# Evaluating Maize Height on Sloped Area by Unmanned Aerial Vehicle

Bour Khem, Wanwisa Pansak, Nuttapon Khongdee, Sittichai Choosumrong, and Suwit Kiravittaya*

***Abstract***— *This work describes an experimental evaluation of the maize height on the sloped area by using an automatic image capturing system installed in an Unmanned Aerial Vehicle (UAV). In combination with the image processing and geographic data, spatially distributed information on the maize height can be obtained. Initially, high-resolution photos are taken at a regular position over the cultivated land by a UAV. Then, they are registered and globally aligned. The dense cloud data is generated based on the overlapped image data. The desired digital surface model (DSM) can be finally extracted. Post-processing of DSM data allows us to extract the average land slope as well as the maize height for further growth analysis in different scenarios.*

***Keywords***— **Sloped area, unmanned aerial vehicle (UAV), image processing, digital surface model.**

## 1. INTRODUCTION

Recently, Unmanned Aerial Vehicle (UAV) becomes very popular in many research areas including agricultural science and industry [1-4]. Many emerging applications are proposed and demonstrated such as predicting rice yield [2], counting plants [3,4] and fertilizer and pesticide spraying [5]. This combination of UAV and remote-controlled camera allows us to do remote sensing of the plant and land properties at the desired spatial resolution and length scales. In addition, the image taken from UAV can be very informative when the real-time geographic data are simultaneously recorded and embedded into the taken image.

Maize is an important agricultural product of Thailand especially for feed industry [6]. Most of the maize (70%) is constantly grown in the North of Thailand, which contains largely sloped areas [7]. The maize-cultivated land might be on a highly slope area and the growth cannot be well controlled due to many difficulties. Maize height, which indicates the growth state, is an important factor to evaluate the maize growth.

In this work, we describe the usage of the UAV to evaluate the maize growth on the sloped area. The experimental plot is first prepared with various conditions/treatments. After that, set of photos is taken by a camera installed in a commercial UAV. Then they are processed by image registration and three-dimensional (3D) data so-called digital surface model (DSM) is reconstructed. The spatial maize height is extracted from this DSM data and it is compared with the same data obtained by a conventional method. Result shows that this method is a feasible alternative for achieving maize height/growth information on the sloped area.

## 2. FIELD PREPARATION AND IMAGE CAPTURING CONDITIONS

The experimental field is located in Wang Thong District, Phitsanulok Province in the lower North region of Thailand (at the latitude of 16.906 and the longitude of 100.542). It consists of 24 maize plots aligned into 3 blocks (named R1, R2 and R3). Each plot has the area of $18 \times 4$ m$^2$ and the gap between each plot is ~80 cm. Various treatments of the maize growth (with organic / chemical fertilizer, with or without relay cropped Mungbean) are being tested and the detail will be reported elsewhere. For the main investigated plot, the maize is regularly placed at the distance of ~75 cm between rows and there are 20 rows in the plot. Height of the maize in the middle of each row is measured as it indicates the growth characteristics of the maize in the plot.

For obtaining the raw aerial images, a commercial UAV (Phantom 4 Pro) installed with a high-resolution camera (DJI FC6310) is used. Aerial images are collected on the 21$^{st}$ August 2017 (38 days after sowing) to assess maize height. The UAV is programmed to fly at the height of ~50 m above the ground. The flying area is about 4 times larger than the total field area, i.e., ~$105 \times 106$ m$^2$. The photo is taken as the UAV is flying with the pattern shown in Fig. 1. During the image capturing, the camera is tilted in a regular pattern in order to obtain the image at different view angles. This method provides image data for the systematic 3D image reconstruction. Moreover, the corresponding geometric

Bour Khem is with the Department of Agricultural Science, Faculty of Agriculture, Natural Resources and Environment, Naresuan University, 65000 Phitsanulok, Thailand.

Wanwisa Pansak is with the Department of Agricultural Science, Faculty of Agriculture, Natural Resources and Environment, Naresuan University, 65000 Phitsanulok, Thailand.

Nuttapon Khongdee is with the Department of Agricultural Science, Faculty of Agriculture, Natural Resources and Environment, Naresuan University, 65000 Phitsanulok, Thailand.

Sittichai Choosumrong is with Department of Natural Resources and Environment, Faculty of Agriculture, Natural Resources and Environment, Naresuan University, 65000 Phitsanulok, Thailand.

Suwit Kiravittaya (corresponding author) is with the Department of Electrical and Computer Engineering, Faculty of Engineering, Naresuan University, Phitsanulok 65000, Thailand and the Center of Excellence on Energy Technology and Environment, Naresuan University, Phitsanulok 65000, Thailand. Phone: +66-8-6930-9339; Fax: +66-55-96-4005; E-mail: suwitki@gmail.com.

information (latitude, longitude and altitude) are recorded into the captured image. Note that large captured area on different images are overlapped and the starting point and the end point of the applied flying pattern is overlapped as shown in Fig. 1.

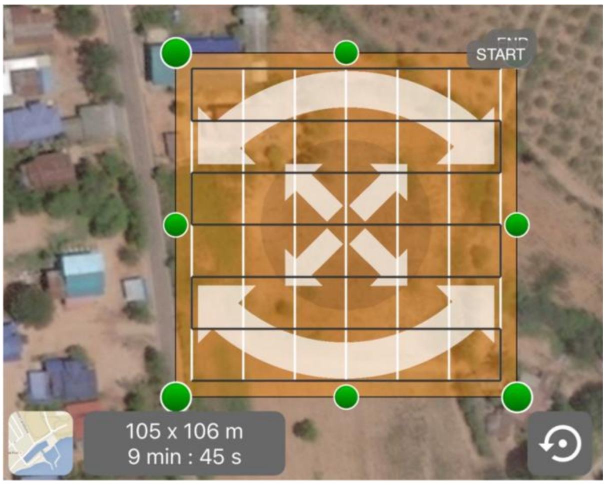


**Fig. 1. UAV flying pattern for taking photos.**

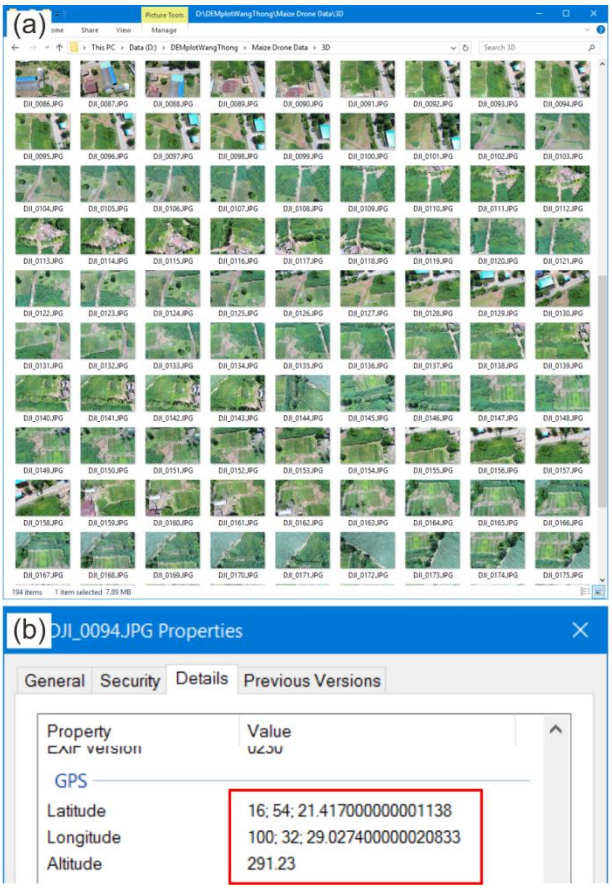


**Fig. 2 (a) Overview of the raw photos and (b) dialog box shown the geometric information embedded in the image file.**

## 3. IMAGE CONSTRUCTIONS

After transferring the taken photos from the camera into a computer, they are further manipulated. Figure 2(a) shows an overview of the raw photos. Each photo (size of 5472×3648 pixel, 20 megapixel, 7-8 megabyte, JPEG file format) is taken in a regular pattern at different camera positions/angles. Geometric information (latitude, longitude and altitude above sea level) is included into each image as shown as an example in Fig. 2(b). For this experiment, batch of 194 photos is registered and globally aligned. Result is a single large registered image as shown in Fig. 3(a). In the figure, three blocks (R1, R2, and R3) are marked. The dotted rectangle shows the overall region of interest. When the geometric information, i.e., the latitude and the longitude, are considered and the registered image can well be matched with the satellite image obtained from Google Map as shown in Fig. 3(b). Both image area and position are consistent but for the satellite image, the image capturing cannot be precisely known/controlled.

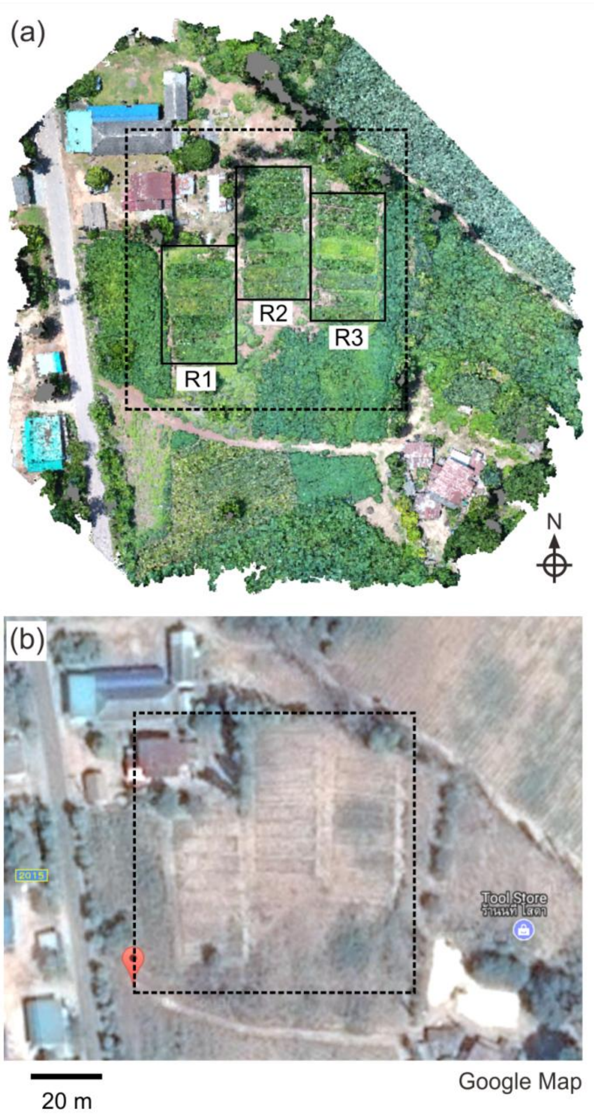


**Fig. 3 (a) The registered image and (b) the satellite image (Google Map) of the experimental plots and their surroundings. Interesting area is marked by the dash rectangle. Three rows of the total 24 maize plots are marked by three rectangles labelled as R1, R2 and R3 in (a). The red mark in (b) is at the latitude 16.9056 and longitude 100.5414.**

After the image registration, dense cloud image is generated. Figure 4(a) shows the 3D perspective view image of the dense cloud image. The view is tilted toward the uphill (west) direction in order to clearly observe each plot in the region of interest. Qualitative height information is included in this image as one can notice from the tree/house shadows. However, the initial colors of the original image are dominant in this image. In order to extract the height information, the DSM is further generated. The resultant DSM is shown in Fig. 4(b).

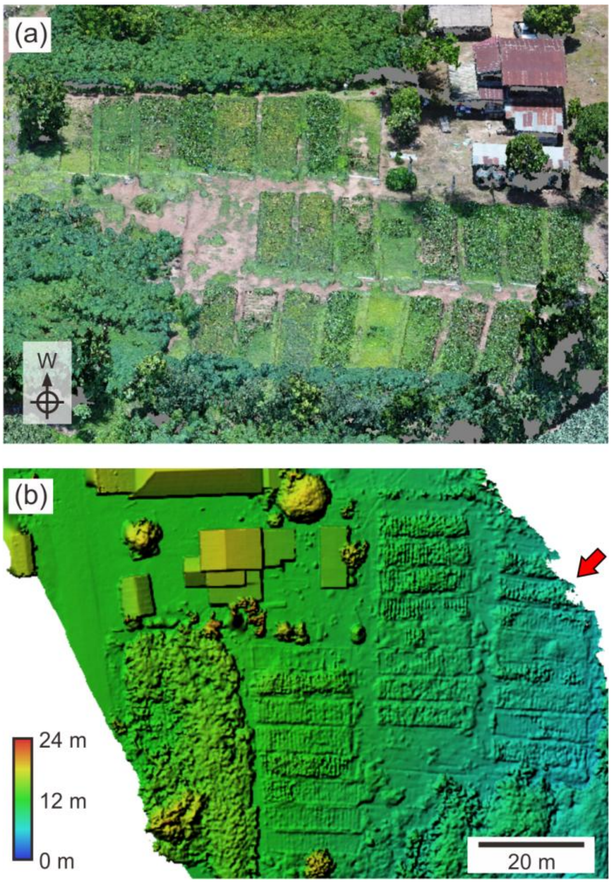


**Fig. 4 (a) 3D perspective view image and (b) the generated DSM image of the interested area. In (b), the height information is encoded into the shaded color. Its value is relative to the minimum data value. The red arrow in (b) marks the problematic area where the height data cannot be retrieved.**

The DSM shows mainly the height information. Due to the high trees and houses, the presented height scale is large (0 – 24 m relative to the minimum value, which is 245 m above the sea level) and therefore the slope in the maize plot is not clearly seen in this image. However, the numerical data can be further analysis. In this work, we use MATLAB 2017b for this purpose. Height information in some parts of the DSM cannot be retrieved because of the data uncertainty. The problematic area is marked by the red arrow in Fig. 4(b). The problem might originate from the moving of the shadows from the nearby trees in different images. Moreover, due to the lower altitude of that area, the area covered by shadows is large.

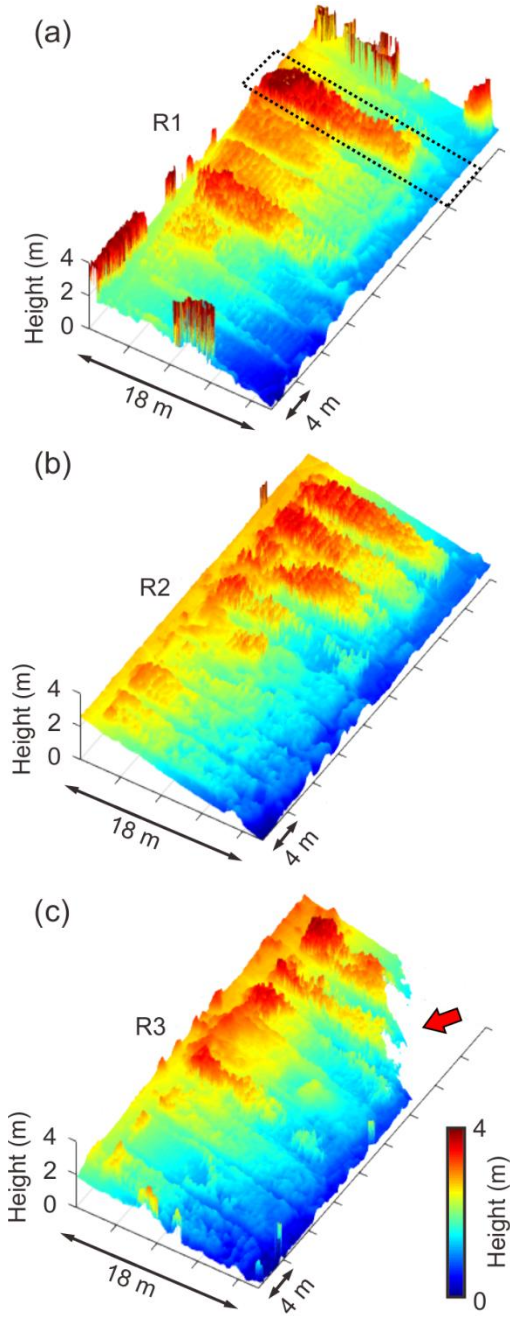


**Fig. 5 Extracted height profiles for the maize plots: R1 in (a), R2 in (b) and R3 in (c). Each plot has the length of 18 m and the width of 4 m. Dotted polygon in (a) is considered for the further maize height analysis. The red arrow in (c) marks the area where the height data cannot be retrieved.**

## 4. MAIZE HEIGHT EVALUATION

For the evaluation of the maize growth, the maize height is an important factor. Height information for each plots can be extracted and post-evaluated. The result is shown in Figs. 5(a)-(c). Each image has 900×1800 pixel with the resolution of 2.37 cm per pixel. Height scale is adjusted to 0-4 m. Each maize plot in the image has 18 m long × 4 m wide. Some rows of maize can well be recognized in these extracted height profiles. From these images, the slope of the land can well be estimated and it is ~$\tan^{-1}$(2 m/18 m) = 6°. The dotted polygon in Fig. 5(a) marks interesting maize for further height analysis (described below). The missing height data in Fig. 5(c) marked by red arrow corresponds to the problematic area in Fig. 4(b).

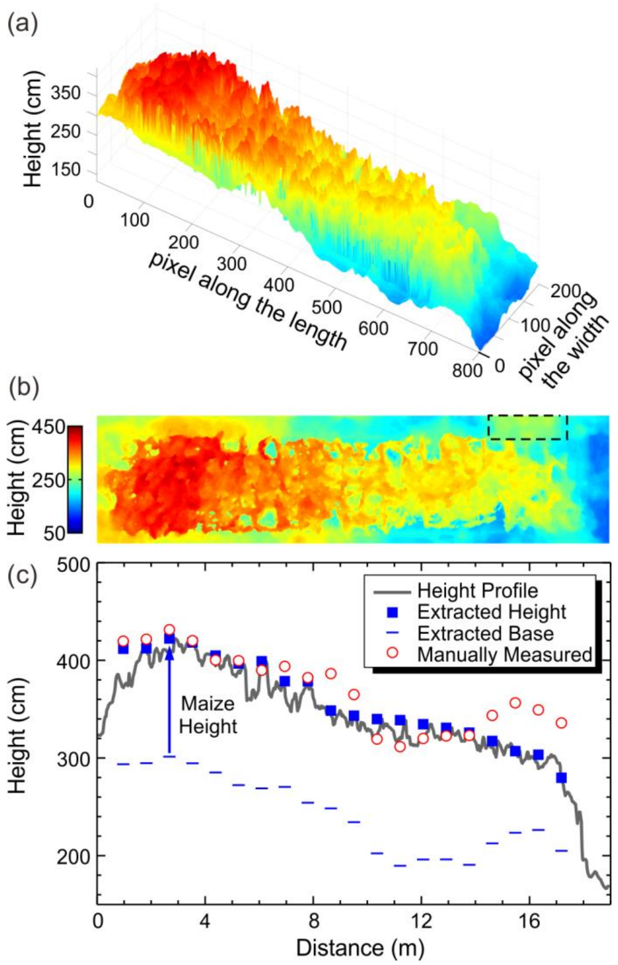


**Fig. 6 (a) and (b) are the 3D and 2D height profiles of the maize plot and (c) the extracted maize height and land base as compared with the manually measured maize height. The dashed rectangular box in (b) marks the mound area, which produces error in the extracted maize height.**

Figure 6(a) shows the magnified image (800×200 pixel) of the maize plot shown in Fig. 5(a) while Figure 6(b) shows the top-view. The height scales of both images are adjusted. The twenty rows of the maize can well be recognized. The extraction of the maize height is done by the following procedure. First, the 1D height profile is extracted by considering the maximum height in the middle band (pixel no. 51-150 along the width). Then, the local maxima for every 36 pixels along the length are extracted. This number of pixels corresponds to 85 cm (a bit more than the set row-to-row distance of 75 cm) because it best matches to the regularity of the height profile. The 1D height profile and the extracted maize height are plotted in Fig. 6(c). The average base level for each row is obtained by considering the average height at the edge of the plot (10 pixels from the edge on both side). The value is plotted in Fig 6(c). Difference between the extracted height and the extracted base height is the maize height. The data from the manual height measurement of the maize in the middle of the maize row is collected. Since the data is measured relative to the local ground, we therefore add the extracted base level and plotted it in the Fig. 6(c).

Comparison between the manually measured maize height and the extracted height we observe the similar trend on the top part of the plot (the distance between 1 to 14 m). However, there exists the discrepancy of these data at some rows especially at the distance between 14 and 17 m. This is due to the local roughness of the base surface. Since there is a mound on the edge of the plot (as marked by a dashed rectangle in Fig. 6(b)), the base level cannot correctly be extracted. However, since the slope of this plot is in two directions, one cannot correctly be extracted the base level from only one edge. This suggests that the area near the plot should be flattened in order to be used as a reference for maize height extraction.

Alternative technique to measure the maize height is also evaluated. It bases on the fitting of the 3D height profile with a 3D plane. Only the height data at four corners of the investigated plot are used. Base level at any position in the plot can then be extracted from the fitted plane. However, we found that this method gives less accurate value of the maize height on the sloped area. This is due to the roughness of the land and the uncertainty in the selection of the reference corners. We therefore recommend the division of the maize data into separated rows and locally measure the maize height (maximum height value in the middle row) in each row relative to the base level, which is the average height level on the land near that row.

## 5. CONCLUSION

In conclusion, we demonstrate the technique to evaluate the maize growth in the sloped area by using UAV and image processing technique. The spatially distributed height data with a few centimeter resolutions can be obtained from the set of photos. The extracted height is compared with the manual measured height and we found a good agreement when the reference base area (next to the maize row) is flat. This work will enhance the knowledge on the usage of an advanced technology to promote the precision agricultural study.

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## REFERENCES

[1] Zhang, C.; and Kovacs, J. M. 2012. The application

of small unmanned aerial systems for precision agriculture: a review. *Precision Agriculture* 13(6): 693-712.

[2] Zhou, X.; Zheng, H. B.; Xu, X. Q.; He, J. Y.; Ge, X. K.; Yao, X.; Cheng, T.; Zhu, Y.; Cao, W. X.; and Tian, Y. C. 2017. Predicting grain yield in rice using multi-temporal vegetation indices from UAV-based multispectral and digital imagery. *ISPRS Journal of Photogrammetry and Remote Sensing* 130: 246–255.

[3] Gnädinger, F.; and Schmidhalter, U. 2017. Digital counts of maize plants by unmanned aerial vehicles (UAVs). *Remote Sensing* 9: 544.

[4] Jin, X.; Liu, S.; Baret, F.; Hemerlé, M.; and Comar, A. 2017. Estimates of plant density of wheat crops at emergence from very low altitude UAV imagery. *Remote Sensing of Environment* 198: 105–114.

[5] Faiçal, B. S.; Freitas, H.; Gomes, P. H.; Mano, L. Y.; Pessin, G.; de Carvalho, A. C. P. L. F.; Krishnamachari, B.; and Ueyama, J. 2017. An adaptive approach for UAV-based pesticide spraying in dynamic environments. *Computers and Electronics in Agriculture* 138: 210-233.

[6] Office of Agricultural Economics 2016. Maize production area by provinces 2013. Bangkok: Center for Agricultural Information.

[7] Ekasingh, B.; Gypmantasiri, P.; Thong-ngam, K.; and Grudloyma, P. 2004. Maize in Thailand: Production Systems, Constraints, and Research. Priorities Mexico, D.F.: CIMMYT.