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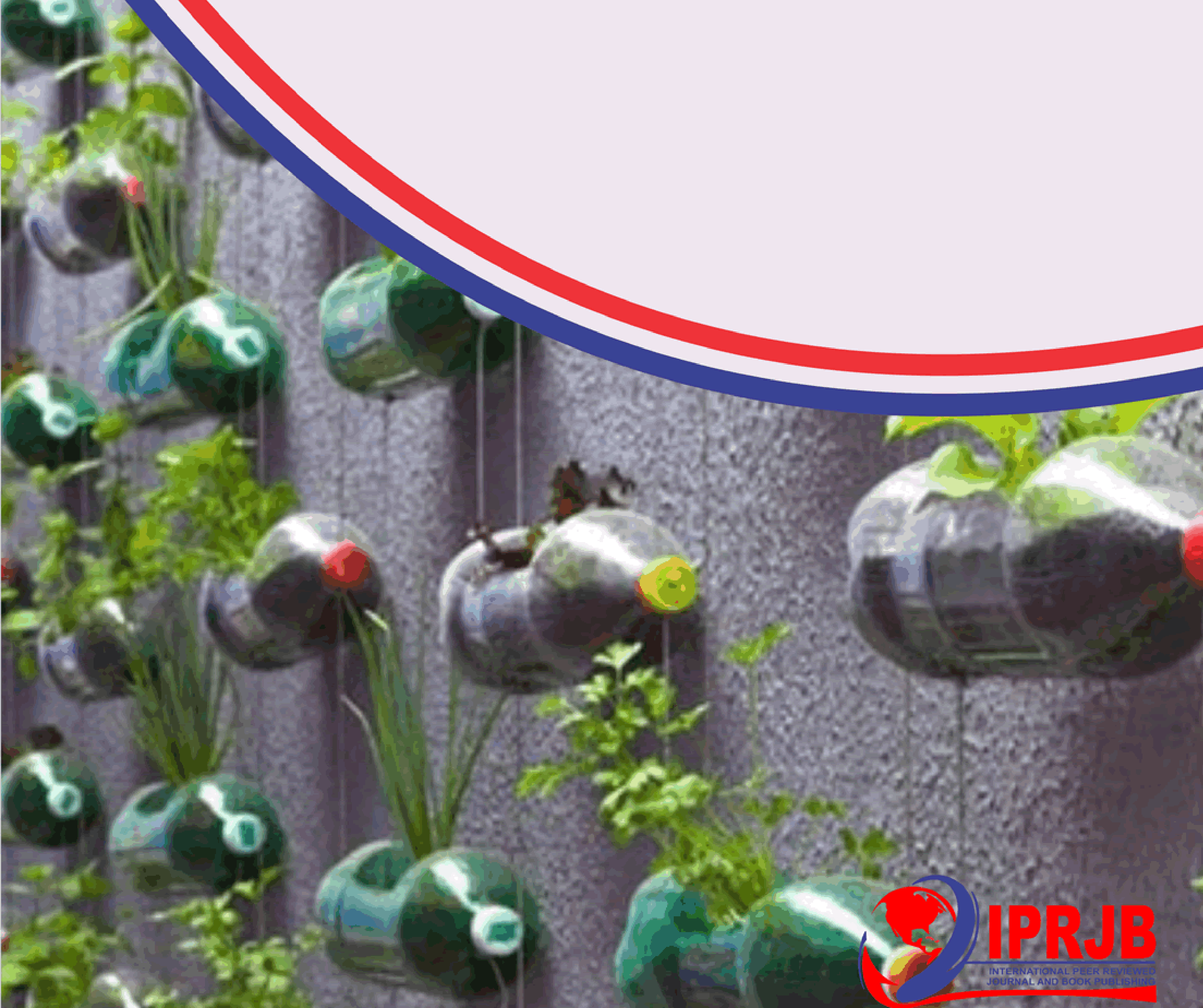

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Abstract

Purpose: To aim of the study was to analyze the effects of agricultural practices on water quality in river basins in United States.

Methodology: This study adopted a desk methodology. A desk study research design is commonly known as secondary data collection. This is basically collecting data from existing resources preferably because of its low cost advantage as compared to a field research. Our current study looked into already published studies and reports as the data was easily accessed through online journals and libraries.

Findings: Agricultural practices in the U.S., particularly fertilizer and pesticide use, significantly degrade water quality in river basins. Excessive nutrient runoff causes eutrophication, harmful algal blooms, and oxygen depletion, while pesticide use contaminates both surface and groundwater. Soil erosion and irrigation return flows further contribute to water quality issues by increasing sediment and nutrient pollution.

Unique Contribution to Theory, Practice and Policy: The theory of ecological modernization, the tragedy of the commons & the systems theory may be used to anchor future studies on the effects of agricultural practices on water quality in river basins in United States. Farmers should be encouraged to adopt best management practices (BMPs), such as reduced pesticide use, organic farming, and crop rotation, which have been shown to reduce agricultural runoff and improve water quality. Policies should be enacted or strengthened to regulate the use of fertilizers and pesticides, particularly in regions where intensive agriculture is prevalent.

Keywords: *Agricultural Practices, Water Quality*

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INTRODUCTION

Water quality in developed economies in developed economies like the United States, Japan, and the United Kingdom, water quality is a significant concern, particularly regarding nitrate levels, pH balance, and turbidity. In the U.S., agricultural runoff contributes to elevated nitrate concentrations in groundwater, especially in regions like California's Central Valley, where nitrate levels exceed the safe drinking water standard of 10 mg/L (U.S. EPA, 2022). This contamination is primarily due to the extensive use of fertilizers and manure in farming practices. Similarly, in the UK, rivers are heavily polluted with chemicals, including high levels of nitrates and phosphates from agricultural runoff and sewage effluent. A study by Earthwatch revealed that 61% of UK freshwater bodies are in poor condition due to these pollutants, with the worst affected areas being the Anglian and Thames river basins (Earthwatch, 2024). These elevated nitrate levels can lead to eutrophication, disrupting aquatic ecosystems and posing risks to human health. In Japan, water quality monitoring has shown that inorganic nitrogen levels, including nitrates, remain high in certain coastal areas. For instance, a study by Funaki (2025) reported that from 1980 to 2020, concentrations of dissolved inorganic nitrogen (DIN-N) were intermittently high in the Uranouchi Inlet, indicating ongoing nutrient pollution. Such conditions can lead to algal blooms, reducing oxygen levels in water and harming marine life. These examples underscore the global challenge of managing agricultural runoff and its impact on water quality, necessitating stringent regulations and sustainable farming practices to protect aquatic ecosystems.

In developing economies, water quality issues are often exacerbated by limited infrastructure and resources for monitoring and treatment. For example, in parts of Sub-Saharan Africa, agricultural runoff contributes to elevated nitrate levels in water sources, posing health risks to communities relying on these water bodies for drinking and irrigation. A study by Lynch (2023) highlighted that in regions with intensive farming, nitrate concentrations often exceed safe limits, leading to health issues such as methemoglobinemia, especially in infants. Additionally, the lack of proper sanitation and wastewater treatment facilities further deteriorates water quality, leading to the contamination of freshwater sources with pathogens and chemicals. Efforts to improve water quality in these regions include implementing sustainable agricultural practices, such as integrated nutrient management and the establishment of buffer zones along water bodies. However, challenges remain due to inadequate enforcement of regulations and limited public awareness. Addressing these issues requires a multifaceted approach, including capacity building, community engagement, and investment in water quality monitoring and treatment infrastructure to ensure safe and clean water for all.

Agricultural practices, such as the use of pesticides, irrigation techniques, and crop rotation, directly influence water quality in river basins. The use of pesticides in agriculture can lead to the contamination of water sources through runoff, which introduces harmful chemicals into rivers and streams. This runoff can elevate nitrate levels, particularly from nitrogen-based fertilizers, causing nutrient overload in water bodies and contributing to eutrophication (Juncal, 2023). Irrigation techniques, especially flood irrigation, exacerbate water quality issues by increasing water flow and carrying excess nutrients, pesticides, and sediments into nearby rivers, affecting pH balance and leading to reduced oxygen availability in aquatic environments (Kang, 2024). Crop rotation, on the other hand, is an agricultural practice that can help reduce soil erosion and nutrient depletion, leading to improved water quality by minimizing nutrient runoff and stabilizing pH levels in surrounding water bodies (Ramiãoz, 2022).

The link between agricultural practices and water quality is further evident when examining the impact of these practices on water turbidity and nitrate levels. Excessive use of pesticides and improper irrigation techniques increase water turbidity by introducing sediments and chemicals into river systems, which degrade the clarity of the water and disrupt aquatic life (Xu, 2022). High levels of nitrogen and phosphorus, often from over-fertilization, significantly contribute to nutrient pollution, causing high nitrate concentrations in water, which affect the health of both aquatic organisms and humans. Sustainable practices, like controlled irrigation and crop rotation, offer potential solutions by reducing runoff and minimizing the introduction of harmful substances into water systems, thus maintaining water quality (Pakoksung, 2025). These practices play a crucial role in mitigating water pollution, supporting ecological balance, and ensuring the availability of clean water for future generations.

Problem Statement

Agricultural practices have been identified as significant contributors to the degradation of water quality in river basins worldwide. Intensive farming activities, including the excessive use of fertilizers, pesticides, and improper irrigation techniques, lead to nutrient runoff and chemical leaching into nearby water bodies. This influx of pollutants results in eutrophication, characterized by algal blooms that deplete dissolved oxygen levels, harming aquatic life and disrupting ecosystem services. For instance, studies have shown that agricultural runoff is a primary source of nitrogen and phosphorus in rivers, leading to hypoxic conditions detrimental to fish populations (U.S. Environmental Protection Agency, 2021). Moreover, the seasonal dynamics of water quality are closely linked to agricultural activities, with nutrient levels peaking during planting and harvest periods, exacerbating pollution levels (Pakoksung, 2025). Despite the implementation of best management practices, such as buffer zones and controlled fertilizer application, the persistence of agricultural runoff continues to challenge efforts aimed at improving water quality. Therefore, understanding the complex interactions between agricultural practices and water quality is crucial for developing effective strategies to mitigate pollution and protect aquatic ecosystems (Juncal, 2023).

Theoretical Review

The Theory of Ecological Modernization

Ecological modernization theory, developed by Arthur P. J. Mol and David A. Sonnenfeld (2000), posits that economic growth and environmental sustainability can coexist through the adoption of green technologies and sustainable practices. The theory emphasizes that technological advancements, regulatory frameworks, and societal commitment to environmental protection can facilitate a sustainable future. In the context of agricultural practices, this theory is relevant because it supports the idea that modern farming techniques, such as precision farming and sustainable irrigation, can reduce environmental impacts, including water pollution. By integrating innovative practices into agricultural systems, the theory suggests that water quality in river basins can be preserved while maintaining agricultural productivity. This aligns with the need to address the negative consequences of agricultural runoff, such as nutrient loading and pesticide contamination, through technological and policy solutions (Mol & Sonnenfeld, 2020).

The Tragedy of the Commons

The tragedy of the commons, introduced by Garrett Hardin in 1968, illustrates how individuals acting in their self-interest can overuse and degrade shared resources, such as water and land, leading to long-term environmental harm. Hardin argued that when resources are freely available, individuals tend to exploit them without regard for the collective good, resulting in resource depletion. This theory is particularly relevant to the effects of agricultural practices on water quality in river basins. Without regulation or collective action, agricultural activities like excessive fertilizer use and pesticide runoff can degrade water quality, leading to eutrophication and harm to aquatic life. The Tragedy of the Commons highlights the importance of managing agricultural practices through policies that promote shared responsibility and regulate resource use, ensuring that water resources are preserved for future generations (Hardin, 2018).

The Systems Theory

The systems theory, developed by Ludwig von Bertalanffy in 1968, proposes that all components of a system are interconnected, and changes to one element affect the entire system. In environmental science, this theory is valuable for understanding how different components, such as agricultural practices, land use, and water bodies, interact with one another. Applying this theory to agricultural practices and water quality in river basins allows for a holistic understanding of how farming activities, including fertilizer application, irrigation practices, and land management, impact water quality. The Systems Theory suggests that addressing water quality issues requires a comprehensive approach that considers the relationships between agricultural inputs, land use changes, and water bodies. By recognizing the interdependence of these factors, the theory advocates for integrated strategies to mitigate agricultural impacts on water quality (Bertalanffy, 2021).

Empirical Review

Rey-Romero (2022) assessed the impact of agricultural activities on surface water quality in a river basin. The purpose of the study was to understand how agricultural practices, such as fertilizer and pesticide use, contribute to water contamination. Using water quality monitoring data from various locations across the basin from 2015 to 2019, the researchers employed a quantitative research methodology. The study measured parameters like nitrate levels, potassium, and the presence of Escherichia coli. Their findings showed that agricultural activities significantly raised the concentrations of nitrates and E. coli in river waters, particularly in areas with intensive farming. This increased pollution was attributed to the high use of chemical fertilizers and poorly managed livestock waste. The study also revealed that the levels of potassium and phosphates exceeded safe thresholds for aquatic ecosystems, leading to eutrophication. The health risks of elevated nitrate levels were discussed, including increased risks for respiratory issues and cancers. Based on the findings, the authors recommend promoting sustainable agricultural practices, such as organic farming, proper waste disposal, and controlled pesticide use. The study also calls for better regulations on fertilizer application to prevent runoff into water bodies. It concludes by urging for more robust enforcement of water quality standards and government incentives for adopting ecofriendly practices. By implementing such changes, the study posits that it is possible to reduce the harmful impacts of agriculture on river water quality. The researchers emphasize the need for long-term studies to monitor the effectiveness of these measures. This study highlights the ongoing challenge of balancing agricultural productivity with environmental sustainability. It contributes to understanding the significant environmental footprint of conventional farming practices. The study provides a clear path toward improving water quality through stricter regulation and sustainable practices. (Rey-Romero, 2022)

Juncal (2023) performed a comprehensive review of nutrient runoff from agricultural practices and its effects on waterway health. The purpose of the review was to examine the extent to which agricultural runoff contributes to water quality degradation. The study analyzed existing literature and compiled data from various case studies globally. The authors found that nutrient runoff, particularly from fertilizers, is a primary driver of water quality problems in river basins. High concentrations of nitrogen and phosphorus from agricultural runoff were identified as key contributors to eutrophication in freshwater bodies. This nutrient overload leads to algal blooms, which degrade water quality and harm aquatic life by depleting oxygen levels. The review further highlighted that nutrient enrichment alters the composition of aquatic ecosystems, favoring species that thrive in polluted environments. The study suggested that nutrient management practices, such as precision farming, can reduce nutrient loss and improve water quality. Moreover, the authors recommended buffer strips and riparian zones to absorb excess nutrients before they enter water bodies. The study emphasized the importance of adopting integrated nutrient management systems that balance the needs of agriculture with environmental protection. The authors also advocated for more public awareness campaigns about the environmental impacts of excessive fertilizer use. Overall, the review concluded that addressing nutrient runoff requires both technological solutions and changes in farming behavior. The authors suggested that policymakers should implement stronger regulations on fertilizer use, with incentives for farmers to adopt sustainable practices. Additionally, they recommended that long-term monitoring of water bodies be carried out to assess the effectiveness of these measures. The review calls for further research into low-cost, sustainable farming techniques that can help mitigate agricultural runoff without compromising yields.

Xu (2022) investigated the effects of fertilizer application on river water quality across 46 cities in China. The purpose of this study was to understand how different levels of fertilizer use in agriculture influence water pollution in river basins. The researchers used panel data spanning several years, combining water quality data from 18 state-controlled monitoring points with agricultural practices data. A hierarchical regression model was applied to analyze the relationship between fertilizer use and water quality. The study revealed that increased fertilizer application led to higher concentrations of nitrogen and phosphorus in river systems. The findings also indicated that excessive fertilizer use crossed a threshold, beyond which the water quality rapidly deteriorated. The study found a clear link between high fertilizer usage and the worsening of water quality, particularly during the wet seasons when runoff was more intense. One of the key recommendations was to reduce fertilizer use to below the threshold levels identified in the study to prevent water quality degradation. Additionally, the study suggested that farmers should adopt alternative methods, such as organic fertilizers and better timing of fertilizer applications. The authors proposed that policy changes, including financial incentives for low-input farming and stricter regulations on fertilizer usage, could help mitigate the impact of fertilizers on water quality.

They also recommended the implementation of watershed management strategies that account for the cumulative effects of fertilizer use. To tackle the root causes of water quality deterioration, the authors suggested promoting training for farmers on sustainable farming practices. The study concluded that inter-basin and inter-regional collaborations are essential for controlling agricultural non-point source pollution. It emphasized that a coordinated approach, involving both governmental and non-governmental organizations, could significantly improve water quality across China's river basins.

Kang (2024) examined the effect of agricultural return flow on river water quality in a small basin in South Korea. The purpose of the study was to evaluate the impact of return flows from irrigation and agricultural drainage systems on the quality of river water. The researchers employed field surveys and water quality monitoring techniques over a one-year period. They collected water samples from various points along the river, both upstream and downstream of agricultural areas. The study found that agricultural return flow significantly affected the river's water quality, but the impact was more pronounced during peak agricultural periods, particularly during the summer months. Nutrient levels, including nitrates and phosphates, were elevated during irrigation cycles, leading to temporary water quality degradation. However, outside of peak farming periods, the agricultural return flow had a negligible effect on the river's overall water quality. The study recommended that the use of advanced irrigation systems, such as drip irrigation, could help reduce the volume of runoff and improve water quality. It also suggested that farmers adopt better management practices to minimize nutrient leaching, such as proper fertilizer application techniques. Furthermore, the authors proposed that local authorities enforce stricter guidelines on water quality monitoring and pollution control, particularly during irrigation seasons. The study concluded by emphasizing the need for a balance between agricultural practices and river basin protection, calling for sustainable practices that prevent long-term ecological damage.

Ramião (2022) investigated the effectiveness of sustainable agricultural practices in reducing nutrient and sediment export from river basins in Portugal. The purpose of this study was to evaluate how the adoption of sustainable farming practices, such as reduced tillage and crop rotations, could improve water quality in agricultural watersheds. The researchers employed both field-based water quality monitoring and computer modeling to simulate the impact of different agricultural practices on water quality over a five-year period. Their findings showed that sustainable practices significantly reduced the export of nutrients and sediments into nearby rivers, with the highest improvements observed when multiple sustainable practices were implemented simultaneously. For example, the combination of crop rotation, no-till farming, and controlled fertilizer application led to a 40% reduction in nutrient runoff. The study also found that using buffer strips along watercourses further mitigated the impact of farming on water quality. The researchers recommended that policies incentivizing the adoption of sustainable farming practices, such as financial support for farmers transitioning to organic farming, could further reduce nutrient runoff. The study also suggested that regular monitoring of water quality is essential to assess the effectiveness of these practices over time. The authors concluded that while sustainable farming practices have a positive impact on water quality, the widespread adoption of these methods requires continuous support from both the government and agricultural extension services.

Pakoksung (2025) analyzed the seasonal dynamics of water quality in relation to land use changes in an agricultural river basin in Thailand. The purpose of the study was to understand how seasonal variations in land use, particularly in agricultural regions, affect river water quality. The study used satellite imagery and water quality sampling over the course of two years to analyze the relationship between land cover and water quality indicators. The results showed that land use changes, especially the conversion of forests to agricultural land, significantly affected water quality, with the impact being more pronounced during the wet season when runoff was highest. During the wet season, nutrient levels, particularly nitrogen and phosphorus, were significantly higher, resulting in poorer water quality. The study found that the loss of forested areas led to reduced natural filtration of runoff, contributing to the degradation of water quality. Based on these findings, the researchers recommended implementing land use zoning to protect riparian buffers and wetlands, which can help maintain water quality. They also suggested that sustainable agricultural practices, such as agroforestry, should be promoted to maintain vegetation cover in vulnerable areas. The study concluded that addressing water quality issues requires a holistic approach that includes both land use management and sustainable farming practices.

Liu (2024) explored the influence of small water bodies on river water quality in agricultural watersheds. The purpose of the study was to investigate how the presence of small ponds and wetlands within agricultural basins affects the quality of river water. The researchers conducted a longitudinal study, collecting water samples from both small water bodies and the river over a two-year period. They found that small ponds, particularly those located close to agricultural fields, played a crucial role in filtering out pollutants before they reached the main river. These small bodies of water trapped sediments and absorbed nutrients from runoff, thus preventing nutrient overload in the river. The study concluded that the restoration and maintenance of small ponds could significantly improve water quality in agricultural watersheds. The researchers recommended that farmers and local authorities collaborate to restore degraded ponds and implement small-scale water retention practices. Furthermore, the study emphasized the need for policies that incentivize pond restoration, as this could be a cost-effective strategy for improving water quality in agricultural regions. The authors also suggested that future research should focus on quantifying the exact contributions of these small water bodies to the overall water quality of river basins.

METHODOLOGY

This study adopted a desk methodology. A desk study research design is commonly known as secondary data collection. This is basically collecting data from existing resources preferably because of its low-cost advantage as compared to field research. Our current study looked into already published studies and reports as the data was easily accessed through online journals and libraries.

FINDINGS

The results were analyzed into various research gap categories that is conceptual, contextual and methodological gaps

Conceptual Research Gaps: Many studies have highlighted the effectiveness of sustainable practices like crop rotation and buffer strips, there is still a lack of research on the long-term effects of these practices on river basin health. Most studies, including Ramião (2022), focus on short-term outcomes, leaving a gap in understanding the durability of these practices over multiple agricultural cycles. Juncal (2023) emphasized the need for integrated nutrient management systems but do not offer concrete models for their implementation. There is a gap in defining and testing the most effective integrated management systems across different agricultural contexts. Although Xu (2022) suggested organic fertilizers as an alternative to conventional fertilizers, there is a gap in research about the cost-effectiveness and practical feasibility of these alternatives in diverse agricultural economies.

Contextual Research Gaps: Most studies, including those by Kang (2024) and Liu (2024), focus on specific geographical regions like South Korea and Thailand. There is a lack of comparative research across different regions with varied agricultural practices, particularly in developing countries. This would help generalize findings to a global context. The studies suggest various policies, like financial support for sustainable practices (Ramião, 2022), but do not explore how these policies might vary in effectiveness across different agricultural systems, particularly between developed and developing regions. Pakoksung (2025) highlight the importance of seasonal land use changes, but there is a gap in understanding how seasonality interacts with other agricultural factors, such as pesticide use or irrigation, to affect water quality.

Geographical Research Gaps: Underrepresentation of African agricultural systems: The studies reviewed primarily focus on regions like Asia and Europe. There is a significant gap in research addressing agricultural runoff and water quality issues in Sub-Saharan Africa. Given the region's diverse agricultural practices, further studies could offer valuable insights into the applicability of solutions tested elsewhere. While Kang (2024) studied return flow in a small basin, there is little research focusing on irrigation practices in arid regions where water conservation is critical. Understanding how irrigation systems like drip irrigation affect water quality in these areas would help optimize water management strategies.

CONCLUSION AND RECOMMENDATIONS

Conclusions

The effects of agricultural practices on water quality in river basins are profound and multifaceted. Agricultural activities, such as the use of chemical fertilizers, pesticides, and improper land management practices, significantly contribute to the contamination of water sources in surrounding river basins. These practices lead to nutrient runoff, which can cause eutrophication, disrupting aquatic ecosystems and reducing biodiversity. Moreover, the excess use of chemicals can introduce harmful substances into the water, posing risks to both aquatic life and human health. The agricultural runoff, containing nitrates and phosphates, can degrade water quality, making it unsuitable for consumption and reducing its overall ecological value.

While agriculture remains a critical aspect of economic development, it is essential to adopt sustainable farming practices to mitigate these negative effects. These practices include reducing chemical inputs, improving irrigation techniques, implementing soil conservation methods, and using buffer zones to filter runoff. Policymakers, environmentalists, and agricultural stakeholders must collaborate to develop and enforce regulations that promote sustainable agricultural practices, ensuring the protection of water resources and the long-term health of river basins. Through these efforts, it is possible to strike a balance between agricultural productivity and water quality conservation.

Recommendations

Theory

Future research should focus on developing integrated models that combine agricultural practices with hydrological and water quality models to understand the complex interactions between land use, agricultural runoff, and water quality. This approach will offer new insights into how different agricultural techniques impact nutrient loading and sediment runoff in river basins, contributing to the ecological health of freshwater systems. The current agricultural sustainability theories should evolve to better incorporate the water quality aspect, expanding on how crop management, irrigation techniques, and soil conservation can directly affect water quality in nearby river basins. Incorporating these factors will enhance our understanding of sustainable agricultural systems from an interdisciplinary perspective, addressing both food security and environmental sustainability.

Practice

Farmers should be encouraged to adopt best management practices (BMPs), such as reduced pesticide use, organic farming, and crop rotation, which have been shown to reduce agricultural runoff and improve water quality. Educational programs should be implemented to inform farmers about the long-term benefits of conservation tillage, buffer strips, and cover crops that prevent soil erosion and minimize nutrient loss into water systems. The use of efficient irrigation systems, such as drip irrigation and precision irrigation technologies, can significantly reduce the overuse of water and minimize nutrient leaching into river basins. This would mitigate the effects of excessive nitrate and phosphorus runoff, which contribute to eutrophication and hypoxia in aquatic ecosystems. Local agricultural policies should support the implementation of integrated water and land management strategies that connect agricultural practices with river basin protection efforts. This can include designing watershed-based agricultural practices that balance agricultural productivity with the health of river systems.

Policy

Policies should be enacted or strengthened to regulate the use of fertilizers and pesticides, particularly in regions where intensive agriculture is prevalent. Regulations should require buffer zones around water bodies to reduce nutrient runoff, ensuring that agricultural runoff does not exceed safe levels for river ecosystems. Governments can provide financial incentives such as subsidies or tax breaks for farmers who adopt sustainable agricultural practices, including organic farming or reduced pesticide usage. This can help farmers transition to practices that reduce their environmental impact while maintaining productivity. Policymakers should work towards developing cross-sectoral policies that involve both the agriculture and water management sectors. These policies should encourage collaboration between agricultural stakeholders, environmental agencies, and water authorities to develop sustainable agricultural practices that align with water quality goals. Policies such as the EU's Common Agricultural Policy (CAP) can serve as a model for implementing environmentally sustainable practices across agricultural sectors.

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