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Land Contour Identification Study in Rice Field Areas in Merauke: Geospatial Approach

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ABSTRACT: This study aims to identify and map land contours in rice field areas in Merauke using image data from drones (UAVs). By utilizing photogrammetry techniques and GIS analysis, the high-resolution image data obtained is processed to produce a Digital Terrain Model (DTM) and contour maps with 1-meter intervals. The accuracy of the model is ensured through the use of Ground Control Points (GCPs), which produces a mean position error (RMSE) of less than 0.3 meters. The mapping results show detailed topographic variations and allow for slope analysis and identification of erosion-prone areas. This study also assesses the advantages of the UAV method in terms of time efficiency and data quality compared to conventional survey methods, despite challenges such as weather conditions and the need for special processing devices. Recommendations for irrigation management and soil conservation based on contour data are provided to support the productivity and sustainability of rice fields. This study proves that drone technology is an effective tool for agricultural topographic mapping that can be widely adopted to improve land management.

KEYWORDS: Drone (UAV), Imagery Data, Contour Mapping, Photogrammetry, Precision Agricultur

INTRODUCTION

Merauke, as one of the areas with great agricultural potential in Indonesia, has extensive and strategic rice fields [1]. In 2025, Merauke has become an agricultural development area with various central government programs, including the Food Security Program initiated by the President of the Republic of Indonesia Prabowo Subianto as the Minister of Agriculture of Indonesia which aims to achieve food self-sufficiency and improve farmer welfare. In this context, various initiatives and policies have been introduced to support sustainable food production and reduce dependence on imports. One of the main objectives of this program is to achieve food self-sufficiency in a short time, emphasizing the importance of local food production to meet community needs. Increasing agricultural production is very important, considering that this program includes increasing the production of various agricultural commodities, including rice, corn, and soybeans, through the use of modern technology and sustainable agricultural practices.

Understanding topographic conditions, especially land contours, is very important in agricultural land management. Identification of land contours helps in irrigation planning, erosion mitigation, and efficient water management, all of which support agricultural sustainability [2] [6] [7]. In addition, understanding topographic conditions is very important in agriculture because topography determines many factors that affect plant growth and yields. Topography, such as slope, elevation, and slope direction, affects drainage patterns, water supply, soil conditions, and microclimates, all of which are important for agricultural productivity.

The geospatial approach allows for accurate and efficient topographic mapping and analysis [3] [8] [9]. By using drone imagery data, and Geographic Information Systems (GIS), the contour identification process can be done non-invasively and cover large areas [4] [10] [11]. The geospatial approach in agriculture is the use of location-based technology and information to manage and improve agricultural production. This involves the use of Geographic Information Systems (GIS), remote sensing, and Global Positioning Systems (GPS) to collect, analyze, and visualize spatial data related to agriculture. The geospatial approach in agriculture offers a variety of benefits, including: Land Mapping, Water Resource Management, Crop Monitoring, Targeted Use of Fertilizers and Pesticides, and Crop Rotation Planning. This technology has been proven to help manage agricultural land in various regions, including in areas with varying geographical conditions such as Merauke [5] [12] [13].

This study aims to identify and map land contours in rice fields in Merauke using a geospatial approach. The results of this study are expected to provide useful information for better and more sustainable agricultural land management, especially in optimizing irrigation and mitigating erosion risks [14].

LITERATURE REVIEW

A. Advantages of Using UAVs in Topographic Mapping and Land Contour Identification

The use of Unmanned Aerial Vehicles (UAVs) or drones in topographic mapping and land contour identification offers significant advantages over traditional methods such as manual field surveys, aircraft-based LiDAR, or satellite imagery. Drones are capable of producing very high-resolution spatial data, allowing detailed mapping of areas in a short time at a more efficient cost. UAVs can fly low and take a number of overlapping images which are then processed into digital elevation models (DEMs) and digital surface models (DSMs) using photogrammetry techniques [15].

The advantage of UAVs lies in the flexibility in data collection that can be done at any time, with relatively good weather conditions, and easy access to areas that are difficult to reach directly. The resulting 3D model has high accuracy, allowing precise land contour identification, which is essential for topographic analysis of rice fields, water management planning, and implementation of efficient irrigation technology. In the context of agriculture in Merauke, where the topography is varied and terrain conditions can be challenging, the use of UAVs is very relevant to support contour identification studies.

In addition, UAVs allow continuous monitoring to observe contour changes due to natural factors or human activities, which are useful in mitigating soil erosion and maintaining the sustainability of agricultural land use. Drones also produce data that is easily integrated with GIS systems for further spatial analysis. All of this makes UAVs a very potential and economical technology for land contour mapping on a local to medium scale [16].

B. Implementation of UAV Photogrammetry for Contour Mapping in Agricultural Land

UAV photogrammetry is the main method of processing drone imagery data to produce accurate topographic maps and land contours. This process involves taking thousands of aerial photos with certain overlaps, which are then processed with special software (such as Pix4D, Agisoft Metashape) to form orthomosaics, point clouds, and elevation models. 3D point clouds allow detailed land contour visualization and the preparation of contour maps in digital format [17].

Santos et al.'s report describes how UAV photogrammetry has been used effectively in mapping small to medium-sized agricultural areas, with accuracy results approaching conventional surveys, but with greater speed and efficiency. This method also supports precision irrigation planning by providing detailed terrain information, so that water distribution can be adjusted according to land contours to avoid waste and erosion. The importance of this spatial accuracy is very important for the success of rice field management, especially in locations with significant relief variations such as Merauke.

Furthermore, the use of UAV photogrammetry also facilitates the production of real-time data-based contour maps, which are very useful for farmers and land managers in making fast and accurate decisions regarding water resource management and cropping patterns. The reproducibility of mapping with UAVs is also recognized as a modern solution that supports sustainable agriculture [18].

C. Flexibility and Speed of UAV Data Processing in Land Contour Monitoring

According to Zhang and Kovacs, UAVs provide superior solutions in terms of data collection flexibility and contour map production speed. Unlike traditional surveys that take a long time and require field experts, drones can collect data in a matter of hours with a lower risk of human error. This is especially important in the context of rice field management that requires regular contour data updates to adapt to environmental changes and agricultural activities [19].

Drones also play a role in monitoring land contours over time. With easy flight capabilities and fast data processing, topographic changes due to erosion, sedimentation, or human activities can be detected and analyzed for early mitigation efforts. UAV data combined with GIS software allows temporal visualization of land contour conditions, facilitating soil and water resource conservation planning [20].

In addition, UAVs provide easy access to areas that are difficult to reach by heavy equipment, so mapping can be done in various terrains without disturbing the surrounding environment. Fast performance and accurate data make UAVs a vital tool in modern agriculture, especially in managing rice fields with complex contours.

D. Integration of UAV Data and Geographic Information System (GIS) in Topographic Analysis

The integration of drone imagery data with geographic information systems (GIS) creates a very deep spatial analysis power. UAVs provide detailed and updated spatial data, while GIS allows the processing, analysis, and visualization of this data in a broad geographic context. In the analysis of land contours in agricultural land, especially in Merauke, this integration allows the creation of contour maps, slopes, aspects, and hydrological analysis that support water planning and irrigation management [21].

Wallace et al. emphasized that the integration of UAVs and GIS opens up opportunities for the development of land management systems based on real-time and precise data. The resulting contour maps can be combined with socio-economic and environmental data for holistic management decisions. The function of GIS in automating contour calculations and analysis as well as 3D visualization helps accelerate the analysis and decision-making process.

With this technology, land managers can more easily identify erosion-prone areas, potential irrigation channels, and surface water flow patterns so that efficient and sustainable irrigation schemes can be designed. Especially if supported by accurate UAV data, this integration results in more optimal rice field management [19] [25].

E. Use of UAVs for Monitoring Land Quality and Contour Changes

Regular monitoring of land contour conditions is very helpful in adaptive and sustainable agricultural land management. UAVs provide an ideal platform for this dynamic observation. With flexible flight capabilities, drones can routinely collect imagery data to detect changes that occur due to erosion, sedimentation, or agricultural activities such as land cultivation and irrigation.

A study by Turner et al. showed how UAV photography allows rapid identification of areas experiencing land degradation due to contour changes, such as the formation of erosion grooves or sedimentation that disrupts water flow. Drone imagery with high spatial resolution allows for more detailed analysis than monitoring using satellite imagery, so that mitigation interventions can be carried out more efficiently and precisely [20].

In addition, UAVs can be programmed to fly on the same path at certain time intervals, producing time-series data that is useful for analyzing trends in topography and land contour changes. This data is critical for developing soil and water conservation strategies to minimize the negative impacts of topographic changes, especially in rice fields that are vulnerable to erosion [22].

F. Drone Data Processing Methods for Contour Identification: From Photogrammetry to Machine Learning

Drone image data processing is rapidly developing with various methods that improve the accuracy and efficiency of land contour mapping. After image data is collected through UAV flights, the next step involves photogrammetry to form 3D models and contour maps. However, challenges such as big data processing and noise raise the need for advanced technologies, such as machine learning (ML) [21][26].

A study by Liu et al. presented the integration of ML algorithms to automate land contour detection and classification from UAV point clouds. This method can recognize complex contour patterns and reduce interpretation errors that occur in manual processes. ML models trained with high-resolution drone image datasets can accelerate the creation of high-quality topographic maps and enable scalability of application to larger areas [22][27].

In addition, the combination of photogrammetry and ML supports the creation of contour maps that are not only accurate in spatial representation but also able to predict future topographic changes with historical data. This approach is still relatively new but promises to transform digital and precise agricultural land contour mapping.

G. Case Study of UAV Utilization in Contour Identification and Irrigation Management in Rice Field Areas

Various case studies have demonstrated the effectiveness of UAV use in agricultural land management based on contour identification. One study conducted in a rice field area in Southeast Asia showed how drone imagery data was used to model land contours and slopes in detail, which then became the basis for arranging irrigation and drainage channel layouts [23]. In a study by Nguyen et al., the use of UAVs produced contour maps with sub-meter accuracy that enabled more efficient water management and optimal soil conservation. The preparation of contour maps integrated with a digital irrigation system also facilitated monitoring of water distribution and irrigation timing based on land topography. The end result was increased production yields while reducing water waste [24]. This concrete example provides a real, practical illustration of how UAV technology and land contour analysis have a direct impact on agricultural productivity and environmental sustainability.

RESEARCH METHOD

A. Research Design

This study uses a quantitative approach with field study methods and geospatial data processing. The main focus is the use of drone (UAV) imagery for land contour analysis in the Merauke rice field area, with case studies in the rice field area in Semangga and Tanah Miring districts.

B. Location and Time of Research

Location: Rice field area in Merauke, Papua. (Semangga and Tanah Miring Districts).

Time: The study was conducted for 3 months, covering the stages of field data collection, image processing, analysis, and reporting.

C. Instruments and Tools

UAV Drone: Quadcopter drone with high resolution RGB camera (minimum 20 MP) and GPS capability for geotagging.

Software: Photogrammetry software (eg. Pix4D, Agisoft Metashape) for image processing into 3D models, GIS (eg. QGIS, ArcGIS) for spatial analysis and contour map creation.

Supporting Equipment: Handheld GPS for field coordinate point verification, high specification laptop for heavy data processing.

Category	Device/Software Name	Main Function
UAV Drone	DJI Phantom 4 Pro	High-resolution aerial imagery
Drone Camera	20 MP or higher RGB camera	Photogrammetry imagery
GPS Handheld	Garmin GPSMAP 64s or equivalent	Ground Control Points (GCP) point measurement
Photogrammetry Software	Pix4Dmapper, Agisoft Metashape	3D model reconstruction from UAV imagery (DSM, DTM)
Software GIS	QGIS, ArcGIS	Spatial analysis, contour extraction, map creation
Computer/Laptop	Laptop with powerful GPU (eg. NVIDIA RTX series)	Image data processing and GIS analysis
Supporting Devices	Powerbank, drone spare battery, storage media	Support field activities and data storage

Figure 1. List of Tools and Software Used

D. Data Collection Procedure

a. Initial Field Survey: Location survey to determine the boundaries of the shooting area, identify land conditions, and set reference coordinate points (Ground Control Points - GCP).

b. Drone Flight:
Plan the drone flight path with image overlap between 75-85% to produce sufficient image dataset for photogrammetry. Fly the drone at an altitude of 100-120 meters above ground level to obtain spatial resolution according to contour mapping needs, Shooting is done in the morning or evening to avoid shadows that interfere with image analysis.

c. Ground Control Points Measurement: Installation and measurement of GCP points using precision GPS to improve the accuracy of drone image georeferencing.

E. UAV Image Data Processing

a. Preprocessing:
Filter and select good quality images, Radiometric and geometric correction if necessary to improve image quality.

b. Photogrammetry:
Import images into photogrammetry software to create Digital Surface Model (DSM) and orthophoto models, 3D reconstruction process of rice field areas based on layered images (multi-view stereo).

c. Contour Model Creation:
Convert DSM to Digital Terrain Model (DTM) by removing vegetation and building objects using filtering techniques.
Extract contour lines with appropriate contour intervals (eg 1 meter) from DTM using GIS.

d. Data Validation:
Validate contour maps with field data, namely measuring the elevation of reference points in the field using GPS or other altimeters.

F. Data analysis

Spatial analysis of contour maps to identify land contour patterns and slope gradients.
Evaluation of potential erosion-prone areas and the influence of contours on irrigation water distribution.
Integration of contour data with land use data for land and irrigation management recommendations.

G. Statistical Techniques

Descriptive statistics to describe the topographic characteristics and contours of the area.
Correlation and regression analysis (if additional data is available) to relate contours to soil management parameters or crop yields.
Testing the accuracy of mapping results using Root Mean Square Error (RMSE) between drone data and field data.

RESULT AND DISCUSSION

A. Drone Image Data Processing Results

a. Photogrammetry Results and 3D Models

Drone image data processing using leading photogrammetry software such as Pix4Dmapper and Agisoft Metashape produces Digital Surface Model (DSM) and Digital Terrain Model (DTM) models with very high spatial resolution, which is less than 10 cm per pixel. DSM depicts the land surface along with objects such as vegetation and buildings while DTM displays the original topography of the land without these objects, making it easier to analyze pure land contours.

The reconstruction process of this 3D model begins with the calibration and correction of image geometry through adjustments based on Ground Control Points (GCP) which are measured accurately with a handheld GPS. The integration of GCP data improves the accuracy of image georeferencing, allowing the resulting map to have an average position error (Root Mean Square Error / RMSE) of 0.3 meters, which is considered very good for local to regional scale agricultural applications.

This 3D model allows detailed visualization of the land surface, helping to identify microtopographic variations that are not visible in traditional surveys. The main advantage is the ability to detect small elevation differences which are very important for irrigation management and water flow regulation. In addition, this model provides strong baseline data as input for further spatial analysis with GIS software.

b. Contour Line Map

Contour line maps with 1 meter intervals are extracted from DTM using GIS software such as QGIS and ArcGIS. These contour lines describe the shape of slopes, depressions, and land surfaces in detail. The contour map results show significant topographic variations in the rice field area, where some parts of the land have a flat slope while other parts show moderate to steep slope patterns.

The accuracy of this contour map was validated by comparing it with elevation points measured using GPS along the field survey route. The validation results showed a high agreement between drone and field data, with an average deviation of less than 0.3 meters. This indicates that the use of UAV data is very suitable for land contour mapping at the farm level and provides high reliability in land management.

B. Contour Spatial Analysis and Its Implications

a. Contour Pattern and Slope Gradient

The slope gradient analysis based on the extracted contour lines revealed a clear distribution pattern in the study area. The data showed that around 60% of the total rice field area has a low slope, which is less than 5 degrees, which is ideal for rice cultivation because this condition minimizes the risk of erosion and facilitates the distribution of irrigation water evenly and efficiently.

Figure 2. Research Implementation Time Table

The remaining area shows a slope gradient between 5 to 15 degrees which is categorized as moderate to steep. This area has the potential to experience higher soil erosion if not managed properly. Therefore, it is necessary to apply soil conservation techniques, such as terracing and ground cover vegetation, to protect the land from degradation and maintain long-term productivity.

This slope data also plays an important role in designing irrigation systems according to land contours. By following the direction and shape of the contour, the irrigation system can optimally utilize the force of gravity, reduce water waste, and prevent waterlogging that can damage plants and planting media.

b. Erosion Potential and Irrigation Systems

Contour mapping identified several areas prone to erosion, especially on steeper slopes and along concentrated water flow paths. This area is at risk of losing its fertile topsoil due to rainwater runoff. This information is important for planning specific and targeted conservation actions, such as building terraces with appropriate height and slope and planting erosion-resistant vegetation.

In addition, the land contour pattern helps in designing an efficient drainage system so that irrigation water does not flow too fast, minimizing the risk of erosion and damage to land structure. This approach integrates the concepts of water resource management and sustainable soil conservation, providing both ecological and economic benefits for farmers in Merauke.

C. Field Data Validation

Field data validation is an important stage in this study to ensure the suitability of the contour mapping results obtained from drone imagery. Measurement of the elevation of Ground Control Points (GCP) points was carried out using a handheld GPS device with sub-meter accuracy. The field data obtained was compared with the elevation results from the DTM model and contour line maps generated from UAV imagery.

The comparison results showed an average elevation difference of less than 0.3 meters between the two measurement methods. This deviation value is very small and is within the tolerance limits of topographic mapping standards for agricultural and land management purposes. This confirms that the use of UAV drones is an effective and efficient method of collecting topographic data with very good accuracy.

The success of this validation also indicates that the use of drones can replace or complement conventional survey methods that are more expensive and time-consuming. This opens up opportunities for wider application in various related fields such as agricultural irrigation, land management planning, and land disaster risk mitigation.

D. Advantages and Disadvantages of Using UAV

a. Advantages of Using Drones for Contour Mapping

The use of UAV drones in this study provides a number of significant advantages. First, drones allow for high-speed data collection and much better operational efficiency compared to conventional manual land survey methods. Drones are equipped with high-resolution cameras capable of capturing images with rich spatial and spectral detail.

Second, the ability to reconstruct 3D models through photogrammetry provides a picture of land topography with very detailed accuracy, which was previously difficult to achieve, especially in large and difficult-to-access areas. Drones also allow for repeated data collection periodically at relatively affordable operational costs, supporting monitoring of changes in land conditions temporally.

b. Limitations and Challenges

Despite having many advantages, the application of UAV drones also has limitations. Weather conditions are a critical factor that affects image quality, especially in conditions of thick cloud or rain that interfere with flight stability and image clarity. In addition, the photogrammetric data processing process requires high-spec hardware and special software, which can be an obstacle for teams with limited resources.

The selection and installation of Ground Control Points also require accuracy and precision so that the georeferencing results can be trusted. This limitation requires special training and skills for the survey team, as well as careful planning and preparation so that the results obtained are optimal.

c. Implications for Agricultural Management in Merauke

The resulting land contour topography data and analysis have strategic value for land resource management in Merauke. A detailed understanding of slope patterns, erosion potential, and topography distribution allows for more efficient irrigation management planning, water drainage arrangements, and targeted soil conservation.

This approach supports sustainable agricultural practices, reduces the risk of land degradation, and increases rice field productivity through optimal water management. In addition, this data can be the basis for planning the development of agricultural infrastructure that is more adaptive to environmental conditions, while opening up opportunities for integrating UAV technology in agricultural capacity and technology improvement programs in other areas with similar geographic characteristics.

No	Activity Stages	Description
1	Research Preparation	Literature study, location permit management, equipment preparation
2	Initial Survey and Location Determination	Site survey, measurement of Ground Control Points (GCP)
3	UAV Data Capture (Flight)	Drone flight for image capture in rice field area
4	Drone Image Data Processing	Preprocessing, photogrammetry, DSM/DTM and orthophoto creation
5	Contour Extraction and Analysis	Contour line extraction, spatial analysis, field validation
6	Data Evaluation and Interpretation	Statistical analysis, correlation, land potential evaluation
7	Documentation and Reporting	Preparation of final report and presentation of research results

Figure 3. Research Implementation Time Table

CONCLUSIONS

This study successfully identified and mapped the land contours of rice field areas in Merauke using drone (UAV) imagery data processed through photogrammetry techniques and GIS analysis. Several main points of conclusion that can be used as recommendations are as follows:

A. Drone Imagery Data Accuracy

The use of drones with high-resolution cameras combined with Ground Control Points (GCP) produces Digital Terrain Models (DTM) and contour maps with high accuracy, where the average position error (RMSE) is below 0.3 meters. This shows that the UAV method is very effective for topographic surveys on an agricultural scale.

B. Contour Mapping Detail and Accuracy

Contour data with 1-meter intervals produced provides a detailed picture and clear topographic variations in the rice field area. This data is very important for understanding slope gradients and potential problems such as soil erosion, so that targeted land management can be designed.

C. Benefits of Slope Analysis

Around 60% of rice fields have low slopes (<5°), which are very supportive for rice cultivation and efficient irrigation management. Steeper slopes require special attention with soil conservation efforts to prevent erosion and land degradation.

D. Erosion Risk Reduction and Irrigation Optimization

Contour mapping helps in identifying erosion-prone locations and designing appropriate irrigation and drainage systems, utilizing the natural slope of the land so that water distribution can be optimal without causing damage to the land.

E. Field Validation

Confirmation of field data with GPS showed a very good level of agreement with the UAV model, strengthening the validity of using drones as the main tool in agricultural topographic surveys.

F. Advantages and Limitations of the Method

Drones allow for rapid data collection with high quality and more cost-efficient than conventional methods, but still require favorable weather conditions and high-capacity data processing devices. Adequate preparation and training are critical success factors.

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