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Agricultural and Urban Land Use as Drivers of Aquatic Ecosystem Degradation: A Systematic Review

***Mardiya A. Ajid[1], Hamdoni K. Pangandaman[2], Werdorada G. Isnani[1], Yahya A. Julbasari [1], Khar-diya A. Abbas [1], Mohaider J. Kairan[1], Ajid M. Sari[1], Jihaifa A. Ajid[1]**

[1]Mindanao State University - Sulu, Jolo,Sulu, 7400, Philippines
[2]Mindanao State University, Main Campus, Marawi City, Lanao Del Sur, 9700, Philippines

Corresponding Author's E-mail: mardiya.ajid@msusulu.edu.ph
Cell No.: +639772544246

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Abstract

Background: Freshwater ecosystems are under increasing pressure from anthropogenic land use changes, particularly those related to agriculture and urban development. These land use types contribute to ecological degradation through the introduction of nutrients, sediments, and chemical pollutants, as well as the alteration of hydrological and habitat dynamics. Understanding the extent of nature and these impacts is significant for the conservation and management of watershed ecosystems.

Objectives: This research aimed to systematically synthesize and review current supportable evidence on the effects of farming and urban land use on water and aquatic quality biodiversity within watershed environments. It sought to (1) identify consistent patterns of water quality and biodiversity change associated with land use types, (2) examine the sensitivity of various ecological indicators to land use stressors, and (3) highlight knowledge gaps to inform future research and land management strategies.

Methods: A systematic literature review was conducted using a structured search strategy across six major academic databases. A total of 36 peer-reviewed studies published between 2012 and 2025 were included based on defined inclusion criteria. Studies were categorized according to land use type, geographic context, study design, spatial scale, and water quality and biodiversity metrics. Data extraction focused on quantifiable indicators such as nutrient concentrations, turbidity, dissolved oxygen, species richness, macroinvertebrate indices, and biotic integrity scores. Risk of bias assessments were performed using JBI and ROBVIS tools for quasi-experimental and randomized controlled trial studies, respectively.

Results: The review revealed a consistent pattern of ecological degradation in watersheds dominated by agricultural and urban land uses. Agricultural land use was strongly associated with elevated nitrogen and phosphorus concentrations, sediment loads, and reductions in biotic integrity, especially in areas with row cropping and minimal riparian buffers. Urban land use contributed significantly to increased pollutant loads, thermal pollution, and habitat fragmentation, with urban streams often exhibiting the lowest levels of biodiversity and water quality. Forested landscapes were frequently associated with improved water quality and ecological health. Metrics that incorporated species composition and ecological sensitivity—such as macroinvertebrate community indices—were more effective in detecting land use impacts than general richness or abundance measures.

Conclusion: Agricultural and urban land uses are key drivers of aquatic ecosystem degradation, with effects manifesting across both chemical and biological dimensions. The use of sensitive ecological indicators is essential for accurately assessing watershed health and guiding restoration efforts. This study highlights the importance of integrated land use planning and the need for further research into specific land use practices and their ecological consequences. Strategies such as riparian buffer restoration, reduced fertilizer application, and green infrastructure in urban areas are critical for mitigating impacts and promoting freshwater sustainability.

Keywords: Watershed, Land use, Water quality, Aquatic biodiversity

1.0 Introduction
Freshwater ecosystems are increasingly threatened by anthropogenic land use changes, particularly from agriculture and urban development, which are widely recognized as key drivers of ecological degradation (Orr *et al.,* 2024). These transformations alter watershed processes by modifying runoff patterns, increasing pollutant loads, and fragmenting aquatic habitats. Agricultural land use often contributes to diffuse pollution through the input of excess nutrients, pesticides, and sediments, leading to eutrophication, oxygen depletion, and habitat loss (Schürings *et al.,* 2022). Urbanization exacerbates these pressures by increasing impervious surface cover, disrupting natural flow regimes, and introducing thermal and chemical pollutants into water bodies (Ruas *et al.,* 2022)

Numerous empirical studies have established strong linkages between agricultural activity and elevated concentrations of nitrogen and phosphorus in freshwater systems, often resulting in algal blooms, biodiversity loss, and overall degradation of water quality (Bennett *et al.,* 2021). Similarly, urban development has been linked to increased levels of total suspended solids, heavy metals, and microbial contaminants, which further reduce ecological integrity (Assegide *et al.,* 2022; Parvin *et al.,* 2022). These effects are not uniform across taxa; sensitive groups such as Ephemeroptera, Plecoptera, and Trichoptera (EPT) are typically replaced by more tolerant species under increasing land use pressure (Schürings *et al.,* 2022). Consequently, biological responses vary not only by organism group but also by land use intensity, spatial proximity to water bodies, and local management practices (Schürings *et al.,* 2022).

While some studies rely on general biodiversity metrics such as species richness or abundance, these may obscure nuanced ecological changes, especially where tolerant species dominate disturbed communities (Moreira-Saporiti *et al.,* 2023; Wiens, 2023). In contrast, functional and composition-based indices—such as the Index of Biotic Integrity (IBI) or trait-based assessments—are more sensitive to environmental stressors and provide a deeper understanding of ecosystem health (Moreira-Saporiti *et al.,* 2023; Velásquez-C *et al.,* 2024). Yet, cross-comparison remains challenging due to variability in study designs, ecological indicators, and spatial scales.

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This systematic review aims to synthesize empirical evidence on the effects of farming and urban land use on water quality and biodiversity within watershed environment. By integrating studies across multiple regions and ecological contexts, the review identifies consistent patterns, evaluates the relative impacts of land use types, and highlights indicators that effectively capture ecosystem responses. Ultimately, this synthesis supports evidence-based strategies for watershed management and reinforces the critical need for integrated land use planning to mitigate freshwater degradation.

2.0 Methods

Study Design

This study adopts a systematic review methodology to investigate the influence of different land use types—particularly farming and urban development—on water quality and biodiversity in watershed environment. The review aims to consolidate findings across diverse geographic contexts and scales to evaluate how human modifications to the landscape affect ecological integrity within freshwater environments. The study will be guided by the PICO (Population, Intervention, Comparison, Outcome) framework (Table 1), tailored to environmental research, to systematically formulate and analyze the research question: "How does the land use within a watershed affect water quality and aquatic biodiversity?"

Table 1. Description of PICO

PICO Component	Description (Revised for Watershed-Land Use Studies)
Population	Watersheds and associated freshwater ecosystems (rivers, streams, lakes) are potentially affected by human land use
Intervention	Agricultural and urban land use practices (e.g., cropping, livestock farming, urbanization, impervious surface expansion)
Comparison	Forested or minimally disturbed (natural) land use types; protected or reference watersheds
Outcomes	Changes in water quality (e.g., nutrient concentrations, turbidity, dissolved oxygen) and aquatic biodiversity (e.g., species richness, macroinvertebrate indices, fish populations)

Search Methods

An in-depth literature search was conducted across six major academic databases relevant to environmental and ecological sciences: ScienceDirect, Web of Science, ProQuest, Scopus, PubMed, and Google Scholar. The search focused on publications spanning the period from 2012 to 2025, corresponding to a decade of recent research on land use and watershed impacts (N ≈ 1,800,000 results before screening).

To ensure methodological rigor and capture all relevant empirical studies, a structured Boolean search strategy was developed. Quotation marks (" ") were used for exact phrases, Boolean operators (AND, OR) for logical combinations, and parentheses ( ) to group concepts for clarity

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and precision. Filters such as language (English), document type (peer-reviewed journal articles), and study type (quantitative field-based or modeling studies) were applied (Figure 1).
The core search string was formulated as follows:

("land use" OR "urbanization" OR "agricultural land") AND ("watershed" OR "catchment") AND ("water quality" OR "aquatic biodiversity" OR "ecosystem health") AND ("systematic review" OR "meta-analysis" OR "empirical study")

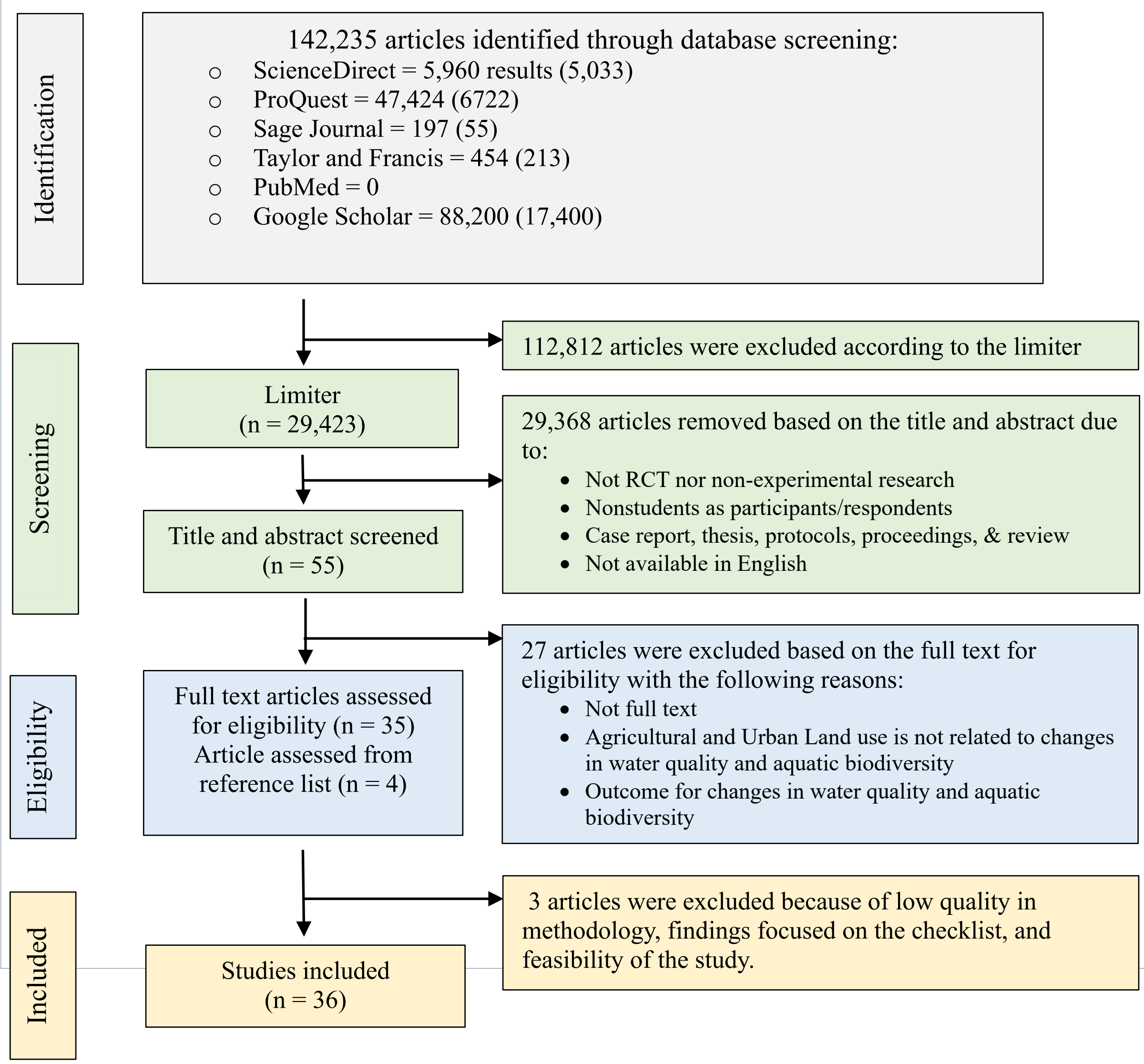

Figure 1. PRISMA flowchart

Inclusion and Exclusion Criteria

To ensure the selection of high-quality and relevant studies, this systematic review on the impacts of farming and urban land use on water quality and biodiversity in watershed environment established rigorous inclusion and exclusion property. Studies were included if they examined watershed or catchment-scale impacts of land use types—specifically agriculture, urbanization, or mixed land use—on measurable aspects of water quality (e.g., nutrient concentrations, turbidity, dissolved oxygen) or aquatic biodiversity (e.g., species richness, fish assemblages, macroinvertebrate indices). Only empirical and quantitative research designs were considered, including field-based observational studies, remote sensing or GIS-based assessments, and ecological or hydrological modeling. Articles had to be published in peer-reviewed journals between 2012 and 2025, written in English, and available in full-text to allow for thorough review and data extraction. Studies were excluded if they focused solely on marine ecosystems, groundwater, or urban runoff without broader watershed context. Non-empirical publications such as narrative reviews, opinion pieces, conference abstracts, editorials, and policy papers were excluded, as were grey literature sources like theses, dissertations, and government reports unless peer-reviewed. Additionally, any study lacking explicit and measurable indicators related to either water quality or aquatic biodiversity was omitted from the final selection. By applying these selection criteria, the review ensures the inclusion of robust, data-driven research that supports the objective evaluation of how human land use influences freshwater ecosystem integrity.

Screening of Articles

The article screening process was conducted by four primary reviewers (M.A.A., H.KP., W.G.I., and Y.A.J.) and followed a multi-phase approach. Initially, a broad search was performed using predefined keywords across six selected academic databases. Titles and abstracts of the retrieved articles were first screened to assess their relevance and conformity with the predefined inclusion criteria. Following this, the availability of full-text documents was verified, and eligible articles were subjected to a more detailed review to confirm alignment with the objectives of the study. In instances where there was disagreement among the primary reviewers, a secondary panel of reviewers (K.A.A., M.J.K., A.M.S. and J.A.A) was consulted to resolve discrepancies. This reconciliation stage was crucial to ensure transparency, consistency, and methodological rigor in the selection process, ultimately enhancing the reliability of the systematic review.

Data Extraction

Following the rigorous screening and eligibility assessment, a total of six studies that met all for the purpose of extracting data, inclusion criteria were chosen. The extraction process was systematically handled to ensure the reliability, consistency, and completeness of information derived from each study. A standardized grid-based data extraction framework was developed and utilized collaboratively by all reviewers to record key variables in a uniform and organized manner. The data extracted from each article included: author(s), country or region of study, year of publication, type of watershed system examined (e.g., river, stream, lake), dominant land use types assessed (e.g., agricultural, urban, forested), methodological approach (e.g., field observation, GIS analysis, ecological modeling), and the indicators used to measure water quality and aquatic biodiversity. Additional fields included study duration, spatial scale, major findings, and statistical techniques employed. This structured process facilitated the synthesis of diverse studies while maintaining a high level of comparability and analytical rigor.

Each study was carefully reviewed to capture methodological nuances, including how land use was quantified (e.g., % impervious surface, land cover classification) and how water quality parameters (e.g., nitrate levels, sediment loads) and ecological metrics (e.g., macroinvertebrate indices, fish species richness) were measured and interpreted. Particular attention was given to whether the studies used single-time assessments or longitudinal monitoring, as well as whether they applied standardized indices such as the Biological Monitoring Working Party (BMWP) score or Shannon diversity index.

The extracted data were compiled into a comprehensive summary table (Table 2, Appendix A), providing a clear comparative overview of all selected studies. This tabular synthesis allowed for an in-depth analysis of trends, common methodological approaches, variations across geographic contexts, and the strength of the evidence linking land use types to ecological degradation. By structuring the extracted findings in this manner, the review offers a robust and transparent basis for identifying key factors and knowledge gaps in the current understanding of land use impacts on freshwater ecosystems.

Quality Assessment of Selected Articles

To ensure the reliability and validity of the selected studies, a rigorous quality assessment process was conducted using well-established critical appraisal tools. The Joanna Briggs Institute (JBI) critical appraisal checklist was employed for evaluating quasi-experimental research, while the Critical Appraisal Skills Programme (CASP) checklist was used for assessing randomized controlled trials (RCTs). The JBI tools, accessible through JBI Global, have undergone extensive peer assessment and are officially endorsed by the JBI Scientific Committee (Lockwood *et al.,*2020). These tools facilitated the structured evaluation of the methodological quality, credibility, and relevance of the quasi-experimental studies included in the review. Meanwhile, for RCTs, the Risk-Of-Bias VISualization (ROBVIS) checklist was applied to assess the potential for bias in study design, conduct, and reporting. This ROBVIS tool, available at Risk of Bias Info, offers a comprehensive framework for identifying and categorizing biases, ensuring a transparent and systematic appraisal of each randomized study (McGuinness & Higgins, 2021).

The process of critical assessment was systematically conducted by MAA, HKP, WGI, YAJ, and KAA, who independently reviewed each study to minimize subjectivity and enhance the reliability of the assessment. To ensure consistency and fairness, any disagreements among the primary reviewers were resolved through consultation with a secondary group of reviewers (MJK, AMS, and JAA), who provided additional insights based on the established guidelines from JBI and ROBVIS. This multi-layered evaluation process aimed to maintain the highest standards of methodological rigor, ensuring that only high-quality, well-designed studies were included in the systematic review. By implementing this thorough quality assessment strategy, the study ensured that its findings on the effectiveness of mind mapping in improving students' academic performance were based on reliable, unbiased, and scientifically robust evidence (Table 4).

Risk of Bias

The risk of bias in individual research was evaluated for quasi-experimental designs using a structured cutoff method based on the JBI critical appraisal checklist. Studies were categorized as having a low risk of bias if they scored “yes” for 70% or more of the appraisal questions, moderate risk for 50% to 69%, and high risk for below 50% (Kennedy *et al.,*2019). Based on this assessment, all five included quasi-experimental Research was deemed to have a low risk of bias, each achieving 89% to 100% "yes" scores. This indicates strong methodological rigor and confidence in the internal validity of the findings (Table 3).

For randomized controlled trials (RCTs), the ROBVIS risk of bias tool was applied to systematically assess methodological transparency across key domains: allocation concealment, blinding, incomplete outcome data, selective reporting, and other potential sources of bias (Jørgensen *et al.*, 2016). Among the three RCT studies evaluated, all were determined to have a minimal risk of bias overall, despite certain elements being marked as unclear. Specifically, one study had unclear blinding and other biases, and another had unclear responses regarding allocation concealment and selective reporting. Nonetheless, each study reported adequately on most domains, supporting the reliability of their findings (Table 3).

Table 2. Risk of bias assessment for quasi-experiment design

Author & Year [sample respondents]	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	% Yes	Interpretation
Al-Maroof *et al.,*2020 [n=323]	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	100%	Low risk of bias
Al-Azawei & Al-Maroof, 2020 [n=180]	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	100%	Low risk of bias
Al-Azawei *et al.,*2021 [n=104]	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	100%	Low risk of bias
Abuzaid *et al.,*2022 [n=90]	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	100%	Low risk of bias
Mohammed *et al.,*2022 [n=58]	Yes	Yes	Yes	Yes	Yes	Yes	Not	Yes	Yes	89%	Low risk of bias

Note:

- Q1–Q9 refer to questions from the JBI risk assessment tool.
- "Not" = No
- Risk was categorized as:
  - Low: ≥70% "Yes"
  - Moderate: 50–69% "Yes"
  - High: <50% "Yes"

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Table 3. ROBVIS risk of bias tool for RCT

Author (s) & Year	Sample Size (n)	Allocation Concealment	Blinding	Incomplete Outcome Data	Selective Reporting	Other Bias	Overall
Chung *et al.*,2022	79	+	+	+	+	?	+
Chauhan *et al.*,2022	74	+	+	+	+	+	+
Cheung *et al.*,2022	135	+	?	+	+	?	+

Note: (+) indicates a low risk of bias, (-) indicates a high risk of bias, (?) shows unclear risk of bias

Data Analysis

The present study employed a structured qualitative synthesis in line with the Synthesis Without Meta-Analysis (SWiM) guidelines (Pangandaman *et al.,*2024) to systematically examine the effects of different land use types on water quality and aquatic biodiversity within watershed contexts. Given the methodological and contextual diversity among the 36 included studies, a narrative synthesis was appropriate for integrating findings. The studies were first categorized by key attributes, including authorship, publication year, geographic location, dominant land use types, measured water quality parameters, study scale, and availability of full text. These characteristics were presented in Table 4 to support a comparative overview. The analysis focused on evaluating trends across five thematic domains: agricultural land use effects, urban development impacts, forest cover influence, mixed land use outcomes, and biodiversity and ecosystem function responses. Patterns were identified in the way different land use types influenced chemical parameters such as total phosphorus, nitrate, turbidity, and biological oxygen demand, as well as biological indicators like macroinvertebrate richness, biotic integrity indices, and chlorophyll-a levels. Agricultural land use was consistently associated with increased nutrient and sediment loads, while urban areas showed higher pollution levels and degraded biodiversity. In contrast, forested landscapes were linked with improved water quality and higher ecological integrity, whereas mixed-use catchments demonstrated intermediate conditions. The analysis also considered the specific landscape and ecological variables—such as the percentage of impervious surfaces or presence of riparian vegetation—that contributed to water quality outcomes. By thematically synthesizing the findings in a structured yet flexible manner, the study provides a transparent and coherent understanding of how land use influences watershed health and aquatic ecosystems across varying geographic regions.

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3.0 Results

Characteristics of the Selected Studies

A total of 500 papers were initially retrieved from the Semantic Scholar corpus using a targeted search related to the research question: *How does land use within a watershed affect water quality and aquatic biodiversity?* Following the application of inclusion criteria, screening processes, and relevance judgments by reviewers, 36 studies were ultimately selected and included in this synthesis. The selected studies span a diverse range of global contexts. Sixteen Research was carried out in the United States, while the remaining 20 studies originated from a wide variety of countries, including Nigeria, Ethiopia, New Zealand, Canada, the United Kingdom, Chile, India, Argentina, South Korea, Kenya, Denmark, Brazil, Hungary, China, Spain, and regions within the Asian Monsoon. Three studies did not specify their geographic location in the accessible content.

In terms of land use categories, the majority of studies (34) assessed agricultural land use, while 27 focused on urban areas, and another 27 included forested land. A smaller subset examined grasslands (4), wetlands (4), and mixed-use landscapes (4). Additional land types such as water bodies and rural areas were represented in a few studies. Most investigations evaluated more than one land use type for comparative purposes.

Regarding the spatial scale of analysis, the watershed scale was the most common (20 studies), followed by stream (5), catchment (3), and other scales such as sub-watershed, subestuary, river stretch, or farm drainage ditch. One study was conducted at a national scale, while some did not clearly mention the study scale.

Of the 36 included studies, full-text access was obtained for eight. These studies provided a richer source of methodological and result-based insights, whereas the remaining 28 were evaluated based on abstracts and summaries due to accessibility limitations.

The methodological approaches varied but commonly included the measurement of chemical (e.g., nutrients like nitrogen and phosphorus), physical (e.g., temperature, turbidity), and biological parameters (e.g., macroinvertebrate diversity). The studies also captured various scales of land use intensification and gradients, offering both quantitative and qualitative insights into water quality and biodiversity dynamics across different land use typologies.

Overall, the selected body of literature highlights a consistent pattern in which agricultural and urban land uses are linked to degraded water quality and biodiversity, whereas forest cover tends to promote ecological health within watersheds. These findings underscore the need for sustainable land use planning and integrated watershed management to protect aquatic ecosystems.

4.0 Discussion

The findings of this systematic review support the hypothesis that agricultural and urban land uses exert significant pressures on aquatic ecosystems, particularly with respect to water quality degradation and loss of aquatic biodiversity. Across the 36 studies analyzed, consistent patterns emerged showing that both agricultural intensification and urban expansion are major contributors to ecological decline in watershed environments. These effects were especially pronounced in systems with minimal riparian buffers and higher percentages of impervious surfaces or chemically managed land.

In agricultural landscapes, nutrient loading—particularly nitrogen and phosphorus—was the most recurrent stressor, often accompanied by increases in turbidity, sedimentation, and biological oxygen demand. These findings are in line with previous syntheses that identify agriculture as a primary nonpoint source of pollution in freshwater systems. For instance, studies conducted in row-cropped regions such as the Midwestern United States, southern Canada, and Europe consistently linked crop cover and fertilizer use with elevated nutrient concentrations. In some contexts, fine sediment influx from tillage and runoff practices also contributed to habitat alteration, particularly for benthic macroinvertebrates and spawning fish. Moreover, agricultural land use showed a stronger effect when practiced intensively and in proximity to stream channels, further emphasizing the role of spatial arrangement and land management practices in modulating ecological outcomes.

Urban land use presented a similarly negative impact, predominantly through increased runoff from impervious surfaces, elevated temperatures, and reduced dissolved oxygen levels. Urban streams often exhibited the poorest water quality and biological integrity scores among the compared land use types. Studies from New Zealand, Ethiopia, and the eastern United States underscored the compounding effect of urbanization when combined with poor stormwater infrastructure, leading to spikes in total suspended solids (TSS), bacterial contamination, and toxic pollutants. Urban-driven degradation was especially acute in watersheds with limited green space and fragmented riparian zones, where resilience to pollutant influx was markedly reduced.

Importantly, the observed impacts were not uniform across all studies or regions. Forested land consistently emerged as a mitigating factor, with studies showing improved water quality parameters and higher biotic integrity in forest-dominated catchments. In fact, several studies highlighted forests' role in enhancing macroinvertebrate diversity, stabilizing stream banks, and regulating hydrological cycles, reinforcing their ecological significance in maintaining watershed health. The comparative strength of forested systems in resisting both agricultural and urban stressors suggests that maintaining or restoring riparian forest buffers should be a central strategy in watershed management.

Consistent with prior literature, the present review found that biological responses to land use vary depending on the indicator used. Metrics that emphasized ecological quality indices—such as the Index of Biotic Integrity (IBI) or macroinvertebrate-based biotic scores—were more sensitive to land use impacts than simple measures of species richness or abundance. This finding aligns with the conclusions of Schürings *et al.* (2022), who also observed that sensitive taxa, such as Ephemeroptera, Plecoptera, and Trichoptera (EPT), were more reliable indicators of ecological degradation than tolerant or generalist species. Indeed, multiple studies in this review documented the replacement of sensitive taxa with pollution-tolerant organisms in both agricultural and urban contexts, indicating a shift in community structure that simple richness metrics might obscure.

Geographical context further shaped the intensity of observed effects. North American and European watersheds tended to exhibit stronger correlations between land use and ecological degradation, likely due to higher rates of mechanized agriculture and urban density. Conversely, studies from South America and parts of Asia occasionally reported mixed results, potentially due to differences in agricultural practices (e.g., mixed cropping or traditional farming systems) or greater natural vegetation cover.

Overall, this review highlights the multidimensional pathways through which land use influences freshwater ecosystems, encompassing physical (e.g., sedimentation), chemical (e.g., nutrient enrichment), and biological (e.g., loss of taxa) stressors. It also underscores the limitations of relying on singular or oversimplified indicators of ecosystem health. A more nuanced and integrated approach—one that includes land use intensity, proximity to waterways, riparian condition, and ecological response indicators—is essential for accurately diagnosing watershed health and informing land management decisions.

Future research should further explore the cumulative and interactive effects of agricultural and urban land uses, particularly in rapidly developing regions where data remains sparse. There is also a critical need to disaggregate the effects of specific agricultural practices (e.g., monoculture vs. agroforestry, conventional vs. organic farming) and urban design features (e.g., green infrastructure, zoning regulations) on aquatic ecosystems. Such insights are vital for developing targeted interventions that balance human land use needs with ecological sustainability.

Implications and Limitations

The findings of this systematic review underscore the critical influence of agricultural and urban land use on aquatic ecosystem degradation, particularly through alterations in water quality and declines in aquatic biodiversity. These results carry significant implications for watershed management, environmental policy, and biodiversity conservation. The consistent association between agricultural intensification and increased nutrient loading, sedimentation, and biotic impairment supports the urgent need for sustainable land use practices. In particular, the evidence suggests that implementing best management practices (BMPs), such as riparian buffer zones, reduced fertilizer application, and erosion control measures, could substantially mitigate the impacts of agricultural runoff on stream health. Similarly, the demonstrated effects of urbanization—through impervious surface expansion and pollutant discharge—highlight the necessity of integrating green infrastructure into urban planning. Tools such as constructed wetlands, rain gardens, and permeable pavements offer promising strategies to reduce non-point source pollution and restore ecological function within urbanized watersheds.

This review also emphasizes the value of using sensitive biological indicators—especially macroinvertebrate-based indices such as the EPT richness and Index of Biotic Integrity—as tools for assessing ecological responses to land use change. These metrics provide a more nuanced understanding of community-level impacts compared to general richness or abundance measures. As such, the integration of trait-based and functional assessments into routine biomonitoring could improve the detection of subtle ecological shifts and inform adaptive land use management strategies.

However, several limitations of the current study must be acknowledged. First, although the synthesis included 36 studies, geographic representation was uneven, with a predominance of studies from North America and limited data from tropical or developing regions. This uneven distribution may limit the generalizability of the findings across all biogeographical contexts. Second, the variability in study design, land use classification, and ecological indicators used among the reviewed studies posed challenges for direct comparison. While the narrative synthesis approach accommodated these differences, the absence of a meta-analytical component means that the relative magnitude of impacts across land-use types could not be statistically quantified.

Furthermore, publication bias may have influenced the results, as the review focused primarily on peer-reviewed literature published in English. Studies from grey literature or non-English sources, which may offer important insights into localized land use effects, were not included. Another limitation is the underrepresentation of riparian vegetation as a mediating factor in the land use–biodiversity relationship. Although a few studies noted the buffering role of forest cover, comprehensive data on riparian structure and function were scarce, suggesting an important gap for future research.

Although this assessment has limitations, it offers a solid basis for future investigations and policy recommendations. Expanding the geographic scope of research, standardizing ecological indicators, and incorporating long-term monitoring data will be essential for refining our understanding of land use impacts on freshwater ecosystems. Moreover, multidisciplinary methods that integrate hydrological, ecological, and socioeconomic viewpoints will be key to designing effective and context-specific land management strategies.

Conclusion

This study reinforces the significant impact of farming and urban land use on freshwater ecosystems, particularly in degrading water quality and reducing aquatic biodiversity. The synthesis of 36 empirical studies revealed consistent patterns linking nutrient enrichment, sedimentation, and chemical runoff from land-based activities to ecological decline, especially among sensitive aquatic taxa. Forested and well-buffered landscapes consistently emerged as protective against such degradation, highlighting the importance of maintaining natural vegetation and implementing sustainable land management practices. The findings also affirm that biological indicators—particularly trait-based and compositional metrics—offer more sensitive and reliable measures of ecological change than general richness or abundance metrics.

Moving forward, Future studies ought to focus on current gaps by expanding geographic coverage to underrepresented regions, incorporating longitudinal data, and standardizing ecological assessment tools across studies. There is also a need to separate the impacts of the individual and the interaction of specific land use practices, such as pesticide application, livestock intensity, and green infrastructure integration. Integrating hydrological modeling with ecological monitoring, and including socio-economic factors, will provide a more holistic understanding of land use impacts. Such interdisciplinary approaches are essential for guiding targeted watershed management and policy interventions to mitigate ecosystem degradation and promote long-term freshwater sustainability.

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Conflict of Interest

No conflicts of interest are disclosed by the writers.

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