International Journal of Engineering and Advanced Technology (IJEAT)
ISSN: 2249-8958 (Online), Volume-8 Issue-3S, February 2019

Application of UAV-Derived Digital Elevation Model in Agricultural Field to Determine Waterlogged Soil Areas in Amur Region, Russia

Boris Boiarskii, Hideo Hasegawa, Aleksei Muratov, Vladimir Sudeykin

Abstract: ***This study evaluated elevation data in an agricultural field using an unmanned aerial vehicle (UAV) and a multispectral camera at an experimental site in the Amur Region, Russia. This region experiences waterlogging of soils, which prevents the use of agricultural machinery. Combine harvesters and transports are unable to perform technological processes on overmoistened soils. UAV surveying technology may help achieve a higher level of efficiency of agricultural land management. We processed captured Geo-TIF images using photogrammetry algorithms and recorded deviations in soil moisture on the experimental site. We produced a digital terrain model (DTM) that allowed us to determine areas of low-lying ground in the field that were prone to flooding and waterlogging. Using the UAV derived elevation model to determine low-lying ground may provide new opportunities for the region. Advanced land management may reduce farmers' costs for maintaining machinery and labor in the field, especially during the harvest season.***

Keywords - UAV, DTM, Amur Region, drone surveying

I. INTRODUCTION

The introduction of new technologies in agriculture stems from the need to improve the quality and profitability of agricultural production. Government agencies, scientists, and farmers have been increasingly aware of the growth of smart agriculture and importance of development in this direction in recent years (Boiarskii and Hasegawa, 2017).

Drones can be instrumental at the start of the crop cycle. They produce precise map data for early soil analysis, which is useful in planning seed planting (Hugenholtz *et al.*, 2013). Before the planting season, it is necessary to arrange for land monitoring, including the geography of the field (Whelan and McBratney, 2012). Current limitations in technologies need to be improved, such as imperfect hovering capabilities, constrained flight time and payload (Tauro *et al.*, 2016).

Manuscript published on 28 February 2019.
***** Correspondence Author (s)
Boris Boiarskii, Graduate School of Science and Technology, Niigata University, Niigata, Japan. Federal State Budget Scientific Institution All-Russian Scientific Research Institute of Soybean, Blagoveshchensk, Russia.
Hideo Hasegawa, Institute of Science and Technology, Niigata University, Niigata, Japan.
Aleksei Muratov, Science and Research Department, Far Eastern State Agrarian University, Blagoveschensk, Russia.
Vladimir Sudeykin, Foreign Affairs Department, Far Eastern State Agrarian University, Blagoveschensk, Russia.

This paper presents a study on elevation data in an agricultural field using a drone and a multispectral camera on the experimental farm of Far Eastern State Agrarian University, located in the Amur Region, Russia. Waterlogging of soils and the inability of machinery to work in the conditions of flooded areas are serious problems in the region. Due to the climatic features of the Far Eastern Region, over 95% of arable land is subjected to waterlogging. This factor is aggravated by regional soils composed of heavy clay loams, including dominant brown podzolic soil and meadow gley soils in Amur Region (Kashpura, 1964).

The purpose of this study was to determine low-lying ground with the use of drone surveying technologies for further land management. The processed data were made available to farmers to help them to predict flooding before the planting season.

II. THE STUDY SITE

The city of Blagoveshchensk, Amur Region, Russia was chosen as the study area. The Amur Region is a federal territory of Russia, located in the upper and mid Amur River basin, about 8,000 km east of Moscow. The city is located in the south of the Amur-Zeia plain, on the left bank of the Amur, with the confluence of the Zeia river. The study site is a 41.2 ha cropping field located in Gribskoe village, used for breeding and agriculture studies by Far Eastern State Agrarian University (Fig. 1). Amur Region is an area with high soil moisture. The conditions for soil formation in Amur region are characterized by several features: 1) a cold winter with little snow promotes deep freezing of the soil; 2) a cold arid lingering spring slows down the thawing of the soil and plant growth; 3) a warm and rainy summer (half of the annual rainfall falls in July and August) leads to waterlogging. In the central part of the floodplain, meadow vegetation develops, beneath which floodplain-meadow soils are formed. This factor makes it favorable for agriculture, but the farmlands of the region are subject to flooding (Pavluk, 2005).

Published By:
Blue Eyes Intelligence Engineering and Sciences Publication (BEIESP)

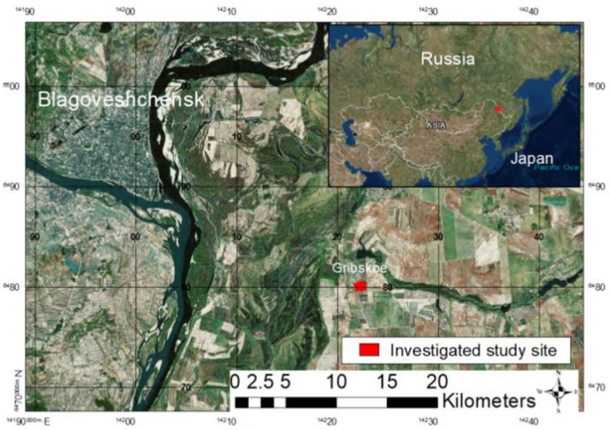

Fig. 1: Study site in Amur Region

III. MATERIALS AND METHODS

The study used the unmanned aerial vehicle (UAV) model Matrice-100 (rotary wing drone), manufactured by DJI, China (Fig. 2). The UAV had a multispectral Rededge camera manufactured by MicaSense, USA. The camera had five bands. Different combinations of the bands allowed us to observe different analytical layers.

We tested the UAV at various altitudes and speeds. In this study the UAV flew 120 m high over the site at 15 m/s. The UAV mission was planned by "Pix4Dcapture" on an Apple iPad.

Fig. 2: DJI Matrice-100 UAV

We configured camera settings and flight parameters in the app settings. The camera focal size was 5.5 x 4.8 mm, and the ground sampling distance (GSD) from the 120 m altitude flight was 8.18 cm/px. Front overlap and side overlap were set at 80% and 85%, respectively. We obtained 1910 raw images in 5 bands or 382-point images (Fig. 3). Elevation can be derived if a high proportion of overlap is selected (Hirschmuller *et al.* 2012). The obtained images were processed in "Pix4Dmapper" software. Based on these estimations we acquired a digital terrain model (DTM) and orthophoto plan. The elevation model was calculated in ArcMap.

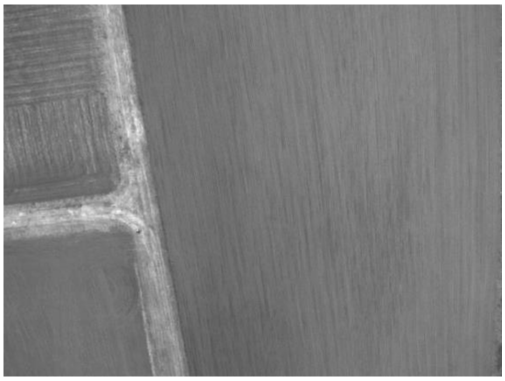

Fig. 3: Raw image from camera

The UAV images were processed into stereo pairs using photogrammetry algorithms. The stereo pairs consisted of images with different geolocations. The stereo image pairs were used to generate a point cloud (3D points) (Fig. 4) from which we derived an orthophoto plan, digital surface model (DSM) and DTM.

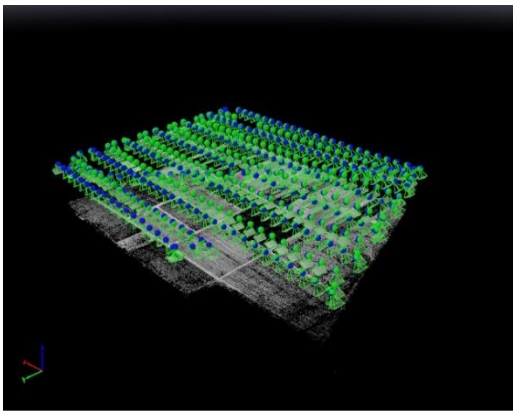

Fig. 4: Cloud points

IV. RESULTS AND DISCUSSION

The Amur Region has unpredictable weather conditions with regular flooding and soil waterlogging, which causes additional expenses for farmers (Tilba, 2003). Combine harvesters and transports have difficulty moving around fields and performing technological processes in waterlogged soil conditions (Fig. 5). Combines frequently get stuck in the field during the harvest season and can stay there until next spring. This leads to loss of crops and equipment failure.

Fig. 5: A stuck combine harvester

In this study, we introduced UAV technologies to rapidly identify low-lying ground areas in the field, prone to flooding and waterlogging, which can help farmers to adapt their decisions on cultivation.

We used a UAV with a camera to obtain images with meta-data on elevation. First, we rendered gray scale layers to get an RGB map (Fig. 6). We used this map to arrange plots on the fields and observe the surface. We managed territory over several hectares working with the map in digital format.

Fig.6: RGB map of the experimental field

The elevation data were obtained from Geo-TIF images with many locations on the ground, so each point was covered by multiple images. Based on these estimations we acquired a precise DTM with elevation data. The elevation was calculated in ArcMap by building a graph with meters above sea level (MASL) based on GPS and compass position (Fig. 7).

We analyzed elevation data on the site and identified the deviation. A 3% slope was observed from the elevation data, which had a maximum of 145.3 meters and minimum of 139.7 meters above sea level.

The gentle angle of the slope affected water running downhill that gained energy during heavy rain as it continued to move due to the earth's gravitational pull. This transported the nutrient-rich organic matter in the topsoil down the slope (Fig. 8).

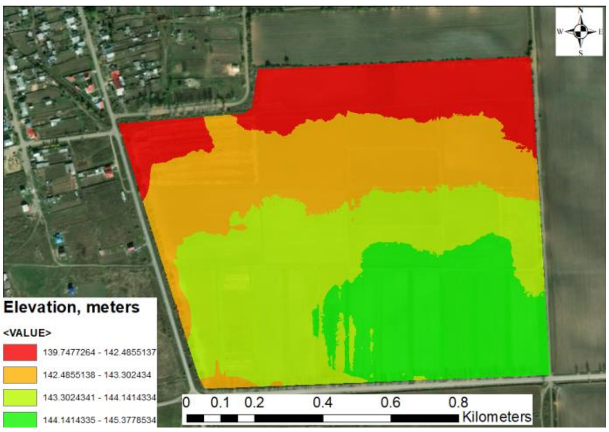

Fig. 7: Elevation model processed in ArcMap

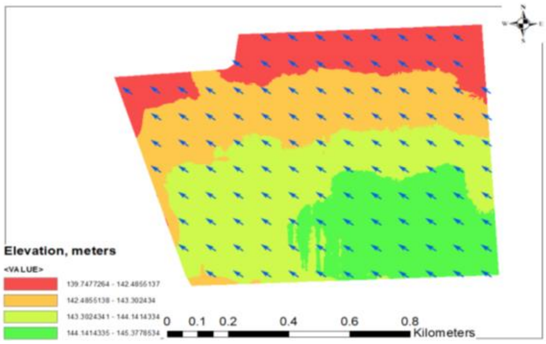

Fig. 8: Water flow from topsoil

V. CONCLUSION

1. UAVs provided field surveying and high-resolution monitoring capabilities, which allowed us to estimate different data. They produced precise map data for early soil analysis, which is useful in planning seed planting.
2. In this study we analyzed an experimental field and observed low-lying ground areas on the field, inclined to flooding and waterlogging.
3. The data we obtained and processed were communicated to farmers to help them evaluate land management. When the low ground has been identified, farmers have an opportunity to decide on the methods to manage it effectively.
4. Our study introduced the provision of elevation data via UAV in the Far East of Russia. This experience may affect the development of new technologies in this region.
5. Further work needs to be done on the relationship between UAV speed and flight altitude, which affect the precision and quality of the final data.
6. The current limitations, such as constrained flight time and payload, need to be improved to obtain better quality data faster.

ACKNOWLEDGEMENTS

This study was made possible due to the collaboration of researchers from Niigata University (Japan) and Far Eastern State Agrarian University (Russia). We wish to thank scientists and specialists from both sides who donated their time and efforts as well as their expertise to realize this work and help those who are involved in agricultural production on all its levels and in experimental studies. We thank Leonie Seabrook, PhD, from Liwen Bianji, Edanz Group China (www.liwenbianji.cn/ac), for editing the English text of a draft of this manuscript.

REFERENCES

1. Boiarskii, B. and H. Hasegawa, 2017. Technologies of cartography and field monitoring using unmanned aerial vehicles (UAV). Actual problems of agroindustrial complex: a view of young researchers, Smolensk State Agricultural Academy: 213–216, from https://elibrary.ru
2. Hirschmuller, H., M. Buder, and I. Ernst, 2012. Memory efficient semi-global matching, ISPRS Ann. Photogramm., 1–3: 371–376.

Published By:
Blue Eyes Intelligence Engineering
and Sciences Publication (BEIESP)

3. Hugenholtz, C.H., K. Whitehead, O.W. Brown, T.E. Barchyn, B.J. Moorman, A. LeClair, K.D.A. Riddell and T.K. Hamilton, 2013. Geomorphological mapping with a small unmanned aircraft system (sUAV): feature detection and accuracy assessment of a photogrammetrically-derived digital terrain model. Geomorphology, 194: 16–24.
4. Kashpura, B.I., 1964. Soil cover of the Amur Region and Primorsky Krai, physical and mechanical properties of soils. Far Eastern State Agrarian University, Blagoveshchensk.
5. Pavluk, N.G., 2005. Geography of the Amur Region: textbook, BGPU, Blagoveschensk, Pages: 364.
6. Tauro, F., M. Porifiri and S. Grimaldi, 2016. Surface flow measurements from drones. J. Hydrol., 540: 240–245.
7. Tilba, V.A., 2003. The system of agriculture in Amur Region. IPK (Publishing and Printing Complex) “Priamurye”, Blagoveshchensk.
8. Whelan, B.M. and A.B. McBratney, 2012. Downscaling for site-specific crop management needs? In: B. Minasny, B.P. Malone and A.B. McBratney (eds), Digital Soil Assessments and Beyond, Taylor and Francis: 353–356.

Published By:
Blue Eyes Intelligence Engineering
and Sciences Publication (BEIESP)