Using UAV technology for basic data collection of *Firmiana danxiaensis* H. H. Hsue & H. S. Kiu, J. S. (Malvaceae), an important, nationally protected wild plant in Zhanglao Peak, Danxiashan Mountain, South China

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Abstract. The protection of rare species is an urgent task for all of mankind, however this task is challenging because it is usually difficult to determine their numbers and spatial distribution. *Firmiana danxiaensis* H. H. Hsue & H. S. Kiu, J. S. (Malvaceae), which is listed at the highest grade of critically endangered (CR) plants in the first volume of “The China Species Red List,” can be found at Danxiashan Mountain, one of the six World Nature Heritage sites of China Danxia, in Northern Guangdong Province, China. At present, UAV low-altitude photogrammetry technology can complete and produce orthophoto maps of 1:2000 resolution and high-precision DEM data, and has a high application value in the collection and research of rare species’ basic data. For this study, UAV technology was used especially for mapping, quantifying and monitoring plant species. *F. danxiaensis* is a good fit for automated identification from UAV imagery due to its leaf coloration making it stand out during the end of October. A fixed-wing UAV was used to aerially survey the Zhanglao Peak Tourist Area of Danxiashan Mountain (the aerial survey area is 4.25 km²) and the valleys and cliffs where it is difficult to conduct field surveys. 638 high-precision image data were obtained. Photoscan software was used to produce mosaic image data, an orthophoto map, and DEM data. Analyses of the targets’ locations and data visualizations were done with Arc GIS 10.5 software. 1,515 individuals of *F. danxiaensis* have been found in the aerial survey area. The results suggest that the red line boundary of ecological protection should be delineated in the densely distributed areas of *F. danxiaensis*, and scientific research plans should be formulated to protect the rare species and their natural environment so as to ensure sustainable development and utilization for human beings.
1. Introduction

Rare species are the common wealth of all humankind. They reveal important information about the origins of species, phylogenetic evolution, genetic breeding, reproductive ecology, medicinal applications, paleogeology, paleoclimate, etc. [1] Therefore, it is an urgent task to conserve these valuable resources. The losses will be enormous and irreparable without timely strengthening of our understanding of conservation best practices via basic data investigations, research and protection before the species are extinct. However, it has been difficult to accurately investigate the number and spatial distribution of rare species, which has brought great difficulties to scientific research and protection.

Danxiashan Mountain is an example of the large areas of Chinese plant regionalization. It is located in the north of “South China” and is part of the “China-Japan Forest Plant Sub-region.” [2] Danxiashan Mountain is an important base for plant provenance and plant genealogy because of its rich and diverse vegetation type [3]. In addition, its unique Danxia landforms [4-7] have allowed for the preservation of a large number of rare and endangered species. At present, the representative rare plants found at Danxiashan Mountain have Firmiana danxiaensis H. H. Hsue & H. S. Kiu, J. S. (Malvaceae); Danxiaorchis singchiana J. W. Zhai, F. W. Xing et Z. J. Liu (Orchidaceae); Spiradiclis danxiashanensis R.J.Wang (Rubiaceae); and Viola hybanthoides W. B. Liao et Q. Fan (Violaceae), etc. It is of great significance and urgency to strengthen the investigation of basic data of rare species in Danxiashan Mountain, obtain accurate data and formulate scientific research and protection plan. More scientific research must be conducted in order to discover and confirm the potential economic, medical, and phylogenetic values of Firmiana danxiaensis. Our research team (2017) [8] discussed the micro-geomorphological environment of slopes in the intensive zone of F. danxiaensis, which is found in the Yangyuanshan Tourist Area (top-left of Figure 1). We provided relatively accurate spatial locations of F. danxiaensis in this small regional distribution zone of Danxiashan Mountain (Figure 1). The urgent problem now is to conduct research on the population and distribution of F. danxiaensis in the Zhanglao Peak area (Figure 1). Therefore, this study used a fixed-wing UAV aerial survey to quickly obtain accurate image data and identify the population and position of the rare species of F. danxiaensis.
2. Method

UAV low-altitude photogrammetry technology not only has the advantages of convenient transportation, but also has the advantages of fast and convenient image acquisition, flexibility, safety, less vulnerability to weather conditions, multi-angle (perspective) image acquisition, high resolution, and is economically superior in comparison to traditional remote sensing technology [9]. A low-altitude aerial survey UAV generally flies under clouds, using a CCD digital camera as its sensor. It is capable of vertical and inclined photography, it carries a GPS positioning device, and can obtain texture data of the side of the target object from multi-angle photography, which solves the problem of occlusion of high-rise buildings encountered by satellite remote sensing and general aerial photography.

At present, UAV low-altitude photogrammetry technology can quickly complete the production of a 1:2000 orthophoto map and high-precision DEM data (the resolution can reach 0.2m). The image data acquired by a UAV aerial survey with ground image control points can meet the requirements of 1:500 mapping (the resolution can reach 0.05m) after intensive computerized matching. This technology can be used to construct high-precision digital terrain models and three-dimensional landscape maps, and has a great application and popularization value in the visual analysis of data collected from a rare species resource survey, and the delineation of an ecological protection red line[10].

3. Data collection in the field

Plants usually have their own feature recognition periods, such as flowering, fruit bearing, leaf discoloration, and others. These stages are the best times for investigation and data collection. *Firmiana danxiaensis* blossoms purple from May to June every year, and leaves fall off after yellowing at the end of October. During this period, leaves of other trees in Danxiashan Mountains remain green. So *F. danxiaensis* has obvious seasonal differences with other surrounding plants, and is easy to identify and obtain data from UAV aerial surveys.

The data were acquired via a fixed wing aerial survey on October 20, 2018. The weather was cloudy to clear, with a slight breeze. The fixed-wing UAV model used in this aerial survey is MTD-100. The length of the UAV fuselage is 1.23m, the wing is 1.8m, and the weight of the airplane is 1.5kg. The material of the UAV is made of EPO, airborne Sony RX1 camera with a focal length of 35mm and a maximum resolution of 6000X4000. The control mode is fully automatic driving after a hand-thrown take off (Figure 2). Also it has a parachute recovery capability (Figure 2). The UAV can fly for 80 minutes and has a maximum flight speed of 120 km/h. Its single voyage operation area can reach 8-20 km². Its aerial survey accuracy can reach 5 cm, which greatly improves the efficiency and accuracy of data acquisition. The main parameters of this aerial survey are as follows: altitude 718m; course overlap 80%; side overlap 65%; course distance 168m; shooting distance 64m; survey area 4.25 km²; ground resolution 8cm. This flight lasted 44 minutes, and 638 aerial photographs (4.78GB) were obtained, which successfully completed the data acquisition work.

![Aerial survey research area by fixed-wing UAV.](image)
In order to increase the accuracy of the image mosaic in the later stage, South S86RTK (Figure 3) was used for data acquisition of ground image control points. The image control points were selected in open areas, the bubble of the level instrument was kept in the middle, and the data was received by hand-held GPS. The data accuracy may have reached 2 cm, which is based on the latest national standard: 2000 coordinate system: CGCS2000_3_Degree_GK_CM_114E_3°Zone, part of the image control point data acquisition is shown in Table 1.

![Field collection and acquisition data of image control points.](image)

**Table 1.** Data of image control points.

| Number | DX/m       | DY/m       | DZ/m   |
|--------|------------|------------|--------|
| G1     | 475116.565 | 2771301.849| 81.18  |
| G2     | 474468.098 | 2770307.952| 82.143 |
| G3     | 473814.812 | 2769952.094| 76.593 |
| G4     | 473049.024 | 2768922.035| 76.589 |
| G5     | 475467.866 | 2770086.083| 90.754 |

4. **Image and DEM data Production**

4.1. Using Agisoft photoscan software for image mosaic, orthophoto map and DEM data production

After acquiring the aerial survey images, the next work needed was to produce the aerial survey image mosaic, orthophoto map and DEM data. The software Smart 3D, Pix4D, Agisoft Photoscan are commonly used for this. Pix4 image processing is fast and efficient but does not allow for interactive edits of aerial triangulation data. The Smart 3D cluster operation is suitable for a large area image mosaic and three-dimensional modeling. Agisoft Photoscan functions excellently with aerial triangulation and has a high fault-tolerance rate. It is suitable for image mosaics in small areas. Its main functions include automatic aerial triangulation encryption, automatic camera calibration, automatic result definition, DEM, DOM mapping, automatic generation of dense point clouds, automatic modeling and so on. This research used Agisoft Photoscan to produce DEM and DOM data. In the software, to produce the area’s orthophoto, the menu bar tools - "workflow" - - "adding photos", "aligning photos", "building dense point clouds" (left of Figure 4), "generating grids" and "generating textures" (right of Figure 4) were successively employed. Finally, the Orthophoto Image (left of Figure 5) can be exported to .TIF, .JPG, .PNG or .KMZ formats. The DEM digital elevation model can be exported to .TIF format (right of Figure 5).
Figure 4. The image mosaic of dense point clouds (left) and texture generation (right) in Agisoft Photoscan.

Figure 5. The final image data (left) and DEM data (right) produced by Agisoft Photoscan.

4.2. Arc GIS 10.5 used for target searching, image segmentation and point data addition. The image data accuracy (ground resolution 8 cm) collected by UAV low altitude (718 m altitude) can meet the requirements of visual identification of the rare species *Firmiana danxiaensis*. The image data produced by Agisoft Photoscan (left of Figure 5) is imported into Arc Map 10.5. The image data are divided into 470 images (Figure 6) (scale 1:1000) according to the range of 100mX100 m in length and width to find the number and position of *F. danxiaensis* in every one of the 470 maps respectively.

Figure 7 is an image map of the northeastern part of Shaoyingting. On the image, we can visually identify many *Firmiana danxiaensis*. However, in the field survey of Danxiashan Mountain, under the cover of trees, visual observation is unable to observe and count these 50 rare species of *F. danxiaensis*, which leads to incomplete statistical information. This is also one of the reasons why the results of a field visual survey are lower in number than reality.
Figure 6. Three of 470 image maps segmented by Arc GIS 10.5 (The yellow leaves are *Firmiana danxiaensis*).

Figure 7. Image map of *Firmiana danxiaensis* on the cliff near Shaoyingting.
After visual recognition, right-click on the layer of points of *F. danxiaensis* in ArcGIS 10.5 software, open the table attributes, calculate the coordinates (X, Y) of each point in the table through the "Calculate Geometry" function, and calculate the elevation of each point through the ArcToolbox-Spatial Analyst Tools-Extraction-values to points command. In this way, data for each plant in the aerial survey area: coordinates (X,Y values) and elevation data, can be obtained (part of the data are shown in Table 2). This human-computer interaction searches for the rare species of *F. danxiaensis* in large scale (1:1000 or so) and small range (100mX100m) image data, which greatly improves accuracy and efficiency. Finally, the locations of 1,515 individuals of *F. danxiaensis* in the entire aerial survey area are positioned on the image and DEM data (Figures 8-9).

**Table 2.** The coordinates (X, Y) and elevation values (last column, unit meter) of each *Firmiana danxiaensis* calculated and obtained from the attributes of the ArcGIS 10.5 table.
Figure 8. Data superposition of *Firmiana danxiaensis* to image in the aerial survey area.

Figure 9. Data superposition of *Firmiana danxiaensis* to DEM in the aerial survey area.

5. Conclusions
Use of UAV photogrammetry technology to obtain rare species image data, image mosaics, target recognition, extraction and data visualization combined with application of computer software to obtain the number of rare species and their spatial distribution, has the advantages of high speed, low cost and high accuracy. In the investigation and study of rare species resources in small areas, this method has high value in popularization and application. At present, UAV photogrammetry technology can complete 1:2000 orthophoto maps and DEM data production. The image data with ground control points can meet the map accuracy requirement of 1:500 after intensive matching with computer software.
In this study, the fixed-wing MTD-100 UAV was used to aerially survey 4.25 km² of Changlao Peak, and 638 image data were obtained. Agisoft Photoscan was used to densely match images, and produce orthophoto map and DEM data. Finally, using ArcGIS 10.5, batch data segmentation, target recognition and data visualization analyses were carried out to obtain the number and position of 1,515 individuals of *Firmiana danxiaensis* in the aerial survey area. At present, research on the number and spatial distribution accuracy of *F. danxiaensis* in the Zhanglao Peak of Danxiashan Mountain is relatively high, and the research results are authentic and credible.

The rare and endangered plant species *Firmiana danxiaensis* is a kind of drought tolerant plant which growing mainly along very narrow sites of Danxia cliffs with joints or beddings of thin barren soils [11]. Suggesting the conservation of the rare plant in the limited sites could be increased by extending their range by active propagation and planting.

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