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A Quick Generation Method for Key Parameters of Grassland at the Hourly Scale in Ranch Scale

Wang, D. L.

Key Laboratory of Land Surface Pattern and Simulation, Institute of Geographic Sciences and Natural Resources Research, Chinese Academy of Sciences, Beijing 100101, China

Abstract: Real-time forage distribution data is critical for guiding herders to graze. In this study, a method of rapidly producing key parameters for the first pasture of Hulunbuir Youran Animal Husbandry Co., Ltd. based on unmanned aerial vehicles (UAVs) was proposed. The forage distribution data were acquired in 5 hours and 22 minutes. This method used a fixed-wing UAV to quickly acquire imagery for the pasture, mosaicked the UAV image titles based the ODM library, calculated fractional vegetation cover (FVC) based on visible-band difference vegetation index (VDVI), estimated above ground biomass (AGB) using an inversion model established based on archived quadrats. Although the accuracy needs to be verified, this research has certain practical significance for guiding on-site grazing in natural grasslands. The dataset for the first pasture of Hulunbuir Youran Animal Husbandry Co., Ltd. includes: (1) a orthophoto map, with a size of 21,754×13,188; (2) a FVC map, with a size of 21,754×13,188; (3) a VDVI map, with a size of 21,754×13,188; (4) a AGB map, with a size of 21,754×13,188. The dataset is archived in .shp data format, consists of 16 data files with data size of 1.23 MB (Compressed to 1 file with data size of 237 KB).

Keywords: UAV imagery; VDVI; FVC; AGB

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Dataset Availability Statement:

The dataset supporting this paper was published and is accessible through the *Digital Journal of Global Change* https://doi.org/10.3974/geodb.2024.02.03.V1 or https://cstr.escience.org.cn/CSTR:20146.11.2024.02.03.V1.

1 Introduction

Owing to less precipitation, the vegetation in the grasslands grows slow and the land is prone to desertification[1]. Chasing water and grass for grazing is a way for herders to adapt to the ecological environment of grasslands. By constantly shifting and searching for new grasslands, the grasslands can be satisfied the food needs of livestock without damaging grasslands, which demonstrates the survival wisdom of grassland people to fully utilize the

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***Corresponding Author:** Wang, D. L. 0000-0002-1377-8394, IGSNRR/CAS, wangdongliang@igsnrr.ac.cn

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[2] Wang, D. L., Li, Y. Z., Zhang, A. C. Experimental dataset for rapid generation of grassland key parameters from UAV images [J/DB/OL]. *Digital Journal of Global Change Data Repository*, 2024. https://doi.org/10.3974/geodb.2024.02.03.V1. https://cstr.escience.org.cn/CSTR:20146.11.2024.02.03.V1.

grasslands and adapt to the environment, as well as their pursuit of harmonious coexistence between humans and nature[2].

Accurate and real-time forage distribution data is the basis of choosing the place which around water and grass to live. However, these forage distribution data are mainly estimated by naked eyes, thus the geographic coverage and the accuracy are limited. Satellite-based grassland vegetation monitoring methods can be used collect the historical and latest data for a wide range at low cost[3], thus are suitable for continually and dynamically monitoring grasslands at large scale. However, the satellite data resolution is coarse, the accuracy is low, and is updated with low frequency, which cannot be directly provided for on-site grazing. In recent years, unmanned aerial vehicle (UAV) remote sensing technology has emerged with advantages such as high resolution, low cost, and flexibility, and has been applied in high-precision vertical structure parameter extraction of grasslands, above ground biomass (AGB) inversion[4], and animal population surveys[5, 6]. However, unmanned aerial vehicle remote sensing products typically needs to be validated using ground measurement data, the collection and processing of ground data is time-consuming and laborious, thus cause the failure to produce UAV remote sensing products for on-site grazing decision-making support.

In this study, a method of rapidly mapping grassland key parameters, such as VDVI, FVC, and AGB, was developed after rapidly mosaicking images collected by a fixed-wing UAV. The timeliness analysis showed that the proposed method for rapidly generating grassland key parameters could meet the grazing needs and could provide forage distribution data in a few hours.

2 Metadata of the Dataset

Experimental dataset for rapid generation of grassland key parameters from UAV images[7] is summarized in Table 1. It includes the dataset full name, short name, authors, geographical region, year of the dataset, spatial resolution, data format, data size, data files, data publisher, and data sharing policy, etc.

Table 1 Metadata summary of the Experimental dataset for rapid generation of grassland key parameters from UAV images

Items	Description
Dataset full name	Experimental dataset for rapid generation of grassland key parameters from UAV images
Dataset short name	UAV_AGB_FVC
Authors	Wang, D. L. 0000-0002-1377-8394, IGSNRR/CAS, wangdongliang@igsnrr.ac.cn Li, Y. Z., IGSNRR/CAS, liyuzhe@igsnrr.ac.cn Zhang, A. C., IGSNRR/CAS, zhangaochong0013@igsnrr.ac.cn
Geographical region	First pasture of Hulunbuir Youran Animal Husbandry Co., Ltd., Hulunbuir city , Inner Mongolia autonomous region: 49.318°N–49.334°N, 119.497°E–119°543′E
Year	July 19, 2023, from 14:02 to 14:54
Spatial resolution	3 cm
Data format	.shp
Data size	1.23 MB
Data files	Including a orthophoto image, a FVC map, a VDVI map, and a AGB map
Foundations	Ministry of Science and Technology of P. R. China (2021YFD1300501); Chinese Academy of Sciences (XDA23100200)
Data publisher	Global Change Research Data Publishing & Repository, http://www.geodoi.ac.cn
Address	No. 11A, Datun Road, Chaoyang District, Beijing 100101, China
Data sharing policy	(1) ***Data*** are openly available and can be free downloaded via the Internet; (2) End users are encouraged to use ***Data*** subject to citation; (3) Users, who are by definition also value-added service providers, are welcome to redistribute ***Data*** subject to written permission from the GCdataPR Editorial Office and the issuance of a ***Data*** redistribution license; and (4) If ***Data*** are used to compile new datasets, the 'ten per cent principal' should be followed such that ***Data*** records utilized should not surpass 10% of the new dataset contents, while sources should be clearly noted in suitable places in the new dataset[8]
Communication and searchable system	DOI, CSTR, Crossref, DCI, CSCD, CNKI, SciEngine, WDS/ISC, GEOSS

3 Methods

3.1 Study Area

The first pasture of Hulunbuir Youran Animal Husbandry Co., Ltd. (formerly Hulunbuir Yili Animal Husbandry Development Co., Ltd.) is located in the center of the Hulunbuir meadow steppe, within the territory of Chenbaerhu Banner (119°30′55.40″E, 49°19′05.40″N, Figure 1). The climate is temperate semi-arid continental, with an annual average precipitation of 320 mm. Annual average frost-free days is 100–114. Annual average temperature is approximately –6 ℃. Annual average rainfall is 308 mm. Across the pasture, elevation varies from 595 m to 602 m. The grassland area of the pasture is 5,910 mu (3.94 km^2).

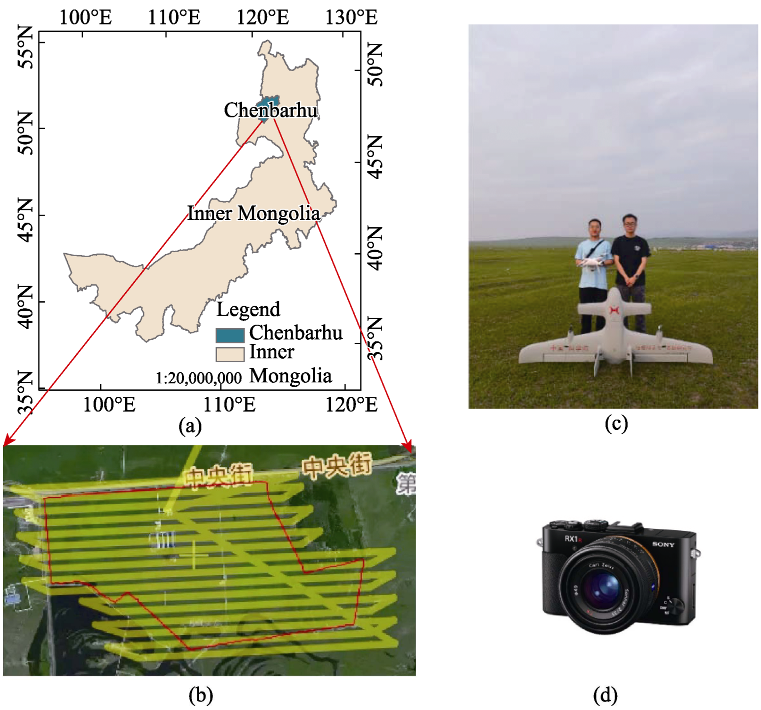

Figure 1 (a) Map of location of Inner Mongolia, China and the study site in Inner Mongolia; (b) UAV trajectory; (c) fixed-wing UAV employed in this study; and (d) Sony camera equipped on the UAV

3.2 UAV Data Collection

Considering the large area of the pasture, it is impossible to complete the data collection using a multi-rotor UAV in a day. On July 19, 2023, a customized electric vertical take-off and landing fixed-wing UAV (Figure 1) was used to collect UAV imagery. The aircraft weighs 2 kg, has a wing span of 2.2 m, and offers a payload capacity of up to 3 kg. Its endurance is 120 min flying at an altitude of 500 m with a load of 600 g. The cruising speed is 72 km/h. The UAS is equipped with autopilot, enabling fully autonomous navigation from takeoff to landing when following a predefined flight plan. The UAS was mounted with a Sony RX1R II camera. The camera was programmed to capture RGB images simultaneously with approximately 80% forward-overlap and 50% side overlap. The flight altitude was 300 m above the take-off location. It took 52 minutes to capture 1072 images with a resolution of about 3 cm. Each image has a size of 7,952 × 5,304 pixels. The flight route is shown in Figure 1b.The UAV campaign covered an area of 6.67 km^2.

3.3 UAV Image Mosaicking

ODM (OpenDroneMap) is an open source library of processing UAV images that can easily create orthophotos, DEMs, 3D models and point clouds from UAV images[9]. In this study, an image fast-stitching software allowing one-click mosaicking of UAV images was developed based on the ODM open source library. The original ODM open source library cannot read UAV images collected in this study, and the mosaicking process is complex because of requiring many parameters to be set. This study made adaptations for the input and output parameters according to UAV data collected in this study. The software can automatic read images and corresponding positioning and orientation system (POS) data from the specified file path, and calls the ODM library to perform image mosaicking. Finally, the orthophoto map is outputted to the specified output file path. The usability and efficiency of the software are greatly improved via pre-setting default parameters and one-click mosaicking.

3.4 VDVI Calculating

Pervious study showed that VDVIs have excellent performance in distinguishing between green vegetation and non-vegetation[10]. VDVI is calculated with the blue, green, and red bands of visible light images[11]:

$$VDVI = \frac{2 \times B_{green} - B_{blue} - B_{red}}{2 \times B_{green} + B_{blue} + B_{red}} \quad (1)$$

where, B_{red}, B_{green}, B_{blue} indicates the band value of red, blue, and green, respectively.

3.5 FVC Calculating

FVC of the study area is calculated by the pixel binary model[11] based on the VDVI:

$$FVC = \frac{VDVI - VDVI_{soil}}{VDVI_{veg} - VDVI_{soil}} \quad (2)$$

where, $VDVI_{soil}$ and $VDVI_{veg}$ indicate the VDVI value of the pure soil pixel and the soil vegetation pixel, respectively. In this study, the measured results shows that $VDVI_{veg}$ varies from 0.007404 to 0.212268.

3.6 AGB Calculating

Using the 66 ground measured data collected nearby the study area in August 2015 by Wang *et al.*[12], an empirical equation for estimating biomass based on FVC (R^2=0.440,7) is constructed as follows:

$$AGB = 678.625 \times FVC^{4.2653} \ (0\% \leqslant FVC \leqslant 100\%) \quad (3)$$

4 Data Results and Validation

4.1 Data Composition

The dataset includes: (1) a orthophoto map, (2) a FVC map, (3) a VDVI map, and (4) a AGB map, and consists of 4 data files with data size of 1.23 MB.

4.2 Data Products and Validation

The orthophoto map was generated by the fast-mosaicking software. VDVI, FVC, and AGB were calculated with Equations (1)–(3), respectively. The orthophoto map covered an area of

6.67 km^2, as shown in Figure 2a. VDVI, FVC, and AGB are shown in Figure 2b–2d.

The visual interpretation method was used to evaluate the accuracy of the data products. This study aims to quickly generate key dataset, such as orthophotos, vegetation cover, and biomass, which are urgently needed for on-site grazing. On-site grazing typically expects higher requirements for the overall trend (relative accuracy) and timeliness of the forage distribution data than the absolute accuracy. Namely, the region where the forage is more abundant is more expected to know so as to follow. Therefore, the results were validated via visual inspection. Visual inspection showed that the orthophoto map was seamless around houses, roads, and fences, and no significant geometric deformation was found. The overall trend of the vegetation fraction cover and biomass was consistent with ground observations. As consequence, these products are accurate enough for on-site grazing.

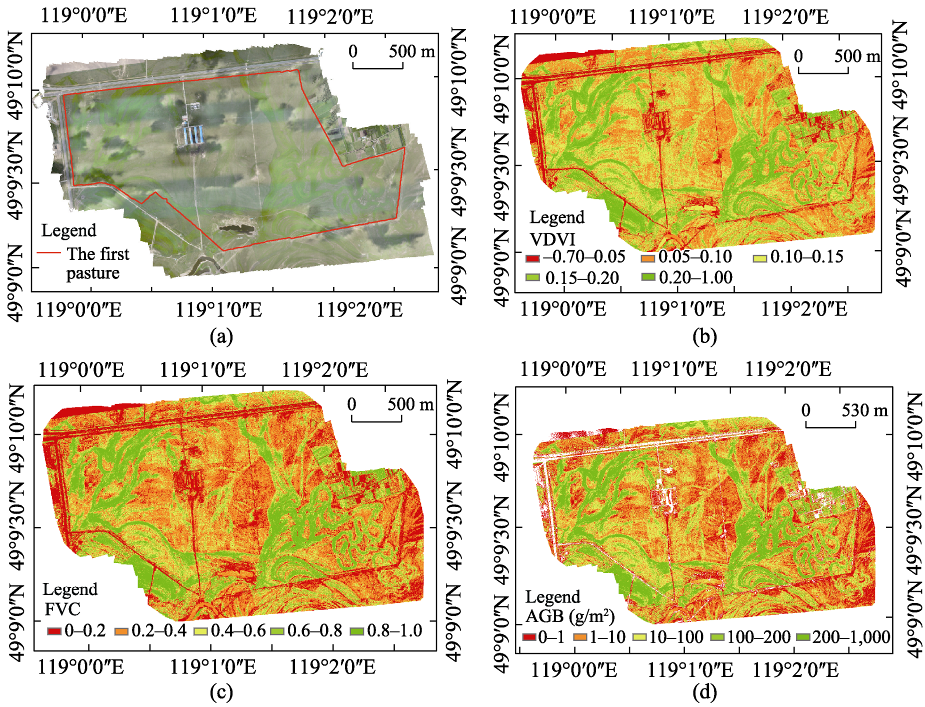

Figure 2 Orthophoto maps of the first pasture (a), VDVI (b), FVC (c) and AGB (d)

Analysis of the accuracy of vegetation coverage and biomass inversion models: The proposed image fast mosaicking method can be utilized for unmanned aerial vehicle data collected in different seasons. However, the threshold values of $VDVI_{soil}$ and $VDVI_{veg}$ shown in Equation (2) for vegetation coverage extraction were measured according to the truth values of soil and vegetation in the UAV imagery. This threshold values may vary as different lighting conditions and should be re-measured. In addition, the biomass inversion model was constructed based on the quadrats collected in July. The grassland vegetation renewal and litter accumulation speed varies in spring, summer, and autumn, and in winter, grass completely withers or falls. To insure the accuracy, it is better to retrain the biomass inversion model shown in the Equation (3) for different seasons using the quadrats collected in the same month as UAV data or to construct a new biomass inversion model.

Analysis of advantages and disadvantages of the proposed method: the proposed method could complete the entire process from data collection to vegetation coverage and biomass inversion for the first pasture of Hulunbuir Youran Animal Husbandry Co., Ltd. in less than

5 and a half hours. The generated key parameters for grasslands have high timeliness and can be used to guide on-site grazing. The proposed method hold the promise of developing smart animal husbandry in the future. However, the fixed-wing UAV used in this article is easily affected by weather and terrains. In cloudy weather, the UAV can operate under the clouds, but could not work under harsh weather conditions such as rain, snow, and strong winds. When the terrains of the operating point is not suitable for the takeoff and landing of fixed-wing UAVs, the multi-rotor UAV may be used as a substitute. Furthermore, due to the limitation of the battery capacity of the drone, it is not possible to perform a long distance flight. For example, the fixed-wing UAV employed in this article could cover a survey area of approximately 10 km^2 at a time, and it is necessary to replace batteries or using multiple drones for synchronous operation to ensure the timeliness of data collection for the larger area.

5 Discussion and Conclusion

To acquire and process UAV imagery for the first pasture of Hulunbuir Youran Animal Husbandry Co., Ltd. in a few hours, a method for rapidly producing grassland key parameters based on UAVs was proposed. The main points to boost efficiency includes: (1) it is impossible to capture the imagery using multi-rotor UAVs for the first pasture with an area of over 3.94 km^2. Therefore, a new customized fixed-wing vertical take-off and landing (VTOL) UAV was utilized to capture UAV imagery for the pasture. VTOL UAVs become less dependent on landing sites by taking off and landing vertically, and reduce the air resistance during the cruise phase by using fixed-wing horizontal flight in the air. Therefore, VTOL UAVs have the advantages of both multi-rotor UAVs that can take-off vertical and fixed-wing UAVs that have a long endurance at a high speed. Under the same take-off weight, wingspan, battery energy density, and battery weight, VTOL UAVs have longer endurance times than the other types of UAVs, and provide an efficient solution for aerial photography in complex terrain areas such as Inner Mongolian Plateau[13]. (2) To accelerate image mosaicking, a one-click fast mosaicking software was developed based on the open source library ODM to generate orthophoto maps. The mosaicking time was shorten significantly. (3) Finally, FVC was calculated based on VDVIs, and biomass was estimated using the model established based on archived quadrats. Due to the absence of field data collection and processing missions, the period of mapping products was greatly shortened.

As shown in Figure 2, the VDVI values varying from –0.68 to 0.87 fall into five categories. The regions with VDVI values less than 0.05 are mainly buildings, roads, water and soil, which are shown in red. The regions with VDVI values from 0.05 to 0.15 are mainly grasslands with low biomass, which are shown in yellow or light green. The remaining regions with VDVI values higher than 0.15 are mainly grasslands with high biomass, mostly located away from buildings and near water resources, which are shown in green. The FVC and AGB value also fall into five categories, the low-value regions are mostly corresponding to buildings, roads, and water resources, while the high-value regions mostly overlap with the grassland with high biomass. It took us 5 hours and 22 minutes to collect the UAV data and mapping key parameters for grasslands, including 52 minutes for data collection, 4 hours for image mosaicking, and 30 minutes for mapping grassland key parameters. The data products can meet the requirements of herders regarding the relative accuracy and timeliness of forage distribution data, which has great theoretical significance and expected application prospects.

The visually inspection ensures the data products generated in this study have a high relative accuracy. However, the FVC and AGB generated in this study have not been validated using the field measurements. We will use field data to calibrate the products for improving its accuracy in our future studies. In addition, the image mosaicking algorithm will be optimized to improve the mosaicking efficiency, and real-time image mosaicking algorithms will be also developed for on-site grazing and emergency rescue with strong pursuit of the higher effectiveness.

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Conflicts of Interest
The authors declare no conflicts of interest.

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