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Agro-landscapes under armed conflicts: global research trends and recovery priorities (2000–2026)

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Abstract
Armed conflicts are among the most disruptive forces acting on agro-landscapes, yet their impact on land-use systems and ecosystem services remains insufficiently integrated into landscape ecology and agroecological research. This paper aims to systematise the international body of knowledge on the mechanisms of war-induced impacts on agro-landscapes, to identify reproducible causal patterns of ecosystem service degradation, and to propose methodological priorities for comprehensive assessment and monitoring of agro-landscapes under active armed conflict and post-conflict recovery. The study is based on a bibliometric analysis of 1,502 publications (WoS/Scopus, 2000–2026) and a comparative analysis of five literature clusters reflecting the evolution of research paradigms from foundational ecological concepts to conflict-specific environmental impact studies. The synthesis shows that conflicts disrupt agro-landscapes through direct destruction, forced displacement, land abandonment, and institutional collapse, triggering cascading degradation of provisioning, regulating, supporting, and cultural ecosystem services. Resilience theory and socio-ecological systems frameworks are identified as essential but systematically underutilised analytical lenses. A pronounced geographic bias favouring East Africa and Latin America was detected, with Eastern Europe and the Middle East comparatively understudied — a gap being rapidly addressed by the Ukrainian case post-2022. Remote sensing has emerged as the dominant methodology for assessing conflict-induced land-use change, yet integration with socio-economic and institutional dimensions remains limited. The paper argues that the next priority is the development of coupled models — Earth observation + field validation + ecological-economic assessment + scenario analysis — capable of underpinning evidence-based agro-landscape recovery policy under conditions of prolonged uncertainty.

Keywords: *war, ecosystem services, resilience, remote sensing, food security, Ukraine*

Introduction

Russia's full-scale war against Ukraine has fundamentally altered not only Europe's security architecture but also the ecological and agricultural reality of vast territories. In Ukraine, the agro-landscape is no longer an abstract land-use category but a space of daily risk, loss, and recovery: mined fields, damaged drainage systems, soil degradation, destroyed logistics, water deficits, fragmented settlements, declining yields, and rising production costs. In this context, the academic debate on the impacts of armed conflict on agro-landscapes has acquired not only scholarly but also strategic significance for food security, regional development, and long-term ecological sustainability. Armed conflicts have affected more than 60 countries since 2000, displacing millions and disrupting agricultural systems upon which both local livelihoods and global food supply chains depend (Rawtani et al., 2022). The humanitarian consequences of warfare are widely documented, yet the environmental and agro-ecological dimensions — how conflict transforms landscapes that produce food, regulate water, and sustain biodiversity — have received comparatively fragmented attention. This fragmentation is both disciplinary and geographic: conflict–environment research has developed largely in isolation from landscape ecology,

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resilience theory, and agroecological science, despite sharing the fundamental question of how socio - ecological systems respond to disturbance. Agricultural landscapes are not passive recipients of wartime damage but complex socio-ecological systems (Berkes, 2005) whose trajectories are shaped by biophysical processes, institutional arrangements, and human agency. When conflict destroys not only physical infrastructure but also the social institutions, knowledge systems, and governance structures sustaining land management, agro-landscapes may undergo regime shifts — transitions to alternative stable states from which recovery is slow, costly, or impossible (Scheffer et al., 2000). Understanding these dynamics requires synthesising parallel research streams: ecological theory of catastrophic regime shifts, adaptive co-management scholarship, land-change science, and food-systems research linking agricultural disruption to food security. A bibliometric profile generated in Biblioshiny from the merged WoS/Scopus dataset reveals a mature and rapidly expanding field. The corpus comprises 1,502 publications (2000–2026) spanning 764 sources and 5,257 authors, with an annual growth rate of 8.17%, a mean document age of 6.53 years, and an average citation rate of 22.59 per document. Analysis of the 50 most-cited publications confirms that the field sits at the intersection of ecology, spatial planning, natural resource governance, and sustainability policy. These works collectively accumulate 9,619 citations, and their thematic structure signals a transition from foundational socio-ecological and land-degradation concepts towards research centred on conflict-induced food losses, satellite-based monitoring of wartime change, and risks to soil and water resources. Keyword co-occurrence networks consistently identify four thematic clusters: (I) conflict–agriculture–food security; (II) climate vulnerability–resilience–adaptation; (III) sustainable land use–biodiversity–ecosystem services; (IV) human dimensions of the environment, environmental protection, and governance. Conceptually, this indicates that contemporary research increasingly frames war not merely as a destructive event but as a systemic shock that alters agro-landscape trajectories, restructures ecosystem functions, and reshapes governance frameworks. The ecosystem services concept is a methodologically critical tool enabling the shift from fragmented damage description towards a systemic assessment of landscape functional loss. For Ukraine, this requires simultaneously evaluating all three service groups under CICES V5.2 (Common International Classification of Ecosystem Services): provisioning (crops, biomass, irrigation water), regulating (carbon retention, erosion control, water regulation), and cultural (local identity, landscape heritage, recreational value of de-occupied territories). Disruption of each group in active combat zones generates cumulative effects: soil degradation amplifies yield losses, biodiversity loss reduces self-recovery capacity, and destruction of water infrastructure increases vulnerability to drought and extreme events. The aim of this paper is, through bibliometric mapping and comparative spatio-temporal analysis of conflict cases (Caucasus, Middle East, Africa, Ukraine), to systematise the international body of knowledge on the mechanisms of war-induced impacts on agro-landscapes, to identify reproducible causal patterns of ecosystem service degradation, and to propose methodological priorities for comprehensive assessment and monitoring of agro-landscapes under active armed conflict and post-conflict recovery.

Methodology and data

The empirical dataset was assembled by merging records from Web of Science and Scopus (2000–2026), followed by deduplication, field unification, and metadata harmonisation in Zotero, with subsequent bibliometric analysis in bibliometrix/Biblioshiny (Aria and Cuccurullo, 2017; Donthu et al., 2021). The final corpus comprised 1,502 documents. The methodological design comprised four sequential stages: (1) descriptive bibliometrics (publication dynamics, citation structure, source and authorship profiles); (2) performance analysis (most-cited works, authors' productivity over time); (3) science mapping (keyword co-occurrence networks, thematic maps, thematic evolution, MCA factorial analysis); (4) analytical interpretation within the Ukrainian context of war-induced impacts on agro-landscapes and ecosystem services. Clustering was performed using the Louvain algorithm; link normalisation was performed using association strength; strategic maps employed KW_Merged (n=250, minfreq=7, without stemming or n-grams). A qualitative in-depth analysis was additionally conducted comprising a review of the 50 most-cited publications and a comparative analysis of five chronological clusters (2000–2007; 2008–2013; 2014–2018; 2018–2022; 2023–2026) reflecting the evolution of research paradigms. Internal validity was ensured through triangulation across the Main Information, Trend Topics, Thematic Map, Thematic Evolution, Co-occurrence Network, Facto-

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rial Analysis, Life Cycle, and Authors' Production over Time components. A limitation is the incomplete Cited References field in the merged dataset, which constrains co-citation analysis; however, reliability of findings was strengthened by cross-comparison of independent bibliometric indicators (Page *et al.*, 2021). The publication selection design follows an adapted PRISMA protocol (Table 1).

Identification	Search in WoS + Scopus (2000–2026)
Screening	Field unification, deduplication, and technical metadata cleaning (Zotero)
Eligibility	Relevance check: armed conflict, agro-landscapes, ecosystem services
Inclusion	Final corpus: 1,502 documents; bibliometric and thematic mapping (Biblioshiny)

Table 1. *Adapted PRISMA protocol for the bibliometric review design.*

Overall structure of the bibliometric dataset

The bibliometric corpus (1,502 documents, 2000–2026) reveals a sustained transition from descriptive case studies towards an integrated conflict–agro-landscapes–ecosystem services framework (Aria and Cuccurullo, 2017; Donthu *et al.*, 2021). The annual scientific production curve (Fig. 1) shows an accelerating trend consistent with rapid field expansion and growing policy relevance for food security. Over time, a qualitative shift in thematic focus is evident: from 'war/agricultural land' towards interconnected clusters of 'food security–ecosystem services–resilience–remote sensing–climate change' (Fig. 2). This reflects a gradual international shift from documenting direct damage towards modelling long-term consequences for agroecosystem functioning (MacDonald *et al.*, 2000; Robinson and Sutherland, 2002). The most likely drivers are the accumulation of high-resolution satellite data and growing demand for evidence-based policy under conditions of climatic uncertainty.

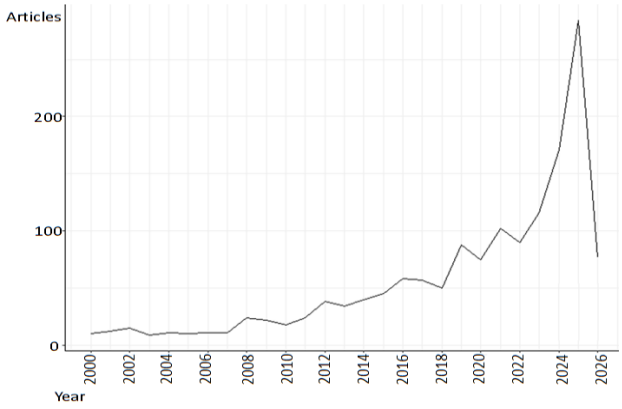

Figure 1. *Annual scientific production as reported by bibliometrix/Biblioshiny*

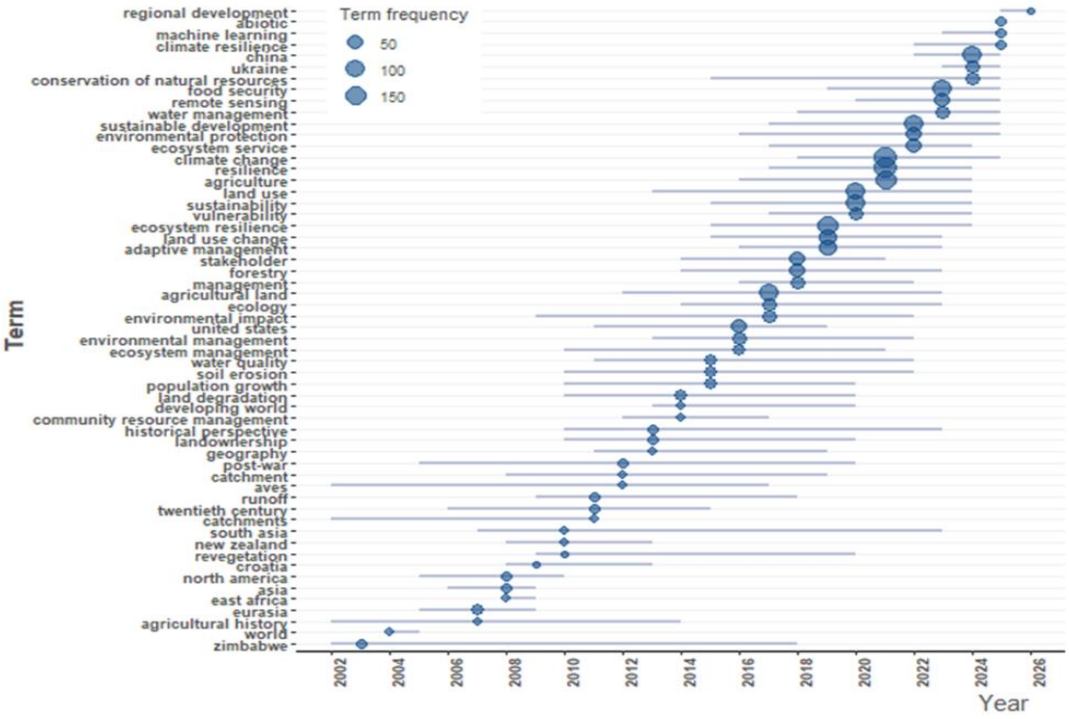

Figure 2
Evolution of trending topics in research on war-induced impacts on agro-landscapes

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The thematic map (Fig. 3) confirms the dominance of the motor clusters 'agriculture–agricultural land–war' and 'human–environmental protection'. The 'sustainable development' and 'ecosystem resilience' clusters occupy the emerging zone - conceptually significant but not yet fully integrated into the core. This reflects an asymmetry between the speed of damage documentation and the slower institutionalisation of recovery assessment and ecological-economic compensation methodologies (Berke et al., 2015; Bush and Doyon, 2019).

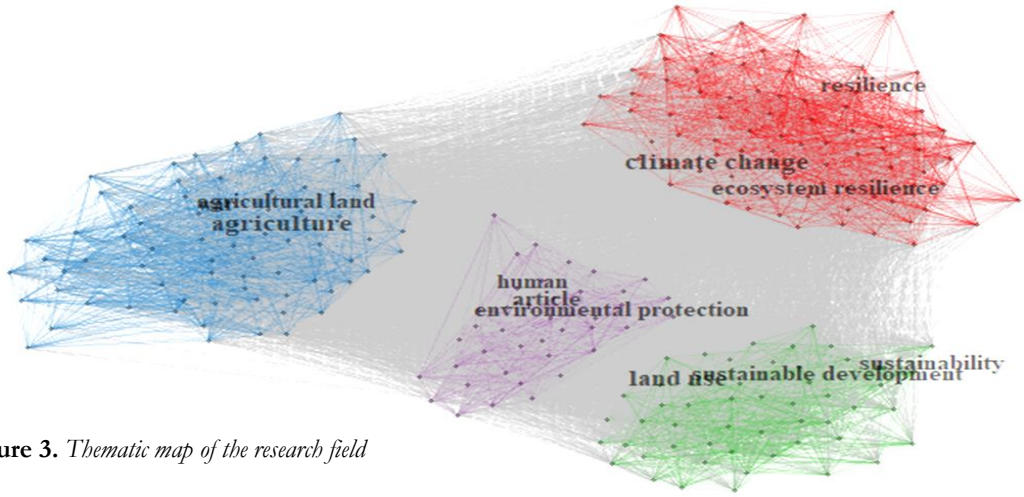

Figure 3. *Thematic map of the research field*

Evolution of research paradigms: analysis of chronological clusters

Cluster 1 (2000–2007): foundational paradigms. The earliest cluster (Fig. 4) is dominated by foundational ecological and land-system works that provide the theoretical infrastructure for subsequent research. The most influential studies — MacDonald *et al.* (2000) on the drivers of agricultural change in Europe and Robinson and Sutherland (2002) on farmland bird declines from agricultural intensification — define the central question of this period: how agro-landscapes and their biodiversity respond to socio-economic and policy-driven change. Theoretical frameworks centre on resilience and socio-ecological systems (SES). Scheffer et al. (2001) introduced the concept of catastrophic regime shifts in ecosystems, demonstrating that gradual environmental change can trigger sudden, irreversible state transitions — a framework that would later prove essential for interpreting war impacts on agro-landscapes. F. Berkes (2005) extended resilience thinking to commons governance, demonstrating that cross-scale institutional linkages sustain adaptive management. Hahn et al. (2006) developed the adaptive co-management paradigm, showing how trust-building and social networks underpin ecosystem governance.

Methodologically, this cluster relies on field-based ecological surveys, statistical modelling, and spatial analysis (Aspinall and Pearson, 2000). Remote sensing

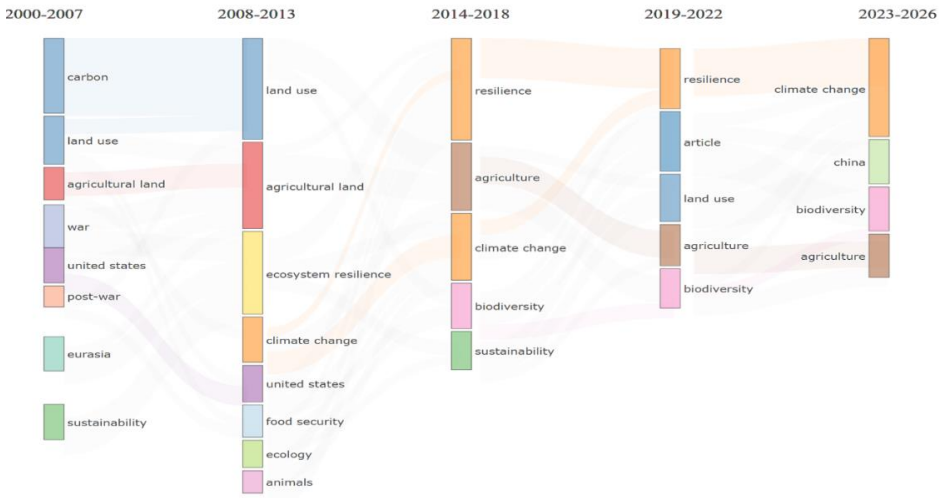

Figure 4
Thematic evolution across chronological clusters (2000–2026)

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is present but secondary. Armed conflict is essentially absent as a theme, not yet conceptualised as a driver of agro-landscape change. The cluster's significance for subsequent research lies entirely in its theoretical contribution: the concepts of regime shifts, adaptive capacity, and institutional resilience were later retroactively applied to understanding war-induced impacts.

Cluster 2 (2008–2013): emergence of the climate-conflict nexus. This cluster marks a decisive shift towards direct examination of the environmental determinants of conflict and, to a lesser extent, conflict's effects on the environment. The paradigmatic transition is captured by Schilling et al. (2012) — the cluster's most-cited work, which documented how climate change intensifies resource competition among Kenyan pastoralists, establishing the climate–conflict nexus as a major research theme. O. Theisen (2012) provided a more cautious counterpoint, showing that the relationship between climate variability and armed conflict in Africa is conditional on political marginalisation - a fundamental disagreement that persists. The theoretical landscape broadens during this period. M. Fernández-Giménez et al. (2012) advanced understanding of adaptive capacity in pastoral systems, whilst Barthel et al. (2013) introduced the concept of social-ecological memory - the idea that accumulated knowledge, practices, and biocultural artefacts sustain adaptive management, and that their loss may be irreversible. Allouche et al. (2011) developed the water–food–energy nexus framework, arguing that these dimensions of security are inseparable - a conceptual advance with direct implications for conflict-affected regions where all three are simultaneously threatened. Remote sensing gained prominence through Hostert et al. (2011), who used Landsat time-series analysis to map land-cover change across the Caucasus, providing some of the first satellite-based evidence of conflict-related land-use change in Eastern Europe. Sánchez-Cuervo and Aide (2013) documented the paradoxical effects of the Colombian armed conflict on forest cover: in some regions, forced displacement reduced deforestation pressure, whilst in others, armed groups actively promoted it.

Cluster 3 (2014–2018): land-system science integrates conflict evidence. The third cluster consolidates the empirical evidence base, particularly for Eastern Europe and post-Soviet regions. Munteanu et al. (2014) provided a comprehensive assessment of agricultural land change across Eastern Europe, documenting how post-socialist transition drove widespread cropland abandonment - processes amplified in conflict-affected areas. Yin et al. (2018) - arguably the single most important study for the conflict–agro-landscape nexus - combined satellite-derived agricultural change maps with conflict-intensity data for the Chechen Wars, demonstrating that proximity to conflict and conflict intensity were both positively correlated with cropland abandonment, whilst recultivation remained limited even years later despite substantial subsidies (Yin et al., 2019). Baumann and Kuemmerle (2016) situated these findings within the broader context of the post-Soviet land transition. Food security also emerges in this cluster as an explicit concern linked to conflict. Solh and Van Ginkel (2014) documented food production challenges in conflict-prone drylands of the Middle East and North Africa. Eklund et al. (2017) employed remote sensing to assess environmental change in conflict-affected areas of the Middle East. Methodologically, remote sensing dominates the empirical conflict work, with increasing analytical sophistication: Yin et al. (2018) employed logistic and panel regressions linking conflict distance to intensity measures.

Cluster 4 (2019–2022): war enters the mainstream. The fourth cluster reflects a period of rapid expansion in conflict–environment research. Schilling et al. (2018; 2020) extended the climate–conflict analysis to broader regional environmental change frameworks. Rawtani et al. (2022) conducted a comprehensive review of the environmental consequences of military conflicts (soil contamination, water pollution, ecosystem destruction), constituting the first high-impact synthesis explicitly framing war as an environmental rather than solely a political problem. Olsen et al. (2021) used satellite remote sensing to reveal that conflict-driven cropland abandonment in South Sudan could have supported a quarter of the affected states' population - a critical link between land-use change and food insecurity. Theoretically significant is the convergence of urban resi-lience (Bush and Doyon, 2019; Sharifi, 2019) and rural agro-landscape research under a shared resilience framework. Ntihinyurwa et al. (2019) documented post-conflict land tenure challenges in Rwanda, sho-wing that insecurity of property rights following the 1994 genocide generated persistent conflicts that undermined agricultural investment. The water–food nexus deepens further: Falkenmark et al. (2019) articulated the green/blue water framework for food production; Benton et al. (2021) argued that food system resilience depends on biodiversity that conflict systematically erodes.

Cluster 5 (2023–2026): Ukraine transforms the field. The most recent cluster represents a paradigm-

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level disruption driven primarily by the Russia–Ukraine war. Alexander et al. (2016) demonstrated how the war disrupted global food systems through cascading effects on commodity prices, trade flows, and food access in import-dependent countries. These works signal that conflict impacts on agro-landscapes are now understood as globally consequential, not merely locally devastating. Several new themes emerged within this cluster. Direct environmental damage assessment has become a research priority: Solokha et al. (2023) and O. Dmytruk et al. (2023) documented soil contamination and agro-landscape degradation in Ukraine in real or near-real time — a qualitative departure from earlier retrospective studies. Food system shock analysis has emerged as a distinct subfield: Tamasiga et al. (2023) and Chai et al. (2024) analyse how the Ukrainian war propagated through global food markets, affecting nutritional outcomes in distant countries. Remote sensing for active conflict zones has advanced markedly: Bun et al. (2024) used satellite data to assess war-induced changes in Ukrainian GHG emissions and land use, employing multi-sensor approaches (Sentinel-1, Sentinel-2, commercial imagery) with near-real-time monitoring and integration with conflict event databases (Kussul et al., 2025; Wagner et al., 2026).

Mechanisms of war-induced impacts on agro-landscapes

Land-use change and land abandonment. Armed conflict drives land-use change through several mechanisms: direct physical destruction, forced displacement leading to land abandonment, military requisitioning of agricultural land, and post-conflict redistribution of land rights. The most robust evidence comes from remote-sensing studies in Eastern Europe and the Caucasus, where the intersection of post-socialist transformation and armed conflict created natural experiments for disentangling conflict-specific from broader political-economic drivers of land change. Munteanu et al. (2014) provided one of the most comprehensive assessments, documenting widespread abandonment of agricultural land across Eastern Europe following the collapse of the Soviet Union. Hostert et al. (2011) used Landsat time-series analysis to map land-cover change across the Caucasus, finding that areas affected by the Chechen and Georgian conflicts experienced substantially higher cropland abandonment rates than comparable non-conflict areas during similar post-socialist transitions. Yin et al. (2019) and Buchner et al. (2022) extended this work, combining satellite agricultural change maps with conflict-intensity data and demonstrating that proximity to conflict events and conflict intensity were both positively correlated with cropland abandonment during the Chechen Wars, whilst recultivation rates remained low even after hostilities ended despite substantial subsidies. Baumann and Kuemmerle (2016) situated these conflict-driven changes within the broader context of post-Soviet land transitions across Eastern Europe. Beyond Eastern Europe, Sánchez-Cuervo and Aide (2013) demonstrated that the Colombian armed conflict had paradoxical effects on forest cover: in some regions, displacement reduced deforestation pressure, whilst in others, armed groups actively promoted it. This highlights that the direction of conflict-driven land-use change is not uniform and depends on the specific political ecology of the conflict — who controls territory, for what purposes, and how displaced populations respond.

Soil degradation and environmental damage. The direct physical impacts of military operations on soils and ecosystems are documented primarily through case studies. Rawtani et al. (2022) catalogued pathways of war-related environmental degradation: explosive ordinance cratering and compaction of agricultural soils, heavy-metal and unexploded-ordnance contamination, destruction of irrigation infrastructure, and deliberate environmental destruction as a military strategy. R. Thomas (2008) provided context on land degradation processes in dryland agroecosystems, showing that even moderate disturbances can trigger feedback loops leading to persistent degradation - a dynamic amplified by the scale and intensity of military operations. Cowie et al. (2011) distinguished between degradation of provisioning services and degradation of supporting and regulating ecosystem services. This framework is critical for war-damaged landscapes, where visible destruction of productive capacity may obscure equally significant but less visible degradation of soil structure, nutrient cycling, and water regulation. For Ukraine, these processes are documented as particularly acute: data on nutrient imbalance and water stress merely outline the scale of the problem (Pichura and Potravka, 2025; Medinets et al., 2025).

Water resources and hydrological stress. Falkenmark et al. (2019) articulated the challenge of water scarcity for food production, distinguishing between 'green water' (soil moisture sustaining rainfed agriculture) and 'blue water' (surface and groundwater). Destruction of water infrastructure disrupts blue water allocation, whilst land abandonment and soil degradation alter green water dynamics. Allouche et al. (2011) deve-

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loped the water–food–energy nexus framework, arguing that these dimensions of security cannot be addressed in isolation - a point that applies with particular force to conflict-affected regions. Ziegler et al. (2009) demonstrated how land-use changes in upland areas alter hydrological processes with downstream consequences - a dynamic that intensifies when watershed management is disrupted by conflict-driven population displacement.

Biodiversity and ecosystem services. The relationship between armed conflict and biodiversity presents one of the most significant contradictions in the literature. On one hand, war directly destroys habitats, wildlife, and ecosystem structure. On the other, conflict-driven depopulation and land abandonment may create de facto conservation areas where biodiversity recovers in the absence of management pressure. Robinson and Sutherland (2002) and MacDonald et al. (2000) documented severe biodiversity declines associated with agricultural intensification in Europe - notably less severe in post-socialist Eastern Europe, where agriculture was less intensive (Bignal and McCracken, 2000). This body of work establishes a critical paradox for conflict-affected landscapes: the conflict-driven 'extensification' or abandonment of farmland may, from a farmland biodiversity perspective, resemble the conservation-friendly low-intensity farming now promoted by agri-environment schemes across Western Europe. Borie and Hulme (2015) critically examined how ecosystem service assessments are constructed and contested, arguing that the framing of environmental values is inherently political — an insight particularly relevant for post-conflict reconstruction, where competing claims over land use, ecosystem services, and environmental priorities reflect the same power dynamics that fuelled the original conflict.

Agricultural productivity and food security. The food security consequences of conflict are perhaps the most immediately critical for affected populations. Alexander et al. (2023) demonstrated how the Russia–Ukraine war disrupted global food systems — not merely through reduced grain production but through cascading effects on commodity prices, trade flows, and food access in import-dependent countries. He et al. (2023) conducted a quantitative analysis of land abandonment and grain production losses in Ukraine, underlining that conflict impacts on agro-landscapes extend far beyond the conflict zone itself (Behnassi and El Haiba, 2022; Zhang et al., 2024). Schilling et al. (2012) provided detailed empirical evidence of how climate change intensifies resource competition, generating pastoral conflicts in East Africa. Schilling et al. (2018; 2020) extended this analysis, showing that the climate–conflict nexus operates through multiple pathways including livelihood disruption, competition for diminishing resources, and erosion of traditional conflict-resolution mechanisms. Kotykova et al. (2025) systematised the regional and global consequences of war-induced impacts on Ukrainian agriculture, confirming Ukraine as the central empirical node of contemporary research.

Conflict nodes: a spatio-temporal overview

Combined thematic and author dynamics analysis reveals that the corpus of 1,502 publications represents several territorial conflict ‘nodes’. In the early period (2000s–early 2010s), post-Soviet Caucasus wars (Nagorno-Karabakh, the Chechen Wars) and Middle Eastern and North African cases dominate; in the later period (post-2014), the share of studies on Russia’s war against Ukraine rises sharply. For the Caucasus node, publications consistently document the mechanism ‘proximity to the conflict line → higher probability of land abandonment → slow or incomplete recovery’. For Nagorno-Karabakh, large-scale withdrawal of arable land in combat zones and partial relocation of agricultural production to adjacent territories have been demonstrated (Baumann et al., 2015). For the Northern Caucasus (Chechnya), event intensity and distance to centres of violence have been shown to be statistically associated with cropland abandonment, whilst post-war land recovery is spatially uneven (Yin et al., 2019). The Middle Eastern node (Syria–Iraq) is represented primarily by remote-sensing studies tracking disruption of seasonal cultivation cycles, declining land-use intensity, and crop structure transformation under prolonged conflict (Eklund et al., 2017; Hazaymeh et al., 2022). For Tigray (Ethiopia, 2020–2022), a different pattern emerges: despite extreme wartime pressure, part of the smallholder system maintained production through local self-organisation, shifting to less resource-intensive crops, and adapting the fieldwork calendar (Nyssen et al., 2023). The Ukrainian node (Donbas from 2014; full-scale war from 2022) exhibits the highest publication growth rate in 2022–2026 and the strongest linkages with 'food security', 'remote sensing', 'resilience', and 'global spillovers' (He et al., 2023; Kussul et al., 2025; Wagner et al., 2026). This signals a transition from local conflict analysis to at minimum a regional — and increasingly global — framing: the destruction of Ukrainian agro-landscapes is understood

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not merely as a national environmental problem but as a factor reshaping global food and ecological structures. The causal logic is consistent across all nodes: (I) violence and restricted field access reduce actual cultivability; (II) infrastructure destruction, labour/capital shortages, and forced migration deepen land abandonment; (III) land-use change triggers losses of ecosystem services (soil protection, water regulation, provisioning); (IV) in open agro-economies, these losses are transmitted through trade and price channels to the supranational level (Baumann and Kuemmerle, 2016; Alexander et al., 2023; Zhang et al., 2024). Ukraine's distinctiveness lies in the simultaneous operation of all these links, most critically within a major grain-producing region.

Theoretical bridges: synthesis of conceptual frameworks

Several conceptual bridges connect the bodies of literature reviewed here. The most significant is the shared concern with thresholds and irreversibility. The theory of Scheffer et al. (2000) on catastrophic regime shifts in ecosystems provides a formal framework for understanding why some war-damaged agro-landscapes fail to recover even when hostilities cease, and reconstruction resources are provided. The finding of Yin et al. (2019) - limited recultivation after the Chechen Wars despite substantial subsidies - is consistent with a regime-shift interpretation: the socio-ecological system crossed a threshold into an alternative stable state (abandoned land with degraded institutions) from which recovery requires qualitatively different interventions. Institutional destruction as resilience erosion constitutes a second critical bridge. F. Berkes (2005) de-monstrated that cross-scale institutional linkages sustain resource management; Hahn et al. (2006) showed that adaptive co-management depends on social networks and trust - features that armed conflict systematically destroys. Ntihinyurwa et al. (2019) docu-mented specific consequences in post-conflict Rwanda, where insecurity of land tenure generated persistent conflicts undermining agricultural investment. Institu-tional destruction is not a temporary disruption but a loss of social-ecological memory (Barthel et al., 2013) that may take generations to rebuild. Land abandon-ment as a shared process bridges the post-socialist transition literature and conflict studies. MacDonald et al. (2000) and Munteanu et al. (2014) documented land abandonment driven by economic liberalisation and institutional change across Eastern Europe. The Caucasus studies (Hostert et al., 2011; Yin et al., 2019; Baumann and Kuemmerle, 2016) show that armed conflict amplifies and spatially con-centrates these processes. The resulting landscapes – fallows and scrub – simultaneously present ecological opportunities (biodiversity recovery, carbon sequestration) and socio-economic challenges (lost food produc-tion, depopulation).

Research field structure: mature themes, emerging trends, and critical gaps

On the basis of the bibliometric analysis, the spatio-temporal analysis of conflict nodes, and the most recent 2025–2026 publications, the thematic landscape may be divided into three levels of maturity (Table 2). Mature research includes studies linking armed conflict to land abandonment, productivity decline, and food security risks — for which a consistent evidence chain across multiple regions already exists. Equally mature is the conceptualisation of resilience and adaptive management in socio-ecological systems (Hahn et al., 2006;

Table 2. *Research field structure: mature themes, emerging trends, and critical gaps*

Category	What is already known / documented	Next steps
Mature themes	Robust evidence across multiple regions linking conflict intensity, land abandonment, yield decline, and food security risks	Translating accumulated empirical findings into damage assessment standards and recovery prioritisation frameworks for state-level policy.
Emerging trends	Rapid growth in satellite monitoring, machine-learning models, and near-real-time crop area assessment under wartime conditions	Integrating remote-sensing data with field validation, official statistics, and food-market projections.
Critical gaps	Insufficient models coupling conflict spatial data with monetary valuation of ecosystem service losses and long-term climate risks	Building 'war + climate' scenario models to inform decisions on demining, land reclamation, irrigation restoration, and investment in resilient land use.

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Berke et al., 2015). Since 2022, there has been rapid growth in high-frequency machine-learning and satellite-based monitoring of wartime agricultural change. In parallel, the research axis 'local war shock → global food/ecological effects' has strengthened, with Ukraine confirmed as a key test of market interdependence (Behnassi and El Haiba, 2022; Zhang et al., 2024; Kotykova et al., 2025).

Geographic and methodological biases

Geographic bias is the most pronounced limitation. East Africa (particularly Kenya) dominates the climate–conflict nexus; Eastern Europe dominates post-Soviet land-use change studies; Ukraine dominates the most recent cluster. Latin American conflict–environment research (Sánchez-Cuervo and Aide, 2013) features in Clusters 2–3 but has not expanded. Conflicts in South and South-East Asia are virtually absent despite major impacts on agricultural regions. Methodological bias towards remote sensing creates blind spots: satellite imagery reveals that land was abandoned but not why - whether due to displacement, insecurity, loss of inputs, infrastructure destruction, or rational decision-making under uncertainty. The institutional, social - psychological, and governance dimensions of conflict–agro-landscape interactions are underrepresented in empirical studies. Temporal bias towards retrospective analysis persists: most studies examine conflict effects after hostilities have ended or stabilised, whilst real-time monitoring during active conflict, although emerging for Ukraine in Cluster 5, remains rare elsewhere. Thematic gaps persist in three areas: (1) post-conflict recovery trajectories - how agro-landscapes recover (or fail to recover) over decades; (2) ecosystem services beyond food production - pollination, water regulation, carbon sequestration in war-damaged landscapes; (3) loss of traditional ecological knowledge . the social-ecological memory framework (Barthel et al., 2013) has not been applied to conflict contexts, despite its obvious relevance for displaced farming communities.

Conclusions

A bibliometric analysis of 1,502 publications (2000–2026) evidences the transition of the research field from descriptions of localised war-ecological disturbances towards an integrated socio-ecological framework in which the links between conflict, land use, ecosystem services, and food security are central. An annual growth rate of 8.17% and a mean citation count of 22.59 per document confirm that the topic has moved well beyond niche status. Analysis of five chronological clusters reveals a sequential paradigm evolution - from foundational resilience and socio-ecological concepts towards spatially explicit studies of conflict-driven agro-landscape change and, subsequently, the measurement of global food system consequences. A theoretical deficit persists: resilience and SES frameworks are applied to wartime contexts largely implicitly rather than systematically. Spatio-temporal analysis of conflict cases (Caucasus, Syria–Iraq, Ethiopia, Ukraine) identifies a reproducible causal chain: combat intensity and restricted field access initiate land abandonment, degradation of landscape functions, and yield losses, which are subsequently transmitted through food and price channels to the supranational level. Armed conflict impacts agro-landscapes through interconnected mechanisms: direct physical destruction, forced displacement and land abandonment, institutional collapse of land governance, contamination of soils and water resources, and destruction of the social-ecological memory that sustains adaptive management. Resilience theory and SES frameworks are essential analytical tools for understanding these impacts as potential regime shifts in coupled human–nature systems. Remote sensing has become the dominant methodological tool for assessing conflict-driven land-use change, yet integration with institutional and socio-economic data remains limited. Cluster 5 defines the methodological frontier: multi-sensor near-real-time monitoring (Sentinel-1/2, commercial imagery) integrated with conflict event databases and machine learning is emerging as the new standard. Despite progress, the principal research–practice gap lies in the insufficient integration of ecological-economic valuation of ecosystem service losses with conflict spatial data. This integration should define priorities for the next research and policy cycle: demining, land reclamation, irrigation restoration, spatial planning, and investment in climate-resilient land use. For Ukraine, the analytically sound architecture is: Earth observation + field validation + economic assessment + scenario modelling — enabling a shift from reactive management of war consequences to proactive management of agro-landscape resilience and long-term food security. Future research should focus on comparative cross-conflict frameworks spanning different types of armed conflict, agroecological zones, and institutional contexts, to distinguish universal patterns from context-specific dynamics.

Limitations. This review is subject to inherent limitations of bibliometric analysis, including potential indexing gaps in WoS/Scopus coverage and reduced

co-citation capacity due to incomplete reference field merging across databases.

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