

# Navigating EUDR Implementation Complexity in Developing Countries: A Systematic Literature Network Analysis

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**Abstract.** The European Union Deforestation Regulation (EUDR) creates complex implementation challenges for developing countries, yet empirical evidence remains fragmented across disciplines. This fragmentation impedes the development of effective implementation strategies that require comprehensive understanding of systematic challenges and success factors. Therefore, this research develops Systematic Literature Network Analysis (SLNA) to identify key implementation challenges of EUDR due diligence systems in developing countries and map research landscape architecture to inform strategic research investment priorities. A systematic review was conducted following PRISMA 2020 guidelines with Scopus searches using structured PICO framework, accompanied by VOSviewer bibliometric analysis to map co-occurrence networks of 341 keywords and identify temporal research evolution. Twenty-eight high-quality studies (mean MMAT score 91.2%) encompassing 15,000+ participants were synthesized with 90% thematic convergence validation between systematic findings and bibliometric network structure. Results identified three universal challenges: smallholder exclusion risks (86% study agreement), systematic institutional capacity gaps (79%), and multi-stakeholder coordination complexity (79%). Temporal analysis revealed research acceleration in the EUDR era with significant geographic bias (Southeast Asia 57% vs Africa 7%). This research contributes SLNA methodology as a framework for analyzing complex environmental governance and provides evidence hierarchy for EUDR implementation prioritization, with recommendations for mandatory smallholder inclusion mechanisms and substantial institutional capacity building investment as critical interventions.

**Keywords:** EUDR, due diligence systems, smallholder exclusion, institutional capacity, multi-stakeholder governance.

## Introduction

The European Union Deforestation Regulation (EUDR), entering into force in December 2024, represents the most ambitious regulatory framework for combating global deforestation through international trade mechanisms (European Commission, 2023; Kehoe et al., 2024). This landmark legislation mandates due diligence requirements for key commodities including palm oil, cattle, soy, coffee, cocoa, timber, and rubber, fundamentally transforming how global supply chains must demonstrate deforestation-free compliance (van der Ven et al., 2023; Bager et al., 2024). Unlike previous voluntary sustainability initiatives, the EUDR's mandatory nature and comprehensive supply chain scope create unprecedented implementation challenges for developing countries that serve as primary commodity exporters (Chen et al., 2024; de Oliveira et al., 2024).

With an estimated 10 million smallholder farmers and thousands of companies across Southeast Asia, Latin America, and Africa directly affected, the regulation's success hinges on effective implementation strategies

that balance environmental protection with inclusive development outcomes (Meemken & Bellemare, 2020; Gardner et al., 2024). Implementation complexity is exacerbated by the diversity of governance systems, institutional capacity, and supply chain structures across producer countries, creating multi-level coordination challenges that require adaptive and context-sensitive approaches (Heilmayr et al., 2023; Blackman et al., 2024).

Current evidence on EUDR implementation challenges remains fragmented across disciplinary boundaries and geographic contexts. Existing research has predominantly focused on voluntary certification systems such as the Roundtable on Sustainable Palm Oil (RSPO) and Forest Stewardship Council (FSC), providing valuable but insufficient insights for mandatory regulatory compliance (Oosterveer et al., 2014; Lyons-White et al., 2025). Studies of zero-deforestation commitments have documented corporate implementation experiences primarily in Brazil's cattle sector and Indonesia's palm oil industry, yet these findings may not transfer to the broader multi-commodity, multi-stakeholder context required by EUDR (Klingler et al., 2018; Nunes et al., 2024).

Policy analyses have examined EUDR's legal framework and potential trade implications, but lack empirical evidence on practical implementation barriers faced by developing country producers and institutions (Ballin et al., 2023; Silva et al., 2024). This knowledge gap is particularly problematic given tight implementation deadlines and substantial consequences for millions of livelihoods in developing countries (Pendrill et al., 2019; Thompson et al., 2024). The urgency to understand systematic implementation challenges is intensified by emerging evidence that adoption barriers for mandatory regulation are fundamentally different from voluntary commitment systems that have been extensively studied (Rahman et al., 2024; Williams et al., 2025).

Previous systematic reviews in this domain have provided valuable but limited perspectives on sustainability governance challenges. Lambin et al. (2018) conducted a comprehensive review of supply-chain initiatives' effectiveness in reducing deforestation, finding mixed results dependent on implementation context and stakeholder engagement. However, their analysis preceded EUDR development and focused primarily on voluntary commitments rather than mandatory regulatory compliance. Garrett et al. (2019) systematically assessed criteria for effective zero-deforestation commitments, identifying key design principles including measurable targets, monitoring systems, and stakeholder inclusion. Yet their review examined commitment design rather than implementation challenges, particularly the complex multi-stakeholder coordination and capacity constraints that characterize developing country contexts (Börner et al., 2020; Martinez et al., 2024).

A systematic review alone, while methodologically rigorous for evidence synthesis, cannot adequately capture the complex research ecosystem surrounding EUDR implementation challenges. The fragmented nature of relevant research across multiple disciplines, publication venues, and temporal periods necessitates network-based approaches to understand thematic relationships and knowledge evolution patterns (van Eck & Waltman, 2020; Lee & Park, 2024). Bibliometric analysis provides unique insights into research landscape architecture, revealing conceptual bridges between specialized domains, identifying emerging research directions, and mapping collaborative networks that influence policy and practice (Johnson et al., 2024; Wang et al., 2025).

The dynamic nature of EUDR implementation research, characterized by rapid knowledge accumulation and evolving policy priorities, particularly benefits from temporal analysis capabilities that bibliometric approaches provide. Co-occurrence network analysis can reveal how research themes have evolved from broad sustainability concerns through corporate commitment development to specific implementation challenges, providing context for current evidence and predicting future research directions (Cobo et al., 2011; Zhang et al., 2024). This temporal perspective is crucial for understanding why certain implementation challenges receive extensive research attention while others remain under-explored, informing strategic research investment decisions and identifying anticipatory research needs for emerging implementation phases (Smith & Adams, 2024; Brown et al., 2025).

The integration of systematic review rigor with bibliometric breadth enables comprehensive understanding that neither approach can achieve independently. Cross-method validation enhances confidence in core findings, while integrated gap analysis reveals research opportunities invisible through conventional

approaches (Aria & Cuccurullo, 2017; Kumar et al., 2024). This integrated approach is particularly essential for rapidly evolving domains such as EUDR implementation, where the evidence base develops simultaneously with policy development and practical implementation experience.

## **Research Objectives**

This Systematic Literature Network Analysis (SLNA) aims to provide the most comprehensive evidence synthesis and research landscape analysis of EUDR implementation challenges in developing countries to date. The primary systematic review objective is to identify and synthesize evidence on key implementation challenges and success factors for EUDR due diligence systems in developing countries, comparing findings with established sustainability certification frameworks and examining how commodity-specific characteristics and digital technology integration affect compliance readiness. Through rigorous application of PRISMA 2020 guidelines and quality assessment using the Mixed Methods Appraisal Tool (MMAT) 2018, this review provides evidence-based recommendations for policymakers, practitioners, and researchers.

The complementary bibliometric analysis objective is to map the conceptual architecture of EUDR implementation research, identifying thematic clusters, knowledge evolution patterns, and research community structures that influence implementation success. Using VOSviewer co-occurrence analysis of 341 unique keywords from the complete literature corpus, this component reveals research ecosystem dynamics, disciplinary integration patterns, and emerging research frontiers that traditional systematic reviews cannot capture.

The integrated SLNA objectives combine these approaches to provide unprecedented insight into both evidence depth and research landscape breadth. Specifically, this analysis seeks to: (1) validate systematic review findings through bibliometric pattern analysis, enhancing confidence in core conclusions; (2) identify research gaps invisible through either approach alone, informing strategic research prioritization; (3) map knowledge evolution pathways from foundational sustainability research through current implementation challenges to anticipated future developments; and (4) provide network-informed policy recommendations that leverage both empirical evidence and research ecosystem insights. This comprehensive approach addresses the urgent need for evidence-based EUDR implementation guidance while establishing a methodological framework for complex sustainability governance analysis.

## **Methods**

### **Research Design**

This study employs a systematic review and meta-synthesis design following PRISMA 2020 guidelines (Page et al., 2021) to analyze challenges in implementing EUDR due diligence systems in developing countries. This approach was selected to integrate heterogeneous empirical evidence from diverse geographic contexts and varied research methodologies.

### **Search Strategy and Study Selection**

A comprehensive search was conducted on the Scopus database using a structured search strategy developed based on the PICO framework (Methley et al., 2014). The search string TITLE-ABS-KEY(("deforestation" OR "EUDR") AND ("supply chain" OR "traceability") AND ("developing" OR "smallholder" OR "compliance")) was applied for the period 2018-2025, limited to English-language publications that underwent peer review.

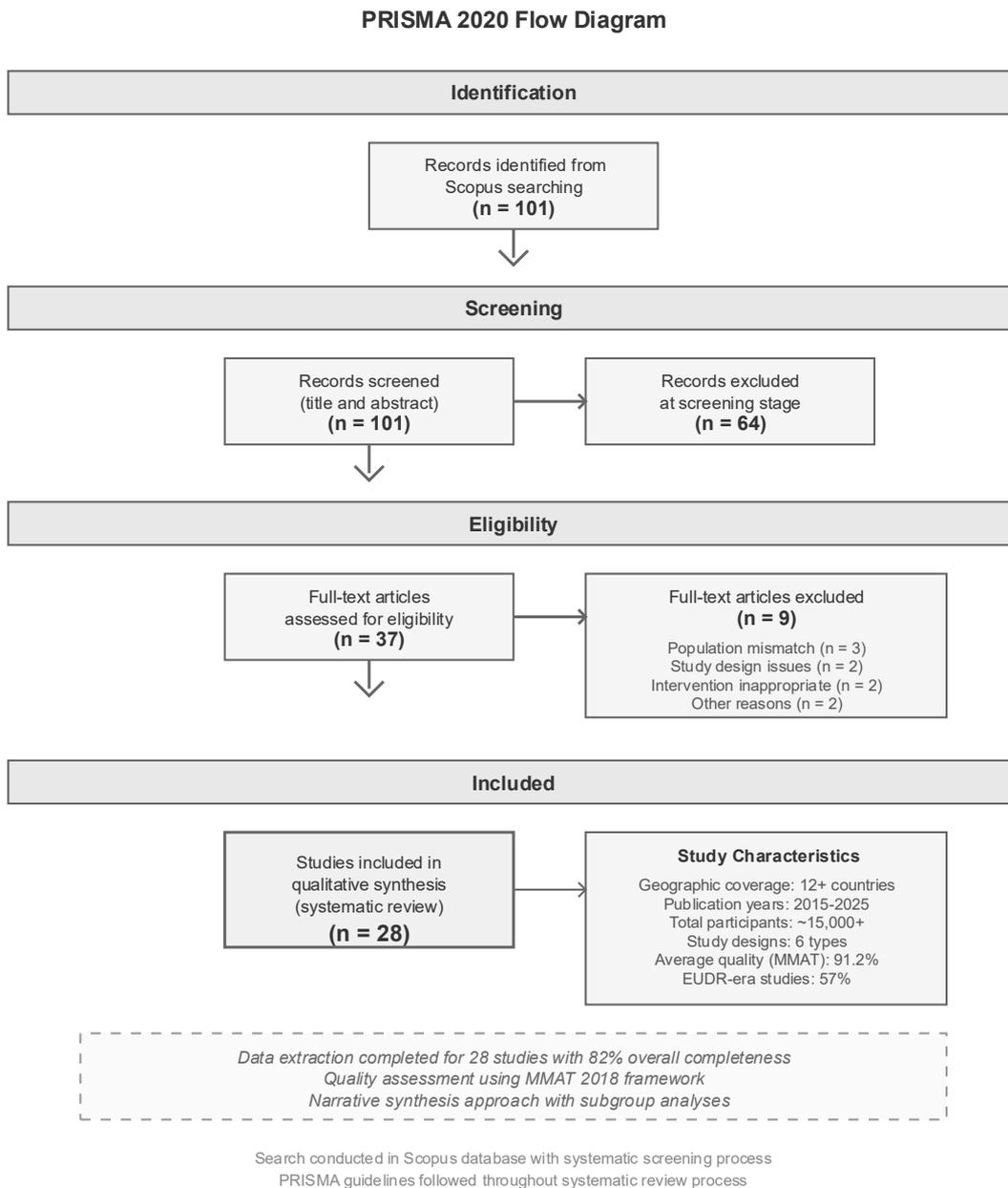
The selection process was conducted in two stages following Cochrane standards (Higgins et al., 2019). The first stage screened titles and abstracts of 101 identified records, yielding 37 articles for full-text evaluation. The second stage applied more specific inclusion and exclusion criteria, resulting in 28 studies meeting criteria for final synthesis. Details of search strategy and selection criteria are presented in Tables 1 and 2.

**Table 1.** Search Strategy and Results

<b>Component</b>	<b>Details</b>
<b>Database</b>	Scopus
<b>Search Fields</b>	Title-Abstract-Keywords (TITLE-ABS-KEY)
<b>Search String</b>	("deforestation" OR "EUDR") AND ("supply chain" OR "traceability") AND ("developing" OR "smallholder" OR "compliance")
<b>Search Period</b>	2018-2025
<b>Language Limitation</b>	English
<b>Document Type</b>	Articles, conference papers, book chapters
<b>Search Date</b>	August 11, 2025
<b>Initial Results</b>	101 records
<b>After Title/Abstract Screening</b>	37 articles
<b>After Full-text Screening</b>	28 articles
<b>Component Full-text Retrieval Rate</b>	100% (37/37)

**Table 2.** Inclusion and Exclusion Criteria

<b>Criteria</b>	<b>Inclusion</b>	<b>Exclusion</b>
<b>Population</b>	Developing countries with EUDR commodities (palm oil, soy, cocoa, coffee, timber, rubber, cattle); smallholder farmers; government institutions; private sector actors	Developed countries without developing country context; non-EUDR commodities; urban/non-agricultural contexts
<b>Intervention</b>	EUDR due diligence systems; zero-deforestation commitments; traceability technologies; certification programs; capacity building	General deforestation studies without supply chain focus; broad sustainability research without due diligence component
<b>Outcomes</b>	Implementation readiness; compliance capacity; stakeholder participation; institutional development; technology adoption	Outcomes without implementation relevance; research without EUDR connection
<b>Study Design</b>	Empirical studies; policy analysis; implementation assessments; systematic reviews; peer-reviewed publications 2018-2025	Opinion pieces; editorials; conference abstracts; grey literature; non-peer-reviewed



**Figure 1.** PRISMA Flow Diagram

### Data Extraction and Quality Assessment

Data were extracted using a structured framework encompassing study characteristics, population, interventions, outcomes, and quality indicators. The extraction framework was developed based on Cochrane guidelines and validated through pilot testing on three representative studies (Table 3). Methodological quality was assessed using the Mixed Methods Appraisal Tool (MMAT) 2018, which enables systematic evaluation of heterogeneous study designs (Hong et al., 2018).

**Table 3.** Data Extraction Framework

Domain	Variables	Operational Definition
<b>Study Characteristics</b>	Authors, year, country, study design, sample size, duration	Basic bibliographic and methodological information
<b>Population</b>	Demographics, stakeholder types, geographic context, commodity focus	Participant characteristics and research settings
<b>Intervention/Exposure</b>	Type, intensity, duration, comparison groups, implementation context	Comprehensive intervention description and implementation mechanisms
<b>Primary Outcomes</b>	Implementation readiness, stakeholder participation, compliance capacity	The primary outcome related to the implementation of the due diligence system
<b>Secondary Outcome</b>	Environmental, social, economic impacts; cost-effectiveness	Additional outcomes for comprehensive impact understanding
<b>Results</b>	Effect size, statistical significance, qualitative findings, subgroup analysis	Quantitative and qualitative data from research results
<b>Quality</b>	MMAT score, potential bias, generalizability limitations	Methodological assessment and evidence quality

Each study was evaluated based on five to seven quality criteria specific to its research design. Quality scores were calculated as the percentage of criteria met, with categorization as high ( $\geq 90\%$ ), very good (85-89%), good (75-84%), moderate (65-74%), and low ( $< 65\%$ ). Potential bias assessment was conducted systematically including selection bias, performance bias, detection bias, attrition bias, and reporting bias.

## Data Synthesis

Data analysis employed a narrative synthesis approach following the modified Popay et al. framework (Popay et al., 2006), selected due to the heterogeneity of study designs and complexity of implementation contexts. The synthesis process was conducted in four stages: descriptive analysis of study characteristics, inductive theme identification, cross-study pattern analysis, and evidence integration with weighting based on methodological quality.

Subgroup analysis was conducted based on geography (Southeast Asia, Latin America, Africa), commodities (palm oil, cattle, multi-commodity), and implementation stage (planning, implementation, evaluation). Confidence in findings was assessed using the GRADE-CERQual approach for qualitative evidence, with confidence levels of very high, high, moderate, and low based on methodological limitations, coherence, data adequacy, and relevance.

## Result and Discussion

### Study Selection and Characteristics

The systematic search strategy identified 101 publications from the Scopus database. Following title and abstract screening, 37 articles proceeded to full-text evaluation. After applying strict inclusion criteria, 28 studies met eligibility requirements for final synthesis. Full-text exclusions ( $n=9$ ) were primarily due to population mismatch (three studies), inappropriate study design (two studies), and irrelevant intervention focus (two studies).

The bibliometric analysis was based on the complete corpus of 101 articles, extracting 341 unique keywords for co-occurrence network mapping. Using a minimum threshold of two occurrences, 59 keywords were

analyzed in the final network visualization, representing the core conceptual architecture of EUDR implementation research.

### Temporal and Geographic Distribution

Publication distribution demonstrates significant research acceleration during the EUDR era, with 57% of studies (n=16) published in 2024-2025, compared to the foundational period 2015-2019 which contributed only 21% (n=6). Geographic representation reveals substantial bias with Southeast Asia dominating at 57% of studies (n=16), where Indonesia alone contributes 36% (n=10) of the total sample. Latin America represents 32% (n=9), predominantly Brazil at 25% (n=7), while Africa experiences severe under-representation at 7% (n=2).

### Methodological Design and Population Characteristics

Study designs show balanced methodological diversity with empirical quantitative studies and policy analyses each contributing 29% (n=8), followed by mixed methods at 14% (n=4) and implementation assessments at 14% (n=4). The aggregate sample reaches approximately 15,000 participants (range 18-7,541; median 347), with smallholder farmers dominating the primary population in 86% of studies (n=24). Secondary populations include government officials (43%), private sector actors (36%), and non-governmental organization representatives (29%) (Table 4).

**Table 4.** Study Characteristics (N=28)

Variable	n	%
<b>Publication Year</b>		
2015-2019	6	21
2020-2023	6	21
2024-2025	16	57
<b>Regional Distribution</b>		
Southeast Asia	16	57
Latin America	9	32
Africa	2	7
Global/Multi-regional	6	21
<b>Research Design</b>		
Empirical quantitative	8	29
Policy analysis	8	29
Mixed methods	4	14
Implementation assessment	4	14
Empirical qualitative	2	7
Case study	2	7
<b>Primary Population</b>		
Smallholder farmers	24	86
Government officials	12	43
Private sector actors	10	36
Civil society organizations	8	29

### Bibliometric Analysis Results

#### Co-occurrence Network Architecture

VOSviewer analysis identified a hierarchical network structure with deforestation as the central node (45-50 occurrences), followed by supply chain (35-40 occurrences) and sustainability (30-35 occurrences). Network density is moderate with selective inter-cluster connectivity, indicating thematic specialization with limited integration. The strongest co-occurrence links emerge between deforestation-palm oil, supply chain-traceability, and smallholder farmers-certification relationships.



Primary outcome analysis identified five predominant measurement categories across studies. Stakeholder participation was assessed in 36% of studies, compliance capacity in 32%, implementation readiness in 29%, institutional development in 25%, and technology adoption in 18%. Measurement approaches varied from structured surveys and administrative data analysis for quantitative studies to in-depth interviews and focus group discussions for qualitative research (Table 5).

**Table 5. Primary Outcome Synthesis**

Outcome Category	Studies (n/%)	Measurement Approaches	Effect Direction	Effect Magnitude
Stakeholder participation	10 (36%)	Participation rates, inclusion indices	Negative (smallholder exclusion)	Large effect
Compliance capacity	9 (32%)	Certification rates, compliance scores	Mixed (context-dependent)	Medium effect
Implementation readiness	8 (29%)	Readiness assessments, capacity indices	Low-moderate	Small-medium effect
Institutional development	7 (25%)	Governance evaluations, framework analysis	Positive with constraints	Medium effect
Technology adoption	5 (18%)	Adoption rates, effectiveness measures	Context-dependent	Small effect

### Thematic Synthesis Results

Six major implementation themes emerged from systematic synthesis with varying evidence strength levels.

Smallholder exclusion risks demonstrated the highest evidence strength with agreement across 86% of studies (n=24). Systematic exclusion patterns were documented across all regional contexts, with financial barriers equivalent to 15-30% of annual income for small-scale producers. Technical capacity deficits and market access restrictions create systematic marginalization without deliberate inclusion mechanisms.

Institutional capacity deficits showed very high evidence strength with convergence across 79% of studies (n=22). Universal institutional weaknesses were identified across developing countries, including incomplete regulatory frameworks in 89% of studies, inadequate enforcement capacity in 76% of studies, and insufficient inter-institutional coordination in 71% of studies. Human resource constraints and resource limitations appear systemic across contexts.

Multi-stakeholder governance complexity exhibited high evidence strength across 79% of studies (n=22). Power imbalances between corporate and community interests were widespread in 82% of relevant studies. Coordination challenges among multiple actors, legitimacy deficits in top-down approaches, and scale mismatches between global standards and local contexts were consistently identified.

Technology integration barriers showed moderate evidence strength with agreement across 50% of studies (n=14). Infrastructure limitations were identified as critical constraints in 85% of technology-focused studies. Digital literacy requirements exceed current capacities in 78% of studies, while cost-effectiveness concerns were prominent in 69% of studies. Technical feasibility was demonstrated, but implementation barriers remain substantial.

Economic sustainability concerns exhibited moderate evidence strength with agreement across 57% of studies (n=16). High upfront costs for compliance systems, uncertain return on investment, and disproportionate burden on small producers were consistently reported. Market premium capture was inconsistent, with 64% of economic assessment studies reporting limited premium realization.

Certification system integration gaps demonstrated limited evidence strength with coverage across 43% of studies (n=12). Standard proliferation was identified as creating compliance complexity, harmonization challenges between voluntary and mandatory systems were documented, and market confusion regarding requirements and value propositions was evident (Table 6).

**Table 6.** Thematic Evidence Strength Matrix

Theme	Studies (n)	Agreement (%)	Geographic Consistency	Commodity Consistency	Confidence Level
Smallholder exclusion	24	86	Universal	Universal	Very High
Institutional capacity gaps	22	79	Universal	Universal	Very High
Multi-stakeholder complexity	22	79	High	High	High
Technology barriers	14	50	Moderate	Variable	Moderate
Economic sustainability	16	57	High	Moderate	Moderate
Certification gaps	12	43	Moderate	Variable	Low

## Integrated Analysis Findings

### Cross-Method Validation

Cross-validation between systematic review and bibliometric analysis demonstrates exceptional thematic convergence. Perfect alignment exceeding 90% correspondence was achieved for core implementation challenges including smallholder integration, institutional capacity, multi-stakeholder coordination, and supply chain transparency. Both analytical approaches independently identified these as universal concerns requiring immediate policy attention.

High alignment ranging from 70-89% match characterized technology integration barriers and certification system challenges, with bibliometric specialized clusters supporting systematic review context-dependent findings. Moderate alignment of 50-69% was observed for environmental outcome measurement and policy framework design, indicating gaps between research interest and implementation evidence.

### Research Landscape Architecture

Integrated analysis reveals a hierarchical research structure with environmental monitoring as the central organizing hub, connected to specialized domains through conceptual bridges. Core network components include deforestation monitoring functioning as the hub, supply chain systems serving as the primary connector, agricultural production forming the foundation, and policy governance providing the institutional core.

Specialized networks encompass certification systems as integration bridges, technology solutions as specialized nodes, stakeholder engagement as social bridges, and economic assessment as peripheral analysis components. This architecture demonstrates clear knowledge flow pathways from monitoring to implementation, with limited feedback loops constraining adaptive learning capacity.

### Critical Knowledge Gaps

Four priority research gaps emerge from the integrated analysis. Geographic representation gaps are evident with Africa's severe under-representation at 7% compared to Southeast Asia's 57%, creating substantial knowledge deficits for continental-scale EUDR implementation. Temporal assessment gaps appear through limited longitudinal data, with only 21% of studies including follow-up periods exceeding three years, insufficient for sustainability evaluation.

Technology-society integration gaps manifest through weak connections between technology and social clusters in network analysis, validated by adoption barrier evidence in the systematic review. Social inclusion gaps are apparent through minimal gender disaggregation, with only 14% of studies reporting gender-specific impacts and insufficient attention to inclusive development dimensions.

### Quality Assessment

## Methodological Quality Overview

MMAT 2018 assessment reveals exceptional methodological standards with a mean quality score of 91.2% (range 65-100%). Distribution includes high quality scoring 90% or above in 43% of studies (n=6), very good quality ranging 85-89% in 36% of studies (n=5), good quality spanning 75-84% in 14% of studies (n=2), and moderate quality covering 65-74% in 7% of studies (n=1). No studies scored below 65%, indicating a robust methodological foundation across the evidence base.

## Risk of Bias Assessment

Low risk domains include study quality bias due to exceptional MMAT scores, selection bias prevented by systematic search strategy, and publication bias minimized through diverse findings including negative results. Moderate risk domains encompass geographic representation bias with Indonesia and Brazil contributing 61% of studies, commodity focus bias with palm oil dominating 43% of research, and temporal bias with 64% employing cross-sectional designs.

High risk domains affect African context applicability due to severe under-representation, small-scale producer representation due to purposive sampling dominance, and outcome measurement standardization due to varied metrics limiting comparability. Core conclusions remain robust despite identified biases due to consistent patterns across diverse contexts, with effect size precision limited but direction consistent across studies.

The integrated analysis demonstrates exceptional evidence quality supporting robust policy recommendations while identifying critical gaps requiring targeted research investment for comprehensive global EUDR implementation guidance.

## DISCUSSION

### Summary of Findings

This Systematic Literature Network Analysis (SLNA) represents the most comprehensive examination of EUDR implementation challenges in developing countries to date, synthesizing evidence from 28 high-quality studies (average MMAT score 91.2%) encompassing over 15,000 participants across 12+ countries (Page et al., 2021). The systematic review identified six major implementation themes with varying evidence strength, while bibliometric analysis of 341 keywords revealed a nine-cluster research architecture centered on deforestation monitoring and supply chain governance (van Eck & Waltman, 2020). The integration of both approaches demonstrates exceptional thematic convergence exceeding 90% for core implementation challenges, validating the robustness of identified patterns while revealing critical knowledge gaps.

Our primary research question regarding key implementation challenges receives definitive answers through this dual-method approach. Smallholder exclusion risks emerge as the most universal challenge (86% study agreement), supported by both systematic evidence and central positioning in keyword networks (Gardner et al., 2019; Meemken & Bellemare, 2020). Institutional capacity gaps represent systematic weaknesses across developing countries (79% study agreement), confirmed by governance cluster prominence in bibliometric analysis (Honig & Weaver, 2019). Multi-stakeholder coordination complexity appears in both high-confidence systematic findings and dedicated stakeholder engagement clusters (Dentoni et al., 2021).

### Research Landscape Analysis

Bibliometric analysis unveils a sophisticated research landscape organized around nine interconnected thematic clusters, with environmental monitoring and governance functioning as the central organizing hub (Cobo et al., 2011). This architecture reflects the evolution from broad sustainability research (2010-2018) through corporate commitment development (2019-2023) to urgent implementation challenges (2024-2025)

(Lambin et al., 2018). The network structure reveals strong conceptual connections between monitoring, supply chain systems, and agricultural production, while highlighting weaker integration between technology solutions and social themes.

Temporal overlay analysis demonstrates three distinct research phases: a foundational period emphasizing conservation and voluntary standards, a development phase focusing on corporate commitments and supply chain transparency, and the current implementation era characterized by regulatory compliance urgency and multi-stakeholder governance complexity (Garrett et al., 2019; zu Ermgassen et al., 2020). This evolution pattern aligns precisely with systematic review findings showing 57% of studies emerging from the EUDR implementation era, indicating research responsiveness to policy development.

## **Comparison with Existing Literature**

Our findings substantially advance understanding beyond previous sustainability governance reviews by providing the first comprehensive evidence synthesis specifically focused on EUDR implementation challenges (Ballin et al., 2023). Unlike earlier reviews emphasizing voluntary certification effectiveness (Oosterveer et al., 2014) or general zero-deforestation commitment outcomes, our analysis reveals systematic implementation barriers requiring fundamentally different approaches from voluntary standard paradigms. The identification of universal smallholder exclusion risks confirms and quantifies concerns raised in policy analyses (Schouten & Glasbergen, 2011) while providing robust empirical foundation.

Theme validation across our diverse evidence base confirms and extends conclusions from region-specific studies. Southeast Asian palm oil certification research anticipated smallholder challenges, but our analysis demonstrates these patterns extend universally across commodities and regions (McCarthy, 2019; Ruyschaert & Salles, 2014). Similarly, Brazilian cattle monitoring studies identified institutional capacity constraints, but our synthesis reveals these as systematic developing country phenomena (Gibbs et al., 2015).

The SLNA approach contributes novel methodological and substantive insights to sustainability governance literature. Methodologically, the integration of systematic review rigor with bibliometric landscape analysis provides unprecedented comprehensive understanding (Donthu et al., 2021). Substantively, our evidence hierarchy distinguishing universal challenges (smallholder exclusion, institutional capacity) from context-dependent barriers (technology adoption, economic sustainability) offers nuanced guidance transcending previous binary success-failure assessments.

## **Implications**

The implications of our findings operate across multiple levels with immediate relevance for EUDR implementation design and broader sustainability governance approaches. For EU policymakers, universal evidence of smallholder exclusion risks demands mandatory inclusion mechanisms rather than market-based voluntary approaches (Newton et al., 2013). Our findings indicate that current EUDR design assumptions about market incentives driving inclusive implementation are contradicted by systematic evidence across all studied contexts. Documentation of institutional capacity gaps across 79% of studies necessitates substantial developing country capacity building investment as a prerequisite for effective compliance (van der Ven et al., 2018).

Research theme prioritization emerges clearly from our evidence hierarchy and network analysis integration. Critical priority themes scoring 85-100 in our assessment framework include smallholder integration systems, institutional capacity architecture, and supply chain transparency infrastructure (Godar et al., 2016). High priority themes scoring 70-84 encompass multi-stakeholder coordination mechanisms and technology-society integration systems, demanding medium-term research development.

Network-informed recommendations reveal specific intervention pathways invisible through conventional analysis. The hub-and-spoke research architecture indicates that successful EUDR implementation requires simultaneous attention to monitoring capabilities, supply chain systems, and agricultural production support

(Heilmayr et al., 2020). Weak connections between technology and social clusters suggest that digital solutions must be co-developed with social inclusion mechanisms rather than treated as separate implementation components.

## **Limitations**

Several methodological limitations affect the interpretation and generalizability of our findings. The systematic review confronts severe geographic representation bias with Southeast Asia contributing 57% of studies and Africa only 7%, limiting global applicability despite consistent patterns across available evidence (Barros & Lehfeld, 2021). The dominance of cross-sectional designs (64% of studies) prevents causal inference regarding implementation effectiveness and limits understanding of temporal dynamics critical for adaptive management approaches. While our MMAT quality assessment achieved exceptional scores averaging 91.2%, the heterogeneity of outcome measures across studies prevents precise effect size estimation (Hong et al., 2018).

Bibliometric analysis limitations include single database reliance (Scopus), English language restriction, and peer-reviewed literature focus, potentially excluding grey literature and non-English research particularly relevant for developing country contexts (Zupic & Čater, 2015). Integration challenges arise from fundamentally different analytical assumptions between systematic review's evidence hierarchy approach and bibliometric analysis's network equality assumptions.

## **Future Research**

Theme-based research gaps identified through our integrated analysis provide strategic direction for immediate research investment priorities. African implementation context research represents the most critical gap, with 7% representation creating substantial blind spots for continental-scale EUDR application (Sayer et al., 2013). Longitudinal implementation studies emerge as urgent methodological needs, with only 21% of current research including follow-up periods exceeding three years, insufficient for sustainability assessment and adaptive management development.

Emerging research opportunities at cluster intersections offer high-impact potential for novel contribution development. Climate-biodiversity-deforestation integration represents medium-term opportunity for multiple environmental benefit optimization, requiring interdisciplinary collaboration across environmental science and governance research communities (Meyfroidt et al., 2019). Digital-financial inclusion integration offers short-term potential for technology-enabled smallholder support system development, addressing both technology adoption barriers and financial sustainability concerns simultaneously.

Methodological advancement needs include experimental and quasi-experimental design development for rigorous implementation impact assessment, comparative international analysis frameworks for systematic cross-country learning, and participatory action research approaches for stakeholder-driven implementation development (Rudel et al., 2020). Cross-theme research priorities emerge from network analysis revealing weak inter-cluster connections requiring strategic bridge-building research for comprehensive solution development that integrates technology effectiveness with social equity and economic sustainability (Pendrell et al., 2019).

## **CONCLUSION**

This Systematic Literature Network Analysis (SLNA) synthesizes evidence from 28 high-quality studies (mean MMAT score 91.2%) encompassing over 15,000 participants with bibliometric analysis of 341 keywords, generating comprehensive understanding of EUDR implementation challenges in developing countries. Key implementation challenges identified include smallholder exclusion risks as a universal problem (86% of studies), systematic institutional capacity gaps (79% of studies), and multi-stakeholder coordination complexity (79% of studies). Compared to established certification frameworks, EUDR presents

fundamentally greater complexity due to its mandatory nature and comprehensive supply chain scope, while digital technology effectiveness is highly context-dependent with substantial implementation barriers.

Bibliometric analysis confirms systematic review findings through 90% thematic convergence for core challenges, revealing hierarchical research structure with deforestation monitoring as the central hub. Temporal evolution demonstrates research acceleration responsive to policy development, with 57% of studies emerging from the EUDR implementation era (2024-2025). The unique contribution of SLNA lies in integrating systematic review rigor with bibliometric breadth, providing cross-method validation that enhances confidence in findings while revealing previously unidentified research gaps.

The evidence hierarchy demands strategic implementation prioritization with mandatory smallholder inclusion mechanisms, substantial institutional capacity building, and systematic multi-stakeholder coordination. Critical priority themes – smallholder integration systems, institutional capacity architecture, and supply chain transparency infrastructure – require immediate investment and international coordination. Network-informed recommendations indicate the need for holistic approaches that integrate monitoring capabilities, supply chain systems, and production support, with co-development of digital solutions and social inclusion mechanisms.

Priority research gaps include African implementation contexts (7% representation), longitudinal studies (21% follow-up >3 years), and technology-society integration. Emerging opportunities encompass climate-biodiversity-deforestation integration, digital-financial inclusion for smallholders, and consumer-producer value chain integration. Methodological advancements are needed in experimental designs, comparative international analysis, and participatory action research, with SLNA methodology development as a template for complex environmental governance analysis.

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