PROCEEDINGS OF SCIENCE

Integrating AI and GIS for local net-zero transition: The AgriVolt Navigator case

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Integrating spatial resource potential, environmental and socio-economic data into actionable plans remains a key challenge for municipalities and local stakeholders seeking evidence-based pathways to achieving climate and sustainability goals. This also applies to agrivoltaic planning, which requires balancing multiple factors, including land use, environmental protection, and access to infrastructure.

This study has aimed to develop and test a two-stage spatial decision-support framework that combines GIS-based analysis with artificial intelligence (AI) to support more accessible and informed agrivoltaic planning. In the first stage, a web-based GIS platform, the AgriVolt Navigator, has been developed to support spatial analysis through the integration of multiple datasets and a co-benefits calculator for evaluating agrivoltaic potential as well as environmental and socio-economic considerations. In the second stage, the platform has been enhanced with a GIS-connected AI assistant designed to interpret spatial information and translate analytical results into concise, user-oriented planning guidance, helping to bridge the gap between complex datasets and practical decision-making at the local level.

The proposed approach is demonstrated through a case study in Hachinohe City, Japan, where agrivoltaics is being explored as a strategy for decarbonization and regional revitalization. The results demonstrate the feasibility of the framework for integrated spatial analysis and co-benefits assessment, while also indicating the potential of AI–GIS integration to enhance accessibility and user-friendliness in spatial planning, particularly by translating complex information into concise summaries and stakeholder-oriented recommendations. Initial user interactions indicate that the tool can encourage engagement with the topic and that stakeholder-specific recommendations can provide useful starting points for considering planning issues from different perspectives. While the AgriVolt Navigator has been developed for a specific geographic and thematic context, the framework provides a transferable approach for integrating GIS and AI into local sustainability planning and could be adapted to other regions, sectors, and climate-related decision-making challenges.

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1. Introduction

Achieving global climate and sustainability goals involves addressing interconnected challenges across multiple domains, requiring consideration of environmental and socio-economic factors, as well as spatial resource potential and existing assets. This creates a growing demand for planning approaches that integrate diverse datasets and support complex decision-making. These challenges also apply to agrivoltaic planning, which integrates solar photovoltaic (PV) systems with agricultural land use, enabling the co-production of energy and food. Agrivoltaic systems can provide multiple co-benefits for rural communities, including supplemental farmer income, enhanced climate resilience, and environmental improvements, while simultaneously contributing to broader sustainability goals [1,2].

Implementing such systems requires balancing multiple factors, including land-use patterns, infrastructure access, environmental considerations, and socio-economic conditions. In practice, this also involves integrating diverse datasets such as land productivity, solar radiation, and regulatory information, which can be challenging to synthesize into actionable guidance [1-5]. In Japan, agrivoltaics has been promoted through national guidelines and local initiatives to optimize land use on underutilized farmland, but adoption remains uneven due to technical, social, and regulatory complexities [6,7].

Geographic Information Systems (GIS) are widely used to support such planning processes by enabling the integration and visualization of diverse spatial datasets. Approaches such as GIS-based multi-criteria decision analysis (GIS-MCDA) allow for the systematic evaluation of site suitability by combining climatological, environmental, and locational data [8,9]. More broadly, Spatial Decision Support Systems (SDSS) combine spatial data, GIS-based analysis, and decision-support functionality to address complex spatial planning problems [10]. Recent studies have explored the integration of large language models (LLMs) with GIS to facilitate interaction with spatial data and support or automate spatial analysis [11,12]. Other emerging applications have examined generative AI as an interface for spatial decision support, including the use of LLMs to facilitate expert consensus, planning support, and access to territorial information [13]. Despite these developments, opportunities remain for AI to support not only spatial analysis and access to spatial information, but also the interpretation of GIS-derived results and their translation into practical planning guidance for different stakeholder groups.

In response, this study has aimed to develop and test a tool-based framework with two stages, comprising a web-based GIS platform for spatial analysis and co-benefits assessment in the first stage, and a GIS-connected AI assistant in the second stage that supports spatial data interpretation and provides user-oriented planning guidance. The research objectives are (1) provide an integrated digital tool to support evidence-based site selection and evaluation of agrivoltaics opportunities; and (2) enhance the accessibility and practical use of complex spatial information through an AI-assisted interface for planning and decision-making.

The approach is demonstrated through a case study in Hachinohe City Region, Japan, where agrivoltaics is being explored as a strategy for regional decarbonization and local revitalization. This study provides a foundation for developing more accessible and scalable tools to support spatial planning in complex, multi-dimensional sustainability contexts, with broader relevance and potential applicability to other regions and environmental challenges.

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2. Materials and Methods

2.1. Study area

The Hachinohe City Region, located in the southeastern part of Aomori Prefecture, Japan, comprises Hachinohe City and seven surrounding towns: Sannohe, Goto, Tago, Nanbu, Hashikami, Shingo, and Oirase. The region features a mix of plains and mountainous terrain, with urban, agricultural, and forested areas. Population is concentrated mainly in Hachinohe City, while surrounding municipalities are experiencing demographic shifts and areas of underutilized farmland.

In 2021, Hachinohe City announced its Carbon Neutrality Declaration, committing to achieve net-zero greenhouse gas emissions by 2050 in alignment with Japan's national "2050 Carbon Neutral Declaration." The climate is mild, with cool summers influenced by easterly winds (Yamase), dry winters, low snowfall, and long sunshine hours, creating favorable conditions for solar energy generation [14].

Renewable energy infrastructure includes biomass and wind power facilities, with new offshore projects planned [15-17]. Despite these initiatives, electricity consumption remains largely dependent on fossil fuels, highlighting the potential for expanding solar energy deployment [18].

2.2. AI-integrated GIS decision support framework

The framework operates in two stages (Figure 1). In the first stage, a GIS-based platform developed within the ArcGIS environment integrates and visualizes diverse spatial datasets to support systematic analysis of land suitability for agrivoltaics. The GIS incorporates climatological factors (such as solar radiation, sunshine hours, and temperature), locational factors (including proximity to electrical substations, transmission lines, major roads, and protected areas), environmental factors (such as slope, aspect, and land use). The spatial datasets were compiled primarily from data provided by the Ministry of Land, Infrastructure, Transport and Tourism (MLIT), together with supplementary data from other public sources. These datasets are combined to generate an overall suitability layer, indicating the relative suitability of land for agrivoltaic deployment based on the selected criteria. Additionally, the platform is linked to a co-benefits calculator, which estimates potential benefits based on the size of selected areas, including renewable energy generation, CO_2 reduction, potential surplus income for farmers, creation of new jobs, and the value of carbon credits.

While the GIS platform provides powerful analytical capabilities, interpreting these complex datasets can remain challenging for planners and broader user groups. To address this, the second stage introduces a GIS-connected AI assistant, which interacts directly with the GIS interface and communicates with the OpenAI API to support spatial data interpretation [19]. When a user selects a location or spatial feature on the map, the assistant automatically reads the associated layers, filters out non-relevant attributes, incorporates language-aware place-name recognition, and summarizes the map context. Based on this information, it generates human-readable summaries of spatial conditions and stakeholder-oriented planning recommendations, providing actionable guidance efficiently to support decision-making in agrivoltaics planning. Through these features, the system transforms complex spatial datasets into accessible insights, providing a foundation for discussion and stakeholder engagement.

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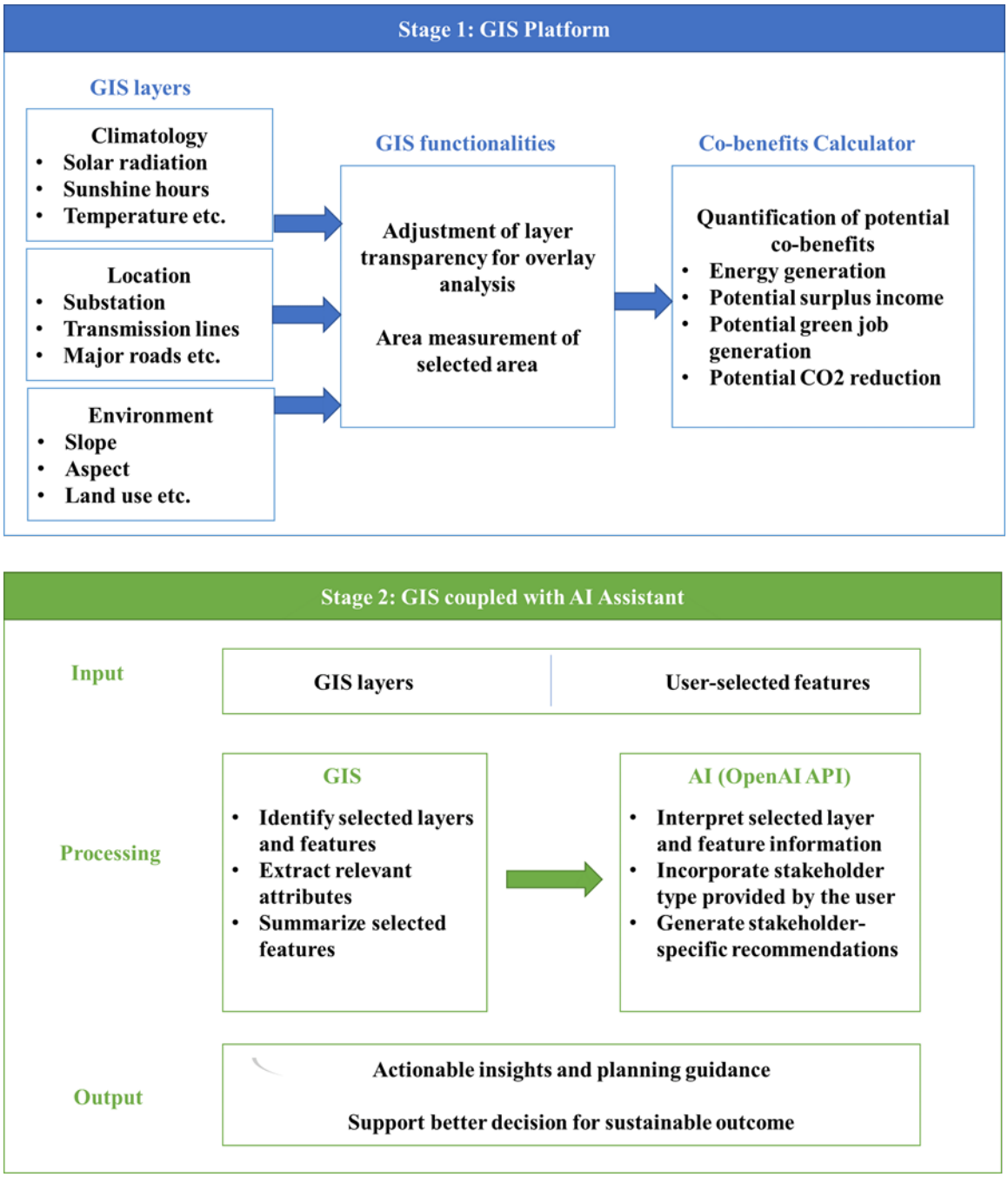

Figure 1: Tool-based framework for GIS-Driven Spatial Analysis coupled with AI-Assisted Decision Making

3. Results

The developed system offers several practical insights for agrivoltaics planning. The GIS-based platform allows users to integrate and visualize multiple spatial datasets, supporting the identification of areas suitable for agrivoltaic deployment (Figure 2). Users can interactively adjust layer transparency, perform overlay analyses, and switch basemaps to explore spatial relationships and patterns more effectively. The integrated co-benefits calculator provides preliminary estimates of environmental and socio-economic impacts, as well as spatial resource

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potential, helping planners evaluate potential outcomes under different deployment scenarios and compare alternative site selections (Figure 3).

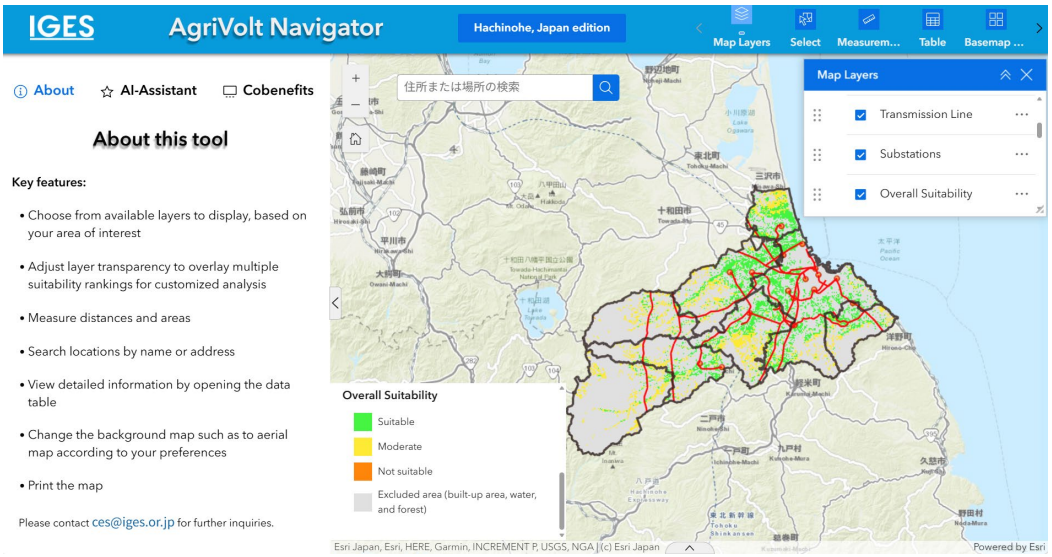

Figure 2: Map layer selection on AgriVolt Navigator.

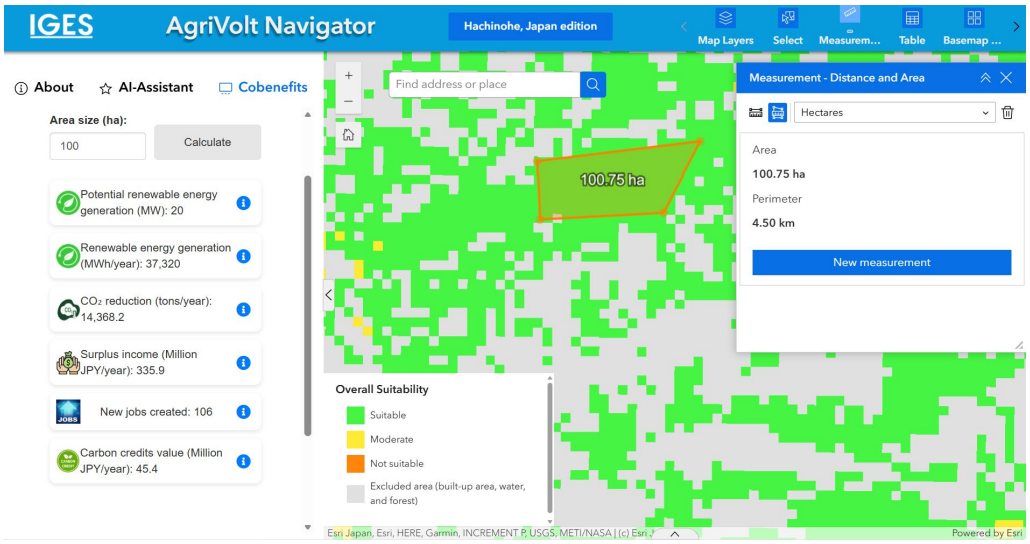

Figure 3: Co-benefits calculator outputs showing potential benefits based on the size of the selected area.

The AI assistant further enhances the usability of the platform by translating complex spatial data into accessible planning insights. Rather than requiring users to manually interpret GIS attributes, the assistant generates human-readable summaries and recommendations tailored to different stakeholders, such as policymakers, investors, farmers, and local planners (Figures 4 and 5). These features have the potential to support more efficient decision-making, facilitate communication among stakeholders, and enable participatory planning processes.

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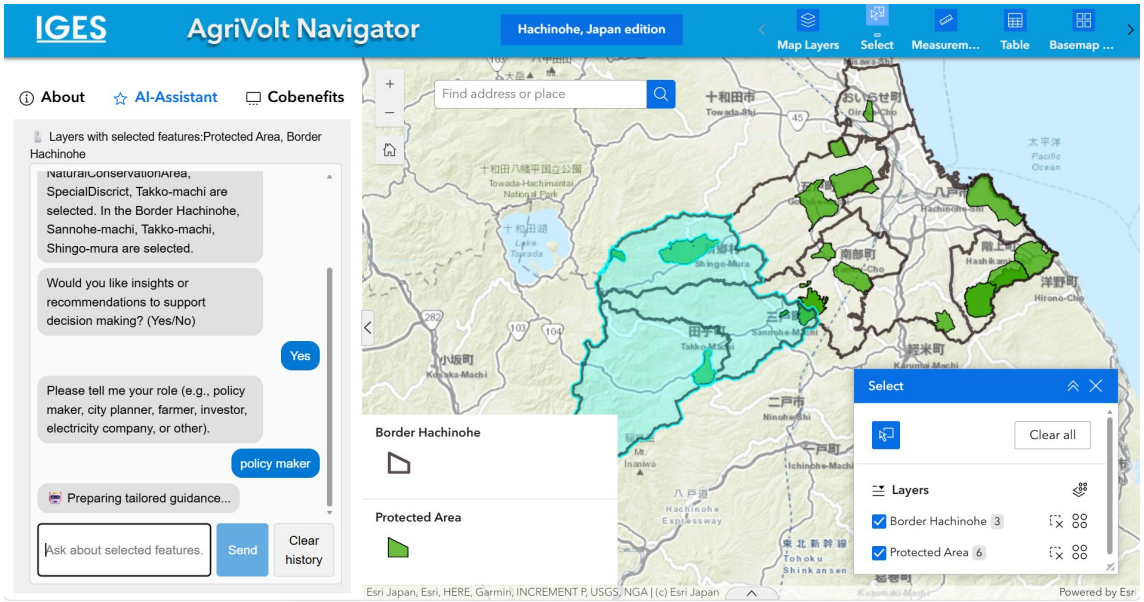

Figure 4: AI assistant summarizing the features of the selected spatial area and prompting the user for additional recommendations.

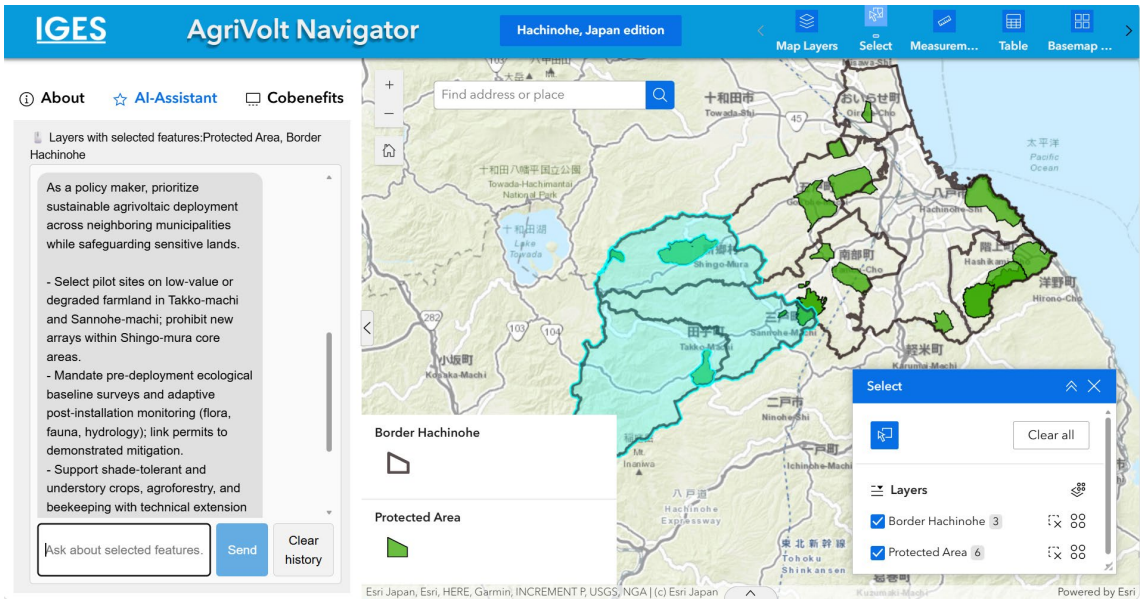

Figure 5: AI assistant generating planning recommendations according to the user's selected area and stakeholder role.

4. Discussion

Advancing tools for spatial planning is critical to support climate and sustainability goals, particularly in contexts where multiple objectives must be balanced. While GIS technologies provide powerful capabilities for spatial analysis, interpreting complex spatial datasets can still be challenging, especially when multiple objectives and diverse stakeholders are involved. This challenge also applies to agrivoltaics, which aims to simultaneously produce energy and food while accounting for environmental, social, and economic considerations.

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The findings of this study highlight the integrated capabilities of GIS and AI in addressing these planning challenges. GIS enables the integration, visualization, and analysis of diverse spatial datasets, supporting systematic identification of suitable areas and estimation of potential co-benefits associated with agrivoltaic deployment. This demonstrates the continuing importance of GIS as a core platform for evidence-based land-use planning, particularly where multiple spatial criteria must be considered simultaneously. At the same time, AI enhances the practical value of GIS outputs by improving the accessibility and usability of spatial information. Rather than requiring users to interpret maps and technical outputs independently, the AI assistant can translate analytical results into concise summaries and stakeholder-oriented recommendations. In this sense, AI can help bridge the gap between complex spatial analysis and practical decision-making, supporting more inclusive and participatory planning processes.

The Hachinohe City case study illustrates the practical value of combining these capabilities. By linking GIS-based analysis with AI-assisted interpretation, the system helps identify areas suitable for agrivoltaics while considering multiple objectives, such as renewable energy generation, surplus income, and CO_2 reduction. It also provides a structured foundation for evidence-based discussions on regional sustainability strategies and land management. These findings align with previous studies highlighting the importance of integrated planning tools and decision-support systems for addressing multi-objective sustainability challenges [2,3].

Despite these advantages, several limitations remain. The framework depends on available data, which may not capture all site-specific complexities or dynamic environmental conditions. Further development and validation are necessary, including integration of on-site data, automatic detection of opportunities and constraints from spatial layers, multilingual support to engage broader user groups, and scenario simulation functions to explore alternative deployment strategies.

Overall, this study demonstrates the practical use of GIS for integrating diverse datasets to support site identification and preliminary co-benefits assessment, while exploring how AI can enhance accessibility through summaries and stakeholder-oriented recommendations. Beyond Hachinohe, the framework has potential applicability in other regions and thematic areas where multi-objective spatial planning is needed, contributing to broader climate and sustainability goals.

5. Conclusion

This study presented a tool-based framework for spatial planning, demonstrated through the case of agrivoltaics, combining GIS-based analysis with AI-enhancement. The Hachinohe City Region case study illustrates how such a framework can be developed in practice to support regional decarbonization strategies and participatory planning processes among diverse stakeholders.

The findings demonstrate the potential of AI-enhanced GIS tools to support complex, multi-objective spatial planning while indicating the opportunities for further refinement through additional testing and stakeholder evaluation. Initial interactions with users indicate that the tool can encourage engagement with the topic, while stakeholder-specific recommendations provide a useful starting point for considering planning issues from different perspectives. Building on these initial experiences, future developments could involve incorporating additional data reflecting local knowledge and enhancing the AI assistant's conversational capabilities, including the diversity and depth of its

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responses across multiple turns. The framework could also be extended to broader sustainability challenges and diverse regional contexts.

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