International Journal of Engineering and Advanced Technology (IJEAT)
ISSN: 2249-8958 (Online), Volume-13 Issue-1, October 2023

Model of WebGIS Based Sustainable Smart Land Use for Merauke Regency South Papua

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***Abstract:** This Smart and sustainable land use is the key to answering development challenges in the modern era. In the context of Merauke Regency, South Papua, rapid economic growth and significant environmental changes demand an integrated approach to managing land use. This research presents an innovative WebGIS-based model that combines geospatial information technology with land use analysis to provide sustainable solutions. Through the integration of spatial data, predictive analysis and stakeholder participation, this model enables stakeholders to explore alternative land use scenarios and evaluate their environmental, economic and societal impacts. The performance evaluation stage of the model shows its ability to accurately represent existing land use patterns. Validation with actual land use data confirms the ability of the model to reproduce the distribution of agricultural areas and protected forest areas. Furthermore, the evaluation of the environmental impact of the model results indicates that the model is capable of predicting the environmental impact of alternative land use scenarios. Consultation sessions with stakeholders proved the importance of their participation in the validation and adaptation of sustainable solutions. The results of this study indicate that WebGIS-based Smart Land Use model has great potential in assisting sustainable planning and decision-making in Merauke Regency. However, further validation and improvement of the model is needed to strengthen its accuracy and validity. This research provides valuable insights on the integration of geospatial information technology in sustainable development and provides guidance for the development of similar models in other regions.*

***Keywords**: Smart Land Use; WebGIS; Sustainable Land Use; Spatial Data Integration; Sustainable Development.*

I. INTRODUCTION

The concept of regional development is not only closely related to the selection of sectors and regions [1], but also related to land use governance. Efficient and sustainable land use has become a major concern in regional and urban development worldwide. Merauke District, located in Papua Province, Indonesia, is a crucial example where the complexity of land use change presents a serious challenge. The impact of climate change, rapid population growth, and increased agricultural and industrial activities have created dynamic and complex patterns of land change. To overcome this challenge, the use of Web-Based Geographic Information System (WebGIS) technology in the Smart Land Use concept promises to be an innovative solution.

The development of a WebGIS-based Smart Land Use model has great potential to integrate spatial data with non-spatial information in making land use decisions. Research conducted by [2] highlights the importance of WebGIS technology in facilitating cross-sector analysis for sustainable regional management. In addition, research conducted by [3] emphasizes the benefits of integrating spatial and non-spatial data in supporting adaptive land use planning. The challenge of sustainable land use in Merauke Regency is increasingly urgent to be solved. Recent research conducted by [4] shows deep understanding of land use dynamics, including socio-economic and environmental factors, which is necessary to achieve effective and sustainable land management. Through WebGIS-Based Smart Land Use approach, the authors can integrate these factors in land use analysis and planning.

The application of the Smart Land Use concept also opens the door for innovation in land management. Research which was conducted by Lee et al. describes how a WebGIS-based model can be adapted to integrate sensor data and internet of things (IoT) technology in land use monitoring and planning [5]. In this context, the research that the researchers conducted provides a new contribution by designing a WebGIS-Based Smart Land Use Model which is adapted to the unique challenges and potentials of Merauke Regency, Papua.

II. LITERATURE REVIEW

The study of sustainable land use and the application of WebGIS technology and the Smart Land Use concept has received wide attention in recent years. Research conducted [6] discusses the successful implementation of WebGIS model in making sustainable land use decisions in urban areas. This study shows an increase in planning efficiency resulted from the integration of spatial and non-spatial data. This efficiency is also inseparable from the WebGIS framework which focuses on spatial analysis for land use decision making. This research highlights the importance of better visualization in addressing complex land management challenges [7]. The application of WebGIS in the research conducted [8, 21] is able to describe changes in land use patterns in a dynamic and sustainable environment. The studies conducted also provide insight into the importance of adaptation in regional planning and management.

Manuscript received on 13 September 2023 | Revised Manuscript received on 20 September 2023 | Manuscript Accepted on 15 October 2023 | Manuscript published on 30 October 2023.
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In addition, WebGIS describes innovation in land management through the integration of Internet of Things (IoT) technology in the WebGIS model. This research shows how real-time monitoring can increase the effectiveness of decision making [9]. The application of WebGIS is also able to examine the relationship between land use and environmental impacts in urban areas as a holistic approach in sustainable planning, analyzing land use conflicts in rural areas. The results of this study provide a guide to addressing related social and economic problems [10].

WebGIS can also be used as a predictive model to anticipate changes in land use patterns in the future. This research contributes to more efficient long-term planning [11], quantitative analysis of the impact of climate change on land use in coastal areas in order to integrate environmental resilience in decision making [12][13], supporting more efficient and friendly agriculture environment [14], analyzing human migration patterns and their impact on land use [15], investigating the sustainability of land use in rural areas and their impact on the welfare of local communities [16], analyzing the influence of public policies on land use patterns and sustainable planning [17], investigates the effects of urbanization on land use and increases urban resilience [18], analyzes challenges in land management especially in the economic and social context [19], and is able to integrate data from various sources [20].

This review of previous research provides a comprehensive overview of the latest developments in sustainable land use, WebGIS technology, and the Smart Land Use concept. These journal articles provide views on various important aspects that are relevant to the research the researchers conducted on the WebGIS-Based Smart Land Use Model, especially in Merauke Regency, South Papua Province.

III. RESEARCH METHOD

A. Data Collection

Data collection started by collecting secondary data which is related to Merauke Regency, South Papua, including land use data, socio-economic data, environmental data, and infrastructure data. This data will be obtained from official sources such as Central Bureau of Statistics (BPS), the local government of Merauke Regency, and related institutions. Spatial data, such as administrative maps, land use maps, and other spatial data, will be obtained from government agencies or related organizations. Remote sensing technology and satellite imagery can also be used to obtain more detailed spatial data.

B. The Development of WebGIS Based Smart Land Use Model

The development of the Smart Land Use model will involve designing the structure of the model which includes elements such as interactive maps, information layers, spatial analysis tools, and user interfaces. This model will leverage WebGIS technology to integrate data and provide a decision-making platform. The data that has been collected will be integrated into the WebGIS model. Data integration involves mapping attributes from multiple sources into relevant information layers, such as land use, socio-economic, environment, and infrastructure.

C. Analisis of Sustainable Land Use

A spatial analysis will be carried out to identify existing patterns of land use and potential conflicts between land uses. This will involve analyzing data layer overlays, statistical calculations, and spatial modeling. In addition, the environmental impacts of existing land use patterns are evaluated using environmental analysis methods. This involves assessing changes in vegetation, potential damage to ecosystems, and other impacts on the environment.

D. Development of Smart Land Use Scenario

Alternatives to sustainable land use will be identified based on the analysis which has been carried out. These alternatives would include land use realignment scenarios that have the potential to reduce conflict and environmental impacts. Simulation and Evaluation by using Smart Land Use model is used to simulate and evaluate the impact of its use. A sensitivity analysis will be carried out to measure the effectiveness of each scenario in achieving sustainable land use goals.

E. Implementation of WebGIS and Decision Making

The Smart Land Use model is implemented in an interactive and easy-to-use WebGIS platform. The user interface is designed to be accessible to the relevant stakeholders. Stakeholders, including local government, local communities and related sectors, will be involved in the decision-making session. Stakeholders will be able to use WebGIS platform to explore alternative scenarios and see their impact.

F. Evaluation and Validation

This research was conducted with two approaches. The first is the evaluation of the performance of the developed model, the second is the validation of the results. The performance of Smart Land Use model will be evaluated based on a comparison between the simulation results and the actual data. Evaluation metrics will include accuracy, precision, and relevance of results. While the second, the results of the model and analysis will be validated by involving stakeholders to ensure that the solutions produced are in accordance with the local context and sustainable goals.

IV. RESULT AND DISCUSSION

A. Land Use Analisis Result

During conducted research of the land use analysis in Merauke Regency, Papua, the researchers were able to identify the dominant land use patterns in the area. Based on the secondary and spatial data analyzed, researchers can observe several important findings related to land use and they are such as:

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- Dominant Agricultural Pattern: Most of the area in Merauke Regency is dedicated to agriculture. Rice, oil palm and other food crops are the dominant land use. This pattern reflects the importance of the agricultural sector in the local economy and also reflects a focus on food production and sources of income.
- Protected and Preserved Forest Areas: Apart from agriculture, some areas are also designated as protected and nature conservation forest areas. This reflects efforts to conserve the environment and preserve biodiversity in Merauke Regency. However, there is a potential conflict between agricultural needs and conservation needs to be considered in further deep consideration.
- Housing and Infrastructure: Residential areas and infrastructure such as roads, bridges and other public facilities are scattered throughout the district. Residential density and urban growth patterns can also be observed, indicating population growth and urbanization.
- Variability in Land Use: Spatial analysis reveals variations in land use patterns in different parts of Merauke District. There are some areas that are more intensive in agricultural use, while other areas are more likely to be maintained for conservation or preservation purposes.

B. Evaluation of Environmental Impact

Headings, In an effort to understand the implications of existing land use patterns, researchers conducted a more in-depth environmental impact evaluation. This evaluation process involves further analysis of the environmental changes that may occur as a result of the current land use. Some of the important findings from the environmental impact evaluation are as follows:

- Decreased Vegetation and Natural Habitat: The environmental impact evaluation revealed a decrease in vegetation and a reduction in natural habitat in some areas used for intensive agriculture. This decline can have a negative impact on biodiversity and ecosystem function.
- Ecosystem and Soil Damage: Intensive land use in agriculture can lcause ecosystem damage and soil degradation. Soil erosion and soil degradation are possible impacts, especially in areas with unsustainable agricultural practices.
- Impact on Water Sources: Inappropriate land use patterns may have an impact on water sources in Merauke District. Intensive farming and the use of pesticides can potentially affect water quality, while deforestation and changes in vegetation can affect the water cycle and drainage.
- Local Climate Change: The evaluation also highlighted the potential for local climate change as a result of changes in land use. Reduction of vegetation can affect temperature, rain patterns and microclimates in certain areas.

Even though the current pattern of land use provides certain economic and social benefits, the environmental impact evaluation indicates the need for mitigation measures to reduce the negative impacts that may arise. It is important to consider sustainable land management measures and environmentally friendly agricultural practices to minimize environmental impacts and support the sustainability of local ecosystems. This environmental impact evaluation provides a deeper understanding of the implications of current land use patterns on the environment and ecosystems in Merauke District. This information is an important basis for formulating recommendations and scenarios for more sustainable land use in the context of holistic and integrated development.

C. Development of Smart Land Use Scenarios

At this stage, the researcher develops several alternative sustainable land use scenarios designed to address the previously identified environmental challenges and impacts. These scenarios are based on a combination of different land uses, with a focus on economic, social and environmental sustainability. Table 1 shows some of the resulting scenarios.

Table 1. Scenarios For Developing Smart Land Use

Number	Land Development Scenario	Description
1	Sustainable Agricultural Development	Focus on improving organic farming and sustainable use of fertilizers.
2	Forest Conservation and Diversity	Expanding protected forest areas and conserving natural resources.
3	Sustainable Urbanization	Integrate urban development with green open space protection.
4	Mixed Land Use Patterns	A balanced combination of agriculture, preservation and settlement.

Each scenario is briefly defined and describes the main focus of land use development. The first scenario, "Development of Sustainable Agriculture," focuses on strengthening organic farming and sustainable practices in the use of fertilizers. The second scenario, "Forest Conservation and Diversity," highlights efforts to preserve the environment through expansion of protected forest areas and preservation of natural resources. The third scenario, "Sustainable Urbanization," attempts to integrate urban development with the protection of green open spaces. The fourth scenario, “Mixed Land Use Pattern,” combines elements from the previous scenarios to create a balanced and diverse land use. Each scenario is designed with the specific objective of supporting sustainable land use, and each option considers social, economic and environmental impacts. Selection of the appropriate scenario will depend on the local context, development priorities and existing policies. These scenarios provide a basis for stakeholders in choosing the direction of developing a more sustainable land use in Merauke District.

D. Implementation pf WebGIS Based Smart Land Use Model

Implementation of the Smart Land Use model involves developing an interactive WebGIS platform that allows stakeholders to explore alternative land use scenarios and see their impacts visually. The following statements below are the implementation steps and some examples of visualizations that might be used:

- WebGIS Interface Development.

At this stage, a user-friendly and informative WebGIS interface was designed and developed. This interface will contain an interactive map of Merauke Regency with different layers of information, such as land use, infrastructure, environment, and socio-economic.

- Integrated Data.

Data from land development analysis and scenarios will be integrated into the WebGIS platform. This data will be displayed in the form of a map with symbols, colors and layers that can be selected by the user.

- Land Use Scenario Visualization

Users can select different land use scenarios and see changes in land use patterns visually on the map. For example, areas allocated for organic farming will be shown in a different color than areas designated as protected forest areas.

- Interactive Analysis

Users can perform interactive analysis, such as overlaying layers, statistical calculations and spatial modeling. This allows them to see the potential impact of land use scenarios on the environment, social and economic sustainability.

- Decision-making

Stakeholders can use WebGIS platform to compare different scenarios and make more informed decisions. For example, stakeholders can see how changes in land use will affect agricultural productivity and environmental sustainability.

The implementation of WebGIS-based Smart Land Use model certainly provides easier and faster access for stakeholders to explore different land use scenarios and make better decisions.

E. Evaluation and Validation

- Model Performance Evaluation.

The model performance evaluation stage aims to measure the extent to which the developed model is able to accurately represent existing land use patterns. The results of this evaluation provide insight into how well the model can describe the actual situation in the field. Based on deeper analysis of the existing data, the researchers observed that the model was able to match most of the land use patterns seen in the actual data. However, there are some variations and discrepancies that need to be corrected, especially in areas that have rapid and complex changes in land use. Table 2 shows an overview of the results of the performance evaluation and validation of the mode.

Table 2. Model Performance Evaluation Result

Number	Evaluation and Validation Stages	Result
1	Evaluation of Model Performance	• The model is able to match most of the land use patterns seen in the actual data. • There are some variations and discrepancies in areas of rapid and complex change.

- Validate Model Results with Real Data

Validation was carried out by comparing the model simulation results with actual land use data in Merauke Regency. The validation results show a good fit between the model results and the actual data in most cases. For example, the model succeeded in accurately reproducing the distribution of agricultural areas and protected forest areas. However, some areas with complex land use dynamics show more significant differences between the model and the actual data. This validation helps identify areas where the model can be improved to improve accuracy (see Table 3).

Table 3. Model Performance Evaluation Results with Actual Data

Number	Evaluation and Validation Stages	Result
1	Validate Model Results with Real Data	• The model succeeded in accurately reproducing the distribution of agricultural areas and protected forest areas. • Several areas with complex land use dynamics show significant differences.

- Environmental Impact Evaluation Model Results

Evaluation of the environmental impact of the model results involves a comparison between the predicted environmental impacts generated by the model with the results of the actual environmental impact analysis. The results of this evaluation indicate that the model is able to properly describe the environmental impacts of alternative land use scenarios. For example, changes in protected forest areas simulated in the model are consistent with findings of actual environmental impacts on ecosystem damage and changes in microclimate temperature (see Table 4).

Table 4. Results of Environmental Impact Evaluation Model Results

Number	Evaluation and Validation Stage	Result
1	Environmental Impact Evaluation Model Results	• The model can describe the environmental impact of alternative land use scenarios well. • Changes in protected forest area according to actual recorded environmental impacts.

- Consultation Session with Stakeholders

Stakeholder consultation sessions assist in validating model solutions and recommendations in a participatory manner. Stakeholders, including local government, local communities, and related sectors, participate in discussion sessions that involve presentation of the results of the model and analysis. In these sessions, they provide valuable feedback on the validity and relevance of the solutions generated by the model. This feedback provides a deeper understanding of how the solutions can be adapted and applied in the real context of Merauke District. The general consultation session results are shown in Table 5.

Table 5. Results of Environmental Impact Evaluation Model Results

Number	Evaluation and Validation Stage	Result
1	Consultation Session with Stakeholders	• Stakeholders provide valuable feedback on the validity and relevance of solutions. • This feedback provides insights into adapting and implementing solutions in real contexts.

Through this comprehensive evaluation and validation stage, researchers have ensured that WebGIS-based Smart Land Use model provides accurate results and solutions that suit the needs and sustainable goals of Merauke Regency.

Retrieval Number:100.1/ijeat.A43011013123
DOI: 10.35940/ijeat.A4301.1013123
Journal Website: www.ijeat.org

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and Sciences Publication (BEIESP)

The adjustments and improvements identified from this evaluation and validation also help strengthen the quality of the model and provide a more robust basis for sustainable land use recommendations.

F. Finding and Discussion

The results of this study indicate that the development of a WebGIS-based Smart Land Use Land Use Model can make a significant contribution to sustainable land use planning in Merauke Regency, Papua. Through the WebGIS platform, stakeholders can participate in informed and informed decision-making, which can reduce conflicts and environmental impacts resulting from sub-optimal land use. The discussion of these findings includes the practical implications of the developed model, the challenges encountered, and suggestions for further development. In the context of Merauke District, this model can be a valuable tool in supporting sustainable planning and decision-making related to land use. In detail, Table 6 shows the findings and discussions in this study.

Table 6. Discussion Results and Findings

Number	Theme	Findings and Analysis
1	Sustainability of Land Use	• WebGIS-based Smart Land Use models can support more sustainable planning and decision making. • Development of alternative scenarios can help strike a balance between economic growth and environmental preservation.
2	Environmental Impact and Solutions	• The model successfully predicts the environmental impact of land use change, but further validation is needed. • Land use-based solutions can reduce negative impacts such as soil degradation and ecosystem damage.
3	Stakeholder Engagement	• Consultation sessions with stakeholders help validate recommendations and identify challenges. • Their participation is important in implementing sustainable solutions and supporting collective agreements.
4	Limitations and Future Developments	• This model requires more accurate and comprehensive data to improve its performance in the future. • Further development including integration with climate models and more complex simulations is a prospect.

V. CONCLUSSION

This research produces a WebGIS-based Smart Land Use model that has great potential to support sustainable planning and decision-making in land use in Merauke Regency. By integrating spatial data and land use analysis, this model is able to produce alternative scenarios that help achieve a balance between economic growth, environmental preservation, and social welfare. The evaluation and validation carried out revealed the model's success in predicting environmental impacts and providing guidance on land use-based solutions. Based on the results of this study, several suggestions can be put forward for the development and implementation of the WebGIS-based Smart Land Use model in Merauke Regency:

- Improved Data Accuracy: This model is highly dependent on initial data accuracy. Therefore, efforts are needed to improve the accuracy and quality of the spatial data and attributes used in the analysis. Integration of data from more diverse sources and field validation can improve model performance.
- Further Validation: Even though the model successfully predicts environmental impacts, further validation with data on actual land use and actual environmental impacts is required to strengthen the validity of the model. Field data collection and further comparisons will help validate the simulation results.
- Stakeholder Engagement: Stakeholder engagement in the planning, validation and implementation stages of the model is an important step. Their involvement can provide better insights, increase acceptance of solutions, and help identify challenges in the fields.
- Future Developments: Further development of this model could involve integration with more comprehensive climate or economic models. Developing more complex scenarios and modeling long-term impacts can provide more comprehensive results.
- Policy and Implementation: The recommendations and solutions generated by this model should be supported by an appropriate policy framework. Implementing sustainable solutions requires coordination with relevant agencies and wider stakeholders.

ACKNOWLEDGMENT

In this occasion, the researcher would like to thank to the Ministry of Education, Culture, Research and Technology, Directorate General of Higher Education, Research and Technology of the Republic of Indonesia who has provided Higher Education Superior Basic Research grants in 2023 to researchers so that the researchers can finish writing this scientific article.

DECLARATION STATEMENT

Funding/ Grants/ Financial Support	Yes, Received research funding from the Ministry of Education and Culture, Research and Technology of the Republic of Indonesia
Conflicts of interest	No conflicts of interest to the best of our knowledge.
Ethical Approval and Consent to Participate	No, this article does not require ethical approval and consent to participate with evidence.
Availability of Data and Material/ Data Access Statement	Not relevant.
Authors Contributions	All authors having equal contribution for this article.

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