education institutions should play a central role in Syria's transition toward resilient agrifood systems. Innovation-

system approaches demonstrate that research organizations are most effective when connected with farmers, extension actors, businesses, and policymakers through collaborative networks that accelerate knowledge exchange and technology adoption (Spielman et al., 2009; Klerkx et al., 2012). Future research priorities should focus on practical challenges facing Syrian agriculture, including climate adaptation, drought resilience, sustainable water management, soil restoration, conservation agriculture, digital technologies, renewable energy applications, and circular bioeconomy innovations. Strengthening participatory research, young scientists, applied education, and innovation platforms will be critical for rebuilding national capacity and ensuring that agricultural solutions respond to local needs (Ceccarelli & Grando, 2007; Barrett et al., 2020).

10.3 Shifting Development Support from Short-Term Assistance to System Transformation

Development support in prolonged crisis contexts increasingly emphasizes linking immediate recovery with long-term resilience and system transformation. Resilience-based approaches focus on strengthening the capacities of households, communities, and institutions to absorb shocks, adapt to changing conditions, and transform unsustainable systems (Folke, 2006; Tendall et al., 2015). For Syria, recovery investments should gradually shift from short-term agricultural assistance toward strengthening local capacities, agricultural services, farmer organizations, value chains, climate-resilient infrastructure, and innovation systems. Applying a humanitarian–development–peace perspective can help align livelihood recovery with sustainable development objectives when implemented through conflict-

sensitive and locally adapted approaches (Justino, 2012; Brück et al., 2019; Barrett et al., 2020).

10.4 Enabling Private-Sector Engagement and Agrifood Value-Chain Development

A resilient agrifood system requires strong interaction among producers, processors, service providers, entrepreneurs, and markets. Evidence shows that inclusive value-chain development can increase rural incomes, create employment opportunities, improve market integration, and support agricultural transformation when supported by effective institutions and enabling environments (Reardon et al., 2009; Barrett et al., 2020). Future recovery strategies in Syria should encourage responsible investment, SMEs, agricultural service providers, processing industries, storage systems, and market infrastructure to move rural economies beyond primary production. Particular attention should be given to youth and women-led agribusiness initiatives through improved access to finance, technologies, skills, and market opportunities (Doss et al., 2018; Klerkx et al., 2019).

10.5 Strengthening Community-Based Agricultural Institutions

Community-based institutions represent an important bridge between national recovery strategies and local agricultural systems. Farmer organizations, cooperatives, water-user associations, and local institutions can facilitate collective action, improve access to services, and strengthen sustainable management of shared natural resources (Ostrom, 1990). For Syria's recovery phase, strengthening inclusive and participatory community structures can help rebuild cooperation, trust, and local ownership. Integrating

farmers and rural communities into planning and implementation processes will improve the relevance of interventions and support locally driven agrifood transformation adapted to diverse social and environmental conditions (Ostrom, 1990; Ratner et al., 2017; Klerkx et al., 2012).

10.6 Toward a Coordinated National Agrifood Transformation Agenda

The future of Syrian agriculture depends on establishing a coordinated transformation agenda that connects government institutions, universities, research organizations, farmers, civil society, private-sector actors, and international partners. Complex agrifood challenges require collaborative governance approaches because no single actor can address climate, economic, technological, and social dimensions independently (Spielman et al., 2009; Barrett et al., 2020).

The SSARTF framework provides a conceptual foundation for guiding this transition by linking immediate recovery priorities with long-term transformation pathways based on resilience, sustainability, innovation, and inclusion. Future implementation should focus on adaptive management, participatory learning, and evidence generation to refine strategies according to Syria's diverse environmental, economic, and social conditions (Folke, 2006; Klerkx et al., 2012).

11. Conclusion

The recovery of Syrian agrifood systems represents a critical opportunity not only to restore agricultural production but also to rethink and transform the foundations of agriculture and rural development after more than a decade of disruption. This review demonstrates that the challenges facing

Syrian agriculture extend beyond production decline and include interconnected impacts on natural resources, infrastructure, markets, institutions, knowledge systems, human capacities, and rural communities.

By analyzing the evolution of Syrian agrifood systems across three major phases—pre-conflict development before 2011, conflict-related disruption between 2011 and 2024, and the emerging post- conflict recovery phase—this review highlights the need to move from a narrow reconstruction approach toward a comprehensive systems-based transformation perspective. Syria's agricultural heritage accumulated scientific expertise, biodiversity resources, and farming traditions provide valuable foundations for recovery; however, future strategies must also address structural vulnerabilities related to climate change, water scarcity, resource degradation, market transformation, and institutional capacity.

The findings emphasize that rebuilding the agrifood sector should not aim to reproduce previous models but should use the recovery process as an opportunity to develop more adaptive, resource-efficient, and inclusive systems. Climate-smart agriculture, conservation agriculture, integrated water–energy–food approaches, circular bioeconomy, digital agriculture, institutional innovation, and inclusive value-chain development represent complementary pathways for strengthening the resilience and sustainability of Syrian agrifood systems.

Beyond food production, agrifood transformation has broader implications for rural recovery. Sustainable agricultural development can support livelihood restoration, strengthen local economies, create

opportunities for youth and women, and contribute to the conditions required for sustainable return and community resilience. Achieving these outcomes requires recognizing agriculture as a multidimensional system connecting economic recovery, environmental sustainability, and social development.

The proposed Syria Sustainable Agrifood Recovery and Transformation Framework (SSARTF) represent a conceptual roadmap for linking short-term recovery with long-term transformation. Future research should focus on validating and adapting this framework through field applications, participatory approaches, and evidence-based monitoring systems. By integrating recovery needs with long-term transformation pathways, SSARTF provides a structured approach for linking climate resilience, natural resource restoration, technological innovation, institutional strengthening, inclusive economic development, and rural community recovery. The framework offers a foundation for guiding future policies, investments, research agendas, and development interventions in Syria's agrifood sector. Attention should be given to assessing implementation models, identifying enabling conditions, measuring transformation outcomes, and adapting strategies to local realities.

Ultimately, the future of Syrian agriculture should not be defined only by the recovery of what was lost, but by the ability to build a more resilient, innovative, and sustainable agrifood system. Transforming current challenges into opportunities can enable agriculture to become a central driver of food security, climate adaptation, rural revitalization, and long-term sustainable development for future generations.

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