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ENHANCING SUSTAINABLE DEVELOPMENT AND LAND UTILISATION THROUGH GIS-BASED MULTI-CRITERIA DECISION METHOD FOR FELDA RAJA ALIAS, NEGERI SEMBILAN AND FELDA GUNONG BESOUT, PERAK IN MALAYSIA

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Abstract
The proposed approach integrates Geographical Information System (GIS) technology and Multi Criteria Decision Analysis (MCDA) techniques to evaluate and prioritise Sustainable and Highest and Best Use (SHBU) lands for sustainable development in FELDA. Spatial data representing various criteria, including accessibility, environmental factors, social amenities, and economic viability, are collected and incorporated into a comprehensive GIS database. The objectives of this study are to evaluate the sustainability potential of SHBU lands in FELDA using a GIS-based MCDA approach and to optimise land utilisation within FELDA by determining the highest and best use of SHBU lands. This study aims to develop a model that utilises GIS and MCDA to assess the suitability of different land parcels within FELDA for SHBU development. Analytical methods, such as weighted overlay analysis and spatial analysis tools, are employed to assess the suitability of different areas within FELDA for SHBU land development. The criteria weights are determined through consultations with stakeholders and expert opinions, ensuring a participatory approach in decision-making processes. The GIS-based MCDA model provides a quantitative framework to evaluate and rank potential SHBU lands in FELDA based on their suitability for sustainable development. The model's outputs can assist land use planners, policymakers, and stakeholders in making informed decisions regarding SHBU land allocation, promoting sustainable housing, and building practices within FELDA's land settlement schemes.

Keywords: FELDA. GIS, Land Use Planning, MCDA, SHBU

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INTRODUCTION

Federal Land Development Authority (FELDA) is a Malaysian government agency known for its land settlement schemes, which aim to provide agricultural land to rural communities. However, with evolving societal and environmental priorities, there is a growing emphasis on incorporating sustainability considerations and optimising land use to achieve the highest and best use of land. Sustainable, Highest and Best Use (SHBU) lands are defined as land parcels that emphasise sustainable development practices while concurrently maximising their intrinsic value. This includes considerations, such as environmental sustainability, economic viability, social welfare, and efficient land utilisation. This research aims to make a meaningful contribution to optimising land development for its highest and most beneficial use. Clearly, this study is closely aligned with two key strategies of FELDA, namely, the New Model of FELDA and the Empowerment of Settlers and the New Generation.

To address these challenges, a GIS-based Multi-Criteria Decision Analysis (MCDA) approach is proposed. Geographic Information Systems (GIS) offer a powerful framework for capturing, storing, analysing, and visualising spatial data. It enables the integration of various data layers representing environmental, social, and economic factors relevant to SHBU land development. MCDA techniques provide a systematic and objective way to evaluate and compare different land use options based on predefined criteria (El Sayed, 2018). By combining GIS and MCDA, the approach allows for comprehensive spatial analysis and decision-making, considering multiple factors simultaneously (Marta Dell'Ovo et al., 2018).

The aim of this study is to develop a model that utilises GIS and MCDA to assess the suitability of different land parcels within FELDA for SHBU development. This involves collecting and analysing relevant spatial data layers, assigning weights to criteria based on stakeholder consultations and expert opinions, and applying analytical tools to prioritise and rank potential SHBU lands. It provides a quantitative framework to guide sustainable development practices, optimise land utilization, and ensure the highest and best use of available land resources.

LITERATURE REVIEW

The Concepts of Sustainable and Highest and Best Use (SHBU)

SHBU lands refer to land parcels that prioritise sustainable development practices while maximising their potential value (Rashid et al., 2022). In the context of FELDA in Malaysia, which is known for its land settlement schemes, there is a growing recognition of the need to incorporate sustainability considerations and optimise land use to achieve the highest and best use of land. To effectively attain this, a GIS-based Multi-Criteria MCDA approach is proposed for SHBU lands model development.

On the other hand, the concept of Highest and Best Use (HBU) refers to the utilisation of an asset in a manner that maximises its potential value, taking into account factors, such as physical feasibility, legal permissions, financial viability, support, and overall financial feasibility (Salbiah et al., 2023). It entails identifying the most advantageous and optimal use of the asset that generates the highest value and aligns with legal and regulatory requirements (Akmaluddin & Christiono Utomo, 2013; SPI, 2015; Christiono Utomo et al., 2018; Adelita Fitriani, 2019).

GIS-based MCDA Model for SHBU Lands in FELDA

Traditionally, decision-making processes in land use planning have relied on subjective judgement and limited spatial analysis. However, the integration of GIS and MCDA techniques offers a more comprehensive and objective approach. The development of a GIS-based MCDA model for SHBU lands in FELDA holds the potential to facilitate sustainable land development, balance economic benefits with environmental and social considerations, and enhance the overall land utilisation practices within the FELDA land settlement schemes. Multiple authors have characterised MCDM as a valuable approach that has demonstrated its utility in a wide range of decision-making scenarios, effectively conducting analyses involving multiple criteria (Guarini et al., 2018; Torrieri & Batà, 2017; Kazak, 2017; Gigović et al., 2017; Bottero et al., 2013).

This approach acknowledges the evolving societal and environmental priorities and aims to guide decision-makers in making informed choices regarding land use planning, resource allocation, and sustainable development in FELDA. The development and implementation of a GIS-based MCDA model for SHBU lands in FELDA have the potential to facilitate sustainable land development by integrating environmental, economic, and social considerations. This approach enables decision-makers to assess and prioritise land use options based on a comprehensive set of criteria. By utilising GIS technology, spatial data can be effectively analysed and visualised, allowing for informed decision-making and the identification of optimal land utilisation practices (Özkan et al., 2019)

RESEARCH METHODOLOGY

Two case studies have been chosen to implement the SHBU model, guided by established criteria related to strategic land development issues and the economic activities of residents. The selection of these case studies, namely FELDA Gunong Besout 3 and FELDA Raja Alias 2, was made in consultation with FELDA officers who are representatives of the organisation (refer to Figure 1).

In this study, only areas within a 2km radius of the central points of each case study were delineated for the execution of the SHBU model. This decision was made due to constraints in capturing UAV images using UAV technologies and generating GIS data layers. However, it was ensured that this approach would maintain the overall outcomes and accuracy of the research.

In this context, palm areas and settlements were considered when preparing the GIS databases based on UAV images. The aim was to provide a comprehensive and up-to-date dataset that would support the execution of the SHBU model. The information and dataset derived from these GIS databases will be instrumental in formulating FELDA land development intervention strategies, taking into account both the agricultural and residential aspects of the selected areas.

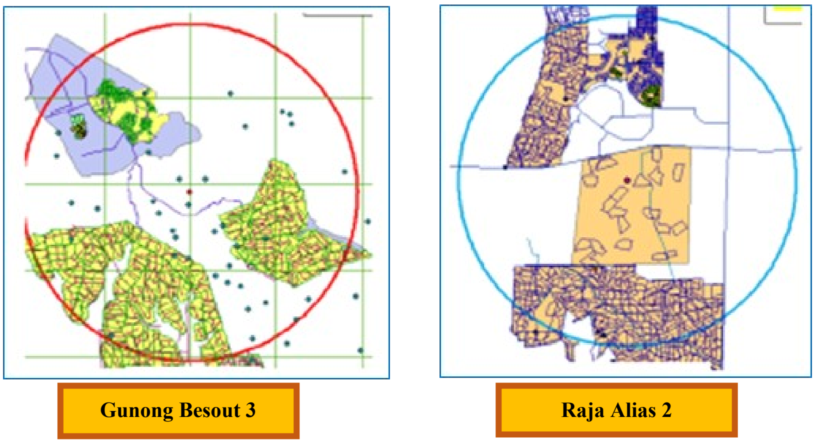

Figure 1: The Boundaries of The Three Case Studies Have Been Defined Within A 2km Radius of Their Central Points.

Data Acquisition for Developing a GIS Database

In this study, the data acquisition process for developing a GIS database for SHBU land development in FELDA involves collecting various spatial and non-spatial data layers such as UAV images, land use, road access, rainfall, contour data, soil and socio-demographic data. These data components form the basis for a comprehensive GIS database that integrates multiple layers of spatial information. By combining these datasets and applying MCDA techniques, it becomes possible to analyse and prioritise SHBU lands based on criteria, such as environmental sustainability, economic viability, social welfare, and efficient land utilisation.

Optimising UAV Image Capture by Drone Technology

On-site UAV image capture was conducted to obtain the latest information on crop patterns and physical land uses. The data acquisition process primarily focused on capturing images of settlements and plantation areas in Raja Alias, and Gunong Besout, utilising UAV technology. Prior to the flight missions, careful consideration was given to flight planning. This involved configuring parameters, such as flight altitude, percentage of side and front overlap, and coverage of the study area. By following this process, all necessary parameters were set up before acquiring the data, as depicted in Figure 2. The image acquisition result during the flight mission was influenced by these parameters. Specifically, in this study, the flight path of the site area was conducted using a stereo-flying mode at a flying height of 200 metres. The image overlapping parameters were set at 85% for front overlap and 75% for side overlap, effectively covering the delineated areas. These predetermined settings ensured comprehensive coverage and optimal image capture for the study.

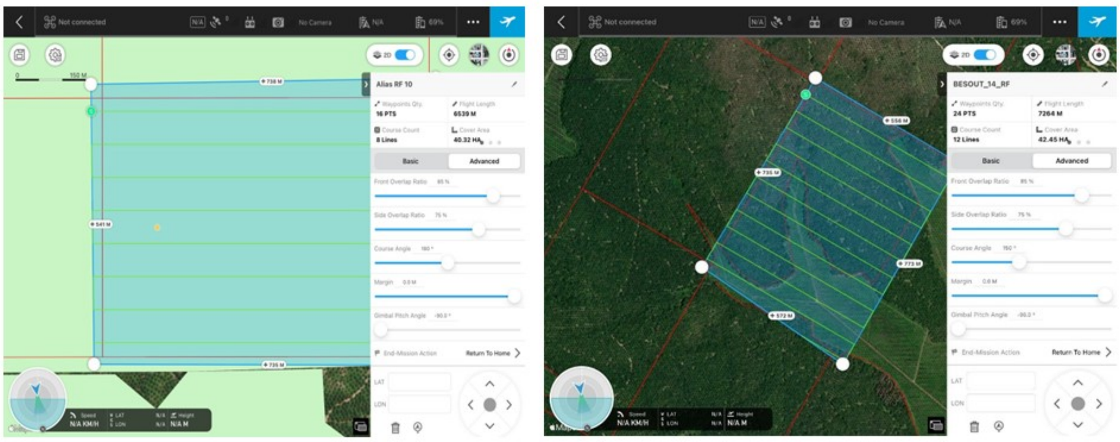

Figure 2: Planning the Flight Path: A Crucial Step in UAV Image Acquisition

UAV Image Capture for Enhancing SHBU Model Generation in FELDA

UAV images were captured as a vital component of the data collection process for generating a SHBU model in FELDA. These high-resolution aerial images provide valuable and up-to-date information about the land and its surrounding features, enabling a comprehensive assessment of the land's potential for sustainable development and optimisation for the highest and best use. In order to achieve the desired outcomes of the SHBU model, the captured UAV images were segmented into two distinct categories: crop areas (specifically, plantation areas) and settlements. These segmented images played a crucial role as the primary source of GIS data for generating the criterion map required for the SHBU model. Through a rigorous and validated process, the UAV images were further processed to generate various GIS databases, including crop areas, slope levels, accessibility information, and other relevant datasets (refer to Figure 3). These GIS databases provide essential spatial information and attributes that are integral to the SHBU model, enabling a comprehensive analysis of the land's suitability for sustainable and optimal land use planning within the FELDA context.

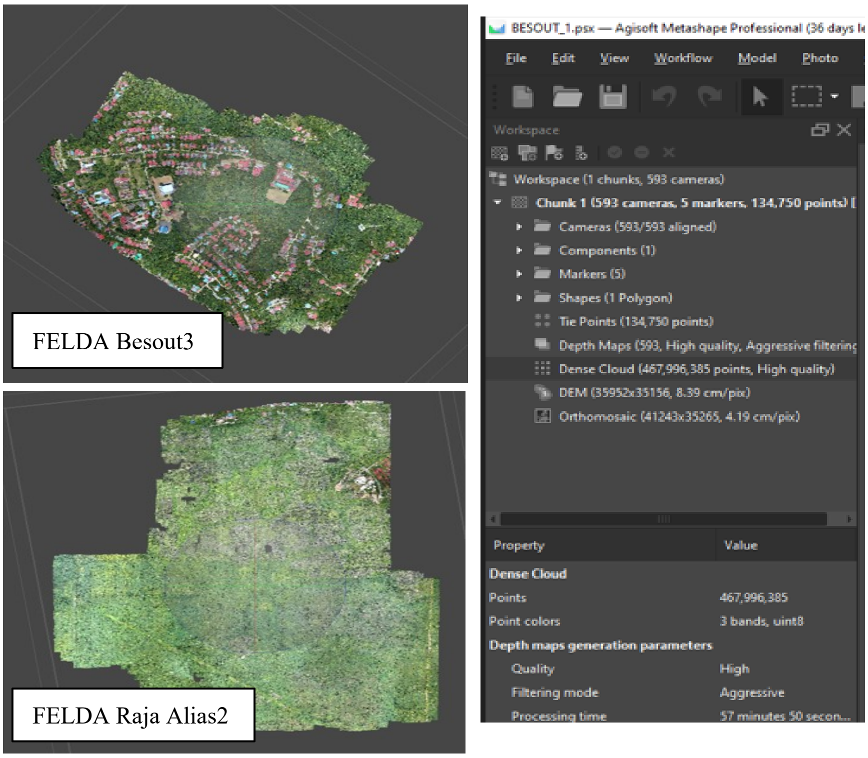

Figure 3: Orthophoto Generation from Aerial Imagery

A Comprehensive Guide to Implementing GIS-MCDA

To accomplish the desired objectives of the SHBU model, the imagery acquired by UAVs was segregated into two distinct classifications: crop areas and settlements. These UAV images served as the primary source of GIS data for generating the criterion map in the SHBU model. Once the process was validated, the UAV images were utilised to create GIS databases, including crop areas, slope levels, and accessibility. Figure 4 demonstrates the utilisation of a GIS-based

MCDA approach as an effective analysis tool (Prieto-Amparán et al., 2021) for handling and managing spatial decision problems. This approach proves valuable in addressing various aspects of FELDA land development, particularly within the HBU (Housing and Business Unit) domain for crop cultivation, as well as future-physical potential projects, such as business centres, residential compounds, and agro-preneur centres within the sustainability domain.

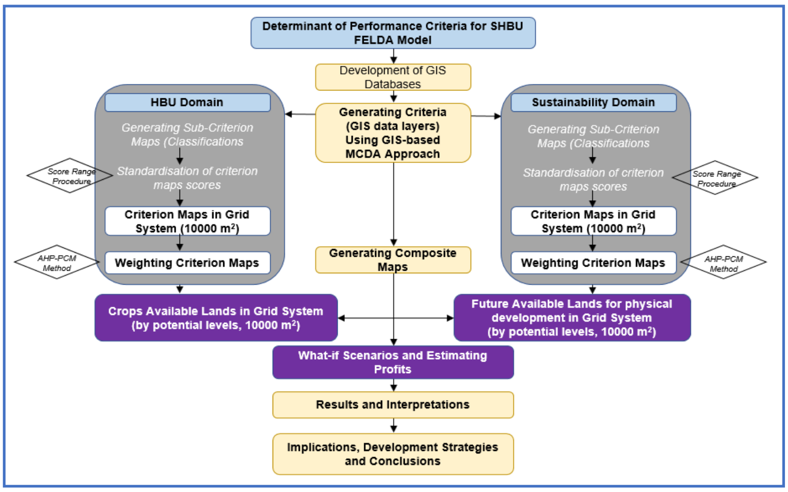

Figure 4: Unlocking Spatial Decision-Making Potential: An In-Depth Process of GIS-MCDA Application

The execution of the SHBU model involves three primary stages: a) generating criterion maps and sub-criterion maps, b) assigning weights to criterion maps, and c) creating composite maps that depict crop land suitability and future-physical development outcomes. The process of generating sub-criterion maps includes a classification step that incorporates the standardisation of criterion scores. Classification is a necessary step to ensure that all criterion maps are inclusive and quantifiable, allowing them to be linearly combined in the generation of composite maps. Each sub-criterion map, after standardising the scores, is subsequently transformed into a grid system (raster data) with a resolution of 100 x 100 square metres.

Additionally, the process continues by assigning weights to the criterion maps, which determines their relative importance in generating the SHBU composite maps. To differentiate the magnitude of impact, the pairwise comparison method (PCM) is employed in this case for weighing the criterion maps. The SHBU outcomes can be categorised into three stages, each serving different purposes, such as planning scenarios, intervention strategies, and profit estimations. Table 1 illustrates that the five criterion maps for assessing crop land suitability possess varying degrees of significance within the overall assessment. It displays how the values (scores) located in the upper right corner, specifically the shaded values, were obtained through pairwise comparisons of the relative significance among the five performance criteria. This process was conducted during group discussions involving the researcher's expert panel.

Table 1: Results (Shaded Scores) Crop Lands Potential Levels

Criterion Maps	Judgment Process					Weights
	C1	C2	C3	C4	C5	
C1	1	2	3	3	5	0.402
C2	0.5	1	2	3	4	0.273
C3	0.33	0.5	1	0.5	2	0.110
C4	0.33	0.33	2	1	2	0.146
C5	0.2	0.25	0.5	0.50	1	0.068
					Total	**1.000**
					Consistency ratio (CR)	**0.012**

Note: C1=Crops map, C2=Slope levels, C3=Access to estate (Estate access network), C4=Fertile Areas map, and C5=River/water bodies (water resources)

The remaining values in Table 1 were calculated through logical reasoning involving reciprocals. For instance, when comparing C1 to C2, where C1 > C2 = 2, it implies that C2 < C1 = 0.5. Similarly, for C1 > C3 = 3, it signifies that C3 < C1 = 0.33. In cases where a dimension is compared to itself, the evaluation scale (ratio) was set to one, indicating "equal importance." A comparable method was employed in the balance judgement process.

ANALYSIS AND DISCUSSION

The SHBU model's ability to generate a composite map of croplands' potential plays a vital role in aiding FELDA management or crop plantation planners to maximise land utilisation for crop cultivation. Moreover, the SHBU model offers valuable information, including attributes like the size and distribution of relevant areas for crop plantation management, as well as cost and profit estimation. Therefore, this undertaking contributes substantial value to the field of cropland development and crop plantation literature. The outcome of cropland suitability for FELDA Raja Alias 2 and FELDA Gunong Besout 3 is illustrated in Figure 5, showcasing four distinct levels or areas based on their potential. These levels are categorised as follows: (a) areas with the highest potential, (b) areas with significant potential, (c) areas with lower potential, and (d) areas constrained by various factors. Importantly, the SHBU composite crop map generation results can provide insights into optimising cropland usage by comparing them to existing plantation areas. This comparison allows for the identification of opportunities to increase and optimise potential cropland areas instead of cultivating on land with constraints.

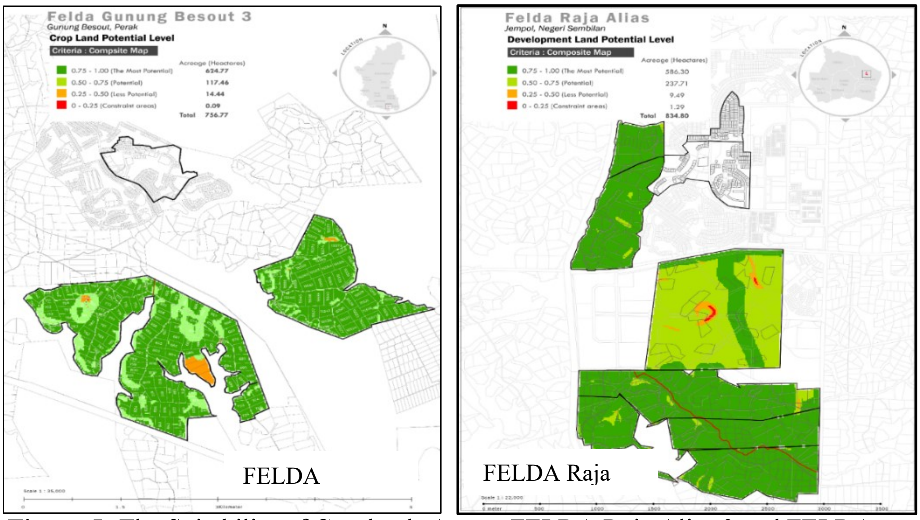

Figure 5: The Suitability of Croplands Across FELDA Raja Alias 2 and FELDA Gunong Besout 3 is Assessed based on Different Potential Levels

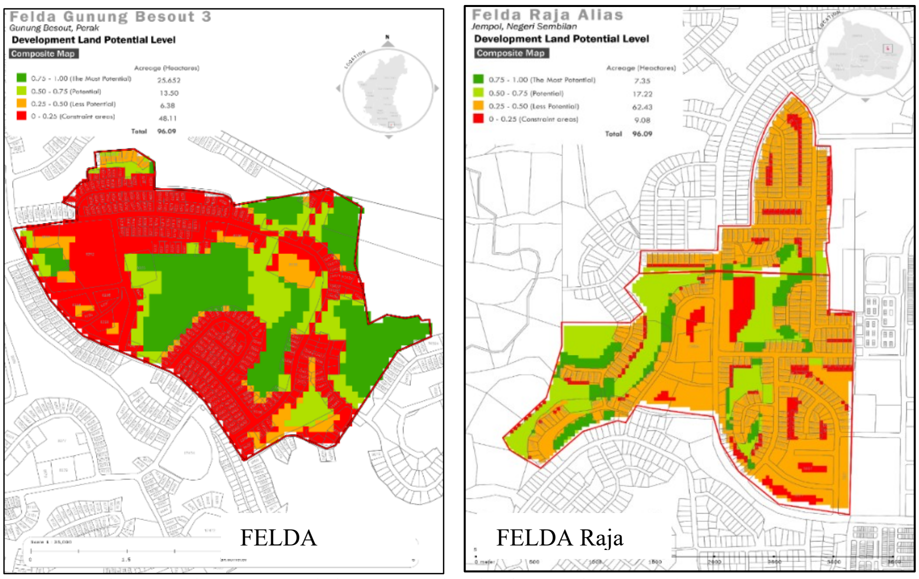

Figure 6: The Levels of Potential Future-Physical Development in FELDA Gunong Besout 3 and FELDA Raja Alias 2

The suitability of future-physical development in FELDA Gunong Besout 3 and FELDA Raja Alias 2 is depicted in Figure 6, showcasing four distinct potential levels. These levels include (a) the most suitable areas, (b) areas with potential, (c) areas with lower potential, and (d) constraint areas. Among these levels, only the areas with the most potential and areas with potential will be taken into consideration for future development. The outcome showcases the effectiveness of the SHBU model in generating a comprehensive map depicting the potential for future-physical development in FELDA Gunong Besout 3 and FELDA Raja Alias 2. This map serves as a valuable resource for FELDA management to strategically utilise available lands for upcoming developmental requirements. Furthermore, the SHBU model offers insightful attributes including area size, distribution of prime locations, and scenario planning. These details are crucial in making informed decisions regarding future land development initiatives.

The following is the outcome of the SHBU implementation which resulted in the identification of suitable regions for crops and land development. This yields a what-if scenario for optimising FELDA land development and achieving a higher return (net profit). What-if planning scenarios are developed by identifying crops and projects based on land potential levels and profit estimation. Table 2 presents the findings derived from the SHBU model, which serve as inputs or foundational elements for recommending and implementing intervention strategies aimed at optimising the land in FELDA Raja Alias 2. These findings provide valuable insights and key information to guide the development of effective strategies for maximising the potential of the land.

Table 2: The Matrix Table of FELDA Raja Alias 2 Crucial Findings (SHBU Model).

Aspects of Findings	**Potentials (P)**			**Challenges (C)**			**Findings (Remarks concerning the SHBU model)**
	L1	L2	L3	L1	L2	L3	
Site location and the existing development (including surroundings)			/		/		P3 – close and easy access to Bandar Seri Jempol (BSJ) C2 – Commercial units already established in BSJ that meets the population threshold.
Residents' Socio-demographic profiles		/			/		P2 – Human resource, age group (youth) is very potential/promising with current the youth-oriented programs C2 – Increase competitive income for youth employment with FRA 2 activities
D1: Felda Industries-based crops (FIbC)					/		C2 - RnD of main crops, i.e., palm oil as the preferred industry-based crop. It is because of the competitive current market price of palm oil.
D2: FELDA business centre (FBC)			/		/		P3 – Small neighbourhood comprises of housing & shoplots

Aspects of Findings	Potentials (P)			Challenges (C)			Findings (Remarks concerning the SHBU model)
	L1	L2	L3	L1	L2	L3	
							C2 – Current business activities in BSJ. Future Felda Jaya commercial units planned. Competition.
D3: FELDA residential compound (FRC)			/		/		P3 - Reserve land is available – from composite map. C2- Ready new residence for sale in BSJ
D4: FELDA agro-preneur (FAgP)			/		/		P3 – create a market of interim product (PPP) - market chain – supplier to end user (including online marketing) C2 – low awareness/skill in IT marketing
D5: SHBU management plan			/		/		P3 – Willingness of management and settlers to new knowledge. P3 – Land title recipients – Boost morale and confidence in FELDA management. P3 – Development strategies included in State Structure and Jempol District Local Development Plan 2045. C2 - 5-10 % own managed – inefficient/ unproductive, high-cost individual burden. C2 - Non-active Cooperative

Table 3 presents significant findings that support the implementation of the SHBU model for the recommendation and intervention strategies in optimising the land in FELDA Gunung Besout 3. These findings provide a concise overview of essential information obtained from the model, enabling a comprehensive understanding of the land's characteristics and potential. These insights serve as a valuable foundation for devising effective strategies and interventions tailored to FELDA Gunung Besout 3.

Table 3: The Matrix Table of FELDA Gunung Besout 3 Critical Findings (SHBU Model).

Aspects of Findings	Potentials (P)			Challenges (C)			Findings (Remarks concerning the SHBU model)
	L1	L2	L3	L1	L2	L3	
Site location and the existing development (including surroundings)	/			/			C1 – location of the study area is quite far from adjacent small towns (Sungkai and Slim River). P1 – the study area has the potential to be a successful small business centre that offers goods and services which suit local demands, such as sundry shops, hardware outlets, vehicle workshops, petrol kiosks, etc.
Residents' Socio-	/			/	/	/	C1 – low mean of settler monthly income (RM3220.15) during the first half of 2021.

Aspects of Findings	Potentials (P)			Challenges (C)			Findings (Remarks concerning the SHBU model)
	L1	L2	L3	L1	L2	L3	
demographic profiles							C2 – all pioneer settlers are elderly now. Most of them cannot operate the oil palm crop as effectively as in their younger days. C3 – the current population is quite small (about 1500). It is insufficient to support the demand of farm operators. P1 – the remaining young generation in the study area can be trained to be agropreneurs.
D1: Felda Industries-based crops (FIbC)	/	/	/	/	/	/	C1 - only oil palm plantation is allowed in the study area. Other crops are prohibited. C2 - illegal oil palm plantation is found on FELDA reserve land. C3- poor drainage system (leads to flood) and soil erosion occur at the farm, especially at Stage 003 of the plantation area. P1 - potential for interim crops (PPP projects), managed by Koperasi (in crops area). But it must get permission from the FELDA management. Suggested interim crops such as bayam, sawi (high productivity). P2 – potential for enhancing Bukit Selfie and oil palm farm as recreation and tourism attractions.
D2: FELDA business centre (FBC)	/			/			C1 - FBC should be proposed at Trolak regional or cluster level to support its viability. P1 – the adjacent business centre at Gunung Besout 01 should be strengthened.
D3: FELDA residential compound (FRC)	/			/	/		C1 - no vacant land to create FRC at the study area. C2 - the proposed 100 units of houses at FELDA Gunung Besout 02 for the second generation are insufficient. P1 – available FELDA reserve land has the potential to develop as a small neighbourhood that comprises a housing and shop lots
D4: FELDA Agropreneur (FAgp)	/	/	/	/			C1 - Previous SDP projects conducted by individuals are not continuous. Nobody took over the projects to run them as usual when the participants died. P1 - the proposed FAgp project that the individual runs should have a protégé to continue the business in case of the death of the participant. P2 - the study area has many potential tourism products, such as a beautiful open view at Bukit Selfie, an oil palm farm tour and a serene FELDA village environment that can be marketed to tourists.

Aspects of Findings	Potentials (P)			Challenges (C)			Findings (Remarks concerning the SHBU model)
	L1	L2	L3	L1	L2	L3	
							P3 - to overcome the labour shortage at the farm, the young generation of FELDA should be attracted and exposed to the oil palm industry.
D5: SHBU plan management	/	/	/	/	/	/	C1 - only 117 settlers (43.2%) surrendered their farm to FELDA management. Other 154 settlers (56.8%) managed the farm themselves. C2 - Loss of oil palm plantation income was due to settlers selling the palm fruit to other oil palm mills. P1 – it is a potential for FELDA management in the study area to take appropriate initiatives and attract 154 other settlers (56.8%) to join the FELDA farm management. P2 - to avoid the loss of oil palm plantation income, FELDA management should encourage all settlers to sell their yield to the FELDA oil palm mill only.

The table highlights that the advantages and potential outweigh the challenges with the identification of key development projects that are necessary for Gunung Besout 3. These include the establishment of a small neighbourhood, a business centre to cater for daily and weekly needs, PPP agricultural projects, and a PPP marketing hub. Additionally, FELDA Gunung Besout 3 boasts various potential tourism products, such as the picturesque Bukit Selfie with its scenic views, an oil palm farm tour, and a tranquil FELDA village environment, all of which can be effectively marketed to attract tourists. Due to the findings, particularly from the composite maps, specific recommendations and suggestions for each case study have been proposed. It is hoped to improve settlers' livelihoods by fully utilising the FELDA lands and human resources to maximise profits.

CONCLUSION

The creation of composite maps for crop and physical land development greatly assists the FELDA management and crop plantation planners in optimising land utilisation for both crop cultivation and future physical development. These maps provide essential spatial information and attributes, including the size and distribution of areas suitable for crop management and the ideal locations for physical development, enabling accurate cost and profit estimation. This endeavour enhances the existing literature on cropland development and FELDA lands, introducing novel contributions, such as performance criteria, processes, and techniques employed in generating composite maps specific to FELDA lands. By utilising the insights derived from the composite maps, targeted recommendations and suggestions have been put forward for each case study, aiming to enhance cropland development within FELDA. These efforts are geared towards improving the livelihoods of settlers by maximising the utilisation of FELDA lands and human resources to optimise profitability. These initiatives are in line with the national rural policies and the Sustainable Development Goals (United Nations, 2020), reflecting a shared commitment to sustainable development. The outcomes of these endeavours contribute to FELDA's ability to ensure sustained high returns, benefiting both current settlers and future generations within the FELDA community in a holistic manner, encompassing various aspects including income generation. These future studies can help refine and enhance the utility of the SHBU framework and MCDA-GIS system, making them valuable assets not only for FELDA but also for rural land development initiatives worldwide.

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