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Review Paper

A Systematic Literature Review on Analysis of Optimal Location for Crop Farming

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Abstract: The increasing demand for sustainable agricultural practices has heightened the importance of identifying optimal locations for crop farming, particularly in tropical regions. This study presents a systematic literature review (SLR) to analyze the methodologies and thematic issues related to plantation and land-use research. Using the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) framework, 69 articles were selected and analyzed based on geospatial technologies, sustainability concerns, and socio-economic impacts. The findings highlight the significant role of GIS, remote sensing, and Analytical Hierarchy Process (AHP) in evaluating land suitability and addressing biodiversity conservation. Key challenges identified include deforestation, habitat loss, and conflicts over land use, which emphasize the need for integrated conservation strategies and community-inclusive approaches. This review underscores the importance of multi-dimensional approaches in plantation management to ensure both economic viability and environmental sustainability. The insights provided are critical for policymakers and stakeholders in developing strategies for future agricultural expansion.

Keywords: Systematic literature review, GIS, AHP, crop farming, land suitability, sustainability, biodiversity conservation, plantation management, optimal location.

Introduction

The crops farming thrives in tropical regions with abundant rainfall, consistent temperatures and fertile soils typically located within 10 degrees of the equator. These conditions make Southeast Asia, Africa and parts of Latin America particularly suitable for agriculture industry. Indonesia and Malaysia, for example dominate global production contributing over 85% of the world's supply. Africa, the crop's place of origin, and Latin America with its expanding plantation areas also play important roles. While oil palm cultivation offers significant economic benefits including employment and export revenue, its rapid expansion has sparked environmental concerns. Deforestation, biodiversity loss and greenhouse gas emissions are closely linked to the conversion of tropical forests into plantations. However, initiatives such as sustainable certification programs and regenerative agricultural practices are being explored to mitigate these impacts. Striking a balance between the economic importance of oil palm and the need for environmental sustainability remains a key challenge. Understanding the suitability of specific regions for oil palm cultivation can help guide policies and practices toward a more sustainable future for this critical crop.

The determination of agricultural and plantation locations often relies on location theory, semiotic theory and GIS technology as the primary approaches. Within the framework of location theory, Von Thünen's model (1826) serves as a foundational reference for understanding how distance from refinery factory influences the choice of agricultural land locations. Further studies, such as those by Weber et al. (2012), incorporate modern factors like infrastructure and technology to identify strategic locations for plantation development. These theories provide a robust scientific framework for understanding economic and logistical factors in location selection. On the other hand, semiotic theory adds a social and cultural dimension to location planning. Eco et al. (1999) discussed the role of symbols and cultural meanings in land-use decisions, including societal perceptions of agricultural land. Research by Colchester et al. (2007) highlighted land conflicts between plantation developers and indigenous communities, often stemming from cultural values associated with the land. This semiotic perspective is essential to ensure plantation development respects cultural sensitivities and local community rights. Larsen et al. (2012) supported these findings, offering an in-depth analysis of land-use conflicts in Kalimantan caused by oil palm plantation expansion. Using GIS technology, researchers mapped conflict areas between plantations and indigenous lands, emphasizing factors such as customary land rights and communal land management. The findings revealed that discrepancies between plantation needs and traditional land rights often lead to disputes, affecting productivity and the plantation industry's reputation. This study underscores the relevance of GIS not only for land suitability analysis but also for identifying potential social conflicts before plantation development.

Advancements in geospatial information technology, particularly in Analytical Hierarchy Process (AHP) analysis, have significantly influenced palm oil plantation management by enabling digital decision-making processes. A palm oil database created through these technologies allows plantation operators to manage their estates more efficiently and systematically. GPS and GIS facilitate accurate calculations and mapping of palm oil plantations to produce precise digital maps (Annuar, 2000). Meanwhile, Xaviar (2001) emphasized the importance of GPS technology in mapping and determining accurate coordinates. Remote Sensing technology, considered the most useful for large-scale quantitative land-use measurement and mapping (Hudak and Wessman, 1998), has opened new opportunities for determining suitable agricultural land locations. AHP's ability to combine quantitative and qualitative criteria makes it invaluable in location determination. Decisions often involve factors like costs, accessibility, environmental risks, and infrastructure that cannot be directly quantified. With its hierarchical structure, AHP analyzes these factors in detail. Additionally, AHP ensures consistency in decision-making through a consistency index, providing confidence that decisions are rational and logical. Its effectiveness has been demonstrated in various studies. For instance, Kumar et al. (2018) applied AHP to identify optimal factory locations based on criteria like transportation costs, labor availability, and market proximity, resulting in efficient operational outcomes. In urban planning, AHP has been used for landfill site selection. Saaty and Vargas (2001) demonstrated AHP's ability to integrate social, economic, and environmental aspects to identify suitable locations, optimizing waste management and minimizing community impact. In tourism, Yavuz and Ülengin (2019) utilized AHP to identify tourism development sites in Turkey, evaluating criteria such as attractiveness, infrastructure, and accessibility. The selected locations significantly boosted the nation's economic returns.

Methodology

2.1 Review Protocol

The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) was chosen as the methodology for conducting the systematic literature review (SLR). It was selected due to its broad acceptance as a protocol and its widespread use across various disciplines and research studies worldwide. The SLR process began with the formulation of research questions based on the PICo method. PICo stands for ‘P’ for Problem or Population, ‘I’ for Interest, and ‘Co’ for Context. The document search was then carried out based on three systematic stages: 1) Identification, 2) Screening, and 3) Eligibility.

2.2 *Systematic searching strategies*

The procedure for selecting the papers was divided into four stages: 1) database selection, 2) paper extraction, 3) abstract screening, and 4) full-text screening. These phases are visualized in Figure 1. Finally, the data extracted from the papers were analyzed using qualitative data synthesis.

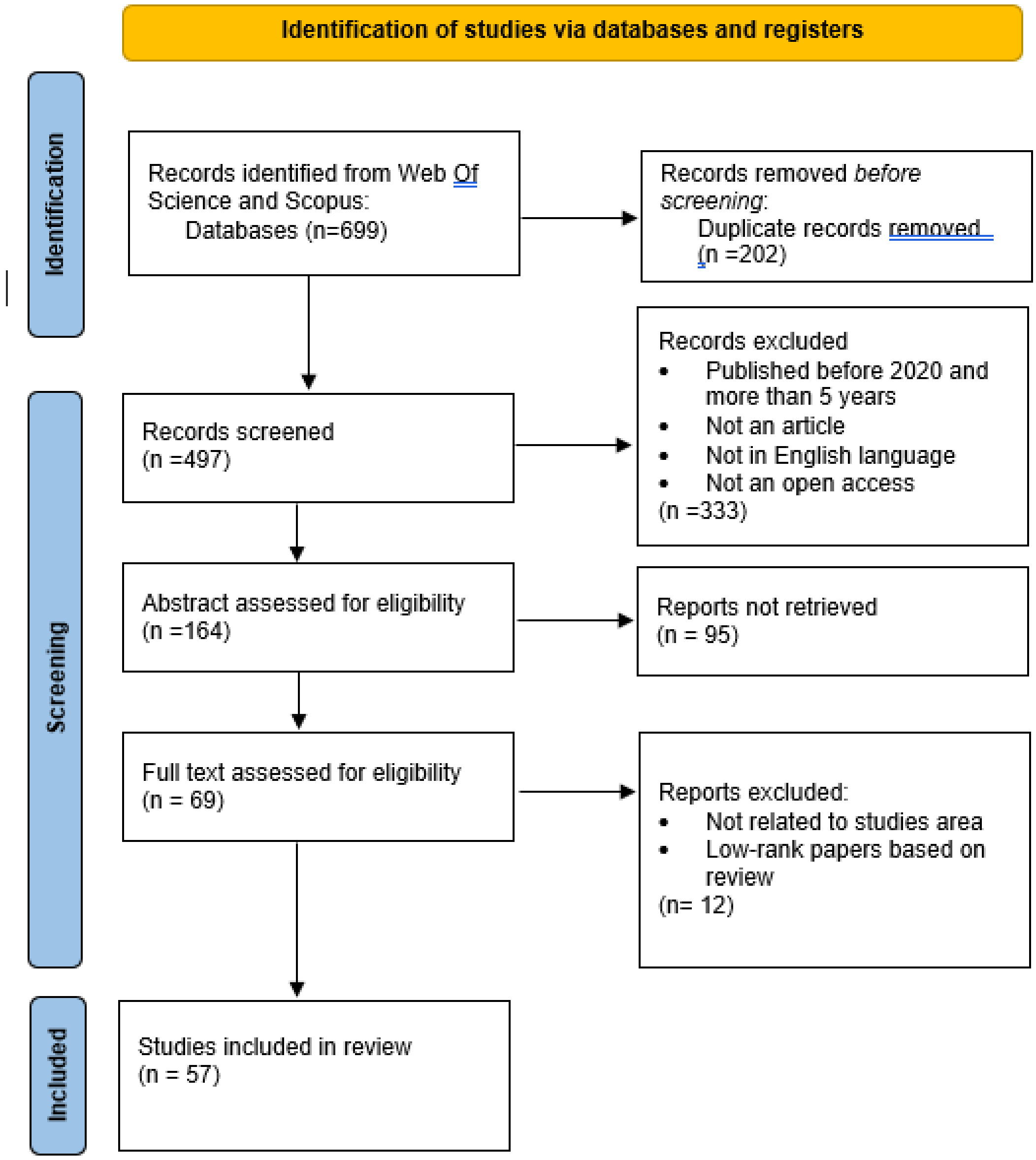


Figure 1: Flow diagram of the process

a) Identification

Identification is the process of locating relevant keywords based on the research questions. Several keywords were used to form search strings for the study. These search strings were applied to the search boxes of the chosen databases. Two databases were selected for the paper search process: 1) Web of Science by Thomson Reuters, and 2) SCOPUS by Elsevier. Table 1 shows the search strings applied during the paper search process.

Table 1. The search strings

Database	Search strings
Web of Science	TS=((Plantation) AND (Location OR Optimal Location) AND (Map OR Mapping OR AHP))
SCOPUS	TITLE-ABS-KEY((Plantation) AND (Location OR Optimal Location) AND (Map OR Mapping OR AHP))

(b) Screening

The screening process involved removing 202 duplicate papers identified across both databases. Following this, the remaining 497 papers were filtered using the following criteria: 1) publication year, 2) document type (only articles were considered for the SLR), 3) papers written in English, and 4) open-access papers only. As a result of this filtering, 333 papers were excluded, leaving 164 papers to be evaluated in the next stage on the eligibility process.

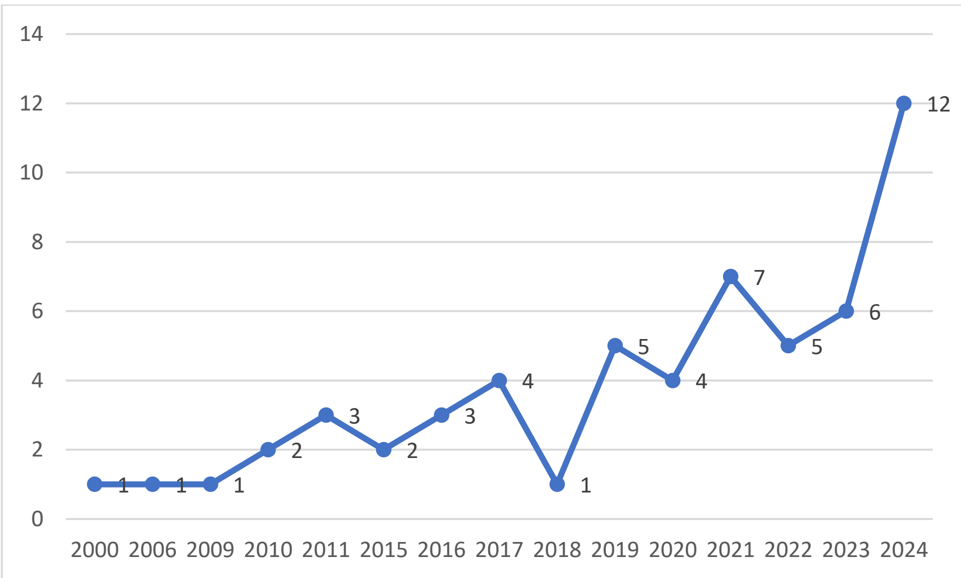
(c) Eligibility

Eligibility involved a manual examination of the papers by the researcher. This process aimed to ensure that all remaining articles met the necessary requirements. It included an abstract assessment to determine whether the papers were appropriate for the review. Following the abstract assessment, 69 papers were selected for the next stage, the full-text assessment, after excluding 95 papers that were unrelated to the study. The selected papers then underwent a full-text assessment, after which only 69 papers proceeded to be ranked through the quality appraisal procedure.

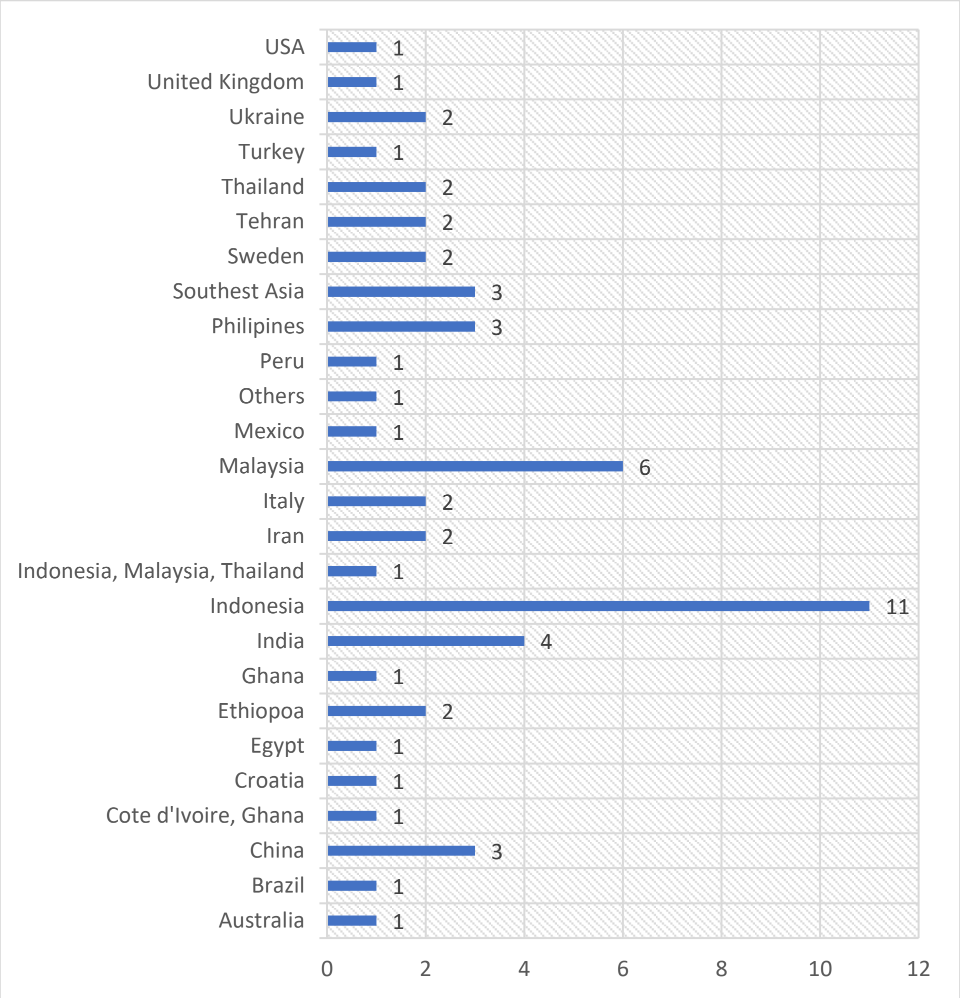
(d) Quality appraisal

The quality of the articles was assessed through quality appraisal procedure. The remaining 69 papers from eligibility procedure were examined by two chosen reviewers. The remaining articles were divided into three quality categories which are high, moderate and low. In this last stage of screening, 12 papers were excluded because of 2 reason which is not related to studies area and also low-rank papers based on review.

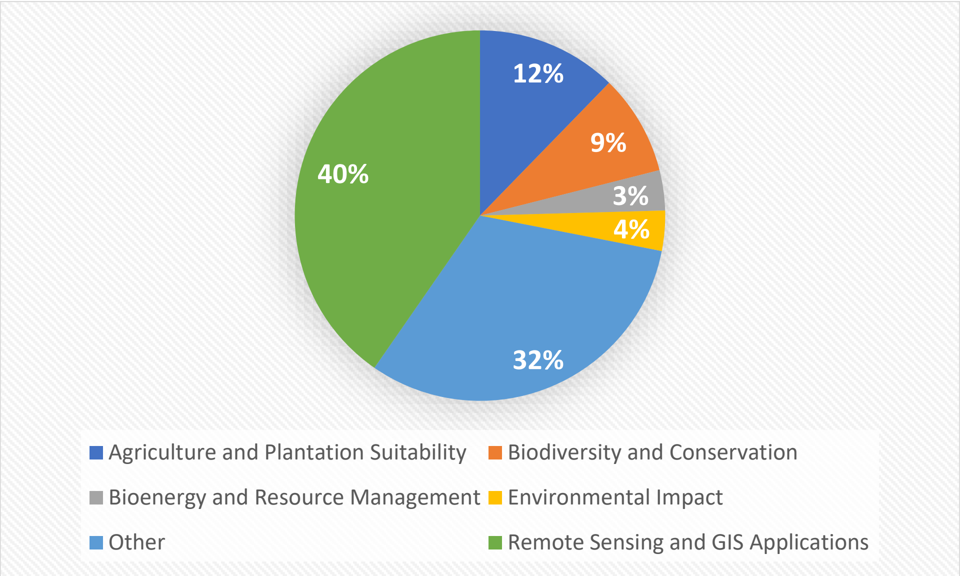
The Findings



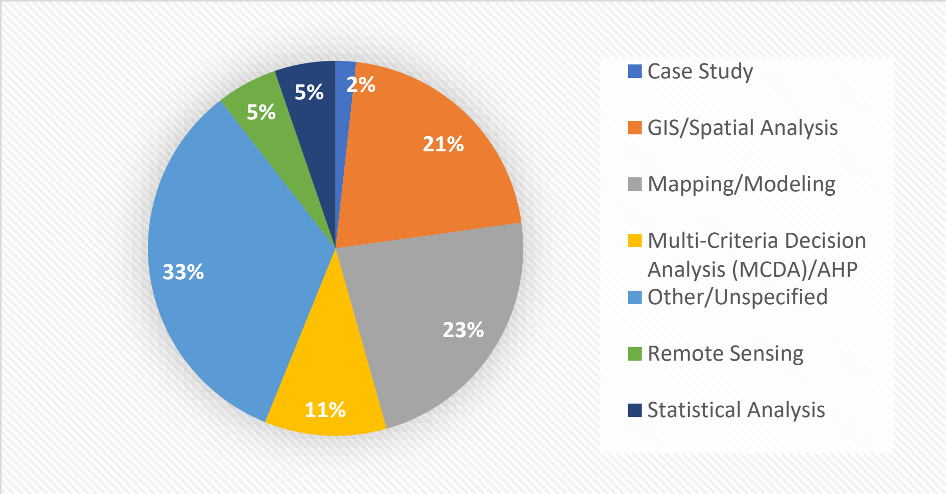
(a) Temporal distribution of the selected articles



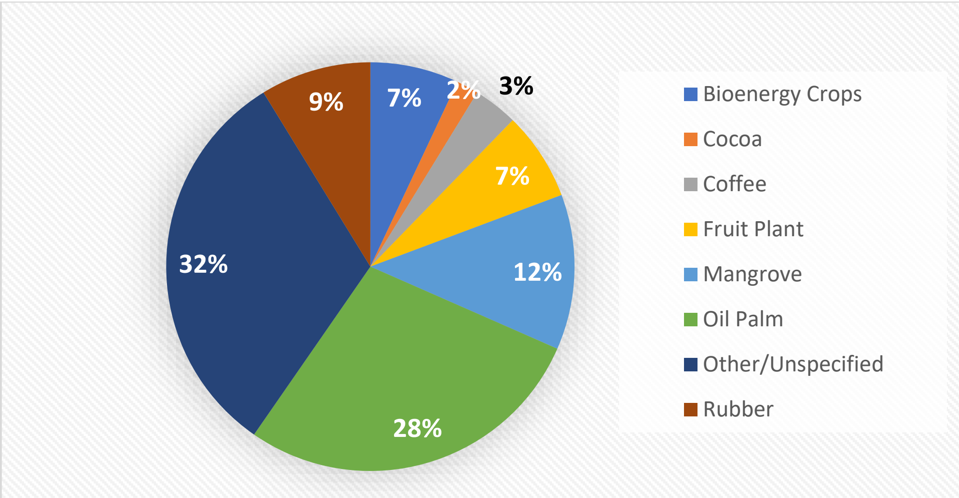
(b) Country distribution of the selected articles



(c) Contextual Issue



(d) Method Used



(e) Type of Plantations

Graph (a) illustrates the temporal distribution of the selected articles from 2000 to 2024, showing a gradual increase in the number of publications over the years, with a significant peak in 2024, where 12 articles were published, indicating growing interest and research focus on the topic in recent years. Chart (b) displays the country distribution of the selected articles related to plantation and land-use research. Indonesia stands out as the most significant contributor with 11 articles, showcasing its prominent role in plantation studies. Malaysia follows with 6 articles, indicating its substantial involvement in this research domain. Countries such as India (4 articles), Southeast Asia collectively (3 articles), Philippines (3 articles) and China (3 articles) also demonstrate notable contributions.

Chart (c) shows the distribution of contextual issues that reveals the majority of studies (40%) focus on Remote Sensing and GIS Applications, reflecting the importance of geospatial technologies in plantation and land-use research. This is followed by Agriculture and Plantation Suitability (32%), which emphasizes the evaluation of suitable land for various crops. Other topics include Biodiversity and Conservation (12%), Environmental Impact (9%), and Bioenergy and Resource Management (3%), demonstrating a diverse range of research themes. A small proportion of studies (4%) fall under the "Other" category, which includes less prominent topics.

Next chart (d) highlights the methodological approaches used in the selected articles. The most frequently used methods are GIS/Spatial Analysis (33%) and Mapping/Modeling (23%), emphasizing the role of spatial and analytical tools in plantation studies. Other methods include Remote Sensing (21%), Multi-Criteria Decision Analysis (MCDA)/Analytic Hierarchy Process (AHP) (11%) and Statistical Analysis (5%), which demonstrate diverse analytical approaches. Only 2% of the studies are categorized as Case Studies, suggesting limited but targeted qualitative research.

The fifth chart (e) categorizes the types of plantations studied. Oil palm plantations dominate the research, accounting for 32% of the articles, reflecting the economic and environmental significance of this crop in tropical regions. Mangroves (28%) and Rubber (12%) are also widely studied, emphasizing their ecological and economic importance. Other plantations include Coffee (9%), Cocoa (7%), and Fruit plants (3%), while 9% of studies fall under the "Other/Unspecified" category, showcasing a variety of less-studied crops.

3.1 Thematic Analysis

3.1.1 Agriculture and Plantation Suitability

One of the dominant themes in plantation research is the evaluation of land suitability for various crops. Studies in this area often utilize geospatial tools and multi-criteria decision-making models to identify optimal locations for agricultural development. For instance, GIS and decision-making frameworks have been employed to evaluate environmental parameters and optimize mangrove plantation suitability (Sahraei et al., 2024). Similarly, Jatropha plantations in Malaysia have been studied using Multi-Criteria Decision Analysis (MCDA) to identify sustainable locations for biofuel crop cultivation (Syahid et al., 2020). These findings highlight the significance of advanced modeling tools in balancing economic development with environmental sustainability. However, challenges remain in integrating real-time data and addressing uncertainties in decision-making processes.

3.1.2 Bioderversity and Conservation

The expansion of plantations poses significant threats to biodiversity, particularly in ecologically sensitive regions. Research within this theme addresses the ecological trade-offs associated with plantation development and highlights conservation strategies. For example, restoration strategies for mangrove forests have been proposed using remote sensing and climate models to identify optimal planting locations (Danylo et al., 2021). Additionally, researchers have emphasized the need for biodiversity corridors to mitigate the impact of oil palm plantations on threatened large mammal species (Kalischek et al., 2023). These studies underscore the delicate balance between economic gains from plantations and the preservation of biodiversity. Future efforts must prioritize strategies that integrate biodiversity considerations into plantation planning.

3.1.3 Environmental Impact

The environmental consequences of plantation expansion, such as deforestation and habitat loss, are critical areas of concern. For instance, cocoa plantations in Côte d'Ivoire and Ghana have been linked to significant deforestation, highlighting the environmental trade-offs of plantation agriculture (Kalischek et al., 2023). Similarly, studies have explored the impact of land conversion on elephant habitats in the Besitang Watershed, demonstrating how land-use changes disrupt wildlife (Xu & Mola-Yudego, 2021). These findings reinforce the need for sustainable land-use practices, such as agroforestry systems, to mitigate negative environmental impacts while maintaining economic productivity.

3.1.4 Remote Sensing and GIS Applications

Remote sensing and GIS technologies have revolutionized plantation research by enabling accurate mapping, monitoring, and management. Spatial analysis has been applied to identify optimal locations for bioenergy crops in tropical regions, providing valuable insights for decision-making (Sahraei et al., 2024). Moreover, the use of satellite data, such as Landsat and PALSAR, has improved the precision of oil palm mapping in Malaysia (Syahid et al., 2020). While these technologies offer immense potential, challenges such as data resolution and the need for ground validation persist. Combining remote sensing with artificial intelligence may further enhance the efficiency and accuracy of plantation management.

3.1.5 Community and Socio-Economic Issues

Plantation development significantly impacts local communities, affecting their livelihoods, land rights, and socio-economic conditions. Research in this theme highlights both conflicts and benefits arising from plantation activities. For example, socio-economic challenges linked to oil palm plantations in Indonesia have been mapped to address community conflicts and improve liaison strategies (Danylo et al., 2021). Additionally, participatory approaches to plantation management, such as social forestry initiatives in the Batanghari KPHP Area, have empowered local communities and enhanced rural livelihoods (Xu & Mola-Yudego, 2021). These findings emphasize the importance of community-inclusive planning to ensure equitable distribution of benefits and reduce land-use conflicts.

3.1.6 Bioenergy and Resource Management

The increasing demand for bioenergy crops has led to a focus on their potential as sustainable alternatives to fossil fuels. Research in this area examines the suitability of marginal lands for bioenergy plantations and their broader implications. For instance, studies have evaluated the potential of marginal lands for sustainable biofuel production, highlighting the environmental benefits of utilizing underutilized lands (Xu & Mola-Yudego, 2021). Similarly, GIS-based spatial tools have been used to optimize the location of bioenergy plants, ensuring efficient resource management (Sahraei et al., 2024). However, ensuring that bioenergy plantations do not compete with food crops or arable land remains a key challenge. Integrating crop diversification and conducting lifecycle analyses could enhance sustainability in this domain.

Discussion

The thematic analysis reveals several critical areas of discussion that contribute to understanding plantation and land-use research. One significant discussion point lies in the use of advanced tools like GIS and Multi-Criteria Decision Analysis (MCDA) to assess land suitability for plantations. For instance, Sahraei et al. (2024) demonstrated how geospatial tools can evaluate environmental parameters for mangrove plantations, while Syahid et al. (2020) highlighted the application of MCDA in identifying suitable locations for Jatropha plantations. These studies underscore the importance of integrating modern technologies to optimize agricultural practices while addressing environmental sustainability challenges.

Another area of discussion focuses on biodiversity conservation amidst plantation expansion. Research has shown that mangrove restoration efforts, guided by remote sensing and climate modeling, play a crucial role in mitigating habitat loss (Danylo et al., 2021). Similarly, Kalischek et al. (2023) emphasized the need for biodiversity corridors to protect threatened mammal species in oil palm-dominated landscapes. These findings raise important questions about how plantation development can be aligned with biodiversity goals, calling for integrated strategies that balance economic and ecological priorities.

Environmental impacts, particularly deforestation and habitat loss also form a central theme in the analysis. Studies have linked cocoa plantations in Côte d'Ivoire and Ghana to significant deforestation highlighting the trade-offs between agricultural expansion and environmental degradation (Kalischek et al., 2023). Xu and Mola-Yudego (2021) further examined how land-use changes disrupt elephant habitats, demonstrating the broader ecological consequences of plantation activities. These findings prompt discussions on sustainable land-use practices, such as agroforestry systems that could mitigate negative environmental impacts while maintaining productivity.

The application of remote sensing and GIS technologies offers another fruitful area of discussion. These tools have been widely used for plantation monitoring and management. For example, spatial analysis has been employed to identify optimal locations for bioenergy crops in tropical regions (Sahraei et al., 2024), and satellite data, such as Landsat and PALSAR, has improved the precision of oil palm mapping in Malaysia (Syahid et al., 2020). While these advancements provide valuable insights, they also raise concerns about data resolution and the need for ground validation. Discussions could explore the potential of combining remote sensing with artificial intelligence to enhance the accuracy and efficiency of plantation management.

The socio-economic implications of plantations also merit in-depth discussion. Research by Danylo et al. (2021) mapped socio-economic conflicts related to oil palm plantations in Indonesia, highlighting the need for better community liaison and conflict resolution strategies. Xu and Mola-Yudego (2021) showcased the benefits of participatory approaches, such as social forestry initiatives, in empowering local communities and enhancing rural livelihoods. These findings encourage discussions on how plantation development can be made more inclusive, ensuring equitable benefits for all stakeholders while minimizing conflicts.

Bioenergy and resource management represent another emerging theme with significant discussion potential. Studies have evaluated the potential of marginal lands for sustainable biofuel production, highlighting the environmental benefits of utilizing underutilized lands (Xu & Mola-Yudego, 2021). However, concerns remain about the competition between bioenergy plantations and food crops. Discussions could focus on strategies to balance these competing demands, such as crop diversification and lifecycle analyses, to ensure sustainable bioenergy development.

Finally, the insights from localized case studies highlight the importance of tailoring plantation strategies to specific regions. For example, satellite data has been used to monitor citrus plantations in selected areas (Syahid et al., 2020), while studies in Assam have explored the potential for expanding rubber plantations (Xu & Mola-Yudego, 2021). These case studies provide valuable lessons that can inform practices in similar ecological and socio-economic contexts.

4.1 Recommendations

To address the challenges identified in plantation and land-use research, several recommendations can be made. First, adopting advanced technologies such as GIS and Multi-Criteria Decision Analysis (MCDA) is crucial for land suitability assessments. These tools provide accurate evaluations of environmental and socio-economic factors, enabling better decision-making for plantation expansion. For instance, Sahraei et al. (2024) demonstrated the effective use of GIS in evaluating mangrove plantation suitability. By integrating such tools into planning processes, policymakers can ensure sustainable land use and resource allocation.

Second, integrated conservation strategies should be prioritized to mitigate biodiversity loss caused by plantation expansion. Research by Kalischek et al. (2023) highlighted the importance of biodiversity corridors in protecting threatened species in oil palm landscapes. Similarly, Danylo et al. (2021) emphasized the role of mangrove restoration in improving coastal resilience and carbon sequestration. Governments and stakeholders must implement policies that align agricultural productivity with ecological goals, ensuring a balance between economic development and biodiversity preservation.

Sustainable land-use practices, such as agroforestry systems, are another vital recommendation. Agroforestry has been shown to maintain productivity while preserving ecological integrity (Kalischek et al., 2023). Policymakers should encourage these practices through subsidies, training programs, and market incentives for sustainably produced goods. Additionally, monitoring tools like those described by Xu and Mola-Yudego (2021) can guide the assessment of land-use changes and inform future planning efforts. These measures would help mitigate the negative environmental impacts of plantation expansion.

Leveraging remote sensing technologies combined with artificial intelligence (AI) offers significant potential for enhancing plantation monitoring and management. Syahid et al. (2020) illustrated the value of satellite data, such as Landsat and PALSAR, in mapping oil palm plantations. However, challenges such as data resolution and the need for validation remain. Integrating AI algorithms to process large datasets could improve the precision and scalability of monitoring efforts. Collaboration between research institutions and governments is essential to incorporate these technologies into national land management systems.

Community-inclusive approaches must also be emphasized to address socio-economic issues associated with plantations. Participatory strategies, such as social forestry programs, empower local communities and reduce conflicts over land use. Xu and Mola-Yudego (2021) highlighted the success of such programs in the Batanghari KPHP Area, where community engagement improved rural livelihoods. Governments and NGOs should prioritize equitable benefit-sharing mechanisms and provide platforms for dialogue to address power imbalances and ensure fair compensation for land use.

To meet the growing demand for bioenergy crops, focusing on the sustainability of bioenergy plantations is critical. Xu and Mola-Yudego (2021) identified the potential of utilizing marginal lands for sustainable biofuel production, which avoids competition with food crops. Policymakers should encourage crop diversification and integrate lifecycle analyses into bioenergy policies to ensure long-term sustainability. These measures can help mitigate environmental and food security concerns while supporting renewable energy goals.

Finally, investing in localized research and case studies is essential to tailor plantation strategies to specific regions. For example, Syahid et al. (2020) demonstrated the utility of Landsat data in monitoring citrus plantations, while Xu and Mola-Yudego (2021) explored the potential for rubber plantation expansion in Assam. These case studies provide valuable lessons that can inform practices in similar ecological and socio-economic contexts. Sharing best practices globally could significantly enhance plantation management strategies.

Conclusion

In conclusion, the review of 69 articles demonstrates that sustainable plantation management depends on a multi-dimensional approach. GIS and spatial tools are critical for optimizing land use, biodiversity conservation strategies help protect ecosystems, and participatory planning ensures social equity. Addressing environmental impacts and drawing insights from localized case studies will further enhance the sustainability of plantations. By leveraging these thematic areas, policymakers and stakeholders can create a balanced approach to plantation development that benefits both people and the planet.

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