DRONE REMOTE SENSING FOR THE CONTROLLED CAPTURE OF SIKA DEER (*Cervus nippon*): CASE STUDY IN VILLAGE OF YAMANAKAKO

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KEY WORDS: UAV, drone, thermal image, sika deer, controlled capture.

ABSTRACT:

In recent years, the population of sika deer in Japan has been increasing, causing animal damage. As for sika deer in the vicinity of the village of Yamanakako, Yamanashi Prefecture, although the total number of individuals is on a downward trend due to the controlled capture that has been conducted throughout the year since 2009, the number of individuals (population) that stay in the vicinity of residential areas (villa areas) has been increasing in recent years. Unmanned aerial vehicle (UAV) or drone has been proven as an effective tool in wildlife research. In particular, thermal images are useful for relatively large mammals such as deer. In this paper, the utility of drone remote sensing using RGB and thermal video is tested for controlled capture of sika deer as a case study in the village of Yamanakako. We develop a methodology to acquire data and to visually identify sika deer specifically for this mission. As a result, the drone remote sensing was considered successful completing within 1 hour and identifying 25 sika deer individuals. Thermal video format was effective to visually identify sika deer on site in terms of time savings, compared to RGB video or RGB/thermal still image format. To have flight area grided and hovering 3 seconds at the centre of a grid during the flight was essential both for visually identifying the number and location of sika deer and for sharing such information later with beaters and shooters using a map.

1. INTRODUCTION

In recent years, the population of sika deer in Japan has been increasing, causing animal damage. As for the sika deer in the vicinity of the village of Yamanakako, Yamanashi Prefecture, although the total number of individuals is on a downward trend due to the controlled capture that has been conducted throughout the year since 2009, the number of individuals (population) that stay in the vicinity of residential areas (villa areas) has been increasing in recent years. As a result, there has been no end to the number of reports of damage such as traffic obstruction and feeding damage to plantings. In the past, sika deer were mainly chased away because the use of firearms was restricted in residential areas, and there are risks associated with the use of traps, such as erroneous trapping, easy exposure of captured animals to the public, and the attraction of black bears. However, chasing them away is not very effective these days, since they prefer staying in residential areas and become less wary of people. Therefore, Yamanakako-mura Government Office decides to conduct experimental controlled capture of sika deer by firearms in Fuji Iyashinomori Woodland Study Center (FIWSC), the University of Tokyo Forests, where locates in residential areas and the use of firearms is normally restricted, hoping to increase the deer's alertness to people.

Unmanned aerial vehicle (UAV) or drone has been proven as an effective tool in wildlife research (Christie et al., 2016). In particular, thermal images are useful for relatively large mammals such as deer (e.g. Maki et al., 2020; Ito et al., 2020; Chretien et al., 2016; Oki et al., 2019; Mcmahon et al., 2021). Ito et al. (2020) compared the result of sika deer population census between drone census by a thermal infrared camera, DJI Zenmuse XT ZXTB19FP and the block count method by walk on Kinkazan Island, northeastern Japan. The drone was manually piloted recording video as well as still image to collect coordinates of visually identified sika deer. It was concluded that the result of drone census over evergreen forests needs to be corrected, however it would be applied with similar or better accuracy than the block count method by walk in other vegetation area. Similar comparison between drone census by a thermal infrared camera, DJI Zenmuse XT and a light census by walk on the boardwalk was made by Maki et al. (2020) for sika deer in Ozegahara, Japan. In the drone census, they used still image taken by auto piloted drone to visually identify sika deer and found that the survey efficiency of the light census was higher than that of the drone, however, the number of deer detected by drone was more than four times higher. Therefore, it was suggested the use of combination of both methods in this area. Some research utilize machine learning method to identify and count animals using data acquired by UAV. Zhou et al. (2021) used RGB image to detect and count four animals: cattle, horses, Canada Geese and white-tailed deer by deep learning neural networks. They found that the ResNet model produced a 99.18% overall accuracy in animal identification. Oki et al. (2019) incorporated a machine learning into Tensorflow Object detection API using thermal images and improved identification of sika deer from approximately 64% to 68%, however, it was concluded that the method needs to be further improved.

In this paper, the utility of drone remote sensing is tested for controlled capture of sika deer as a case study in the village of Yamanakako. In almost all the previous studies using drone to identify and count animals has been aimed to obtain census data and the actual data processing was conducted later indoors. The challenge of this study is that identification of sika deer and its location must be done on site and shared the information with beaters and shooters immediately before hunting. We develop a

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methodology to acquire data and to visually identify sika deer specifically for this mission and evaluate its efficiency.

2. MEHODS

2.1 Study area

Study area covers a part of FIWSC and adjacent Yamanakako Forest Park of Literature in the village of Yamanakako, Yamanashi Prefecture, Japan (Figure 1) and is approximately 47 ha. The area is on the shore of Lake Yamanakako at the foot of Mt. Fuji and one of the most famous resort areas in Japan. The forest is in the upper part of the cool temperate zone, where planted Japanese larch *(Larix kaempferi*) forests dominate the canopy, while a variety of broadleaf trees in the sub-temperate to shrub layer are interspersed. It extends on a gentle slope from 990 m to 1,060 m above sea level on the shore of Lake Yamanakako. The average annual precipitation at the nearby AMEDAS Yamanaka station for the past 10 years (2011-2020) is 2,355mm, the average annual temperature is 9.9 ℃, and the minimum temperature is -19.4 ℃. In winter, the larch and broadleaf trees fall leaves, which provides good visibility of forest floor from above. The area is in national park reserve and hunting is normally prohibited.

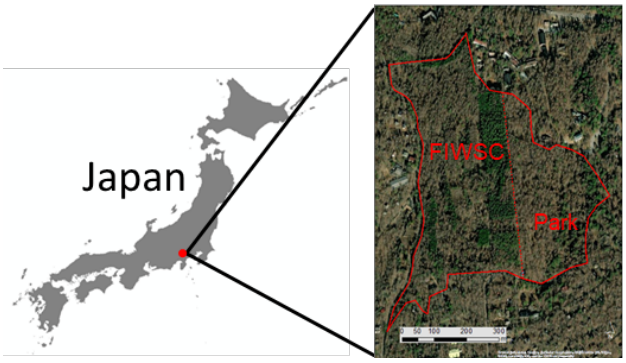

Figure 1. Study area (red line) covers Fuji Iyashinomori Woodland Study Center (FIWSC), the University of Tokyo Forests and adjacent Yamanakako Forest Park of Literature in the village of Yamanakako, Yamanashi Prefecture, Japan.

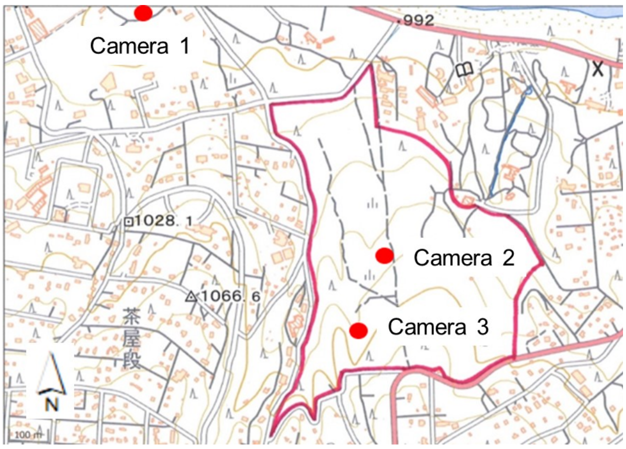

Figure 2. Location of sensor cameras (Camera 1-3) in FIWSC. Red line shows the study area.

Camera / year	2012	2013	2014	2015	2016	2017	2018	2019	2020
Camera 1 head	620	181	259	387	363	248	396	1247	849
Max month /head	12 /178	11 /44	6 /81	6 /90	5 /63	12 /76	1 /73	1 /428	1 /162
Camera 2/ head	811	883	511	669	742	986	1839	2116	2292
Max month /head	12 /302	12 /215	12 /273	1 /100	7 /144	12 /218	12 /381	1 /300	1 /395
Camera 3/ head	473	807	484	769	607	1041	1013	1747	1050
Max month /head	11 /146	11 /130	8 /89	12 /152	7 /123	6 /212	7 /157	7 /280	6 /231
Total head	1904	1871	1254	1825	1712	2275	3248	5110	4191

Table 1. Number of sika deer recorded with sensor cameras in FIWSC.

2.2 Capture plan of sika deer

Capture of sika deer was scheduled in the morning of December 15, 2021. This time of a year was selected based on the number of sika deer recorded with sensor cameras in FIWSC (Figure 2) and the forest condition. The month which recorded maximum number of sika deer in a year has been mostly December followed by January since 2012 (Table 1). Since there is normally a risk of snow accumulation in January, which prevents easy access to the forest, December was a better time for this plan.

Overall schedule of the day begins at 7 o'clock in the morning with a drone survey to identify the location of sika deer in the study area. Drone flight and identification of sika deer is carried out by 2 persons, respectively. Additional 4 persons are allocated to monitor drone flight at the edge of the flight area. As soon as their location is identified, the information is passed to beaters and shooters (totally 10-15 persons). Security guards (7 persons) are positioned surrounding the study area. The beaters enter through the assigned entrance points into the eastern side of the study area, then drive sika deer towards shooters who station at the western side of the study area (Figure 3). Capture was planned in two ways; shooting and trapping which placed behind the shooters around the western edge.

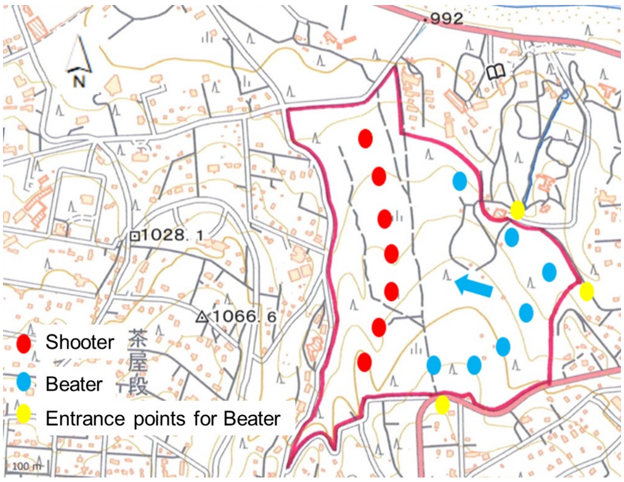

Figure 3. Location of shooter (red circle), beater (blue circle) and entrance points for beater (yellow circle). Red line shows the study area.

2.3 Drone remote sensing

We used DJI Phantom 4 RTK for RGB video and Mavic 2 Enterprise Advanced (M2EA) for recording RGB and thermal video. The reason why we choose video instead of image is to allow for rapid confirmation of sika deer by visual inspection on site. We need to pass the information of sika deer location to beaters and shooters right after the drone survey and do not have time to analyse image with coordinates. Both drones use network RTK for positioning system. Flight altitude was set as 80 m from the ground. Flight area covers mainly east side of the study area, since sika deer is driven from the east side by beaters. The flight area was grided and numbered from 1 to 59 (Figure 4). The size of the grid is 70 m × 49 m for No.1- No.47, and 62 m × 54 m for No.48 -No.59. These are a little smaller than the area which the sensors project at the flight altitude of 80 m. We conducted 3 autopilot flight missions using DJI GS Pro for Phantom 4 RTK and DJI Pilot for M2EA; Phantom 4 RTK flies from No.1 to No.47 (flight mission 1), M2EA does from No.1 to No.47 (flight mission 2) and from No.48 to No.59 (flight mission 3). The drones are programmed to fly at the speed of 25 km/h and stops at the centre of each grid hovering for 3 seconds, then fly to next grid and repeat the same action, while video is recoding all the time.

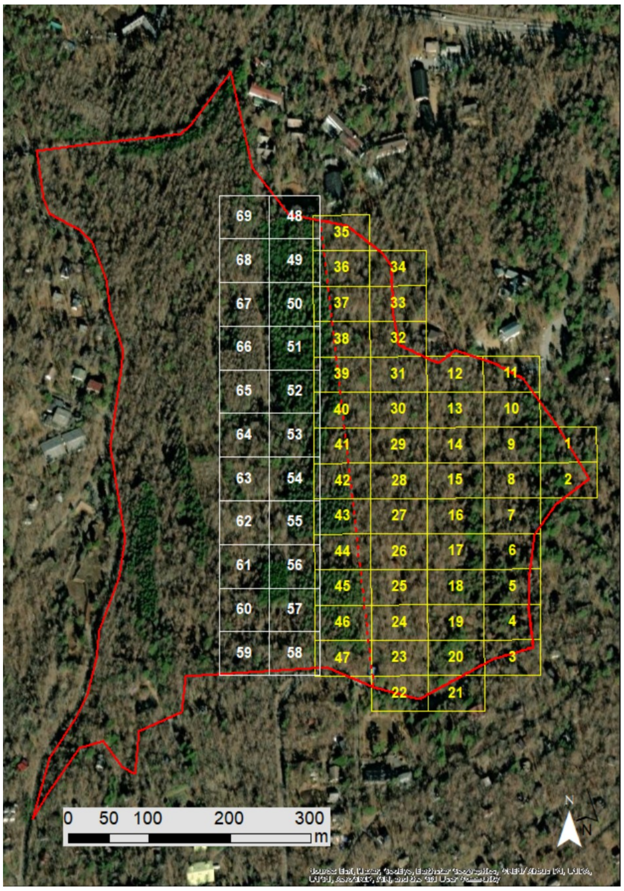

Figure 4. Flight area is grided and numbered. Phantom 4 RTK and M2EA fly at the altitude of 80 m from the ground, from No.1 to No.47, and from No.48 to No.59 hovering at the centre of each grid for 3 seconds.

2.4 Identification of sika deer

Identification of the location of sika deer was carried out on site. We set up a mobile identification station on site using a car (Figure 5), bringing a mobile power generator, a laptop pc connected to a 32-inch monitor and a printed map of the grided flight area (same as Figure 4). Right after each flight mission, memory card is passed to the identification team. The video of each flight mission is projected on the monitor and the presence of sika deer is visually inspected. If sika deer is identified, the number of sika deer is written in the grid on the map, which is shared with beaters later. In this way, the location of sika deer can be shared with beaters who drive sika deer towards shooters.

Figure 5. A mobile identification station to identify sika deer in the video acquired by a drone. It consists of a mobile power generator, a laptop pc connected to a 32-inch monitor and a printed map of the grided flight area.

3. RESULTS

3.1 Drone remote sensing and identification of sika deer

The flight mission of Phantom 4 RTK was completed in approximately 15 minutes including set up and actual flight of 8 minutes 25 seconds. Acquired movie file was immediately investigated by the identification team. The RGB image was clear, however, it was too dark to see the forest floor where evergreens and trees are dense (Figure 6a). Where larch trees are sparse, the forest floor was easily visible (Figure 6b), however, not a single sika deer was identified.

As for M2EA, the drone remote sensing took approximately 30 minutes including set up and two actual flights of 12 minutes 23 seconds and 5 minutes 35 seconds. Grid No. 58 and No. 59 were removed from the flight mission on site because these places were most distant from the drone home point and radio communication between a controller and the drone was unstable. As a result of investigation of the thermal video (Figure 7 & 8), totally 25 sika deer individuals in 10 grids were identified in the study area.

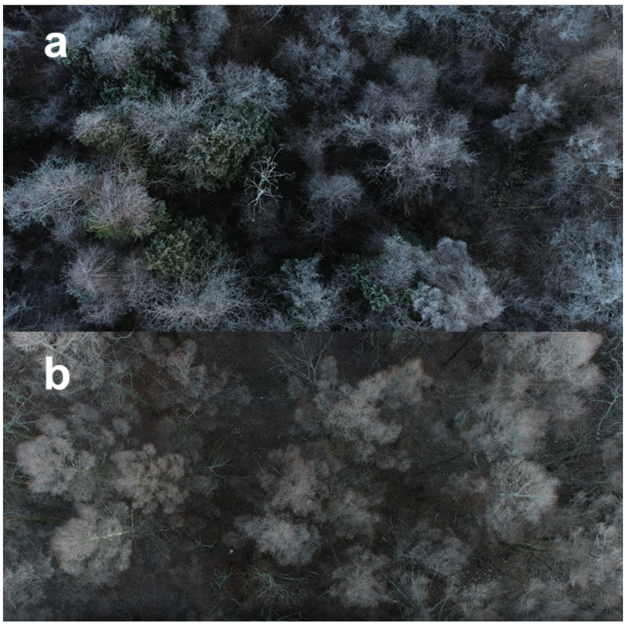

Figure 6. Screen shots of movie file acquired by Phantom 4 RTK; evergreens and dense trees (a) and sparse larch trees (b).

3.2 Capture of sika deer

The number and its location of sika deer was immediately handed over to the beaters (Figure 9). They started taking up their position in the study area (Figure 10), however, it was reported that a herd of approximately 20 sika deer escaped from the area. Furthermore, another herd of 6 sika deer was also witnessed running away from the area. Consequently, hunting was a failure.

4. DISCUSSION

The drone remote sensing to identify sika deer for controlled capture was completed within 1 hour just before hunting. The number of sika deer identified was comparable to those witnessed by beaters in the study area. It was considered successful although the capture was not.

The spatial resolution and projected area of RGB video, which acquired by Phantom 4 RTK, was higher and larger than that of thermal video. However, it was found to be impossible to visually identify sika deer in the RGB video. In some area, the forest floor was too dark to see because of evergreens and dense trees (Figure 6a). In other area, the forest floor was visible (Figure 6b), however, it was still difficult to find sika deer. This is because the colour of the deer's back was the same shade as the ground, and sika deer was resting and not much active in early morning, which made identification difficult. Identification of sika deer might be better if there is snow on the ground. With the thermal video which acquired by M2EA and coloured by relative temperature, it was easy to find sika deer in the image (Figure 7b). The temperature during the drone remote sensing was below freezing. Most of the things in the image was in blue colour except thermostatic animal such as sika deer and sun-exposed tree canopy (Figure 7b), which made visual inspection easier. We also found that sika deer was detectable under deciduous canopy (Figure 7b) and even in coniferous stands (Figure 8b) in the thermal image, while it was impossible in the RGB image (Figure 7a & 8a). This could be a great advantage to use thermal image.

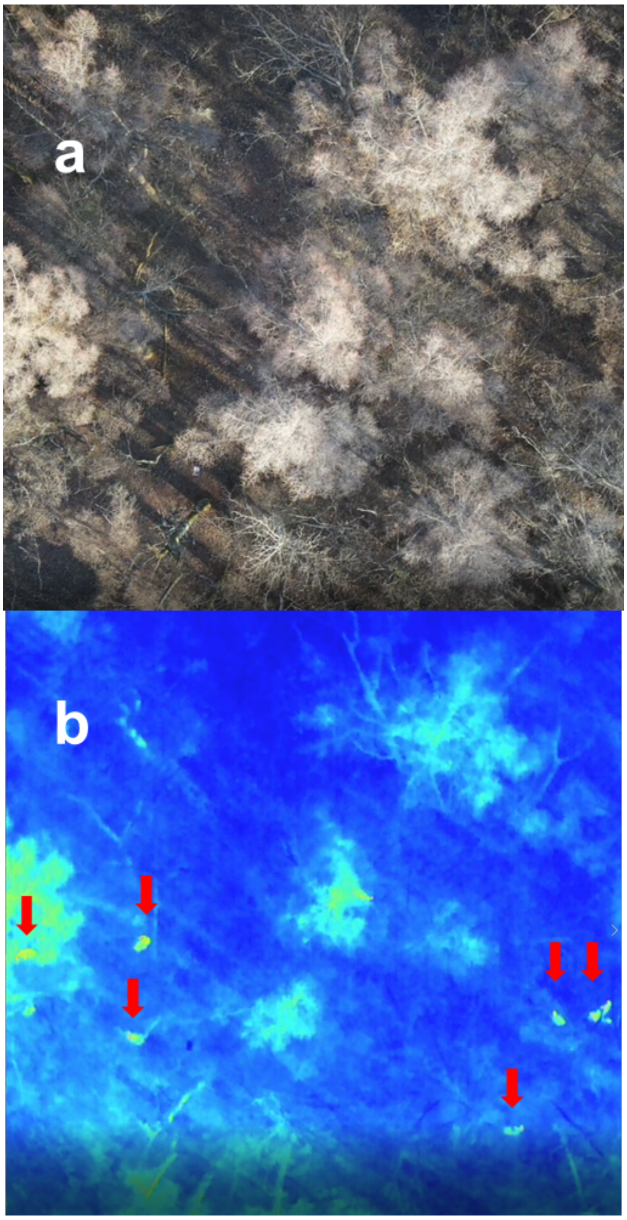

Figure 7. Screen shots of movie files acquired by M2EA; RGB image (a) of a sparse larch stand and thermal image of the same area (b). Colors are shown as relative temperatures, with higher temperatures from blue to red. Red arrow indicates sika deer individuals.

Video format was also found to be effective to visually identify sika deer on site in terms of time savings, compared to still image format which would be better option for AI analysis later in the laboratory. Although sika deer was not so active during the drone remote sensing, it frequently moved its head, which was visually detectable in the thermal video. We found that hovering 3 seconds at the centre of a grid, which gave us enough time to inspect if there is sika deer or not in the grid, was essential when use video format. In this way, we can confirm which grids have sika deer in them.

We chose a paper map to share the location of sika deer with beaters and shooters this time. This is because most of beaters and shooters are elder people, and they are familiar with paper rather than digital format. In future, we could incorporate digital

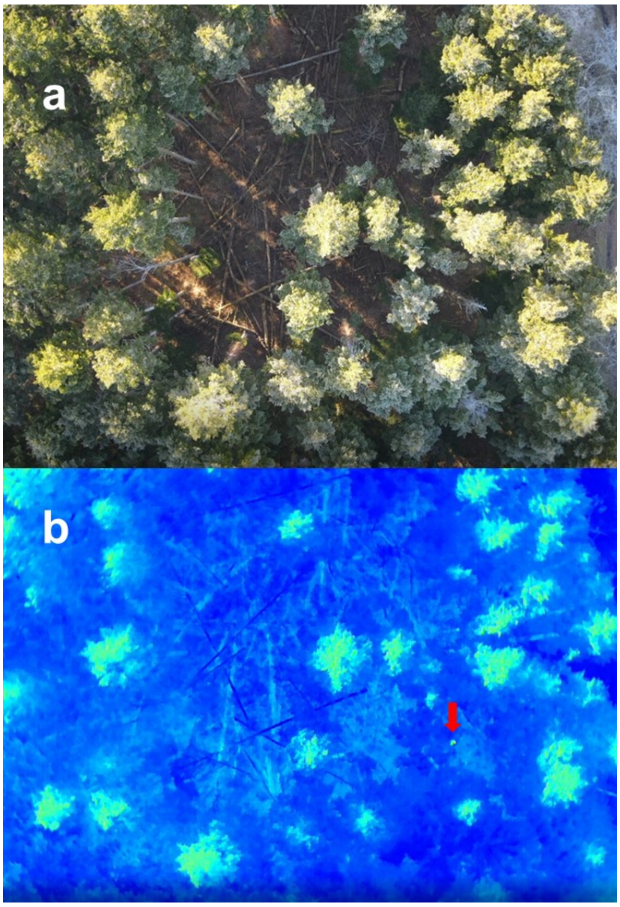

Figure 8. Screen shots of movie files acquired by M2EA; RGB image (a) of a coniferous stand and thermal image of the same area (b). Colors are shown as relative temperatures, with higher temperatures from blue to red. Red arrow indicates sika deer individual.

map such as cloud GIS to share the information using a smart phone.

There was a problem of radio communication between a controller and the drone, and we could not acquire data in 2 grids where were most distant from the drone home point. The area is in a gently sloped forest. The home point was set on the lower side of the slope, which might be a reason for this problem. It is difficult to find better open space in the forest, therefore, moving with the controller during the flight might be a solution for this problem. However, this must be carefully tested to avoid an accident.

In conclusion, the drone remote sensing to identify sika deer for controlled capture was considered successful. Thermal video format acquired by M2EA was effective to visually identify sika deer on site in terms of time savings, compared to RGB video or RGB/thermal still image format. To have flight area grided and hovering 3 seconds at the centre of a grid during the flight was essential both for visually identifying the number and location of sika deer and for sharing such information later with beaters and shooters using a map.

Figure 9. Beaters and shooters who were handed over a map of sika deer presence.

Figure 10. A shooter who stationed in the forest.

ACKNOWLEDGEMENTS

We thank hunters in the village of Yamanakako for their support. We acknowledge technical staff of Ecohydrology Research Institute, the University of Tokyo Forests for their assistance in drone remote sensing. We also appreciate Dr. Wei Guo at the University of Tokyo for his support.

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