# Balancing Food Production and Environmental Sustainability in Ethiopian Agriculture: A Systematic Review

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## Abstract

*Ethiopia faces the dual challenge of increasing food production for a rapidly growing population while preserving the natural resource base that sustains its agricultural systems. This systematic review synthesizes evidence from 130 peer-reviewed studies published between 2010 and 2025 to examine the relationship between agricultural productivity and environmental sustainability in Ethiopia. Findings reveal that conventional agricultural expansion, deforestation, soil erosion, nutrient depletion, and inefficient water management continue to undermine long-term productivity and ecological resilience. At the same time, sustainable agricultural practices, including conservation agriculture, agroforestry, sustainable intensification, regenerative systems, climate-smart technologies, improved water management, and diversified farming demonstrate significant potential to enhance yields while restoring soil health, improving water efficiency, and strengthening climate resilience. However, adoption remains limited due to socioeconomic constraints, insecure land tenure, knowledge gaps, weak extension systems, fragmented policies, and climate-related risks. The review identifies critical trade-offs and synergies between production and environmental outcomes and highlights persistent gaps in integrated, large-scale evidence on the combined effects of multiple sustainable practices. Generally, this review underscores that balancing food production with environmental sustainability is not optional but essential for Ethiopia's long-term food security and ecological stability. It recommends strengthening policy coherence, improving farmer* *support systems, leveraging indigenous knowledge, and expanding investment in climate-resilient and resource-efficient agricultural strategies.*

**Key words:** *Food production, Environmental sustainability, Sustainable agriculture, Land degradation, Soil fertility, Climate-smart agriculture, Ethiopia*

## 1. Introduction

### 1.1. Background and Justifications of the Review

Ensuring food security for a global population approaching 10 billion by 2050 requires agricultural systems that increase productivity while remaining within environmental limits (Barrett, 2017; Finley, 2020; Martin & Vos, 2024). Climate change, shifting consumption patterns, and ecological degradation further intensify this challenge (Saleem et al., 2024). Sustainable food production therefore demands fundamental shifts in resource governance, production practices, and economic development models (Godswill Awuchi & Godswill, 2020; Çakmakçı et al., 2023; Kumar et al., 2024). Achieving higher productivity with lower environmental impacts requires improving efficiency in less productive systems and advancing innovations in agricultural technologies and management (Saxena et al., 2024; Michele, 2025). Yet, agricultural intensification continues to drive greenhouse gas emissions, biodiversity loss, soil degradation, and water pollution worldwide (Okorondu et al., 2022; Stavi & Lal, 2013;FAO, 2019; Christian, 2023).

These global pressures are strongly evident in Ethiopia, where agriculture accounts for about 35% of GDP and employs over 70% of the population (Melsew & Budapest, 2021;.Neglo et al., 2021; Yigezu Wendimu, 2021). Reliance on rain-fed, smallholder farming makes the sector highly vulnerable to environmental degradation and climate variability. Unsustainable practices, such as deforestation, soil erosion, nutrient mining, and inefficient water use, have accelerated land degradation and undermined long-term agricultural productivity (Montgomery & Biklé, 2021). As a result, balancing food production with environmental sustainability has become an existential priority for Ethiopia's socio-economic stability and ecological resilience (Fischer et al., 2021; Jiren et al., 2020). Although multiple Sustainable Agricultural Practices (SAPs), including conservation agriculture, agroforestry, climate-smart agriculture, organic farming, sustainable intensification, improved water management, and diversified farming systems, have been promoted, adoption remains limited. Major barriers include socio-economic constraints, land tenure insecurity, weak institutional support, fragmented policies, and knowledge gaps (Teklewold et al., 2013). Existing studies tend to focus on specific practices or narrow geographic areas, producing fragmented evidence and lacking an integrated assessment of how Ethiopia can balance agricultural productivity with environmental health.

This systematic review fills these gaps by synthesizing the evidence on the interactions between food production and environmental sustainability in Ethiopian agriculture. The novelty of this review lies in its comprehensive, cross-sectoral synthesis of: Trade-offs and synergies between agricultural production and environmental sustainability; Effectiveness of sustainable agricultural practices in enhancing productivity while reducing degradation; and Socio economic, institutional, and policy constraints that hinder widespread adoption of environmentally sustainable farming systems. The review is guided by the following questions:

1. What trade-offs and synergies exist between food production and environmental sustainability in Ethiopia?
2. How effective are current and emerging sustainable agricultural practices in improving productivity while minimizing environmental degradation?
3. What socio-economic, policy, and institutional factors limit the adoption of sustainable agricultural practices?

By synthesizing current evidence, this systematic review provides clearer insight into how Ethiopia can transition toward a more productive, sustainable, and climate-resilient agricultural future.

## 2. Methodology

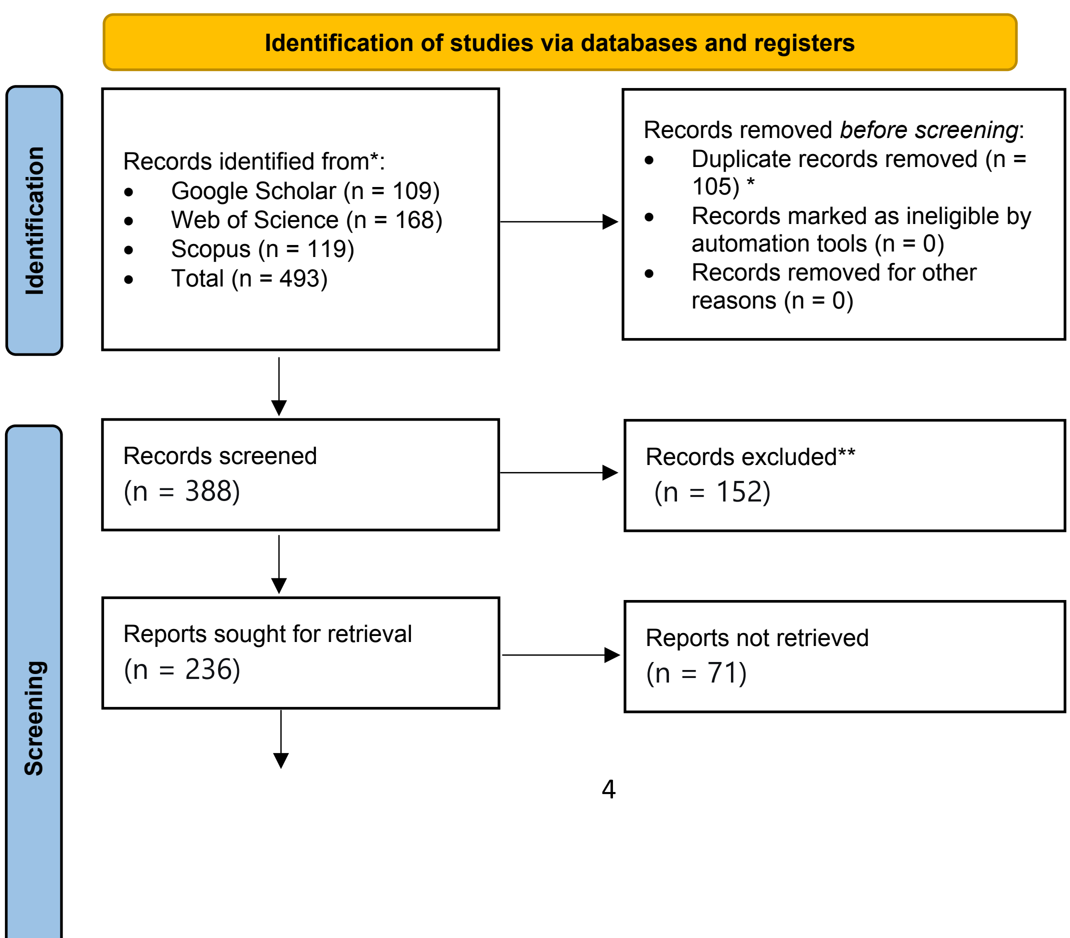
### 2.1. Selection of relevant documents

Full-text articles were searched and screened according to predefined eligibility criteria (inclusion and exclusion) to ensure alignment with the objectives of this study. We critically identified and reviewed studies that focused on evidence-based understanding of whether and how a balance of food production and environmental sustainability in Ethiopian agriculture. The inclusion criteria were as follows: articles published in English; studies conducted exclusively in Ethiopia; cross-sectional and longitudinal research designs; studies where the primary outcome was balancing food production and environmental sustainability in

Ethiopian agriculture, and studies published between 2010 and 2025. Since the concept of balancing food production and environmental sustainability in this context has only been applied in Ethiopia since 2010, no relevant articles were available prior to that year.

Studies were excluded if they did not meet the predefined eligibility conditions. Specifically, articles not written in English, studies conducted outside Ethiopia and research designs other than cross-sectional (experimental designs) were excluded. Likewise, studies in which balancing food production and environmental sustainability was not the primary outcome were not considered. Studies published before 2010 or after 2025, as well as books, commentaries, editorials, policy briefs, and unpublished reports, were also excluded from the analysis. These criteria were applied to maintain procedural consistency during the article selection process. For selecting relevant articles, the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) approach was followed, as illustrated in Figure 1. Using the four-stage article selection procedure (identification, screening, eligibility, and inclusion), duplicates were removed; titles and abstracts were screened to retain only relevant studies; and finally, 130 full-text articles were included for data extraction.

**PRISMA 2020 flow diagram for new systematic reviews which included searches of databases and registers only**



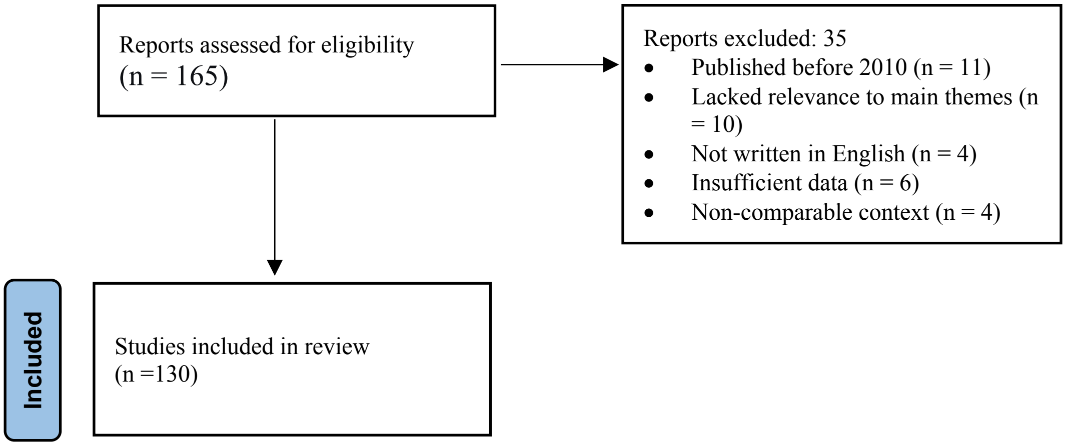



Figure 1: PRISMA Method for article selection

A systematic literature search was conducted using Scopus, Web of Science, Science Direct, PubMed, AGRIS, and Google Scholar. Key terms related to food production, environmental sustainability, and Ethiopian agriculture was used individually and in combination with Boolean operators. The main search terms included "food production," "agricultural productivity," "crop yield," "environmental sustainability," "sustainable agriculture," "soil conservation," "water conservation," "land degradation," and "climate-smart agriculture," along with geographical identifiers such as "Ethiopia" and "Ethiopian agriculture."

The detailed selection process is presented in Figures 1 and 2.

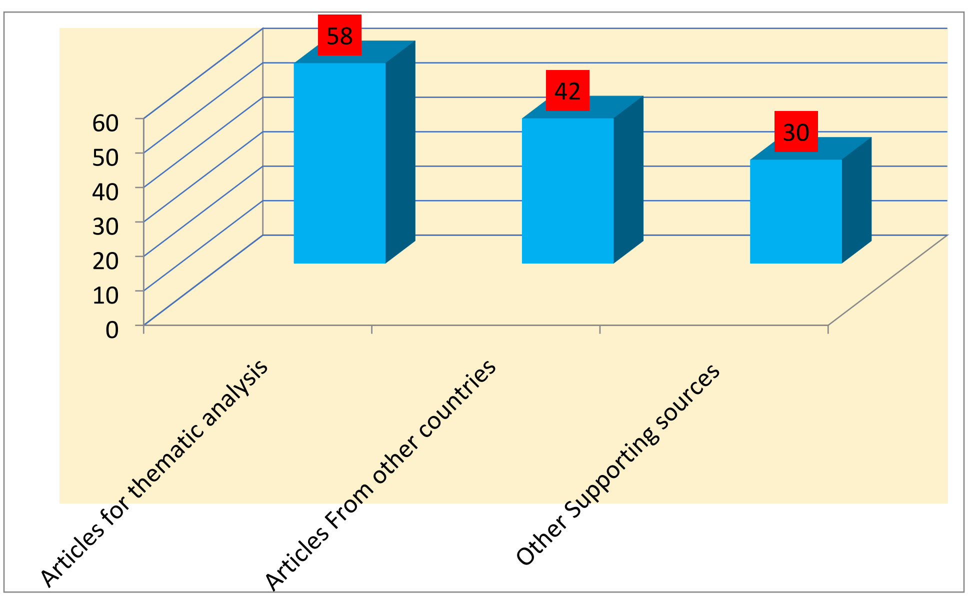



Figure 2: Types of sample articles included in the review

## 3. Results and Discussion

Analysis of the selected articles shows a clear and consistent increase in publications over time. This upward trend indicates that the topic of Ethiopian Agriculture is the main concern to maximize the food production balancing with environmental sustainability, and has received growing attention from researchers, policymakers, and donor agencies. The increasing volume of research reflects the recognition of Ethiopian agriculture is not only as a theoretical concept but also as a practical framework for addressing persistent food insecurity and environmental challenges in Ethiopia. The trend further suggests an expanding interest in evidence-based approaches to improve the adaptive capacity of households and communities in the face of socioeconomic and environmental shocks. Figure 3 illustrates the increasing trend in the number of articles published on maximizing food production and environmental sustainability in Ethiopia over the years.

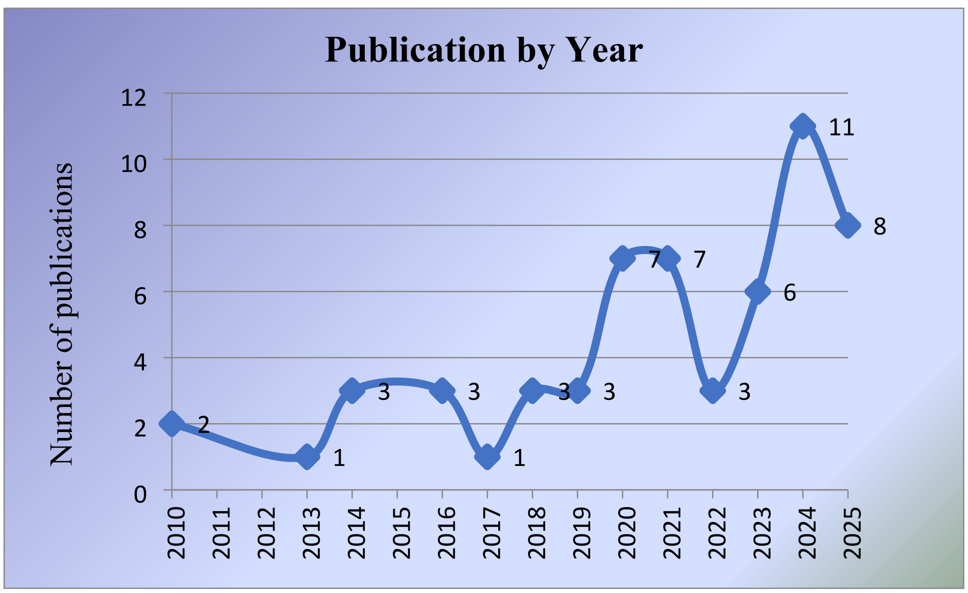



Figure 3: Number of sample articles published by year

### 3.1. The Dual Challenges: Food Production and Environmental Degradation

Ethiopia's agricultural sector is intent in a profound and existential dilemma, perfectly encapsulating the punishing conflict between immediate human survival and long-term ecological sustainability(Yigezu, 2021). The urgent drive for food security is undermining the very environmental resources soil, water, and forests needed to sustain it, trapping Ethiopia in a cycle of poverty and degradation.

Ethiopia's population, exceeding 120 million, continues to grow at a rapid pace, placing unprecedented demand on the country's food systems. The agricultural sector, which employs over 70% of the workforce and contributes approximately 35% to the GDP, is under immense pressure to increase output (World Bank, 2023). This demand is primarily tried to meet through subsistence-oriented, smallholder farming systems, which are characterized by low productivity due to factors like fragmented land holdings, limited access to modern inputs, and reliance on erratic rainfall (Mellor & Dorosh, 2010). The primary strategy for expanding production has historically been extensification clearing new land for cultivation which directly conflicts with environmental conservation goals (Gashaw et al., 2014). As the population grows, inherited farmland is divided among children into ever-smaller, economically unviable plots. This prevents mechanization and economies of scale, forcing farmers to over-cultivate the same depleted soil. Furthermore, the national policies, such as the Agricultural Development-Led Industrialization (ADLI), have long emphasized boosting staple crop production, often at the expense of sustainable land management practices (Jemberu, 2014). On the other hand, the increasing frequency of climate-induced droughts and floods further exacerbates food insecurity, creating a vicious cycle where production shortfalls lead to more desperate measures that degrade the environment, which in turn reduces future productive capacity (W. Wang et al., 2025). This variability makes rain-fed agriculture even more precarious, leading to recurrent crop failures and famines.

Despite the fact that, the environmental cost of meeting food demands is starkly evident in the physical and biological degradation of Ethiopia's landscapes (Tadesse & Hailu, 2024). The most pressing issue is widespread land degradation, primarily driven by catastrophic soil erosion, where an estimated 1.5 to 2 billion tons of topsoil are lost to water annually, drastically reducing fertility, organic matter, and water-holding capacity(Aleminew, 2023). This is visibly worsened by severe gully erosion, which scars the terrain and renders large tracts of land unusable. This loss is accelerated by deforestation, as the clearing of forests for farmland, fuelwood, and construction materials removes vital biodiversity hotspots(Abebe & Debebe, 2019; Debebe & Zekarias, 2020) The disappearance of this forest cover not only exposes soil to the elements but also disrupts local water cycles and eliminates crucial carbon sinks, further destabilizing the environment, reduce the production, and exacerbating climate change.

As a result, this environmental degradation is compounded by unsustainable environmentally agricultural practices and consequences of their poor implementation. A key factor is soil fertility depletion, resulting from continuous cropping without adequate nutrient restitution (Sidique & Hadi, 2016). The low adoption of synthetic fertilizers due to cost and access barriers and insufficient use of organic matter have led to severe nutrient mining, creating negative balancesfor nitrogen and phosphorus(Wassie, 2020). Furthermore, water resource mismanagement presents a growing threat; inappropriate irrigation leads to salinization and waterlogging, while the increasing, though still limited, use of agrochemicals poses an emerging risk of water pollution(Singh, 2015; Tessema et al., 2023).

Ultimately, land degradation is a direct threat to Ethiopia's food security and future. Breaking this cycle requires a holistic approach that empowers farmers, diversifies the economy, and restores the environment to build a sustainable agricultural foundation.

### 3.2. Pathways to Balancing food production and environmental sustainability

Several interconnected pathways offer promising routes to balance food production with environmental sustainability in Ethiopian agriculture. Sustainable intensification integrates soil fertility management and conservation agriculture to boost yields while preserving natural resources (Xie et al., 2019; Tamene et al., 2017). Agroforestry combines trees with crops to enhance soil health, sequester carbon, and diversify farmer incomes (Fahad et al., 2022; Bogale, 2025). Agroecological agriculture applies ecological principles through practices such as intercropping and composting to build resilient, low-input farming systems (Mekuria et al., 2022; Vikas & Ranjan, 2024). Regenerative agriculture focuses on restoring soil health and biodiversity through cover cropping, composting, and managed grazing (Khangura et al., 2023; Sher et al., 2024). Climate-smart technologies improve productivity and resilience while reducing emissions through drought-tolerant crops and small-scale irrigation (Belay et al., 2023; Umer et al., 2024). Organic farming builds on traditional practices to protect water quality and enhance soil organic matter without synthetic inputs (Hailemariam et al., 2019; Teklewold et al., 2013). Improved water management enhances water use efficiency through irrigation and watershed management to sustain productivity under climate variability (Mengistu & Assefa, 2020; Teferi et al., 2025). Diversified farming systems integrate crops, livestock, and trees to spread risk, improve nutrition, and build ecological resilience (Kremen et al., 2012; Sánchez et al., 2022). Collectively, these pathways demonstrate that reconciling agricultural productivity with environmental stewardship is achievable through integrated, context-appropriate approaches (Figure 4).

### 3.2.1. Sustainable Intensification

Sustainable Intensification is a pragmatic pathway to meet rising food demand while conserving the environment (Xie et al., 2019; Helfenstein et al., 2020). This approach is operationalized through two synergistic methodologies. The first is Integrated Soil Fertility Management (ISFM), this strategy directly reverses soil depletion, with evidence from Ethiopia showing it can double or triple yields for both immediate productivity and long-term health (Tamene et al., 2017). The second pillar is Conservation Agriculture (CA, this system is instrumental in conserving soil moisture, drastically curtailing erosion, and building vital soil organic carbon, thereby enhancing the land's resilience to climate shocks(Araya et al., 2024; and Jain et al., 2025).

However, the effectiveness is often limited by the labor-intensive nature of practices like terracing and composting, and many farmers only partially adopt the recommended package of technologies, which diminishes the potential synergistic benefits and long-term sustainability gains(Teklewold et al., 2013; Tadele, 2017; and Eyitayo Raji et al., 2024).

### 3.2.2. Agroforestry

Agroforestry is a premier strategy that synergistically integrates food production with environmental sustainability ( Fahad et al., 2022). By integrating trees into farms, agroforestry creates resilient ecosystems that reduce erosion, enhance fertility, and provide sustainable fuel and timber (Olaniyan et al., 2024). Agroforestry is a comprehensive strategy that sequesters carbon, enhances biodiversity, and fortifies soil health (Bogale, 2025; G et al., 2025). Ultimately, by diversifying income and production, agroforestry rebuilds ecological capital while securing livelihoods and food security.

However, in Ethiopia the effectiveness of agroforestry is constrained by challenges such as long tree maturation periods, which delay returns and discourage farmers with immediate needs, and competition for limited land, water, and labour resources (Tebkew et al., 2024; Yirga et al., 2024). Despite these barriers, agroforestry remains a cornerstone of sustainable intensification strategies in Ethiopia, offering a pathway to restored ecosystems and improved livelihoods.

#### 3.2.3. Agroecological Agriculture

Agroecological agriculture stands as a profoundly holistic and transformative pathway for achieving a true symbiosis between food production and environmental sustainability (CI & MA, 2016; Vikas & Ranjan, 2024). It applies principles of diversity and recycling through context-specific practices that leverage local resources and farmer knowledge.

In Ethiopia, diverse home gardens exemplify agroecology, boosting both nutrition and economic stability (Mellisse et al., 2018; Nega et al., 2025). Agroecology uses practices like intercropping and natural pest control to build resilient, self-sufficient food systems that restore ecosystem health. It uses composting, diversification, and water harvesting to boost soil health and yields sustainably, with minimal external inputs (Mekuria et al., 2022). It builds resilience against climate and pests through biodiversity, empowering communities with local knowledge and resources. However, in Ethiopia, its potential is limited by policies favoring intensive inputs, a lack of tailored support, and socioeconomic barriers like land scarcity (Fiore et al., 2024; G. Tilahun et al., 2025).

#### 3.2.4. Regenerative Agriculture

Regenerative agriculture emerges as a profoundly promising pathway for reconciling the critical, often competing, demands of food production and environmental sustainability (Gordon et al., 2023; Khangura et al., 2023). It focuses on restoring soil health and biodiversity through practices like cover cropping, composting, and managed grazing (Sher et al., 2024). By enhancing soil health, it transforms farming into a system of ecological renewal for a sustainable future (Garbisu et al., 2025; McLennon et al., 2021).

Regenerative agriculture effectively tackles Ethiopia's key challenges of land degradation, climate vulnerability, and food insecurity (Araya, 2022). By restoring soil and biodiversity, practices like composting and agroforestry are revitalizing Ethiopia’s landscapes, improving yields and reducing erosion (McLennon et al., 2021). Its effectiveness is amplified by synergy with national conservation campaigns and social programs that mobilize community labor

(Gebremeskel et al., 2018). However, scaling is hindered by its knowledge-intensive demands and long-term returns, which conflict with farmers' immediate needs (O'donoghue et al., 2022).

#### 3.2.5. Climate-smart technologies

Climate-Smart Agriculture presents a critically important and technologically-informed pathway for achieving the delicate balance between food security and environmental sustainability in a climate-vulnerable world(Belay et al., 2023; Berhanu et al., 2024; Kujur et al., 2025). Its core strength lies in its integrated, three-pronged objective: to proactively increase agricultural productivity, systematically enhance resilience to climate change, and, where feasible, mitigate greenhouse gas emissions (FAO,2016). This holistic approach is being operationalized in contexts like Ethiopia through a suite of innovative and context-specific technologies (Dresen et al., 2014). CSA offers a pragmatic framework to boost productivity, adapt to climate change, and reduce emissions for a sustainable future.

Climate-smart technologies like drought-tolerant crops and small-scale irrigation effectively build resilience in Ethiopia, though adoption remains a challenge (Alemayehu et al., 2024; Umer et al., 2024). These technologies stabilize yields, reduce degradation, and boost incomes, supporting Ethiopia's national climate resilience strategy (Geda et al., 2024). However, their effectiveness is limited by high costs, inadequate support, and insufficient adaptation to local conditions (Umer et al., 2024). Their mitigation benefits, like carbon sequestration, are often unrealized without proper monitoring and incentives (G et al., 2025b).

#### 3.2.6. Organic Farming

Organic farming, while not yet a widespread certified export system in Ethiopia, represents a deeply resonant and historically-grounded pathway for harmonizing agricultural productivity with environmental stewardship (Devi Chaudhary Devi & Kumar, 2007). Organic farming's core principles are deeply rooted in Ethiopia's traditional practices, such as crop rotation, manure use, and natural pest control (Hailemariam et al., 2019). This existing foundation provides a significant cultural and practical advantage for its broader adoption. By eschewing synthetic inputs, this approach inherently protects water quality, enhances soil organic matter, and safeguards biodiversity(Hm et al., 2020). Therefore, organic farming stands as a synergistic model that merges traditional knowledge with modern markets, making environmental health the foundation of a sustainable and profitable system. However, in Ethiopia, its effectiveness is constrained by lower yields, especially during the transition, which risks the food security of subsistence farmers (Teklewold et al., 2013). The certification process remains expensive, complex, and largely out of reach for most smallholders without external support, limiting its adoption.

### 3.2.7. Improved Water Management

Improved Water Management stands as a foundational and non-negotiable pathway for achieving a sustainable equilibrium between agricultural productivity and environmental health, particularly in climate-vulnerable regions(Teweldebrihan & Dinka, 2025; X. Wang, 2025). Smart water use is critical for food security and preserving ecosystems amidst increasing droughts and floods (Kundzewicz & Matczak, 2015). This integrated approach enhances resilience and enabling the cultivation of higher-value, nutrient-rich crops (Haile et al., 2006a; Nyssen et al., 2010; Z. A. Tilahun, 2019; Nikolaou et al., 2020; and Umer et al., 2024).

Improved Water Management (IWM) in Ethiopia has proven to be a fundamentally effective yet challenging pathway for balancing food production and environmental sustainability, demonstrating significant potential through increased agricultural yields, household incomes, and drought resilience achieved (Haile et al., 2006b; Mengistu & Assefa, 2020; Gemeda et al., 2024; Teferi et al., 2025). However, its overall effectiveness is hampered by substantial obstacles including high costs, maintenance issues, risks of groundwater depletion, water conflicts, and institutional weaknesses in governance, which are compounded by climate change, indicating that while IWM is an essential strategic that holistically balances water needs for agriculture, communities, and ecosystems(Alao et al., 2024; Davamani et al., 2024; Mengistu & Assefa, 2020).

### 3.2.8. Diversified Farming Systems

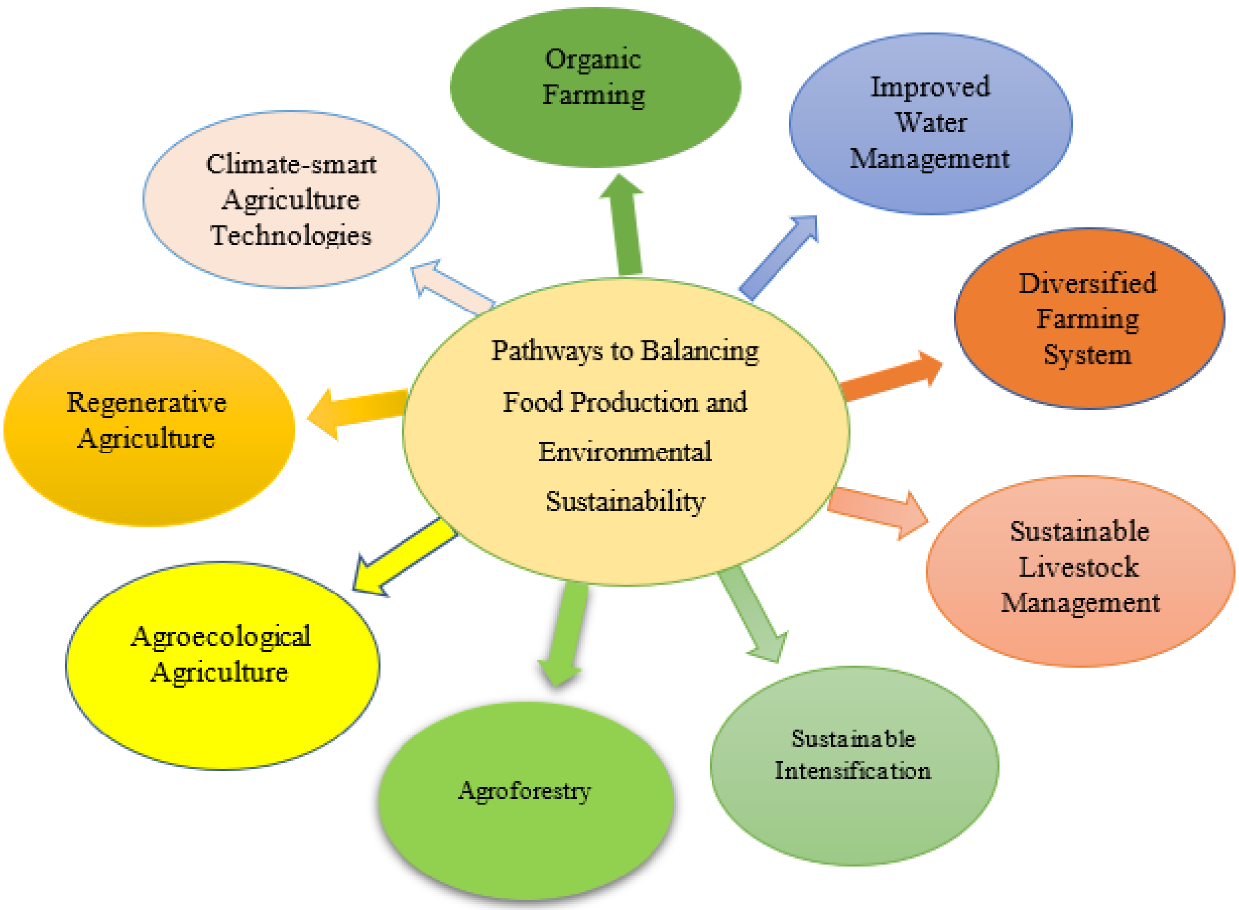
Diversified Farming Systems offer a robust and resilient pathway for harmonizing the imperative of food production with the principles of environmental sustainability, effectively moving beyond the vulnerabilities inherent in monoculture (Kremen et al., 2012). Integrated systems combining crops, livestock, and trees spread risk, create natural fertilizer, and enhance soil fertility (Sánchez et al., 2022). This approach moves beyond mere productivity to foster a holistic resilience; it buffers smallholder households against both market price fluctuations and climate shocks by ensuring that the failure of a single crop does not equate to a total loss(Sánchez Bogado et al., 2024). Furthermore, by producing diverse foods, this approach improves nutrition and creates a resilient, regenerative farming system.

Diversified Farming Systems in Ethiopia build resilience and food security by integrating crops, livestock, and trees, which improves soil health, reduces risks, and provides stable nutrition (Abebe & Amare, 2025; Keneni, n.d.; Mengistu et al., 2021). However, their widespread adoption and scalability are critically constrained by limited landholdings, a lack of access to diverse seeds and seedlings, insufficient extension services tailored to complex agroecological practices, and deeply ingrained traditional practices favoring cereal monocultures (Ahmed et al., 2016; Gebiso et al., 2023; G. W. Kassie et al., 2017). Diversifying farming is promising but requires tailored support, investment, and policies to succeed nationwide.

### 3.2.9. Sustainable Livestock Management

Sustainable Livestock Management represents an essential and transformative pathway for reconciling the critical role of livestock in livelihoods with the urgent need for environmental sustainability(Smith, 2023; Yulianti et al., 2024). While the sector is a cornerstone of agricultural income and nutrition, it has also been a historical driver of overgrazing and land degradation(D & M, 2017; FAO, 2011). Sustainable livestock management involves improved fodder, better animal health, and manure recycling to boost productivity while restoring ecosystems and reducing emissions.

Sustainable livestock management in Ethiopia has demonstrated considerable effectiveness in enhancing both economic resilience and environmental sustainability, particularly within the nation's vast pastoralist and mixed farming systems. By integrating practices such as controlled grazing, improved fodder production, and community-based breeding programs for indigenous livestock, these initiatives have directly increased animal productivity and household incomes while reducing pressure on fragile ecosystems(Guja Amejo, 2024). However, its overall effectiveness is constrained by significant challenges, including climate change-induced droughts, limited access to veterinary services and markets, and land degradation from historical overgrazing(Godde et al., 2021; Bashiru & Oseni, 2025; and Feleke et al., 2025).




Source: Own compilation from previous empirical studies, 2025

Figure 4: Pathways to Balancing Food Production and Environmental Sustainability

### 3.3. Challenges of Environmentally Sustainable Farming Practices

Despite the array of promising pathways, numerous barriers impede their widespread implementation. In Ethiopia, where the vast majority of farmers are smallholders managing plots of less than two hectares, profound socioeconomic constraints, knowledge and information gaps, policy and institutional barriers, population pressure**,** and climate change are the most immediate challenges to adopting sustainable farming practices(Addis & Abirdew, 2021; Zeleke et al., 2023; Zerssa et al., 2021).

#### 3.3.1. Socioeconomic Constraints

In Ethiopia, where the vast majority of farmers are smallholders managing plots of less than two hectares, profound socioeconomic constraints present the most immediate barrier to adopting sustainable practices(Girma Asefa & Ayalew Muluken, 2024). Widespread poverty and a critical lack of capital prevent farmers from investing in the initial costs of new technologies, such as drip irrigation kits, improved seeds, or organic inputs, the poorest farmers, especially female-headed households, frequently lack the necessary land, labor, or cash to invest in or risk adopting new practices(Teklewold et al., 2013b; Tsige et al., 2020). The economic reality forces a short-term perspective; farmers cannot afford the perceived risk of a yield dip during a transition period or the wait for long-term benefits like improved soil health, when the imperative is to feed their families today(Tigre & Heshmati, 2023). This makes high-upfront-cost, long-payoff practices, despite their proven long-term benefits, a luxury that many simply cannot contemplate, locking them into less productive and more environmentally degrading cycles.

Furthermore, while the extension system is extensive, knowledge gaps remain, and continuous training is needed for complex practices(MoA Extension Directorate, 2019; MoANR, 2017). Additionally, a lack of secure land tenure for some farmers disincentivizes long-term investments, and limited access to stable markets reduces the economic incentive for farmers to produce surplus through intensification(Girma Asefa & Ayalew Muluken, 2024; Tesfaye et al., 2023).

### 3.3.2. Knowledge and Information Gaps

The adoption of knowledge-intensive sustainable farming practices, requires comprehensive and continuous farmer training. However, several challenges have determined the effectiveness of the extension system in Ethiopia(Abate et al., 2014; MoANR, 2017; Tesfahun A, 2022). One key issue is the lack of vibrant linkages and coordination among various stakeholders, including government agencies, research institutions, NGOs, and farmers' groups (Kibrom et al., 2025). Extension agents have been also lacked deep training in these complex practices and are frequently tasked with promoting single, simple solutions rather than the integrated, context-specific management required for sustainability(Research Institute (IFPRI), 2018). This creates a critical information gap, leaving farmers without the necessary technical support to confidently navigate the transition from conventional to sustainable methods, leading to apprehension and abandonment if initial attempts do not yield immediate success.

### 3.3.3. Policy and Institutional Barriers

In Ethiopia agricultural policy has often been skewed towards achieving short-term food production targets, sometimes at the expense of long-term environmental sustainability(Shikur, 2020). Subsidies for chemical fertilizers and improved seeds, while boosting immediate yields, can inadvertently discourage the adoption of integrated soil fertility management that combines organic and inorganic sources(Leta et al., 2020). Furthermore, land tenure insecurity a legacy of past land redistribution policies remains a significant disincentive. If farmers lack guaranteed, long-term rights to their land, they are far less likely to invest in soil conservation structures, agroforestry trees, or other improvements that pay off over many years, as they cannot be certain they will be the ones to reap the benefits (Gebremedhin & Nega, n.d.; Kebede, 2008).

### 3.3.4. Population Pressure

Ethiopia's high population growth rate and its overwhelming dependence on agriculture create intense pressure on finite natural resources(Kefiyalew Girma, 2011). The need to feed growing families forces farmers to prioritize immediate calorie production above all else. This pressure manifests in the shortening or elimination of fallow periods, which are crucial for soil recovery, and the expansion of cultivation onto fragile marginal lands, steep slopes, and forest areas that are highly susceptible to degradation(Wassie, 2020). This survival-driven expansion creates a vicious cycle: as yields on existing lands stagnate or decline due to nutrient mining and erosion, the pressure to clear more land only increases, making the adoption of land-saving sustainable practices even more challenging(Gashaw et al., 2014; Tadesse & Hailu, 2024).

### 3.3.5. Climate Change

Acting as a threat multiplier, climate change intensifies every existing vulnerability and raises the perceived risk of adopting new farming practices(UNFCCC, 2014). Increased frequency and severity of droughts, floods, and unpredictable rainfall patterns make farmers more risk-averse(Lemma, 2016). In such a precarious environment, abandoning familiar traditional practices, even if they are low-yielding, for unfamiliar sustainable ones is perceived as an enormous gamble. A failed harvest due to an experimental practice is a catastrophic(Hailemariam et al., 2019). Therefore, climate change paradoxically makes the resilience offered by sustainable farming practices more necessary, while simultaneously making farmers more hesitant to adopt them due to the heightened uncertainty and potential for loss.

### 3.4. Opportunities to implement Sustainable Agriculture Practices

Despite the challenges, several opportunities create a favorable environment for a transition towards implementation of sustainable agriculture practices in Ethiopia.

#### 3.4.1. Strong Policy Commitment

A significant opportunity lies in the Ethiopian government's robust policy commitment to intertwining national development with environmental sustainability(Ayana & Sima, 2018). Foundational strategies like the Climate-Resilient Green Economy (CRGE) framework explicitly position sustainable agriculture as a pillar for achieving low-carbon economic growth. This high-level direction is powerfully complemented by large-scale, actionable initiatives such as the Green Legacy reforestation campaign, which not only restores degraded watersheds critical for agriculture but also fosters a national ethos of environmental stewardship(Ethiopia's Climate Resilient Green Economy National Adaptation Plan Federal Democratic Republic of Ethiopia, 2019). This top-down support creates an enabling environment, aligning public extension services, research agendas, and budgetary allocations towards practices that enhance ecosystem resilience while securing long-term food production.

#### 3.4.2. Existing Indigenous Knowledge

Ethiopia possesses a profound and often underutilized asset in the deep well of indigenous knowledge inherent within its farming communities(Negassa et al., 2025). Time-tested practices such as traditional agroforestry systems, soil and water conservation techniques, and complex crop-livestock diversification methods are already proven to enhance biodiversity and soil fertility(Bogale, 2025; Tebkew et al., 2024; Yirga et al., 2024). This existing foundation provides a culturally resonant and low-risk starting point for scaling up sustainable agriculture. Rather than introducing entirely foreign concepts, development efforts can build upon, refine, and scientifically validate these local practices, significantly accelerating adoption and ensuring that interventions are tailored to the specific socio-ecological context(Negassa et al., 2025; Woldie et al., 2025).

### 3.4.3. Potential for Carbon Financing

Ethiopia's ambitious land restoration and afforestation achievements position it favorably within the global carbon economy(Van Noordwijk et al., 2030). The country's significant carbon sequestration potential through initiatives like the Green Legacy can be translated into financial resources through international carbon credit markets and climate finance mechanisms(Bedhane, 2024). These funds can be strategically reinvested into the agricultural sector, subsidizing the transition to sustainable practices for smallholders for example, by providing payments for ecosystem services, funding agroforestry packages, or supporting soil carbon enrichment projects. This creates a virtuous cycle where environmental restoration generates revenue that further finances sustainable intensification of food production.

### 3.4.4. Youth and Digital Innovation

A transformative opportunity is emerging through the convergence of a young, increasingly educated population and rapid digitalization (CTA), 2019). Growing mobile phone penetration enables the deployment of digital tools such as smartphone-based extension apps, satellite-based weather advisories, and digital market platforms that can overcome traditional knowledge barriers and improve the efficiency of sustainable farming (Abate et al., 2014 & FAO, 2021). Simultaneously, a growing interest in agricultural entrepreneurship among the youth brings fresh perspectives and a willingness to adopt innovative, technology-driven sustainable practices. This synergy can revolutionize the sector, making sustainable agriculture more knowledge-accessible, economically attractive, and resilient to climate challenges.

## 4. Conclusion and Recommendation

### 4.1. Conclusion

This systematic review demonstrates that Ethiopia's agricultural sector is at a crossroads, where the urgent need to increase food production is constrained by escalating environmental degradation. The evidence consistently shows that soil erosion, declining soil fertility, deforestation, water scarcity, and climate variability pose significant threats to the long-term viability of agriculture. Yet, the reviewed literature also provides clear evidence that sustainable agricultural practices offer viable pathways for reversing degradation while improving productivity. Practices such as conservation agriculture, agroforestry, sustainable intensification, regenerative agriculture, organic farming, improved water management, and sustainable livestock systems have shown strong potential to enhance soil health, increase water use efficiency, and boost yields under variable climatic conditions. Despite their proven benefits, adoption of these practices remains low due to intertwine socioeconomic, institutional, and policy constraints. Weak extension services, limited access to inputs and credit, insecure land tenure, fragmented agricultural policies, and limited farmer awareness continue to limit meaningful transitions toward sustainability. However, Ethiopia's existing policy commitments, growing digital innovation, strong indigenous knowledge base, and emerging opportunities in climate finance present significant opportunities for scaling sustainable agricultural solutions.

Overall, achieving a sustainable balance between food production and environmental stewardship is not only feasible but essential for Ethiopia's future. A coordinated, multisectoral, and evidence-driven approach, one that integrates policy reform, capacity building, community participation, technology adoption, and environmental restoration is required to enable a productive, climate-resilient, and ecologically sustainable agricultural system. This review provides a strong foundation for guiding policymakers, development practitioners, and researchers toward interventions that simultaneously safeguard natural resources and support national food security goals.

### 4.2. Recommendation

Based on the findings of this review, the following recommendations are proposed for policymakers, development practitioners, researchers, and other stakeholders:

- Ethiopia should be reform national agricultural policies and subsidy programs to actively promote and incentivize integrated packages of Sustainable Agriculture Practices rather than focusing on single, input-oriented technologies.
- The legal framework should be strengthened to ensure secure and transferable land tenure rights, empowering farmers to make long-term investments in their land.
- The country should be invested in continuous, practical training for extension agents on the principles and implementation of knowledge-intensive sustainable agriculture practices.

- The digital extension tools should be developed and deploy to provide timely, accessible, and context-specific information to farmers on sustainable practices.
- Indigenous knowledge systems should be systematically document, validate, and integrate into the design of sustainable agricultural promotion programs to ensure they are contextually and culturally appropriate.
- It needs aggressively tap into international carbon finance and climate funds by quantifying and monetizing the carbon sequestration and climate resilience benefits of Ethiopia's landscape restoration and sustainable agriculture initiatives.
- Direct research should be conducted towards addressing critical gaps, particularly in understanding the long-term socio-economic and environmental trade-offs and synergies of different sustainable agriculture practices combinations.
- Promote participatory action research that involves farmers in the co-creation and adaptation of technologies to ensure they are suitable for local agroecological and socio-economic conditions.

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**PRISMA 2020 flow diagram for new systematic reviews which included searches of databases and registers only**

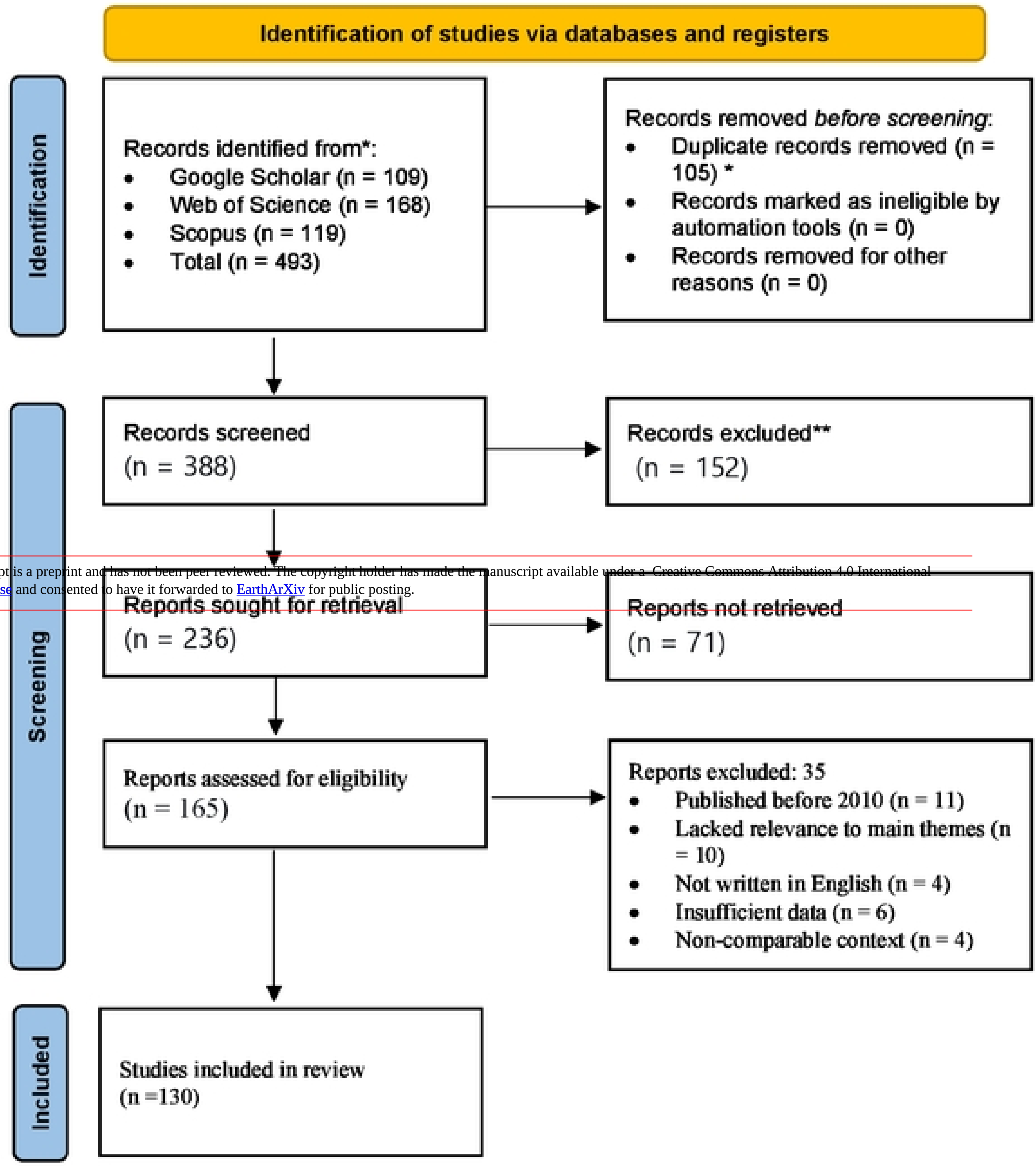




Figure 1: PRISMA Method for article selection

Figure