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DESIGNING COLLABORATIVE AUGMENTED REALITY GEOGRAPHIC INFORMATION SYSTEM FOR LAND SUITABILITY VISUALIZATION

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Abstract

This study aims to visualize the potential agricultural land suitability using the Collaborative Augmented Reality Geographical Information System (AR-GIS). In agriculture decision-making, geographical aspect is one of the important factors to be considered. However, there are plenty of limitation in the early AR platform and one of which is the limitation on the number of users. Cloud-based anchor points are able to overcome this limitation by connecting multiple users via the internet which allows them to see, interact, and synchronize a digital context simultaneously. Through this technology, this research was divided into two stages. The first stage is to make a land suitability map. The second stage is the development of Collaborative AR GIS by adopting a user-centred design approach. This study integrates GIS with AR visualization capabilities to visualize land suitability maps then enable multi-user collaboration work based on AR Object. This study developed an AR-GIS-based system using UNITY 3D. The built AR GIS was based on multi-platform to overcome the various mobile device platforms used by farmers which then integrated with Cloud anchors to connect one device to another. Cloud anchors enable collaborative work between farmers and other stakeholders. This study evaluates the system performance using two devices that have different specifications. Based on the evaluation result, good maps visualization is able to be provided by the collaborative AR-GIS. The collaborative AR technology also gives an alternative visualization as well as alternative interaction with maps that have multiple users. This system is envisioned to improve the understanding of farmers towards land suitability map. It is expected that the collaborative AR-GIS system is able to provide a helpful aid to the farmers in terms of decision-making. With well-informed decision and insight on land suitability map, the risk of crop failure can be minimised, and the agricultural sector's productivity can be increased.

Keywords: Agriculture GIS, Cloud anchors, Collaborative system, GIS, Land suitability maps.

1. Introduction

Geographical factors have a crucial role in agriculture [1]. This role is significant in decision-making in determining commodity selection and land evaluation [2]. The Decision-making process requires a large amount of geographic data [3, 4]. A large amount of data causes difficulties in managing data. A geographic information system (GIS) can handle this issue effectively [5]. This is because geographic information systems have functions that can be used to process and visualize geographic data. However, these functions cause GIS to have a complex user interface [6]. Complex user interfaces require high expertise users. Currently, most GIS developers build computer-based systems [7]. Meanwhile, farmers in Indonesia are novices in operating computers [8]. They are more familiar with mobile devices. Farmers use mobile devices in their daily life activities. To use GIS properly, farmers need good spatial thinking skills. Spatial thinking is crucial for understanding the information contained on the map [9]. The problem is that GIS generally only provides services for single users. So, it is not easy to transfer knowledge between farmers and GIS experts. In addition, this problem makes it difficult to carry out collaborative work between farmers and other relevant stakeholders.

According to several researchers, there are many ways to make it easier for novice users to operate GIS [5, 10, 11]. One solution is to enrich the GIS with a more attractive and interactive map visualization [11]. The presentation of information must be appropriate so that it's not confusing. Transfer of knowledge from GIS experts to farmers is crucial. That way GIS experts can assist farmers in operating the map. Another thing that is also important is that in making a GIS, choosing the appropriate device can increase the user familiarity aspect. Familiar devices can increase the GIS usability level.

Augmented Reality (AR) can merge virtual reality with the real world. AR can bring virtual objects into the real world. The researchers use the game engine to develop an AR system for map visualization. AR is also can visualize land suitability maps in three dimensions. There are study modelled the city by combining 3D maps with AR [12], another study used AR maps to model palm plantations [13]; other research made a prototype AR system for identification and pest management [14]. The researchers concluded that AR Maps help reduce the limitations of using small screens on mobile devices [11, 14, 15]. AR can create an immersive experience for the user. AR also provides new ways to interact with maps. There are plenty of limitation in the early AR platform and one of which is the limitation on the number of users. Cloud-based anchor points are able to overcome this limitation by connecting multiple users via the internet which allows them to see, interact, and synchronize a digital context simultaneously.

This study integrates GIS with AR visualization capabilities to present interactive 3D maps and enable multi-user collaboration work using AR. This study uses Cloud Anchors to enable collaborative work between farmers and other stakeholders. GIS specialists and environmental analysts may share information and help farmers use and comprehend GIS. Another benefit of adopting collaborative AR is that users can maintain their distance from one another. This benefit is significant in overcoming the challenges of collaborating in the COVID-19 pandemic condition. This study conducts performance testing to evaluate the system. Collaborative AR-GIS is expected to be able to provide a better map visualization and interaction. The Collaborative AR-GIS enhances the users' understanding of the land suitability map.

Furthermore, this study considers that the system will have a high level of usability to help farmers in the decision-making process.

2. Related Work

A geographic information system is an information system that can manage geographic data. Agriculture uses GIS to map agricultural areas, irrigation, and map disease [2, 16-18]. However, its use is still limited to large-scale agriculture. GIS requires large amount of data and complex user interfaces. GIS requires a large amount of data and complex user interfaces [2]. Today, many open data sites provide geographic data [19]. However, not every farmer can take advantage of it. That's because the data from open data sites are still in various formats. It is required further processing to be used by farmers. In Indonesia, farmers are already using mobile in their daily life. They are still a novice in using computers [20].

There are many ways to make it easier for farmers to operate GIS. One way is to build a mobile-based GIS [18]. This way can increase the usability of the GIS in terms of familiarity. Another way is to enrich the GIS with informative content and provide interactive interactions.

The development of GIS in the agricultural sector is a hot topic. Researchers use various ways to optimize the use of GIS. One way is to use a game engine to develop 3-Dimensional system [21, 22]. Carrera et al. improve understanding of spatial data using augmented reality [23]. Other researchers use game engines to visualize real- world topography [24].

Using a game engine to display spatial data has a weakness. One problem is that game engines don't have a coordinate or projection system like GIS building software [24]. Currently, there are several extensions such as Mapbox for unity and Koala for Unreal Engine. This extension enables the game engine to manage spatial data. It handles the weakness of the game engine in managing the coordinate system. Laksono et al. [24] use Mapbox for unity extension to provide topography data. The use of 3D maps is a hot topic among researchers. Many researchers conclude that 3D maps are better at visualizing information [21, 22, 24, 25]. The game engine can convert digital elevation model (DEM) files into 3D maps. Researchers use this ability to create 3D maps for various purposes [21, 22]. Some researchers visualize maps with augmented reality (AR) and virtual reality (VR) [15, 26-28]. AR and VR can provide an immersive experience to map users.

Transfer of knowledge from experts can help novice users in operating GIS. Collaborative work between users can improve system usability [29]. Multi-user was one of the limitations of using the early AR platform. Most of the existing GIS applications only provide services for single users. Cloud-based anchor points on the AR platform can currently connect the users via the web. Cloud anchors enable numerous devices to view, interact with, and sync the same digital context at the same time. Collaborative Geo-visualization enables map users to collaborate on projects [29]. Other researchers also stated that the use of collaborative GIS can increase usability.

3.Method

This research is divided into two stages. The first step is to create a map of land suitability. The weighted overlay method was used to create the land suitability map, which was created by integrating multicriteria decision analysis with the weighted overlay method. This study uses land, climate and topographical aspects to create a land suitability map. The second stage is the development of Collaborative AR GIS by adopting a user-centred design approach.

3.1. Land suitability maps development

This study proposes a framework for evaluating land suitability. The first stage of frameworks is to define the thematic map layer. The selected layer is to determine the thematic layer. Referring to FAO, the most important criteria for land evaluations are soil, climate, and topography [1]. The second stage of this study is to classify each map layer of decision criteria based on land suitability guidelines issued by the Indonesian government. The third stage is to determine the alternative weight using the Analytical Hierarchical Process (AHP) method. This stage involves expert assessment. Then the last step is to overlay thematic layers using the weighted overlay method. Figure 1 describes the proposed framework for making a land suitability map.

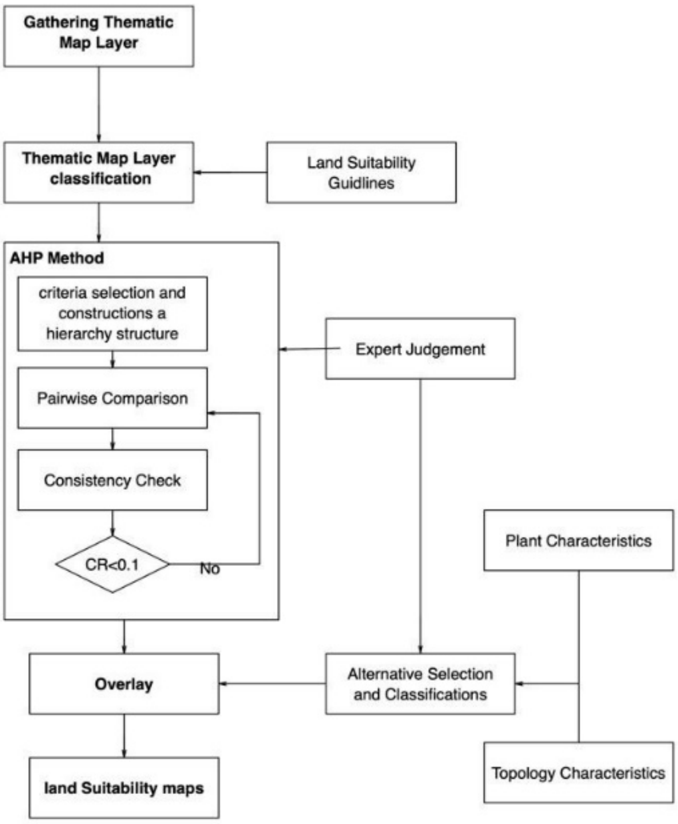

Fig. 1. The proposed framework for making a land suitability map.

3.2. Collaborative AR-GIS development

This study modifies the User-Cantered Design (UCD) method, then proposes a framework for creating AR-GIS. The proposed framework has five stages. The first stage is requirements analysis. This stage aims to determine system requirements. The second stage is data gathering and integration. This stage integrates the thematic map layer, stores data in cloud storage, and integrates the map layer with the UNITY 3D scene. The third stage is the map and attributes visualization. This stage aims to analyses the component map. A 3D map has more components than two dimensions. This study divides the data content into textual, map, imagery, and terrain representations. The Fourth stage is designing the interaction between the user and the system. And the Last is Prototype development and evaluations. This study uses functional and performance testing. Figure 2 describes the proposed framework for AR-GIS development.

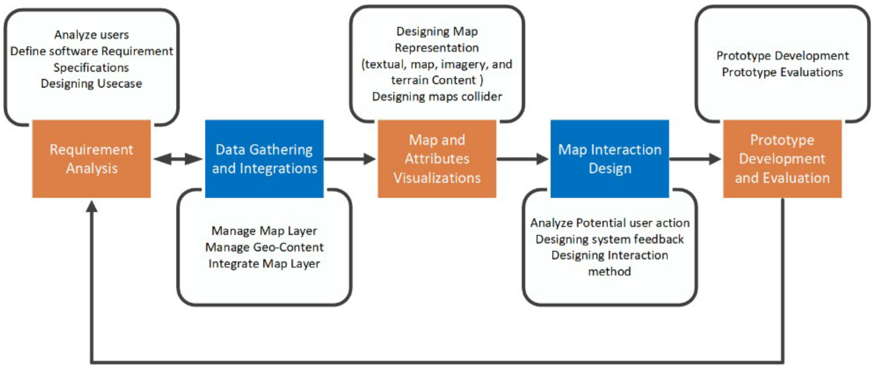

Fig. 2. The proposed framework for AR-GIS development.

4. Results and Discussion

4.1. Land suitability maps development

This study uses data gathered from open data sites, then converts all map layers data into a raster file format. A raster file is crucial to make the land evaluation process more accurate. Furthermore, this research classifies map data and assigns weights based on land suitability class. This study determines the weight of the map layers criteria using multi-criteria decision analysis. There are nine map layers that are derived from soil, climate, and topography factors. Figure 3 describes the thematic map layer as the basis for decision-making.

This study uses online group discussion to determine the pairwise comparison matrix for each criterion. The group discussion involved ten farmers as Agriculture experts. The expert has more than fifteen years of experience as a farmer. Discussions with experts produce weights for each alternative criterion. The resulting weight is then used to perform the overlay process using the weighted overlay method. Table 1 is the final weight of each commodity based on the decision criteria.

A land suitability map is created by overlaying each map layer based on the weight of the criteria. Using the proposed methodology, this study overlays each map layer. Unlike other frameworks, this one conducts classification on each map layer. This classification approach improves the weighted overlay method's result over another framework. Figure 4 depicts the depiction of the resulting land suitability map.

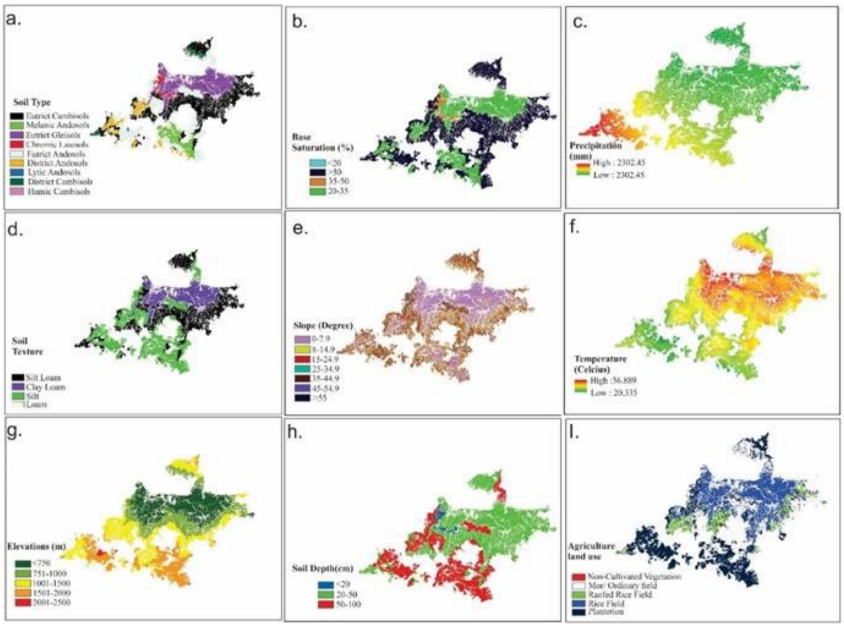

Fig. 3. The thematic map layer as the basis for decision-making.

Table 1. The final weight of each commodity based on the decision criteria.

Criteria	Sub Criteria	Final weight for commodity					
		Rice	Onion	Cassava	Potatoes	Cabbage	Sweet Potatoes
Soil	**Soil Depth**	0.08	0.09	0.17	0.10	0.10	0.15
	Soil Texture	0.10	0.11	0.16	0.12	0.10	0.15
	Soil - Base Saturation	0.09	0.09	0.11	0.09	0.13	0.11
	Soil Type	0.11	0.15	0.17	0.13	0.13	0.15
Climate	**Temperature**	0.12	0.11	0.07	0.15	0.12	0.09
	Precipitation	0.15	0.15	0.06	0.13	0.13	0.07
Topography	**Elevation**	0.11	0.09	0.10	0.13	0.11	0.10
	Slope	0.09	0.08	0.09	0.09	0.9	0.08
	Agricultureland use	0.15	0.13	0.07	0.06	0.9	0.10

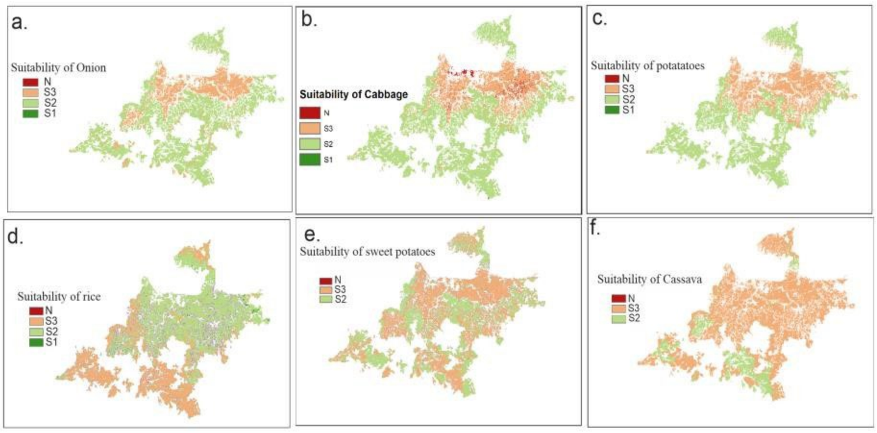

Fig. 4. The resulting land suitability map visualization.

4.2. Collaborative augmented reality GIS development

The goal of Requirement Analysis is to determine the user needs for the AR-GIS. This study looks at the user and the issues they have with GIS. This study also assesses user demands as a basis for developing use cases.

User characteristics are an important consideration in system development. A questionnaire and a literature review are used in this study to evaluate the characteristics of farmers as users. Personas help us grasp the expectations, hopes, fears, and motivations of the AR-GIS target user. We employ in-depth and repeated questions to strengthen the validity of the user analysis data. This strategy can relieve strain on farmers, resulting in data with a high level of validity. Ten farmers are involved in determining user requirements. User personas describe information about the user, such as motivation, farmer expectations, personal information, and device usage for the agricultural land mapping system. An example of a user persona from this study is shown in Fig. 5.

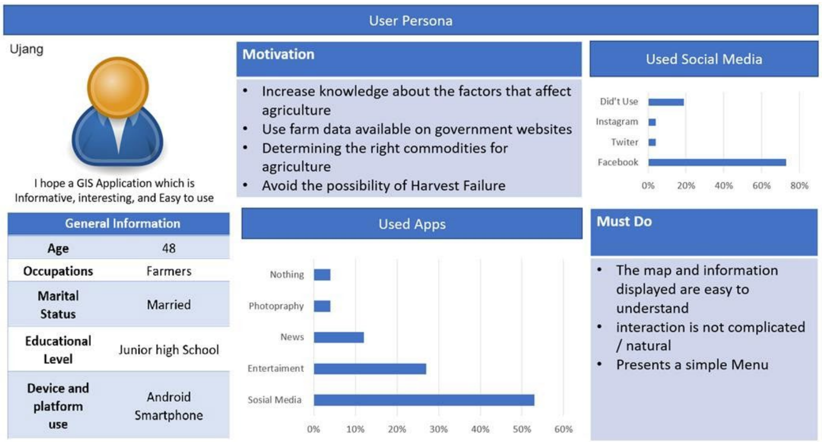

Fig. 5. Example of the user persona in this study.

System Requirement analysis aims to identify and evaluate problems, obstacles that occur, expected needs, and opportunities. Currently, farmers have the following problems related to GIS: 1) Agricultural GIS is generally a computer-based system while most of the farmers in Indonesia are more comfortable with mobile devices [8]; 2) The complex user interface of GIS requires a high degree of expertise of the user; and 3) Most of the GIS software only provides services for single-user. It's difficult to do collaborative work among farmers, environmental analysts and GIS Experts.

This study determines the software requirements specification based on user requirements. Then illustrate the functions contained in AR-GIS using use case diagrams. The use case diagram's primary goal is to describe the interaction between the user (actor) and the AR-GIS. A use-case for an AR-GIS prototype is depicted in Fig. 6.

This work employs the marker-less AR technology to improve the usability of AR-GIS. This approach enables the user to show digital items in the absence of a specified marker. This is why, digital can help and support some understanding

[30]. The plane detection method is used in this study to assess the user's environment. The system searches for a flat plane using the camera and then display the map after the user confirms the spot. The system then displays a map in the form of digital items. The user can show a map on a table or floor using plane detection. Figure 7 depicts the plane detection features of the AR GIS.

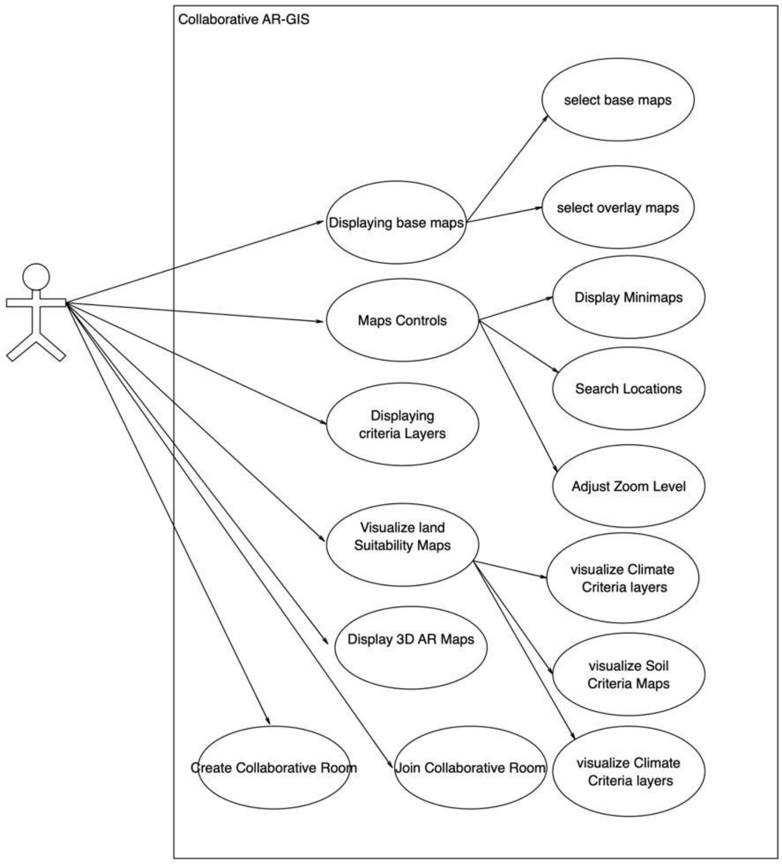

Fig. 6. The use-case of an AR-GIS prototype.

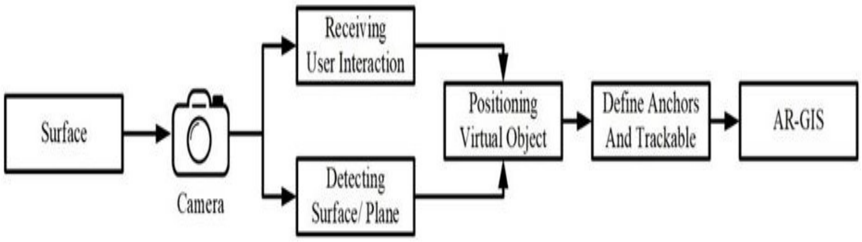

Fig. 7. The features of plane detection in AR-GIS.

This study enables multiple users in AR-GIS. Users can act as hosts as well as clients. The host's task is to create a room and then determine the anchor point. When the host successfully initializes the room, the system will generate a room id.

Clients can enter the room by entering the room id. Once connected, both host and client can interact with the same map object. This enables collaboration work between AR-GIS users. Figure 8 shows the connection process between the host and client devices.

Fig. 8. The connection process between the host and client devices.

Standard features for interacting with maps are provided by game engines such as Unity3D. However, improving interactivity necessitates slight changes to these characteristics. A bespoke C# script is used in this study to display information and govern camera movement. This first-person view is used by AR-GIS so that the user may control camera movement directly from the device. The ray casting approach is used in this study to generate bird's-eye view navigation. The intersection of the rays with the ground surface is used to calculate the camera position in this method.

This study developed AR-GIS based on android and iOS. Then use Cloud Anchors to connect one device to another. Cloud anchors can enable collaborative work between farmers and other stakeholders. This study creates a room so that every user can join in the same environment (see Fig. 8). The system doesn't need markers to visualize maps objects. Collaborative AR-GIS use a plane detection algorithm to detect flat areas such as floors or tabletops. When the system can recognize a flat area, the server can initialize the cloud anchors. Then all devices in the room will display the same object on the screen based on the anchor data stored in a cloud database. Each user can interact and manipulate map layers visualization. With cloud anchors, map layers manipulated by one user can be seen directly by other users. With this collaboration work on the map between users can be done. Figure 9 describe the main interface of the Collaborative AR-GIS.

The system performance is evaluated in this study by utilizing two devices with specifications. The purpose of this performance test is to determine how the system responds to various tasks. Starting the system (initializing maps), executing navigation, and displaying information are all part of the evaluation task. To facilitate data analysis, this study turns tabular data into graphs. Figure 10 depicts the results of a performance test performed on two devices with varying hardware specs. Figure 11 depicts a task time comparison between the two devices.

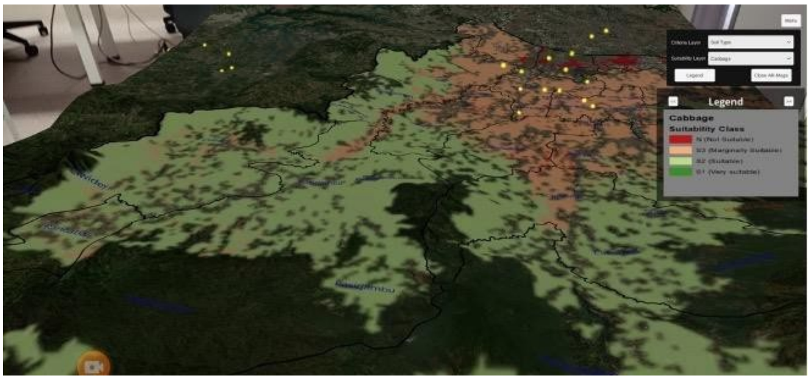

Fig. 9. The main interface of the collaborative AR-GIS.

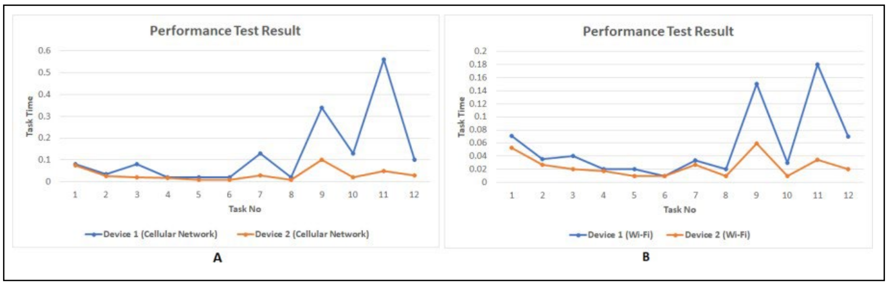

Fig. 10. The task time comparison.

This study also evaluates the influence of internet network speed changes on system response time. A response time comparison based on network speed is shown in Fig. 11.

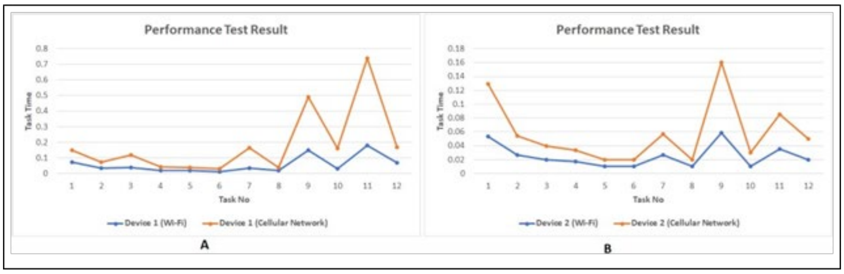

Fig. 11. The response time comparison.

We make the following findings based on the two-device response time: To begin, it is obvious that hardware specs influence AR-GIS performance. The second device has more powerful hardware and the response system is shorter than the first device in showing the map. Then, panning and rotating the map do not place an undue strain on the hardware and when zooming maps, the map load requires more resources because the zoom operation alters the map scale. If the map scale is modified, the map loads a new tile sets and it updates the map information. Second, Mapbox keeps all maps in the cloud. As a result, internet speed influences map loading time but it is taking a longer time because of the weak internet connection.

These five actions necessitate the system to download tile sets from the cloud. These two findings are consistent with those of earlier studies in [14, 15, 26, 31]. According to another research findings, hardware capabilities and internet networks have a considerable impact on system performance [24]. However, according to the results of the performance testing, the system's maximum response time is 0.180 seconds. This figure is still classified as a Short Response Time, hence the user's behavior on the application is unaffected [30].

Based on the evaluation results, this study concludes that collaborative AR-GIS can give good map visualization generally. AR is effective to support the understanding of user [32, 33]. Collaborative AR technology also allows for an alternative method to visualize and interact with multi-user maps. The Collaborative AR-GIS system is expected to improve farmers' knowledge of the land suitability map. This technology could be useful in assisting farmers with decision-making. Furthermore, it is expected that having a comprehensive understanding of the land suitability map lowers the chance of crop failure and boost agricultural productivity.

5. Conclusion

This study integrates GIS with AR visualization capabilities to visualize land suitability maps then enable multi-user collaboration work based on AR Object. This study developed an AR-GIS-based system using UNITY 3D. The built AR GIS was multi-platform based to overcome the various mobile device platforms used by farmers. This study developed AR-GIS based on android and iOS. Then use Cloud Anchors to connect one device to another. Cloud anchors can enable collaborative work between farmers and other stakeholders. Host create a room so that every user can join in the same environment. The system doesn't need markers to visualize maps objects. This study uses a plane detection algorithm to detect flat areas such as floors or tabletops. When the system can recognize a flat area, the host can initialize the cloud anchors. All connected devices in the same room will display the same object on the screen based on the anchor data stored in a cloud database. Each user can interact and manipulate map layers visualization. With cloud anchors, map layers manipulated by one user can be seen directly by other users. With this collaboration work on the map between users can be done.

The system performance is evaluated in this study utilizing two devices with specifications. The purpose of this performance test is to determine how the system responds to various tasks. This test is a performance evaluation on the developer side. This study uses two android-based devices and one iOS-based device. Based on the results of system evaluation, can be drawn following conclusion: First, all devices can connect to the server and display the map without problems. Second, the system The AR -Anchor initialization process is good so that each device can manipulate the map in a synchronized manner. Third, hardware specifications have an impact on AR-GIS performance. When showing the map on a device with a better hardware specification, the response system is faster than on the other device. Finally, Mapbox keeps all maps in the cloud. As a result, internet speed influences map loading time. Based on the evaluation results, this study concludes that collaborative AR-GIS can give good map visualization generally. Collaborative AR technology also allows for a new method to visualize and interact with multi-user maps. The Collaborative AR-GIS system is expected to improve farmers' knowledge of the land suitability map. We believe that the technology will be quite useful in assisting farmers with decision-making. Furthermore, it is expected that having a comprehensive understanding of the land suitability map is able to lower the chance of crop failure and boost agricultural productivity in the future.

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