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Boundary Line Extraction of Forest Land for Cadastral Resurvey Using UAV and GIS

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Abstract

Objectives: The purpose of this study is to propose a way to extract the boundary lines of forest land using a UAV and GIS for small forest area including the cadastral resurvey project zone, and then show its feasibility for the project by analysis of its accuracy. **Methods/Statistical analysis:** High-resolution orthophotos of the selected test area were obtained through UAV photography. These images were used to extract the boundary line of the forest land, and the result was compared with the boundary setting results of existing cadastral resurveys for analysis. **Findings**: For the accuracy of the UAV orthophotos produced, the RMSE of connection errors of X and Y coordinates was calculated as ± 0.0668 m, which appeared applicable to the boundary setting of the forest area. The produced images and GIS data were used to extract the boundary lines of the forest area, which was compared with the boundary determination results of existing cadastral resurveys, and most of them were highly coincident. **Improvements/Applications:** In some areas, the boundary lines were not coincident, due to characteristics of the boundary setting of existing cadastral resurveys. It was expected that it was possible to make these coincident if additional adjustments were applied.

Keywords: Cadastral Resurvey, Forest Area, Gis And Boundary Setting UAV

1. Introduction

In Korea, to resolve the problem of cadastral non-coincidency between the actual land boundary and that on the cadastral record, a lot of effort has been made to promote the cadastral resurvey project since 1995. As a result of such effort, the Special Act on Cadastral Resurvey was enacted, the execution of the cadastral resurvey project was planned for about 20 years from 2012 to 2030, and the project is proceeding in its fourth year as of 2015. The term "cadastral resurvey project" refers to a national project executed to replace existing official cadastral records with new official cadastral records in digital format and to correct descriptions registered in official cadastral records, if records do not accord with the actual conditions of the land, by conducting investigations and surveys of descriptions registered in official cadastral records (Article 2 of the Special Act on Cadastral Resurvey). Building the correct digital cadastral information by correcting inconsistencies between the land usage statuses registered on the cadastral record and the actual status has been promoted not only to establish infrastructure for advanced national land administration but also to protect people's land property rights. The cadastral resurvey project currently in progress is focused on the land parcels where collective cadastral non-coincidency occurred, which accounted for approximately 15% of the entire country. Other land areas were deemed coincident and have been converted to the global coordinate system by using the global coordinate transformation method.

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However, in the case of other land areas, no specific detailed methods have been proposed except the principle that the global coordinate transformation method would be used. This is because forest land areas are relatively wide and the application of the ground surveying method and GPS surveying method is restricted. Specifically, areas registered as forest land have poor surveying conditions due to mountainous areas and trees. Therefore, since the current ground surveying method is limited to resurveying, the project period has been prolonged. Recently in the spatial information sector, technologies are being studied on how to accurately obtain ground location information in the form of images, using surveying methods such as 12cm level aerial photogrammetric and UAVs (unmanned aerial vehicles)[1,2]. More accurate and efficient cadastral resurvey is considered feasible for forest areas if it is possible to find a cadastral resurveying method using such new technologies.

Previous studies have been performed on obtaining spatial information using a UAV in various spatial information fields[3,4,5]. Relating to extraction of land boundary lines in the cadastral area, studies have been performed to set the boundaries of forest area using the high-resolution aerial photogrammetric surveying method[6,7]. In addition, to extract forest land boundaries, studies have been performed using the digital mapping method and the DEM (digital elevation model)[8]. Previous studies mainly used high-resolution aerial photogrammetric images to set forest land boundaries. However, the target areas of the cadastral resurvey project are mostly lands with relatively small forest area. Therefore, for the forest area, the UAV method is more efficient than aerial photogrammetric surveying, which is more suitable for a large-sized area.

The purpose of this study was to propose a way to extract the boundary lines of forest land using a UAV and GIS for the cadastral resurvey project, and then show its feasibility for the project by analysis of its accuracy.

2. Basis and Method of Cadastral Resurvey for Forest Area

For the cadastral resurvey project, the Special Act on Cadastral Resurvey and its basic plan specifies the surveying standards, methods, and procedures. In more detail, according to the basic plan (Notice No. 2013-122 of the Ministry of Land, Infrastructure and Transport), the cadastral resurvey project is supposed to build the digital cadastral record using the world geodetic system transformation result if coincident and to build it by cadastral resurveying if not. In other words, except for areas of collective cadastral non-coincidency out of the total parcels, digital cadastral records are being built by world geodetic system transformation, and digital cadastral records for collectively and individually non-coincident areas are being built by developing new cadastral records through cadastral resurveying. The total project area subject to the world geodetic system is 37.53 million parcels, of which 5.54 million parcels are collectively non-coincident areas, 4.98 million parcels are cadastral confirmation surveying areas, and 27.01 million parcels are other areas[9]. The Special Act specifies that control surveying should be conducted by satellite surveying and total station surveying, and detailed surveying should be conducted by satellite surveying, total station surveying, and aerial photogrammetric surveying. It specifies that the cadastral control points should be within ± 0.03 m and the boundary points within ± 0.07 m for the surveying results.

Since the Special Act currently in force specifies the aerial photogrammetric surveying along with the ground surveying method for the cadastral resurveying method as above, it is possible to use not only the ground surveying method but also the aerial photogrammetric surveying method when setting the forest area boundaries. Since the UAV is included in the scope of the aerial photogrammetric surveying, it was considered that there was no problem in applying the UAV method.

3. Test and Analysis

3.1 Test Area Selection and Ground Control Point Observation

In this study, the whole area of Dunbangnae-ri, Dunnae-myeon, Hoengseong-gun, Gangwon-do, Korea was selected for the study area to test the forest area boundary setting using a UAV and GIS for the cadastral resurvey

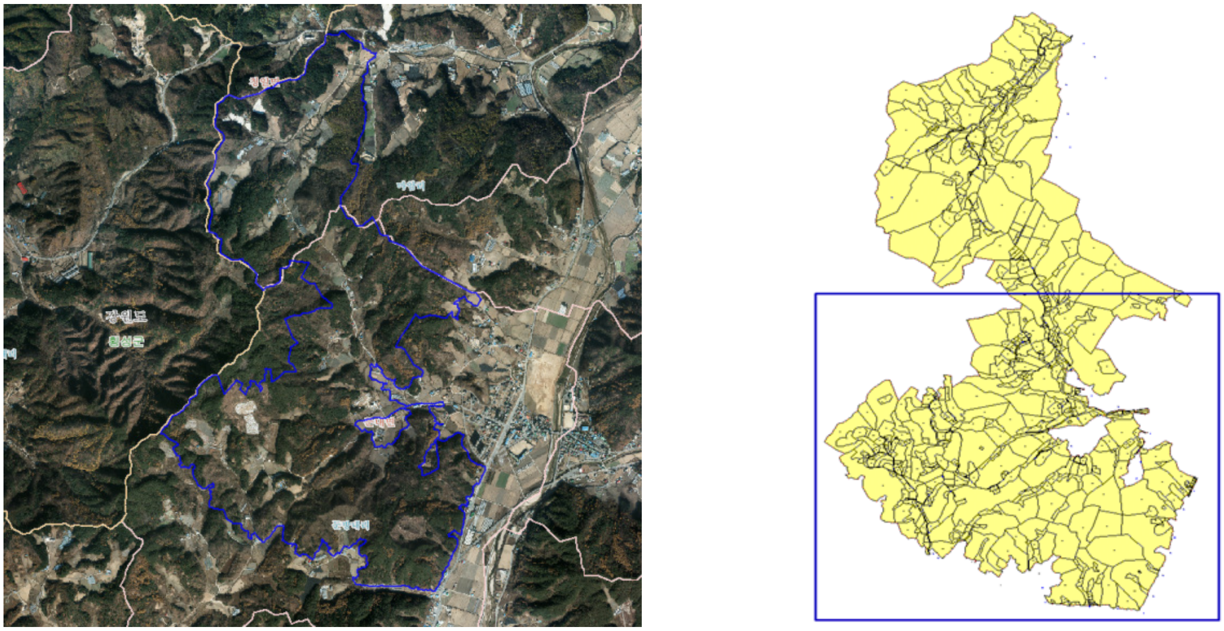

Figure 1. Location Map and Cadastral Map of Test Area (Scale: 1:6,000).

project. The test area was composed of valley-type farmlands and hills, and its spatial range was 4 km north-south and 2 km east-west. The area and number of parcels of forest land were 3,671,000 m^2 and 100 parcels. Since this area had the highest number of forest land parcels in the project zone for the cadastral resurvey project, it was most

Figure 2. Installation of Ground Control Point and RTK GPS Observation Station.

suitable for the test surveying. In addition, it was selected because the cadastral resurvey project was completed and it was possible to compare its results with the test surveying results for analysis. Figure 1 shows the location map and the cadastral map of the test area.

To perform geometric correction on acquired images and to verify their accuracy, ground control points and checkpoints were installed and RTK GPS (real-time kinematic GPS) observation was performed on a total of 80 installation points. Utilizable ground structures were also selected as checkpoints in addition to the checkpoints with signals for aerial survey. In other words, tombstones and crosswalks were selected as structural checkpoints. Figure 2 shows a GCP and RTK GPS observation station installed in the test area.

3.2 UAV Photographing and Orthophoto Production

For the test area, ground control points and checkpoints were installed and observed and UAV photography was performed. A fixed-wing UAV, TopoDrone-100, was used for photography on November 11, 2015. The area was photographed over two sessions, and an automated flight path was planned for each session. The photographing elevation was set to 100–150 m to ensure the image resolution below 5 cm. The flight speed was set to 60 m/h, the overlapping ratio to 30%, and the photographing width to approximately 120 m. (Figure 3)

The Pix4D software was used for data processing to produce the precision orthophoto from the acquired photographic images. The orthophoto was produced on a scale of 1:1,000 to match 1:1 with the cadastral map. For image restitution, the individual images were merged using the GPS location information at the time of image acquisition, and the second precision restitution was conducted on the first restitution images using the location measurements of signals for aerial survey installed at the ground control points (GCPs). After image restitution, the point cloud was created to create the digital surface model. Coordinate values of images and ground points were used for geometric correction and were transformed to the cadastral coordinate system. Figure 4 illustrates the high-precision orthophoto and the DSM data produced through data processing.

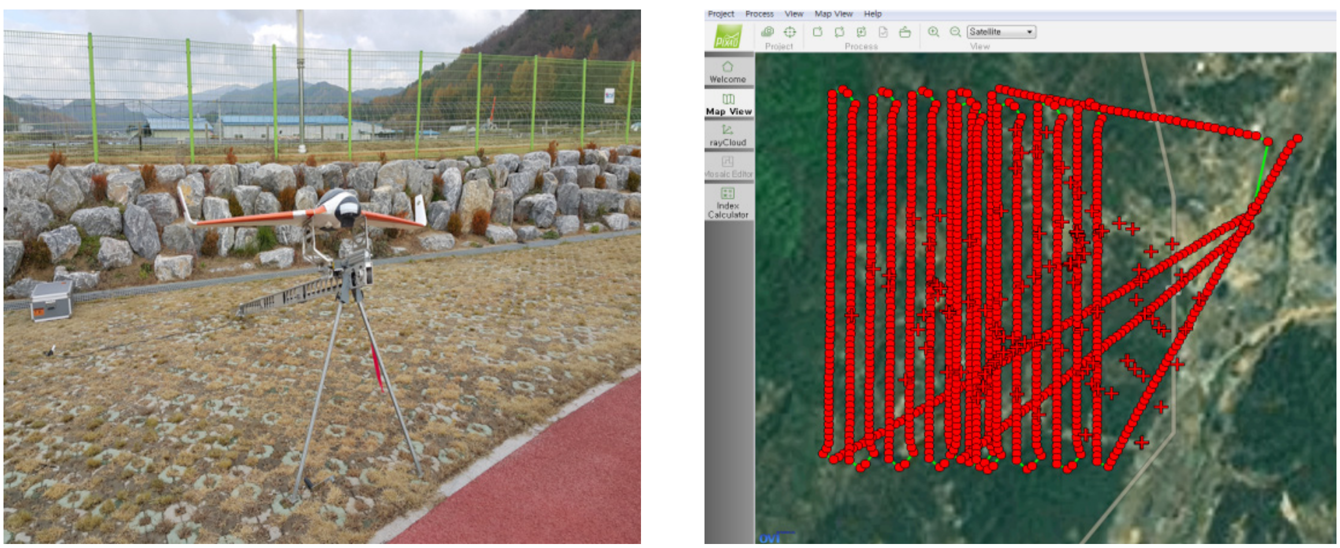

Figure 3. UAV and Photographing Path.

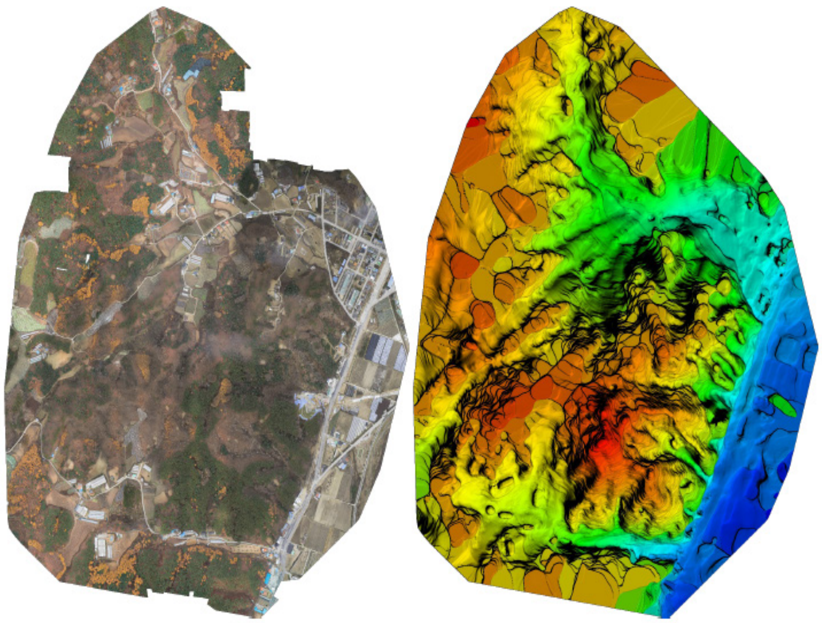

Figure 4. Orthophoto and DSM Data of Test Area

3.3 Boundary Extraction and Accuracy Analysis

Prior to the boundary extraction test for the cadastral resurvey of the forest area, the accuracy of the geometric correction and the accuracy of the image checkpoints used to produce the orthophoto were analyzed. First, for the geometric correction accuracy, the RMSE (root mean square error) of the X coordinate was calculated as ± 0.0085 m and that of the Y coordinate as ± 0.0096 m, which appeared very good. And for accuracy verification of the image checkpoints, the RMSE of the X coordinate was calculated as ± 0.0432 m and that of the Y coordinate as ± 0.0509 m. accordingly, the RMSE of the connection error was calculated as ± 0.0668 m, which proved that the images produced in this study were accurate to approximately 7 cm on average. Since the Special Act on Cadastral Resurvey currently specifies the error allowance of the boundary point of a parcel to be 7 cm, these images were within the error allowance and were considered acceptable for use in the boundary setting of the forest area.(Figure 5)

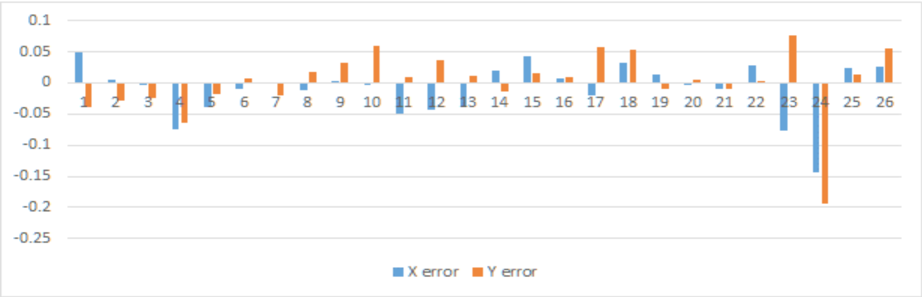

Figure 5. X and Y Errors of Checkpoints.

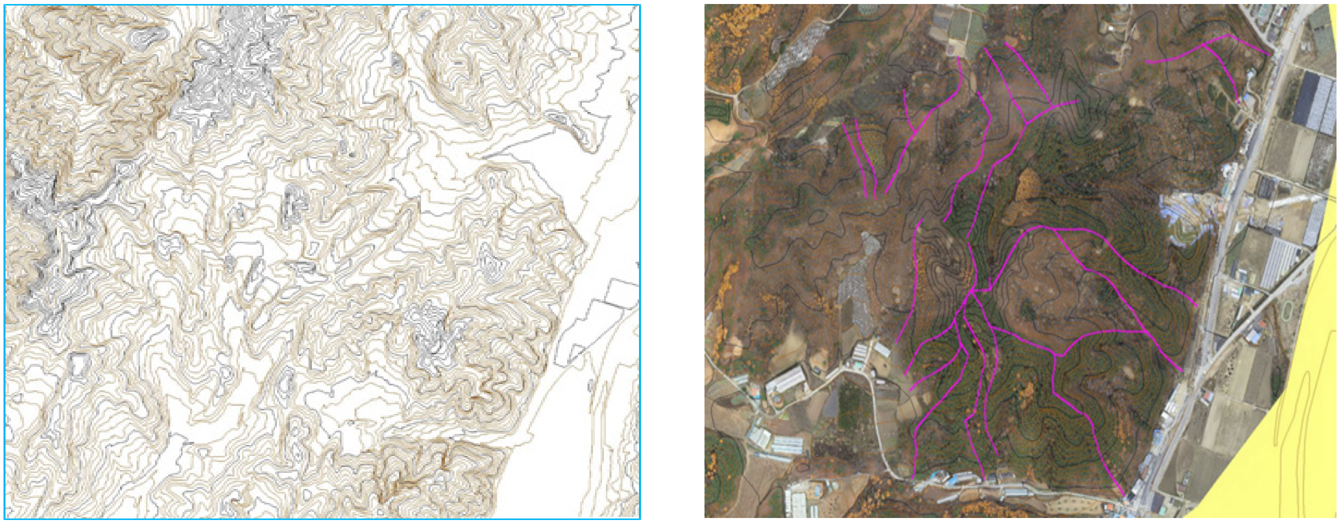

Figure 6. Contour Line Data of Test Area and Boundary Line Extraction.

The produced orthophotos were used to extract the boundary line of the forest area. The boundary line extraction was based on the linear boundaries of valleys and ridges according to the boundary setting method for forest area specified in the current Special Act on Cadastral Resurvey. In addition, contour line data were overlapped to increase extraction accuracy. Figure 6 illustrates contour line data of the test area and the boundary line of the forest land extracted as they were overlapped in the images.

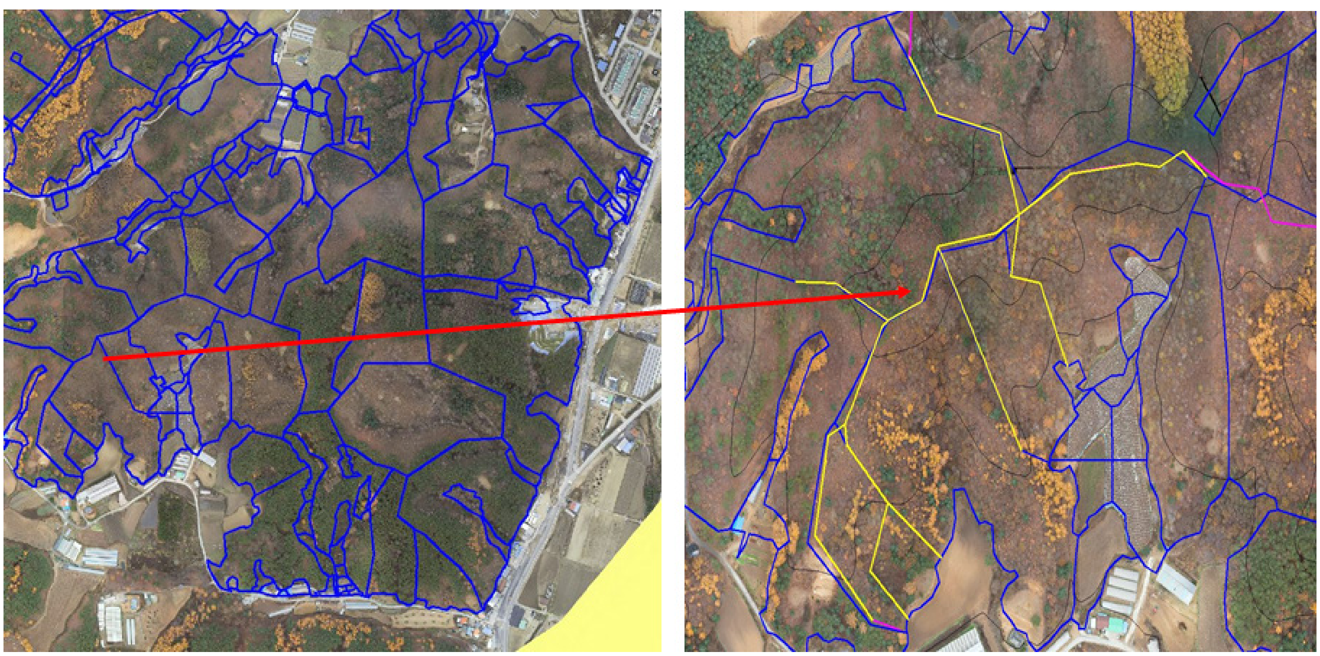

Figure 7. Existing Boundary Determination Record Overlapped with Image-Extracted Boundary Line.

Overlap analysis was performed with the boundary determination results from the existing cadastral resurvey to analyze the accuracy of the extracted ridge lines. By the analysis result, most of them were coincident with existing boundary determination records; however, they were partially non-coincident. It was determined that this was because the forest area boundary during the cadastral resurvey project was inaccurately based on the boundary status to minimize the difference with the areas on the existing records. In addition, by the nature of the forest land boundary setting, the boundary status was often inaccurately reflected and non-coincidence occurred. Consequently, it was expected that coincidence with the boundary of the existing cadastral resurvey would be improved more if the initial boundary line extracted is further adjusted through comparison with the existing forest land boundary line. Figure 7 illustrates the existing boundary line of the existing cadastral resurvey overlapped on the one extracted from the UAV orthophoto in this study.

In this study, to increase the efficiency of the forest land boundary line extraction from UAV images, an automated method was additionally explored using GIS data, which is widely used for spatial analysis in the spatial information sector[10]. The approach used was to automatically extract the ridge boundary lines using contour line data and to match it on the orthophoto. The GIS Arc View software was used for the ridge boundary line extraction. The brief procedure was as follows: The Arc View extensions 3D Analyst and Spatial Analyst were used for their 3D Analyst, Spatial Analyst, and Hydrologic Modeling file menu functions. Then, the contour lines (7111 for the intermediate contour and 7114 for the index contour) were extracted from the digital topographic map (1/5,000), the TIN and DEM were generated using the "Convert to grid" function. After the generated DEM was loaded, the Hydrologic menu was used to extract the ridge boundary (forest land boundary). Figure 8 illustrates the ridge automatically extracted in this study and overlapped with the existing forest land boundary.

When the automatically extracted valley and ridge boundaries were compared with those extracted from UAV images in this study for analysis, they were considered highly coincident overall. In addition, since difference errors occurred at a level that the operator could fully correct for, it was considered that the automated method would be more objective and improve accuracy better than manual extraction. It was considered that accuracy would be improved if the automated method were used to extract forest land boundaries; however, the data would be re-checked and adjusted rather than directly using it as the basis for extraction.

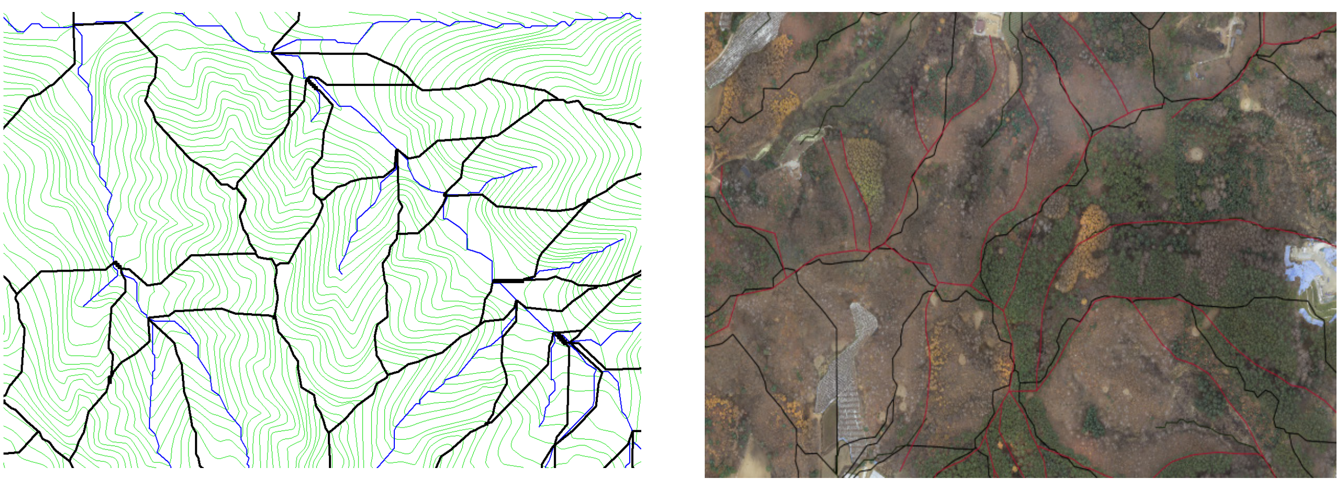

Figure 8. Ridge Boundary Extracted Result Overlapped with Forest Land Boundary.

4. Conclusion

The purpose of this study was intended to propose a way to extract the boundary lines of forest land using a UAV and GIS considering the nature of the forest area cadastral resurvey project in Korea, and then show its feasibility for the project by analysis of its accuracy. Derived study results were as follows:

First, the test area was selected and UAV photography was performed. As the result of analysis of the accuracy of acquired images (checkpoints were used), the RMSE of the X coordinate was calculated as ± 0.0432 m, that of the Y coordinate as ± 0.0509 m, and that of the connection error as ± 0.0668 m. These were within the error allowance (7 cm) specified by the current law, and thus it appeared that there was no problem in applying it to the forest area boundary setting.

Second, the produced orthophotos were used to extract the boundary lines of the forest land and these were analyzed by overlapping them with the boundary determination records of the existing cadastral resurvey. Analysis results showed that these were mostly coincident with the existing boundary determination records. Some boundary lines were non-coincident due to the boundary setting nature of existing cadastral resurveys. However, it was determined that there would be no problem if additional adjustments are made, and therefore it is a feasible surveying method.

Finally, to enhance the extraction work of the forest land boundary, an automated extraction method was explored using GIS data in this study. The extraction result appeared coincident overall when compared and analyzed with the boundary lines extracted from the UAV images. However, there were some partially non-coincident areas. It was considered that adjustment of the boundary lines should be used in these areas.

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