SMALL UAVS-BASED DISASTER DAMAGE INVESTIGATION: FOCUSED ON FLOODING DISASTER AND CHEMICAL ACCIDENT

E. T. Lim [1], Y. H. Jung [1], D. Y. Shin [1], S. S. Kim [1]*

[1] Disaster Scientific Investigation Division, National Disaster Management Research Institute, Ulsan, Republic of Korea - (charmante93, jyh1315, sdy718, sskim73*)@korea.kr

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ABSTRACT:

Disasters that occur in recent years are linked to various factors and occur in a chain, and the scale is also increasing. In order to solve the more complex and serious disaster problem, it is necessary to expand the affect scope of the disaster and to acquire and manage information by integrating and operating various sensors. With the introduction of UAVs for disaster work, various studies such as investigation of the affected area, rescue of survivors, and establishment of emergency communication networks are being conducted. This is useful for strengthening the field of disaster management because it is very effective in terms of time and human resources. In addition, it is possible to acquire high-resolution images, and by using the 3D point cloud data and ortho-mosaic imagery generation, it is possible to produce a disaster scene close to the real world. Therefore, if UAV information can be linked to disaster types and characteristics prior to supporting disaster damage investigation, it is possible to establish a response method according to the disaster damage situation and help decision-making. In order to examine the applicability of UAV technology for actual disaster sites, this study conducted data collection and analysis of damaged areas targeting sites damaged by heavy rain and chemical accidents. In the heavy rain damage site, flooding damage occurred in the ginseng cultivation patches due to river overflow caused by the torrential rain, and the damaged area and lots were investigated. The site of the chemical accident was damaged by hydrochloric acid gas leaking into the atmosphere, and the surrounding forest, crops, and residential facilities were identified and the affected area was calculated. As a result of investigating the damage from heavy rain and chemical accidents using UAV, it was possible to quickly collect data on a wide disaster site. In addition, it was easy to calculate the damaged area based on ortho-imagery, and the limitations of spatial analysis were reduced, so that it could be used more specifically and efficiently to the disaster site.

1. INTRODUCION

Recently, the types of disasters have expanded, and socio-economic damage is increasing due to the complex disasters that occur in connection with various factors. To solve more serious disaster problems, it is necessary to expand the range of disaster impacts, integrate and operate various observation sensors, and acquire and manage information through real-time monitoring.

A variety of advanced mobile observation platforms such as Robots, LiDAR, and UAVs are being used for disaster damage investigations. In particular, the rapid development of UAVs has expanded the areas accessible to humans, and various studies on disasters are being conducted.

UAVs have been introduced and are usefully used in various ranges such as disaster damage investigation, rescue, and establishment of communication networks between infrastructures (Erdelj and Natalizio, 2016). It is also very effective in terms of time and human resources to be input, which is useful for strengthening the disaster management field (Tanzi et al., 2016). UAVs are relatively low-cost and easy to operate and are excellent terms of safety and flexibility in disaster situations (Stuart and Carol., 2011). UAVs can be used in the disaster field in consideration of disaster phase, response method, UAV types, and characteristics (Restas, 2015). In addition, UAV mapping products were used to support disaster management decision-making (Lee et al., 2019).

However, it may be questionable whether UAVs technology and research can be applied to disaster fields yet. In this paper, in cases of flooding damage and chemical accident investigation that occurred in South Korea, monitoring and data collection was performed using UAVs, and utilization of this was reviewed by analysing the situation awareness and damage of disaster fields.

2. METHOD

2.1 Disaster investigation system and procedure using UAV

In order to analyse the damage in the disaster area and establish a recovery plan, it is necessary to promptly investigate the current damage situation and calculate the scale of damage. To meet this goal, the step-by-step procedure of field surveys using UAVs is very important. First, the survey area must be determined, and flight permission and photogrammetry approval for the area must be obtained. Second, arrive at the survey site, answer the surrounding area in advance, and establish a flight plan (flight path, overlap, altitude, range, GSD). Third, to secure the accuracy and integrate the materials, a ground control point survey will be conducted, and a panoramic photograph or damage situation of the relevant area

* Corresponding author

will be taken. Fourth, after completing the flight plan and ground control point survey, UAV-mapping of the damaged area will be carried out in earnest. Fifth, materials will be created based on the results of UAV-mapping, the approximate current situation of the damaged area will be grasped, and an additional damage investigation plan will be established for precise data generation and in-depth analysis. Finally, the damage is presented based on the final result, and the result is submitted.

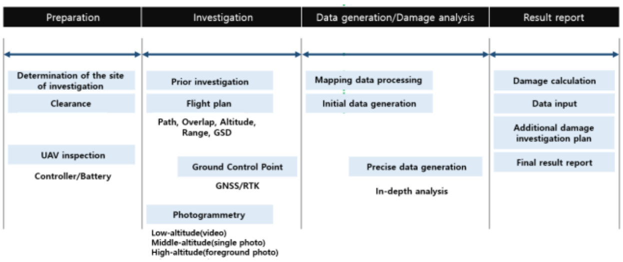


Figure 1. Disaster investigation procedure using UAV

2.2 3D UAV-mapping

in this study, a DJI's Inspire 2 was utilized to acquire high-resolution aerial imagery for UAV mapping. DJI's Inspire 2 is a rotary type UAV which can board on attachable and detachable EO camera sensor for applying for three dimensional mapping and facilities monitoring. Inspire 2 advanced flight, stability and obstacle detection along with excellent safety features. It has a maximum transmission distance of 3.5 km more and approximately 27 minutes with detachable on-board the Zenmuse X4S camera (Table 1).

Inspire 2

Size : 0.45m(B) x 0.45m(L)
Weight : 3.44kg
Air speed : Max. 26m/s
Operation range : > 3.5km
Endurance : Max. 27min
Fight mode : Manual/Auto
Onboard sensor: 4K UHD camera

Table 1. Small Drone (DJI Inspire 2) used in this study

UAV mapping can be considered as a simplified method of the existing aerial photogrammetry-based data processing procedure that has become possible with the advancement of precise small MEMS technology and large-capacity computing technology. Although the accuracy of the interior orientation parameters or the exterior orientation parameters of non-metric camera mounted on the UAV is somewhat guaranteed, it became possible to generate 3 dimensional topographic information similar to that of existing aerial photogrammetry with UAV mapping process by finding the optimal values of interior and exterior orientation parameters through iterative adjustment process with high-speed computing technology. UAV mapping in this study was implemented as followings: disaster scene visitation for understanding UAV mapping environment, aerial photography planning and imaging, calculation of interior orientation parameters through camera calibration, extraction of interest points and image registration to create camera models from aerial photos, camera model optimization and accuracy improvement using GCPs, and finally generation of 3D topographic information (3D point cloud, DSM, and DTM) and ortho-imagery (Figure 2).

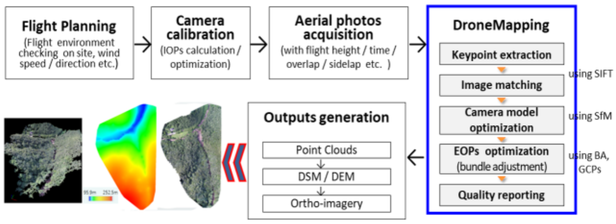


Figure 2. Photogrammetry-based drone mapping procedure

3. FLOODING DAMAGE INVESTIGATION

3.1 Field investigation for flooded area

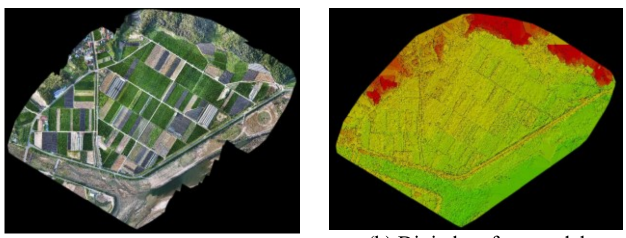
Heavy rain inundation damage occurred at the joint of river where small streams meet. As a result, the river was flooded and all the ginseng cultivation patches down the river were damaged. It was confirmed through a field survey that the damaged ginseng cultivation patches were empty or dead. We understood that all the flooded ginseng patches were the same condition as a field surveying result (Figure 3).

(a) Facilities destruction (b) Damaged ginseng

Figure 3. Damage photos of ginseng cultivation

3.2 Damage investigation using UAV mapping products

UAVs photogrammetry was conducted to investigate the damage and establish a recovery plan for the Ginseng cultivation field where flooding damage occurred due to heavy rain. Aerial photos from UAVs were taken several times at an altitude of 120m, and ortho-mosaic were produced based on the gathered aerial imagery and UAVs flight log data(Figure 4). In addition, the total area of damaged fields, the number and area of Ginseng cultivation patches, and the number and area of damaged Ginseng cultivation patches were analysed.



(a) Ortho-imagery (b) Digital surface model

Figure 4. Final products by UAV mapping at flooded area

3.3 Damage analysis using UAV mapping products

After producing an ortho-mosaic image through the image taken for damage analysis of the area completely inundated by the flooding of the river, the ginseng cultivated area was extracted with a cadastral map. As a result of the analysis, the total flooded fields were 72.1 ha. Flooded Ginseng cultivation patches were 63 out of 350, and the damaged area of Ginseng patches was 94,415 m^2 (Table 2). Comparing the damaged areas of the ortho-mosaic imagery with a cadastral map showed a calculated result between each area was a slight difference (Figure 5).

Number of patch	Ginseng cultivation	Fooling field	Damaged area (cadastral map)	Damaged area (land register)	Vinyl house
350	63	63	94,415	94,727	27

Table 2. Results of damage to ginseng cultivation field

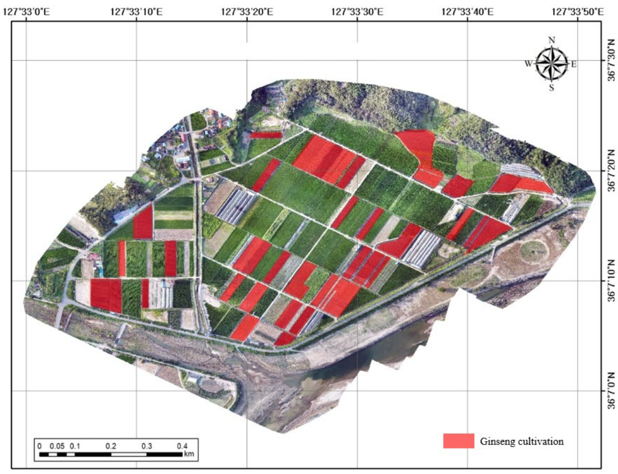


Figure 5. Damage analysis in ginseng cultivation field

4. CHEMICAL ACCIDENT INVESTIGATION

4.1 Field investigation for chemical incident area

The chemical accident details occurred due to an abnormality in the valve of the tank where the hydrochloric acid was stored, and the hydrochloric acid gas was exposed outside the tank. In general, disaster prevention for gaseous substance such as gas uses a large electric fan to generate wind and diffuse harmful gas into the air to minimaze damage. During this process, nearby forests and crops were damaged, which could cause serious secondary damage to the housing facilities around the accident site.

(a) forest damage (b) crop damage

Figure 6. Ground photos at chemical incident area

4.2 Damage investigation using UAV mapping products

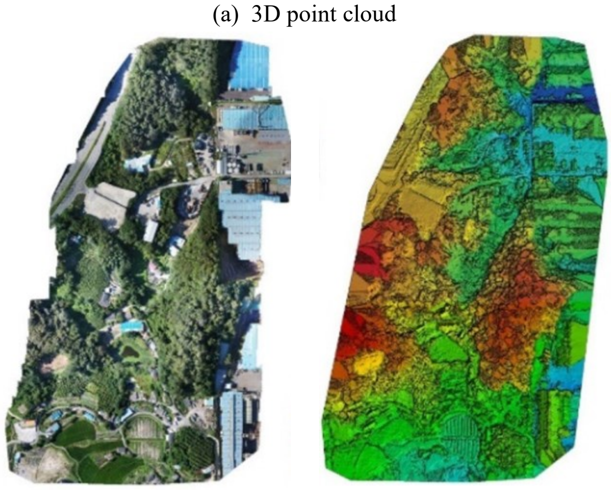
For UAV mapping and damage investigation, RTK-GNSS surveying for ground control points (GCPs) was implemented around study area. Aerial imaging with UAV was conducted as two types of flight: low altitude photographing for understanding detailed damage status of surrounding forests and crops and high altitude photographing at 80 m and 120 m of height for UAV mapping to measure damage area and distance between incident spot and buildings in residential area. At that time, Zenmuse X4S camera mounted on Inspire allows us to collect high-resolution aerial photographs with 75% overlap and a GSD of 1.77 cm/pix. at a flight altitude of 80m and 2.65 cm/pix. at a flight altitude of 120m (Table 3).

No.	Altitude	Overlap	Time	Area	GSD
1	80m	75%	12m 1s	329m×378m	1.77 ㎝/pixel
2	120m		12m 39s	363m×632m	2.65 ㎝/pixel

Table 3. Results of UAV aerial surveying

Through the UAV mapping, we finally generated three dimensional point cloud data, digital terrain model, and ortho-imagery map of study area as shown Figure 7.

(a) 3D point cloud



(b) Ortho-mosaic (c) Digital surface model

Figure 7. Final products by UAV mapping at chemical incident

As assessing damage status of surrounding forests and crops using the low altitude photos acquired from Inspire 2 and ortho-imagery produced by UAV mapping, we can find the location of damage spot and measure approximate damage area. In addition, we can understand distribution status and number of buildings within 300 m from incident spot using high resolution ortho-imagery with professional GIS SW (Figure 8).

(a) Forest damage status (b) crop damage status

Figure 8. Understanding damage status using high resolution photos at low altitude

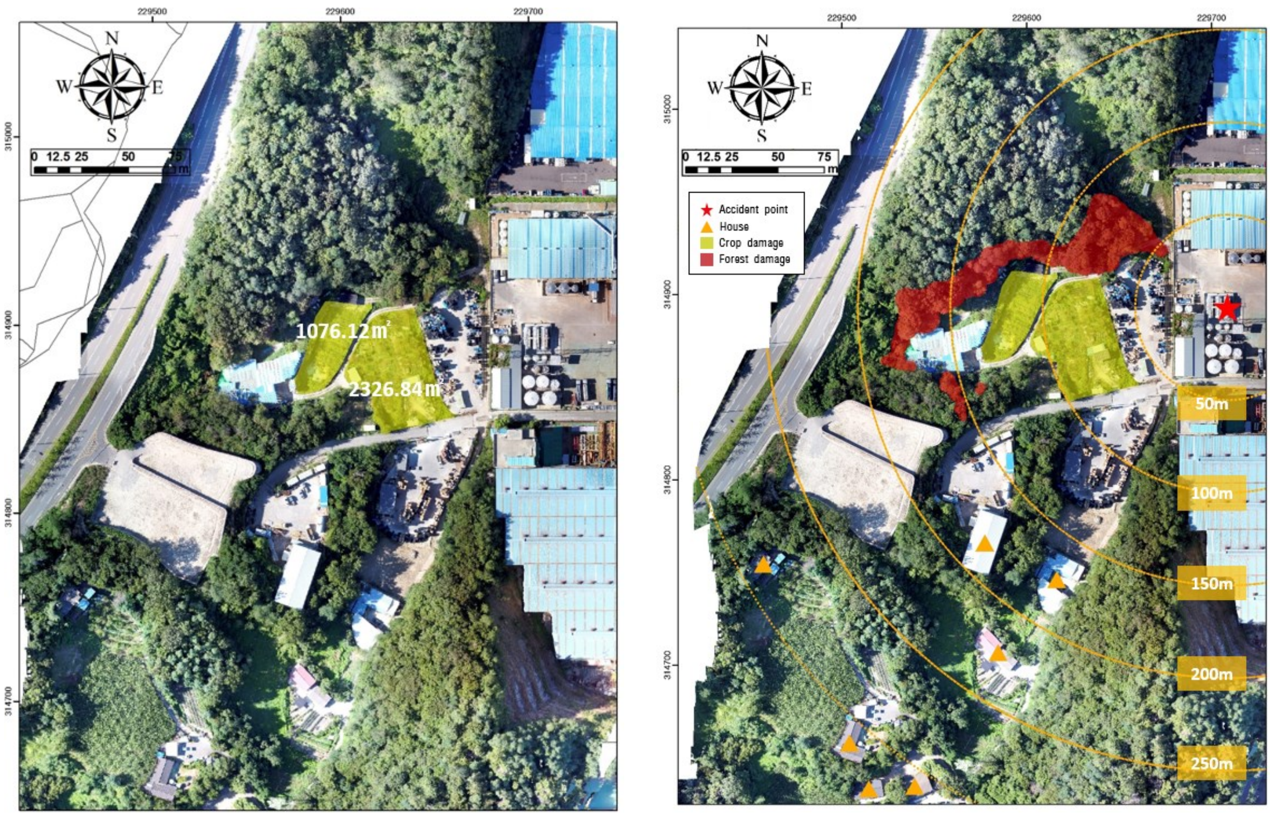


Figure 9. Damage area calculation(left) and Buffer analysis(right) for assessing damage effect by chemical incident

4.3 Damage analysis using UAV mapping products

As a result of the analysis of the chemical accident investigation, it was confirmed that the forest and crops near the accident site were exposed to hydrochloric acid gas and withered. Withered leaves were intensively-observed on the surface of the forest, and the area was 3,461 m^2. The damaged area of the crop was 3,402 m^2 and it showed the calculated area was 115 m^2 difference compared with the area of the cadastral. However, this was because some road areas located between the fields were excluded in the process of generating the ortho-mosaic imagery. Residential facilities that were expected to be damaged are located in low hills areas within 300 m from the accident site, and there were no buffer facilities, so they could give damage directly. Distances between the accident occurrence spot and the near buildings were 171 m, 179 m, 221 m, and 282 m, respectively (Figure 9).

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Figure 10. Residential facility distribution

5. CONCLUSIONS

In conclusion, for investigating flooding damage and chemical accidents, UAVs enable us to collect data on a wide disaster site in a short time. In addition, it provides an efficient and cost-cutting way to calculate the damaged area based on ortho-mosaic imagery of inaccessible disaster fields so that it can be applied more specifically and efficiently to the disaster field. Therefore, it is judged that this study proved the efficiency of the UAV. With the development of UAV technology, it was not difficult to analyse damage without a ground reference point. It can be seen that the use of UAVs is appropriate for preparing initial materials for prompt damage status reporting. However, if we do not have specialized knowledge of the damaged content at the time of damage investigation for in-depth analysis, it seems that there are many difficulties in grasping the seriousness of disaster damage more precisely.
In the case of ginseng cultivated patches, it is difficult to confirm the life or death of ginseng without going directly to the site sunshade. This seems to be difficult to supplement the hanger unless a sensor that can see through the shading film and observe the inside is developed by the development of future technology. In addition, it is difficult to observe damage to crops and forests caused by chemical accidents, except where they can be seen form the images. Therefore, it is necessary to incorporate various sensors into the camera so that the degree of damage to similar vegetation can be more reliably distinguished.

ACKNOWLEDGEMENTS

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