405

Can spatial distribution of cattle manure be controlled? Relationship between cow location and dung pats

Kato, M[1]; Yayota, M[2]; Kawamura, K[3]; Yasuda, T[4]; Kitagawa, M[5]

[1] Graduate School of Natural Science and Technology, Gifu University, Gifu 501-1193, Japan

[2] Faculty of Applied Biological Sciences, Gifu University, Gifu 501-1193, Japan

[3] Obihiro University of Agriculture and Veterinary Medicine, Hokkaido 080-8555, Japan

[4] Mount Fuji Research Institute, Yamanashi Prefectural Government, Yamanashi 403-0005, Japan

[5] Institute of Livestock and Grassland Science, NARO, Nagano 389-0201, Japan

Key words: cow location; deep learning; dung pats; unmanned aerial vehicle (UAV)

Abstract

Controlling the spatial distribution of cattle dung pats in a pasture can enhance nutrient utilization and mitigate greenhouse gas emissions resulting from dung in grazing management. Dung pats are distributed in accordance with cattle behavior and location in a pasture, thus frequent monitoring of cattle location and dung distribution is essential for effective dung control. Recently, the detection of dung pat distribution has been achieved using unmanned aerial vehicle (UAV) images. Additionally, a global positioning system (GPS) can provide continuous monitoring of cattle locations. Therefore, in this study, we monitored the effect of cattle location on dung distribution under strip stocking using UAV images and a deep learning approach. Five dairy cows, equipped with GPS collars, grazed for five days under a strip stocking condition. A 3.5 ha pasture was divided into four paddocks, one of which was expanded each day. UAV images were captured before grazing each day. The training data generated were used to estimate dung pat distribution using YOLO (YOLOv8x), an object detection algorithm. The accuracy of the dung distribution was assessed using the confusion matrix. The paddock was further divided into 10 m grids, and a generalized linear model was employed to evaluate the relationship between cow location and dung pat count within each grid. The detection accuracy of dung distribution was 0.793 (precision), 0.222 (recall), 0.210 (accuracy), and 0.347 (*F*-value), indicating the need to improve the accuracy of detecting undetected dung pats. As the pasture area increased, the cows spread out their location, resulting in an expanded dung distribution. However, the cow location did not correlate with the dung location ($R^2 = 0.053$). This is presumably due to the insufficient recall of the dung distribution estimates. Additionally, not only the location, but also the cow's behavior, such as resting and lying, should be assessed.

Introduction

Cattle play a critical role in nutrient cycling within grazing ecosystems by consuming plants and redistributing nutrients back into pastures through excretion (Hirata et al. 2011). However, the spatial distribution of excreta across pasture is often uneven (Hassan-Vásquez et al. 2022). Consequently, nutrient levels within a pasture can vary significantly, with some areas becoming nutrient-rich or even overloaded, while others remain nutrient-deficient. Moreover, in areas with high concentrations of manure, dung patches are formed (Takigawa et al. 1996), which may reduce the efficiency of grassland utilization (Klootwijk et al. 2019). Recently, cattle dung has also been recognized as a source of greenhouse gas emissions, with nitric oxide and nitrogen dioxide being emitted from dung (Osada 2001). Thus, efforts to reduce greenhouse gas emissions, such as the application of nitrification inhibitors, are required (Cahalan et al. 2015). However, the widespread application of nitrification inhibitors across an entire pasture represents a substantial cost and is a labor-intensive endeavor.

Controlling the spatial distribution of cattle dung pats in a pasture would contribute to solving the above problems and is important from the perspective of grassland management and environmental conservation. Since cattle behavior and location are closely linked to dung distribution, frequent monitoring of cattle movements and dung deposition is essential for effective management. In recent years, global positioning systems (GPSs) or global navigation satellite systems (GNSS) have facilitated continuous monitoring of cattle locations (Yoshitoshi et al. 2020). Moreover, the detection of dung pat distribution has been accomplished through unmanned aerial vehicle (UAV) images, employing deep learning approaches that can accurately recognize images and detect objects. In this study, we monitored the effect of cattle location on dung distribution under strip stocking conditions using UAV images and a deep learning approach. Grazing insight into this relationship can inform the development of targeted strategies to manage dung distribution, enhance pasture utilization, and mitigate environmental impacts.

Methods

The grazing trial was conducted for five days from June 26, 2023, in a 3.5 ha grass-legume mixed pasture located in the eastern region of Hokkaido, Japan (N42°33', E143°14'). The pasture had a single gate in its northeastern part and tree sheds along the fence from the east to the northeast in the pasture. The pasture was divided into four paddocks, and strip grazing was implemented. On the initial day, the entire pasture was utilized for grazing, followed by the sequential opening of one paddock per day, starting with the easternmost paddock on the second day.

A total of 53 cows (47 Holsteins and 6 Jerseys cows) were grazed for approximately 8 hours from 7:30 am. to 3:30 pm. The cows were milked twice a day, once before and once after grazing, and were provided supplementary feed in the barn. Five cows (three Holsteins and two Jerseys), selected based on age (3.6 ± 2.9 years) and breed, were fitted with GPS collars to track their movements during the grazing.

Aerial photography was conducted on four of the five grazing days, excluding June 28 due to rain. An UAV (Parrot, Anafi, France) equipped with a camera (4K HDR) was used for aerial photography. Four Ground Control Points (GCP) were set up to perform geometric corrections prior to aerial photography. The UAV was operated using the Pix4D capture flight management application. The flight altitude was 35 m, the camera angle was 80°, the overlap setting of 80% for forward movement and 60% for lateral movement, and the image resolution was 1.3-1.5 (cm/pixel).

To validate the dung distribution data, three 10 m × 10 m plots were established in the pasture. The dung distribution estimated via aerial imagery was compared to data obtained through direct observation using a Real-Time Kinematic GNSS (RTK-GNSS). Aerial images were geometrically corrected and orthorectified using Agisoft Metashape (Agisoft LLC, Russia).

For the creation of training data, annotations were performed using the Makesense tool (https://www.makesense.ai/). Training was conducted using YOLOv8x (https://github.com/ultralytics/yolov8), a real-time object detection algorithm YOLO (You Only Look Once). The dataset included 3,284 annotations, combining data from the present study and our previous study (Kawamura et al. 2024) conducted at a different location.

Statistical analyses were performed using R version 4.3.2 (R Core Team, 2023), except for estimating cow dung distribution. The accuracy of dung distribution detections was assessed through a confusion matrix. The logarithm of GPS point counts was used to evaluate cow movement patterns. A Poisson regression model (GLM) was used to examine the relationship between cow location and dung distribution. The number of GPS points within each grid of the pasture served as the explanatory variable, while the number of dung detections represented the response variable. The predictive accuracy of dung counts, estimated from the regression equations, was assessed using R^2 (coefficient of determination), RMSE (root mean square error), and AIC (Akaike Information Criterion).

Results

The average vegetation coverage was 62.0%, with meadow fescue (*Festuca pratensis* L.), white clover (*Trifolium repens* L.), and orchard grass (*Dactylis glomerata* L.) as the dominant grass species. The detection accuracy of dung distribution was 0.793 (precision), 0.222 (recall), 0.210 (accuracy), and 0.347 (*F*-value). GPS data were obtained from all five cows on one day, four cows on three days, and three cows on the remaining day.

Figure 1 illustrates the daily counts of GPS points and the cumulative total of detected cow dung. The spatial distribution of cow increased as the grazing paddock expanded, leading to a wider spread of manure distribution. However, despite the paddock expansion, cow tended to concentrate their activities near the tree shades in the southeastern part of the pasture.

The relationship between the time spent by cows in each area and the number of dung was analysed using Poisson regression (GLM), as shown in Figure 2. The regression equation is as follows:

Number of dung = exp (0.37+0.19×log [GPS points]): R^2=0.053, RMSE=2.403, AIC=1600.186

The low R^2 value indicates that cow locations accounted for less than 5% of the variation in the dung distribution.

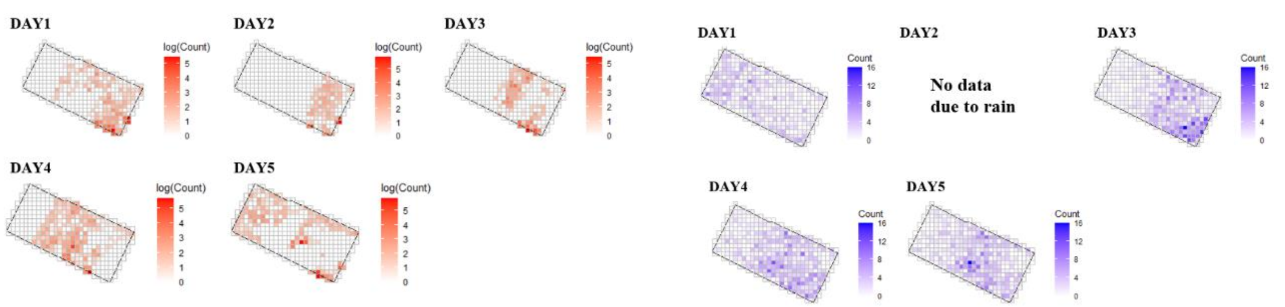

Fig. 1 Cattle location (left) and estimated dung distribution (right) in the strip stocking pasture

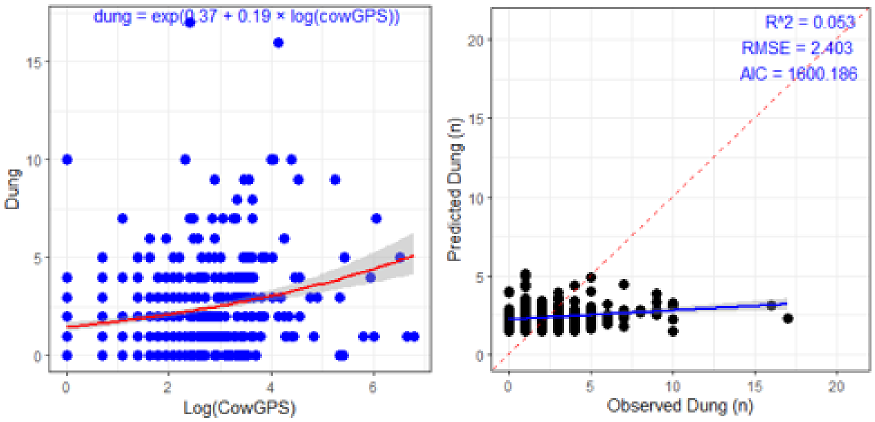

Fig. 2 The regression equation and graph obtained through Poisson regression, based on the number of GPS counts within the grid and the detected number of cow dung (left). The accuracy of the regression equation is evaluated by comparing the number of cow dung estimated from the equation with the actual number of dung detected (right).

Discussion

Strip grazing influenced cattle behavior significantly. As the pasture area increased, cows spread out their location, resulting in an expanded dung distribution. However, the cow location did not correlate with the dung location ($R^2 = 0.053$). This low correlation may be attributed to the low detection rate of cow dung in aerial images (recall: 0.222), which highlights the need for improvement. The resolution of the aerial images, approximately 1.3–1.5 cm/pixel, was coarser than that used in a previous study by the authors (0.9–1.0 cm/pixel), potentially causing smaller dung patches to go undetected. Kawamura et al. (2023) recommend a drone flight altitude of 40 m (resolution: 2 cm) or lower for efficient surveying in large fields. However, achieving higher-resolution images at lower altitudes may be essential for accurate detection in a pasture.

Machine learning models demonstrate enhanced accuracy with larger and more diverse training datasets, thus augmenting their practical applicability (Oki et al. 2019). Therefore, in addition to optimizing aerial photography conditions, it is crucial to enhance detection model accuracy by expanding the variety of supervised data for cow dung images, particularly given the challenges in distinguishing them from their surroundings.

Regardless of the expanded grazing paddocks, cow activity was concentrated in specific areas. This behavior likely reflects cows exploring and grazing in newly opened paddocks but returning to shaded areas for rest and ruminating. Research has indicated that cows defecate less frequently when lying down or foraging and more frequently after standing up and feeding (Suzuki et al., 1983). To enhance the predictability of cow dung distribution, it is essential to analyze not only the duration of stays but also grazing, ruminating, and resting behaviors at each location.

Acknowledgements

We thank to Naito Farm for their support in the field and cattle management. This work was supported by JSPS KAKENHI Grant Number 22H02470 (K. Kawamura). All experimental procedures were approved by the Animal Care and Use Committee of Obihiro University of Agriculture and Veterinary Medicine (Approval Number: 24-87).

References

Cahalan E, Ernfors M, Müller C, Devaney D, Laughlin RJ, Watson CJ, Hennessy D, Grant J, Khalil MI, McGeough KL, Richards KG (2015) The effect of the nitrification inhibitor dicyandiamide (DCD) on nitrous oxide and methane emissions after cattle slurry application to Irish grassland. *Agriculture, Ecosystems and Environment* 199, 339-349.

Hassan-Vásquez JA, Maroto-Molina F, Guerrero-Ginel JE (2022) GPS-tracking to monitor the spatiotemporal dynamics of cattle behavior and their relationship with feces distribution. *Animals* 12, 2383.

Hirata M, Higashiyama M, Hasegawa N (2011) Diurnal pattern of excretion in grazing cattle. *Livestock Science* 142, 23-32.

Klootwijk CW, Holshof G, de Boer IJM, Van denPol-Van Dasselaar A, Engel B, Van Middelaar CE (2019) Correcting fresh grass allowance for rejected patches due to excreta in intensive grazing systems for dairy cows. *Journal of Dairy Science* 102, 10451-10459.

Kawamura K, Yasuda T, Kitagawa M, Yayota M, Kunishige K (2023) Relationship between drone flight altitude and ground resolution: Toward efficient aerial photography. *Japanese Journal of Grassland Science* 69, 58 (Supple).

Kawamura K, Kato Y, Yasuda T, Aozasa E, Yayota M, Kitagawa M, Kunishige K (2024) Cattle dung detection in pastures from drone images using YOLOv5. *Grassland Science* 70, 168-174.

Suzuki S, Ohta K, Satoh S, Kashiwamura F (1983) Behavoral pattern when elimination occurs in dairy cows. Research bulletin of Obihiro Zootechnical University, Series I 13 (2), 79-84.

Takigawa K, Yanagi A, Yamashita N, Hayakawa H, Nakanishi Y, Manda M, Watanabe S, Katahara K, Ynagita K (1996) Relationship between the Quantity of Cattle Dung Pat and the Duration of Dung Patch Existence in Italian Ryegrass (*Lolium multiflorum Lam.*) Pasture. *Grassland Science* 42, 247-250.

Oki K, Maki M, Okumura T, Salem SI (2019) Development of deer population size estimation method with ground and remote sensing. *Journal of the Remote Sensing Society of Japan* 39, 384-392.

Osada T (2001) Environmental load gas emission from livestock waste. *Animal Science Journal* 72, 167-176.

R Core Team (2023) R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. Available at https://www.R-project.org/ [Accessed 09 02 2024].

Yoshitoshi R, Watanabe N, Lim J (2020) Spatial distribution of grazing sites and dung of beef cows in a sloping pasture. *Japan Agricultural Research Quarterly* 54, 299-306.