Journal of Applied and Natural Science
16(2), 637 - 645 (2024)
ISSN : 0974-9411 (Print), 2231-5209 (Online)
journals.ansfoundation.org

Research Article

Aerial photo database model of Indonesia's national territory in a Geospatial intelligence perspective

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Article Info
https://doi.org/10.31018/jans.v16i2.5468
Received: February 6, 2024
Revised: April 29, 2024
Accepted: May 05, 2024

How to Cite
Setiawan, S. *et al.* (2024). Aerial photo database model of Indonesia's national territory in a Geospatial intelligence perspective. *Journal of Applied and Natural Science*, 16(2), 637 - 645. https://doi.org/10.31018/jans.v16i2.5468

Abstract
The National Aerial Photo Database is a collection of aerial photographs obtained through aerial photography using specific cameras or sensors with manned or unmanned aerial vehicles across the territory of the Republic of Indonesia. These photographs are stored in a computer system for easy access, management, and updating. No national aerial photo database system currently meets the need for accurate and complete aerial photos and other geospatial information to support decision-making. The present study aimed to develop a model for the National Aerial Photo Database from a geospatial intelligence perspective based on statutory regulations. The collection of aerial photo data in a centralized database commenced with scanning negative film based on location and flight paths and copying all digital data. The original negative films were scanned at 20 µm resolution in a Vexcel Ultrascan 5000 photogrammetry scanner. The resulting size of one scanned photo is 140 Mb to 160 Mb. This research adopts a qualitative research method with a case study approach. This research involved the electronic implementation of geospatial data and information by utilizing Geographic Information System (GIS) software, image and geospatial information data management, and the Scrum framework. This research concluded that geospatial intelligence efforts can better understand activity patterns, infrastructure development, and potential threats in the national territory. The insights gained from the aerial photo database aid in identifying trends, detecting anomalies, and assessing risks, all of which are critical for better decision-making in national security.

Keywords: Aerial photo database, Aeronautical charts, Geospatial information, Geospatial intelligence, Indonesia's national territory

INTRODUCTION

The significance of geographic data has seen substantial growth in the contemporary digital era, playing a crucial role in several domains of life, particularly in geospatial intelligence. Geospatial intelligence uses geographic knowledge and situational comprehension to help with decision-making procedures concerning national security. A crucial and valuable geospatial intelligence data source is aerial photography, which involves capturing photographic images from aircraft or drones for mapping and monitoring purposes. Aerial photography provides a comprehensive and detailed view of an area, offering essential insights into infrastructure, human activity patterns, land use changes, and other critical elements (Lillesand *et al*., 2015). This accurate spatial data collected through aerial photography finds application in mapping, land change monitoring, environmental analysis, and various other areas. Spatial resolution in aerial photographs is more accurate than data or information sourced from satellite imagery (Prayogo *et al*., 2020). Đorđević (2022) explains that environmental analysis can be conducted using aerial photographs taken over several years to deter-

mine geomorphological and morphometric changes in landslides.

In the context of geospatial intelligence, aerial photography contributes significantly to situational understanding, monitoring potential threats, and making strategic decisions in specific regions. National Territory is the entire territory of the Unitary State of the Republic of Indonesia, including land, sea, air, and space inside the Earth based on laws and regulations (Kementerian Pertahanan, 2020). To support geospatial intelligence efforts, the development of a national aerial photo database model becomes essential. This model is instrumental in acquiring and maintaining geographic information for various purposes.

The use of geospatial data, including aerial photography, will be governed and restricted in compliance with government regulations, especially for areas of national significance, such as vital objects, and for security in surveying and mapping. Survey and mapping security activities are primarily carried out for national defense interests, encompassing both military and non-military defense efforts (Kementerian Pertahanan, 2020). Aerial survey operators are required to submit survey and mapping data and information, including aerial photographs and other geospatial data, for defense purposes. Geospatial information comprises specific locations, geometric details (shape, distance, and dimensions), attribute information (public facilities, population, and other relevant factors), and data derived from geospatial analysis of predetermined data and information (Santos *et al*., 2005).

Geospatial data is important to be stored in a centralized and secure location to minimize the risk of potential damage or loss and its confidentiality. The optimal utilization of aerial photos in geospatial intelligence requires a well-designed database model capable of efficiently integrating, storing, and analyzing aerial photographs of the entire national territory. This database model should have the ability to manage large volumes of data, conduct spatial analysis, and link information from various sources and different image capture times. The objective is to create a national aerial photo database that encompasses aerial photographs of various scales and capture times, covering the entire Indonesian territory. In addition to this, the database would include the Indonesian topographical map and aeronautical charts, which would provide surface information and aeronautical elements to support military operations and exercises (Mabesau, 2013). Aeronautical information is information displayed on a map to assist in the implementation of flights consisting of airports, flight information, seaports, and radio facilities (Mabesau, 2023)

Intelligence refers to activities conducted using specific methods to generate products about various issues from all aspects of life, presented to decision-makers as a basis for decision-making (Kementerian Dalam Negeri, 2011). Intelligence aims to establish facts and then develop accurate, reliable, and valid conclusions (hypotheses, estimates, and predictions) for strategic decision-making or operational planning (Clark, 2013). Geospatial intelligence is an evolving discipline, technique, and art encompassing imagery, imagery intelligence (Imint), and geospatial information. It involves exploiting and analyzing imagery and geospatial information to visually depict and assess physical features and activities geographically referenced on the Earth's surface (National Geospatial-Intelligence Agency, 2018).

A nation and its armed forces are potentially vulnerable to security risks and threats without adequate geospatial intelligence. The national territory currently faces various threats and challenges, including separatism, terrorism, horizontal conflicts, land-use changes, environmental monitoring, and development policies. These threats can encompass ideological, political, economic, social, cultural, technological, and military dimensions, potentially causing significant impacts on a country's existence (Starke, 1989). Examples of threat dimensions include (a) threats to the territory involving border disputes, foreign military infiltrations, open conflicts, or cold wars; (b) threats to society in the form of ethnic tensions, criminal activities, and destruction of public facilities; (c) threats to the government, such as coups, unconstitutional revolutions, assassinations of state officials, and more.

To address these threats and challenges effectively, a complete aerial photo database and comprehensive geospatial information for the national territory are necessary as primary data sources. The utility of aerial photography in the context of geospatial intelligence can be used for surveillance and reconnaissance, target identification and detection, route and terrain analysis, damage assessment and reconstruction, and intelligence analysis (Smithsonian Institutions, 2023; Kovarik, 2011; Baker *et al*., 2004; Oluwole, 1999).

The process of managing and modeling the national aerial photo database is indeed complex, especially when dealing with the diversity of data formats and the integration and analysis of the data. Therefore, conducting research focused on modeling the national aerial photo database becomes crucial to optimize the use of aerial photography in geospatial intelligence. The agile methodology is considered suitable for this research due to its adaptive nature and responsiveness to change, aligning well with the concept of agility (Syaiful, 2015). Among various Agile frameworks, the Scrum framework is the most popular and appropriate choice (Vijay Anand and Dinakaran, 2016). Scrum is a framework designed to develop complex products (Partogi, 2015). It has been widely used in system development, with a vision to create high-value products

regarding creativity and productivity (Murdiani *et al*., 2019).

The present study aimed to develop a model for the National Aerial Photo Database from a geospatial intelligence perspective based on statutory regulations. This research adopts a qualitative research method with a case study approach. It involves the electronic implementation of geospatial data and information by utilizing Geographic Information System (GIS) software, image and geospatial information data management, and Agile software development using the Scrum framework.

MATERIALS AND METHODS

Study area

This research focused on a case study of aerial photos and geospatial information in Indonesia's new capital city. The new capital city of Indonesia is named "Nusantara" or Nusantara Capital City (IKN: Ibu Kota Nusantara). Nusantara Capital City is located in two districts in East Kalimantan Province, namely Kutai Kartanegara Regency and North Penajam Paser Regency (Fig. 1). The data collection process involved using various methods, including interviews, observations, and documentation (Archives of aerial photographs and geospatial information). The interviews were conducted with officials from the Survey and Aerial Photography Service of the Indonesian Air Force (*Dissurpotrudau*) in Jakarta. The aerial photo archives used in this research were obtained from aerial photography conducted in 2023.

Methodology

The qualitative research methodology involved data collection and documentation to compile a final report. A qualitative method is described by Creswell (2008) as an approach to comprehending a primary symptom through unstructured interviews with other individuals to gather descriptive or textual data. The aerial photo database agile method within the Scrum framework was used to develop the model. The working stages within the Scrum method are depicted in Fig. 2.

Datasets

The aerial photos, topographic maps, and aeronautical charts were used to facilitate the study. The database model for aerial photos is expected to accommodate all

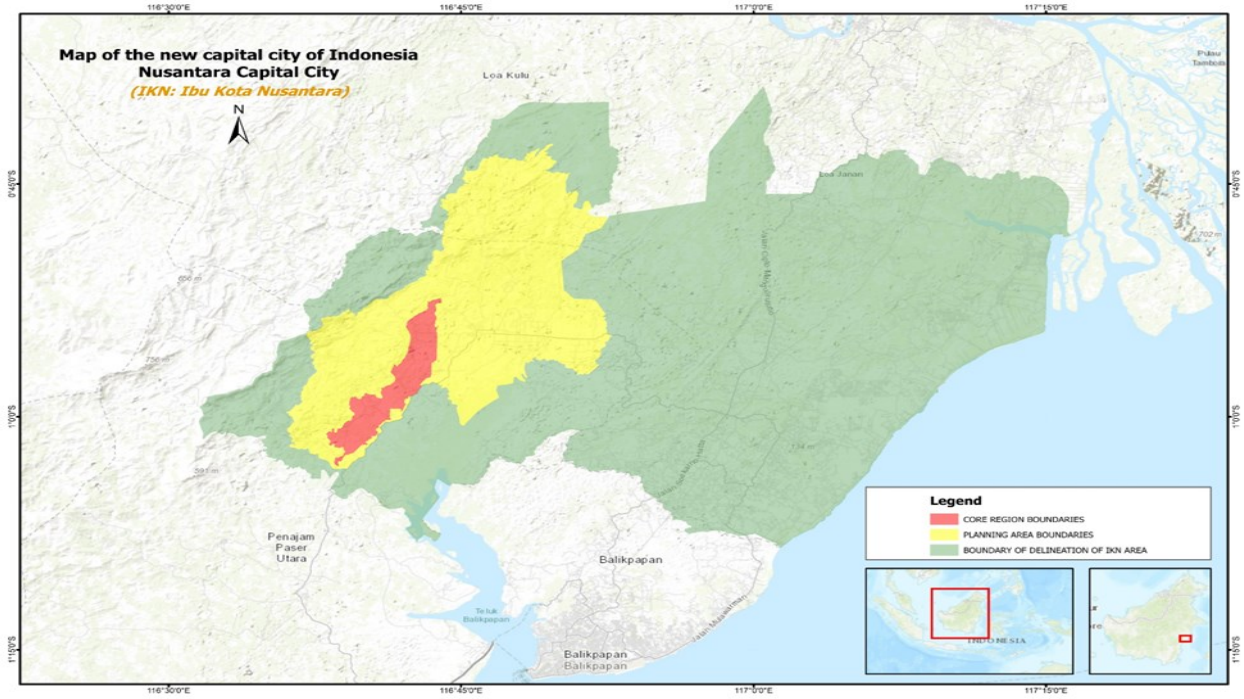

Fig. 1. *Map of Nusantara capital city (IKN: Ibu Kota Nusantara)*

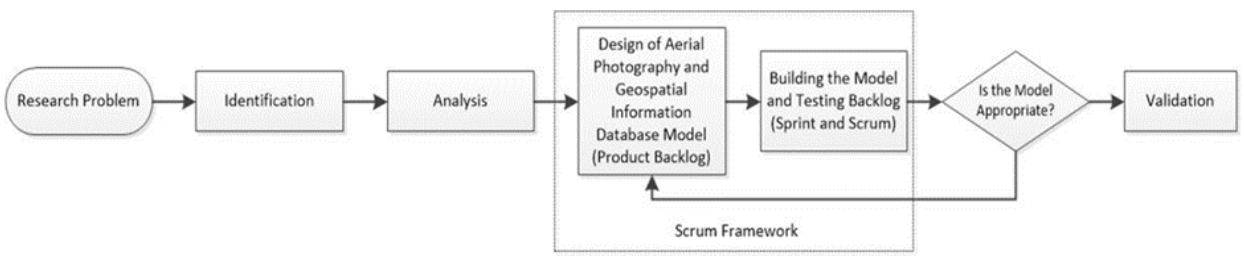

Fig. 2. *Research methodology*

types of data available in *Dissurpotrudau* and can be accessed by the public. The type of storage used for aerial images in *Dissurpotrudau* is mentioned in Table 1.

Design of database

The present study gained insight into the perspectives of individuals closely linked to the issues by exploring unstructured interviews (Jain *et al*., 2016; Kaushik *et al*., 2017; Dev *et al*., 2023) with military and government officials. In this study, the following procedures were used for managing and organizing image data:

The aerial photo data and other geospatial data were collected from various sources and periods. This step involved gathering aerial photographs and geospatial information from different sources, including government agencies, private institutions, and previous surveys conducted at various intervals.

The aerial photo mosaics were quickly automated, with an emphasis on display. The collected aerial photo data needed to be efficiently processed and combined into a mosaic to create a seamless and comprehensive view of the national territory. Automation techniques were used to speed up this process while emphasizing the display of data accurately and coherently.

The aerial photo data was integrated with other geospatial data into a centralized database. The collected aerial photo data and other relevant geospatial information, such as maps, aeronautical charts, and spatial analysis results, were integrated into a centralized database. This centralization facilitates easy access, management, and retrieval of information.

The important objects in aerial photos, such as buildings, roads, rivers, and other essential elements, were identified. This step identified and marked important objects and features within the aerial photos. This process was crucial for understanding the characteristics of the national territory and supporting geospatial intelligence analysis.

The geospatial analysis was to understand patterns and trends within the national territory. Geospatial analysis techniques were employed to analyze the integrated aerial photo and geospatial data. This analysis helps identify patterns, trends, and potential areas of interest within the national territory, providing valuable insights for decision-making.

Aeronautical charts and geospatial information were used to support decision-making and actions in creating a dashboard model of the aerial photo database. The final step involves developing a user-friendly and informative dashboard model that presents the aerial photo database, aeronautical charts, and geospatial information in a visually appealing and intuitive manner. This dashboard aids decision-makers in accessing relevant data and information for strategic planning and taking appropriate actions based on geospatial intelligence insights.

RESULTS AND DISCUSSION

Aerial photo database model

Based on observations, interviews, and analysis of aerial photo archives, it was observed that the management of aerial photos in the Subdivision of Survey and Mapping, *Dissurpotrudau*, involves the following practices:

Storing aerial photos in separate external storage media: Aerial photos are stored in various external storage devices, which can lead to inefficiencies in data management and retrieval.

Diverse data formats and incomplete aerial photo mosaics: The data collected from different sources may have varied formats, making integration and analysis challenging. Additionally, the aerial photo mosaics might be incomplete or fragmented.

Searching for aerial photos is not entirely digital: The method of searching for specific aerial photos may not be fully digitized, which can slow down the retrieval process and hinder efficient data access.

Geospatial analysis

Based on the analysis, it was evident that the national aerial photo database resulting from aerial surveys conducted by various parties did not currently have an electronic management system. The stored aerial imagery is provided by the Directorate of Regional Defense, Ministry of Defense, as the authorized agency for issuing permits for survey and mapping activities in the national territory (Kementerian Pertahanan., 2020). As depicted in Fig. 3, the aerial survey data storage facility in *Dissurpotrudau* was located separately from the Directorate of Regional Defense, Ministry of Defense. To fulfil the requirements of using aerial images as a key data source by geospatial intelligence view-

Table 1. List of Aerial survey data (1971-2023)

No	Utility	Total	Unit
1	Negative Film	5554	Roll
2	Magnetic tape	78	cassettes
3	Digital versatile disc	1520	Discs
4	Universal serial bus flash drive	159	Pieces
5	External hard drive	338	Pieces

Source: *Dissurpotrudau*, 2023

points and to mitigate the risk of data loss or corruption, it is necessary to develop a model that effectively manages and organizes the storage and use of aerial photography in adherence to relevant government regulations.

Based on a series of observations and interviews, the following requirements for an electronic management system for aerial photography were identified, which were based on time, coordinates, and location. The stages of work that have been carried out are as follows:

The collection of aerial photo data in a centralized database commenced with the process of scanning negative film based on location and flight paths and copying all digital data. Specifically, the original negative films were scanned at 20 µm resolution in Ultrascan 5000, a modern photogrammetric scanner manufactured by Vexcel Imaging Austria. The resulting size of one scanned photo is 140 Mb to 160 Mb (depending on the details on the negative films). This process resulted in the arrangement of photo frame maps per flight path, along with associated attributes. Subsequently, all aerial photo data that was digitized is standardized in format to ensure data interoperability.

The establishment of an electronic management system for aerial photography is expected to bring significant improvements in data organization, accessibility, and analysis, enhancing the effectiveness of geospatial intelligence efforts. The national aerial photo database will serve as a valuable resource for decision-making, strategic planning, and national security initiatives by following government regulations and standardizing data formats. This research utilized pre-existing digital aerial photographs of Nusantara Capital City (*IKN: Ibu Kota Nusantara*) taken in 2023. This enabled the immediate data processing to generate an entire region, as seen in Fig. 4.

The integration of aerial photos with other digital geospatial information was facilitated using Erdas Apollo software. This software served a crucial role in managing the database, particularly in creating a catalog with specific settings that align with intelligence perspectives. Erdas Apollo Geoprocessing Server enables multiple end-users within the organization to generate value-added data products by leveraging Spatial Models. These spatial models can be designed by experts and executed by any user with just a web browser and data sourced from the Erdas Apollo catalog. This approach increases accessibility and improves data processing efficiency, as it allows the utilization of powerful server

Fig. 3. *Aerial Survey Data Storage Facility in Dissurpotrudau*

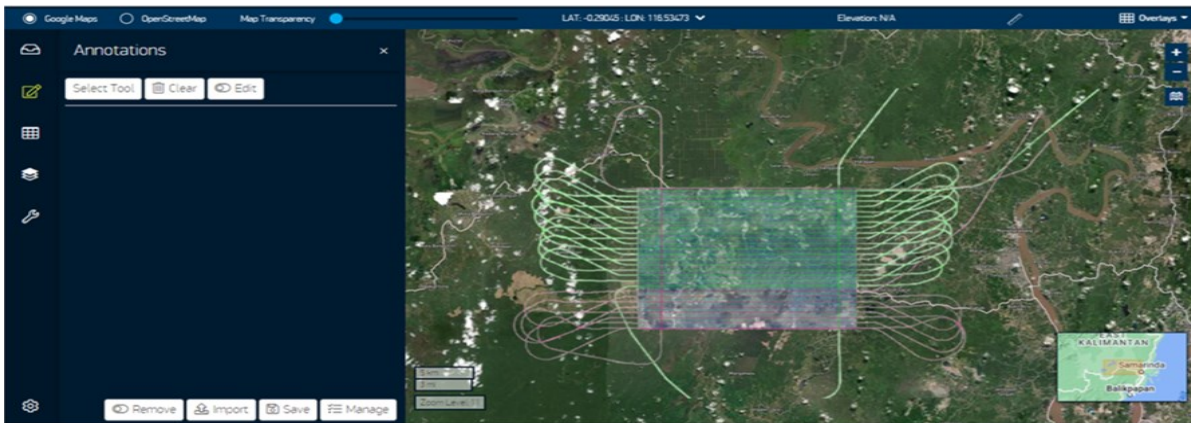

Fig. 4. *Display of aerial photo and flight paths*

hardware deployed closer to the data sources (Huang and Zhou, 2012).

The creation of an e-catalog model for the aerial photo database is a significant outcome of this integration. The results in Fig. 5 display the Indonesian National Territory Aerial Photo Database Model, where users can search and observe according to their needs. The database model shows a comprehensive catalog that provides easy access to the combined aerial photos and geospatial information. This catalog was developed using the Scrum framework, which has the advantage that applications can be completed faster, and application developers can focus more on solving the backlog that the system owner has set. This e-catalog model enhances data organizing and retrieval, making it highly valuable for geospatial intelligence activities, strategic planning, and decision-making processes.

The spatial and attribute layers were prepared for this study using ArcGIS software. A specific database was created for households, and point features were employed to represent individual households. A relationship was established as an integral part of the database to generate a decision tree for determining the first case in a household, its contacts, and household indications (Owusu *et al*., 2021). The creation of a specific database process aids in efficiently organizing and analyzing data related to households.

Furthermore, the creation of layers for various elements such as buildings, roads, rivers, military bases, installations, and training areas was accomplished through delineation on aerial photographs. This process involved marking and outlining these features directly on the aerial photos, generating distinct layers representing each element. In addition to these layers, the aeronautical map layer is also utilized as vector-based geospatial information for intelligence analysis purposes, as depicted in Fig 6.

The integration of various layers and geospatial information improved the capability of geospatial intelligence analysis, allowing joint ground forces to monitor and target the precise locations of their adversaries effectively.

Dashboard modeling within the Scrum framework with backlog options: display aerial photograph graphic data and display vector data (vital objects, rivers, roads, and buildings). Vital objects included military bases, military training areas, military facilities, and the presidential palace, which are susceptible to threats. Roads were displayed to identify potential routes enemy forces may use for ground attacks. Rivers can be utilized as transnational crime routes entering the state border areas of the province of Kalimantan. Geospatial engineering support for geospatial intelligence included standards, processes, and equipment to enable understanding of the physical environment. Fig. 7 illustrates the process of creating the model and evaluating the inventory. The illustration shows the Aerial Photo Database Model of Indonesia's National Territory, in which users can conduct searches and observation procedures based on their respective responsibilities.

Scrum framework

According to the results, digitization of aerial photograph archives possessed by the Indonesian Air Force and Ministry of Defense produced many benefits. Firstly, it significantly improved filing efficiency by eliminating the need for physical data and transitioning to digital data storage. This digital transformation allows fast-

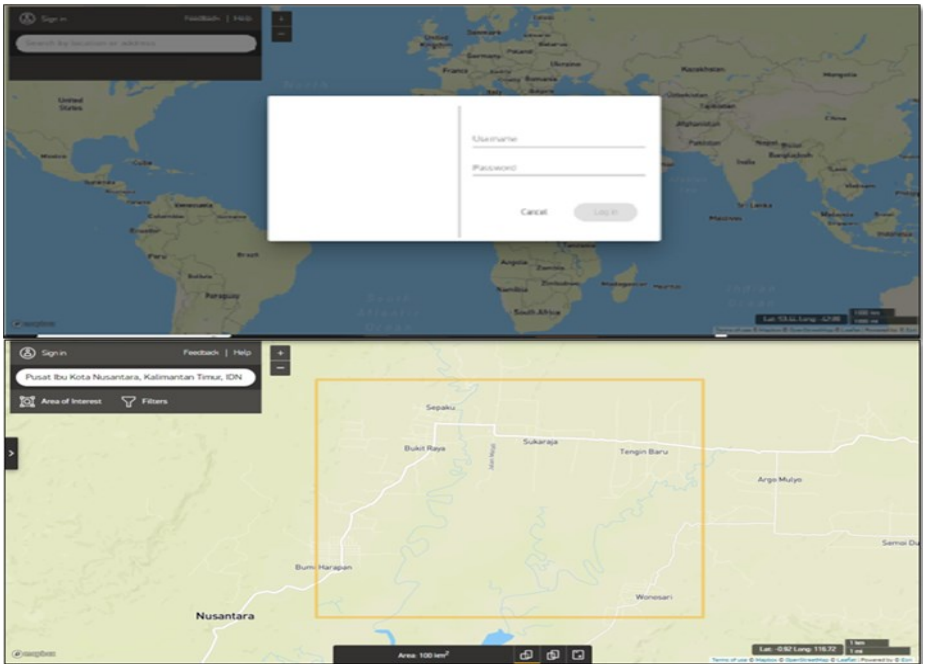

Fig. 5. *Model of the aerial photography database catalog*

er data retrieval, organization, and sharing, streamlining the overall data management process. In addition, implementing account creation and sign-in procedures on the website increases data security and user efficiency due to the digitization process. Access to the aerial picture information can be limited and managed based on user groups if users have to make accounts and sign in. Based on geospatial intelligence research, different user groups, such as users in upper-level positions, can be given different levels of access and rights based on their roles and duties. The Aerial Photo Database Model development can now be implemented effectively and efficiently using the Scrum framework.

Utami *et al*. (2022) in their paper entitled "Survey Paper: Perbandingan Agile Process Development Method (SCRUM dan RUP)" explained that the SCRUM and RUP methods have their advantages and disadvantages, so it cannot be determined which one is better. The Scrum cycle has 3 (three) stages that summarize the basic cycle, which amounts to 7 (seven) stages with 6 (six) repeating stages, used for systems that are created based on certain requests and needs (even situations or conditions) in a case with testing stages in the last process, the RUP cycle has 4 (four) stages that summarize the basic cycle totalling 7 (seven) stages with 1 (one) stage being repeated, used for systems or

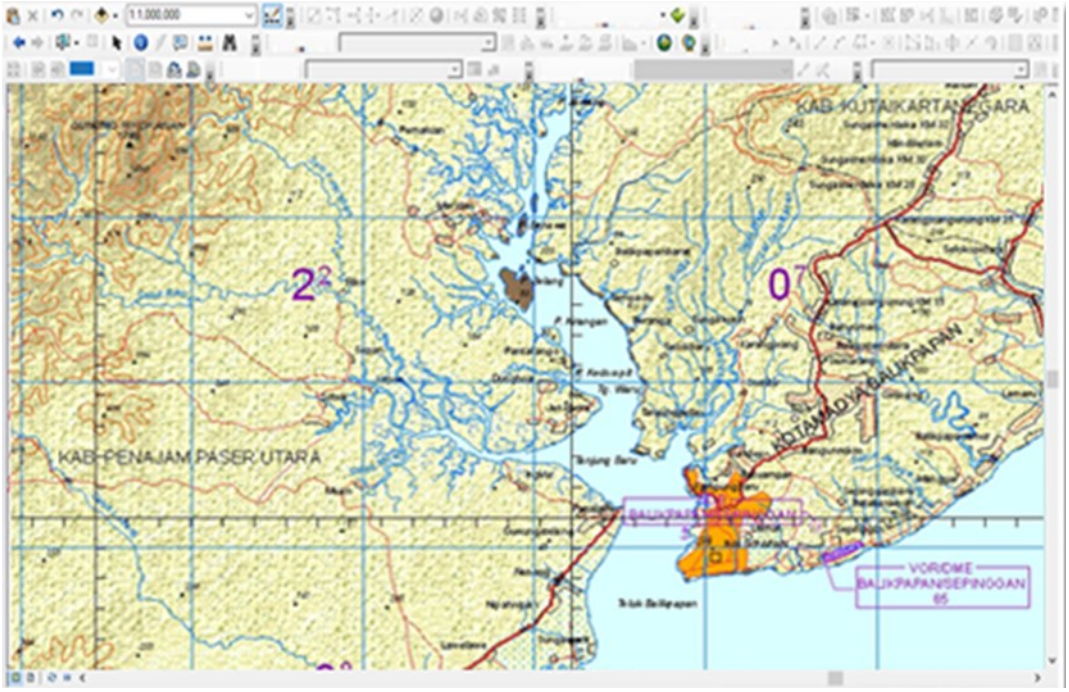

Fig. 6. *Visualization of Aeronautical map in ArcGIS (Dissurpotrudau, 2023)*

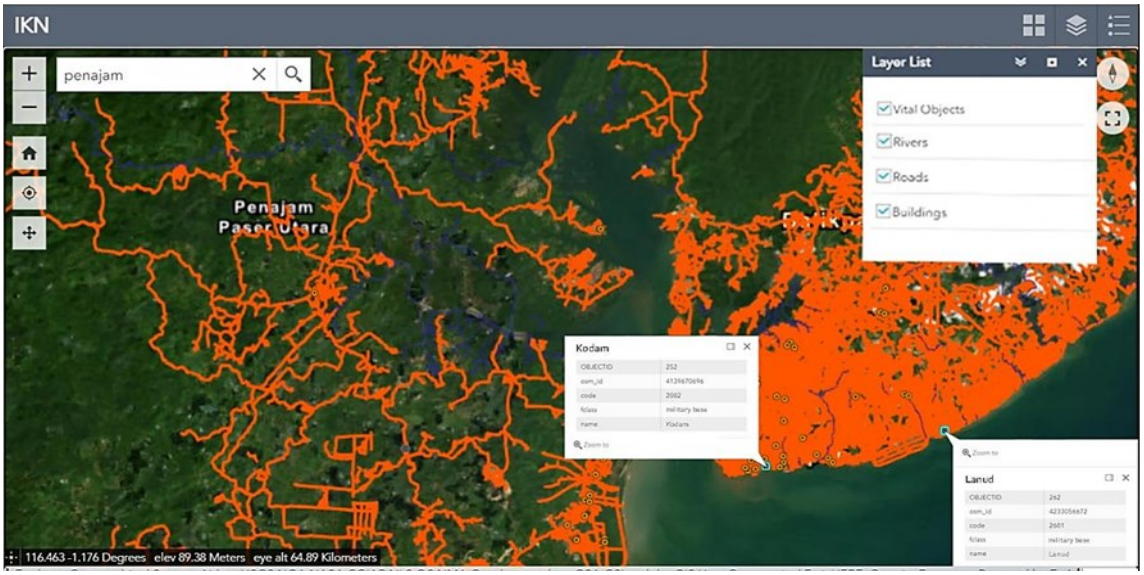

Fig. 7. *Aerial photo database dashboard showing model of Indonesia's national territory, especially the Penajam Paser Utara region*

Table 2. Cycle comparison

Basic Cycle	Scrum Cycle	RUP Cycle
Requirement Gathering	User Story	Inception
Analysis	Product Backlog	Inception
Design	Product Backlog	Elaboration
Coding	Sprint Backlog	Construction
Testing	Sprint Backlog	Inception, Elaboration, Construction
Delivery of partially incremented	Sprint Backlog	Transition
Feedback from customer	Sprint Backlog	Transition

Source: *Utami et al., 2022*

software that can be identified all needs from the beginning with general specifications and appropriate for software that has the aim of building a system from scratch that collects system needs to be built by the chosen research topic with test results in each process (Table 2).

However, based on these advantages and disadvantages, which method best suits the level of needs of system users can be chosen. In this research, the Scrum method is considered the most suitable for the creation of The Aerial Photo Database Model which involves data obtained from interviews, observations, and documentation (archives of aerial photographs and geospatial information).

Conclusion

The development of the national aerial photo database model from a geospatial intelligence perspective held immense potential and offered significant contributions to the field of geospatial intelligence. The management of aerial photos in Dissurpotrudau exhibited several limitations that can lead to inefficiencies in data retrieval, hinder access to important information, and complicate the integration and analysis of images. To align with the geospatial intelligence perspective, overcome existing problems, and protect against data degradation, following government regulations, creating a model for efficient management and utilization of aerial imagery was imperative. Using the Scrum framework, the Aerial Photo Database Model becomes a powerful tool for efficiently managing and analyzing aerial photo data across the national territory by integrating image processing technology, artificial intelligence, and geospatial database concepts.

The model shows vital objects such as military bases, training areas, military facilities, and the presidential palace, which have potential threats and require monitoring. Roads could potentially be utilized as routes for ground attacks by enemy forces. Rivers also have the potential to serve as transnational crime routes, particularly in state border areas of the province of Kalimantan. Intelligence analysis is highly dependent on accurate and credible sources of information, which must be continually updated to meet the needs of mission planners and decision-makers. The research's focus on creating a comprehensive and up-to-date aerial photo database enables intelligence analysts to have access to reliable data, leading to more accurate and informed assessments. With this model, geospatial intelligence efforts can better understand activity patterns, infrastructure development, and potential threats in the national territory. The insights gained from the aerial photo database aid in identifying trends, detecting anomalies, and assessing risks, all of which are critical for better decision-making in national security.

ACKNOWLEDGEMENTS

The authors express their profound gratitude to the Survey and Aerial Photography Service of the Indonesian Air Force (Dissurpotrudau) for providing facilities during the data collection and processing phases.

Conflict of Interest

The authors declare that they have no conflict of interest.

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