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Comparison of the spatial distribution of dung under high and low instantaneous stocking densities.

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Regenerative Agriculture (RA) is attracting the attention of farmers throughout New Zealand. Common features of RA include incorporating a greater diversity of species in a pasture mix and a grazing strategy which leaves more plant material post-grazing, with the aim of improving soil health and nutrient cycling. Regenerative Agriculture does not have a common agreed working definition; However, a list of RA principles has been developed based on a survey of NZ farmers and researchers (Grelet et al., 2021). This paper stated that RA is based around a set of principles rather than a set of defined practices. Grelet et al., (2021) defined 11 key principles common in NZ RA practitioners:

- The farm is a living system;
- Make context specific decisions;
- Question everything;
- Learn together;
- Failure is part of the journey;
- Open and flexible toolbox;
- Plan for what you want, start with what you have;
- Maximise photosynthesis;
- Minimise disturbance;
- Harness diversity; and
- Manage livestock strategically

One example of a RA grazing strategy is grazing at higher instantaneous stocking density by utilizing larger mobs and entering the pasture at higher pre-grazing mass and having high post-grazing residuals compared to conventional management. This management is called adaptive grazing and the approach increases the opportunity for pasture trampling into the soil. It has also been hypothesized that adaptive grazing will have more even excrement distribution compared to conventional management. The more even return of excrement has the potential to reduce the risk of nutrient losses to air and water and also the animal transfer factor that drive nutrient requirements in a grazed pasture. The research in this paper will explore how different instantaneous stocking density influences the distribution of dung.

An example of RA in practice at Mangarara Farm, located in central Hawkes Bay, where RA principles have been followed for the last 20 years. A group of farmers closely associated with Mangarara have been instrumental in the establishment of a grazing study in collaboration with. The overall aims of the research are to quantify the effect of an adaptive grazing practice: higher pre-and post-graze pasture mass, and higher instantaneous stocking density during grazing, in comparison with a control grazing practice: lower pre and post-grazing mass and nine-fold lower instantaneous stocking density during grazing on the pattern of forage supply, beef production, excreta return, input demands, farm performance (production and financial) and environmental footprint (MacKay and Cosgrove, 2022).

To test the influence of the two grazing treatments on dung return a paddock on Mangarara Farm has been divided up into 15 pasture lanes, with each laneway having 3 to 4 cells and a total of 67 cells (Fig. 1). For the control grazing treatment there are 2 sets of 6 cells, located at the top and bottom of the paddock, each grazed by 6 cattle that are moved every 3 to 4 days at a lower instantaneous stocking density. In contrast, the adaptive mob has 56 cattle to create a higher instantaneous stocking density and these animals are moved multiple times a day.

Figure 1: Map of the adaptive grazing study on Mangarara farm

Research objectives

The two research objectives were to:

1. Examine if a drone with an RGB camera can detect dung patches and therefore the spatial distribution of dung over the grazed pasture area.
2. Determine if the spatial distribution of dung deposition changes under high instantaneous stocking density compared to low instantaneous stocking density.

Methods

The traditional method of measuring the spatial distribution of dung deposition is to create a grid pattern over the area of interest and mark if dung is present or absent in each grid point (Morton, & Baird,1990) however, this method can be time consuming. Alternatively, drones have been used to locate urine patches under dairy and other intensive grazing systems in New Zealand (O'Neil et al., 2020), though there is not a lot of information on the use of drones to identify dung patches. Exploring the potential use of a drone to locate dung, required the development of a new method that would then validate. Multiple drone images were collected over the area of interest at an altitude of 30m, with each image having a 75% overlap (photogrammetry). The programme pix4dReact was used to join all of the images together to create a single image. This image was then exported into ArcGIS pro (Esri, 2020) and all of the dung patches were manually reviewed and digitally marked.

To validate the dung patches identified in the drone images, the Trimble survey tool was used to walk each cell of the study and mark every individual dung patch present. The GPS points were then compared to the GPS points created from the drone imagery. If the Trimble GPS dung points and drones image dung patches were both the same, this was considered a positive match. Where the Trimble GPS did not match with drone derived image dung patch, this was labelled a GPS non-match, which was a false negative. Where the drone image dung patches did not match the Trimble GPS mark, this was called a drone miss match, or false positive. These two approaches were then tested by comparing dung deposition between the adaptive and control grazed cells in 12 different cells (4 control cells and 8 adaptive cells).

Results

Drone images

The drone flew the 9ha area in 15 minutes. Figure 2a shows the image of the whole paddock, with the red line showing the paddock boundary. Figure 2b shows a subsampled area of the paddock and the yellow dots are dung patches that are identified by both GPS and drone. The red dots are dung patches that are marked by GPS but is missed by the drone technology, GPS non-match. The blue dots are dung patches identified from the images taken by the drone marked dung matches that are not dung patches and not marked by the GPS, drone miss-match.

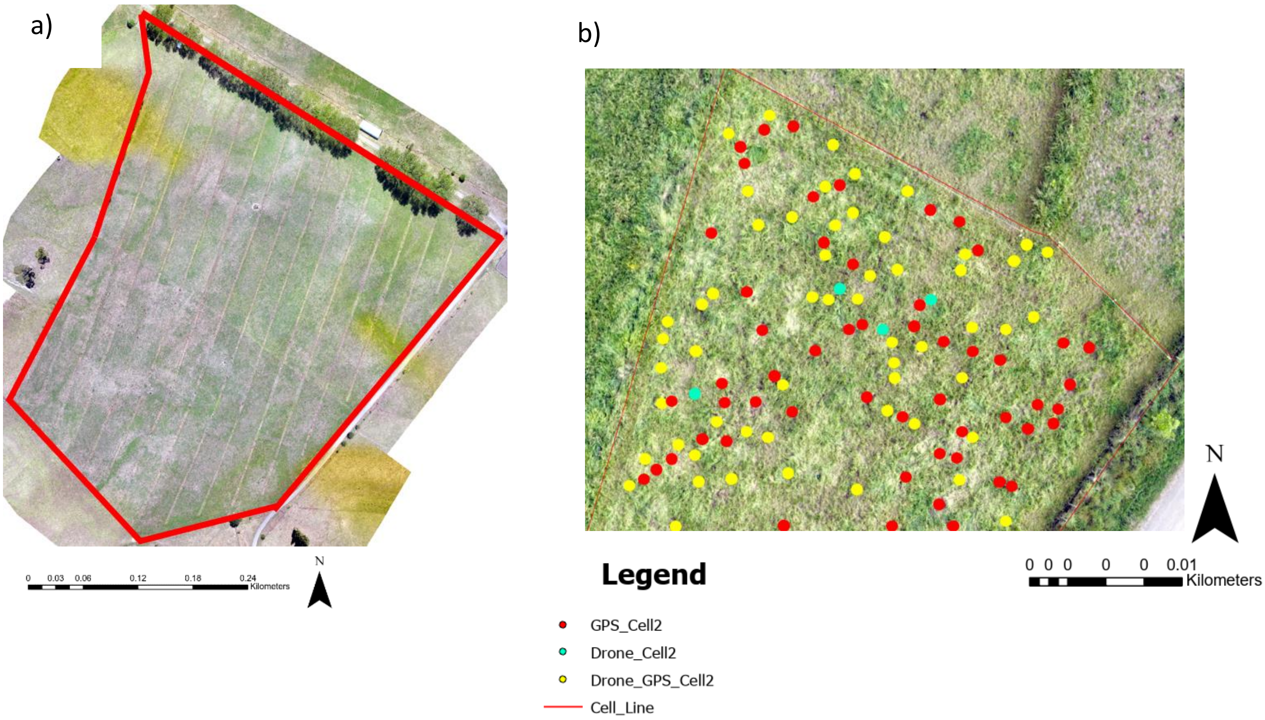

Figure 2: a) Drone image of the paddock and b) a subsample of paddock. Yellow are dung patched identified by drone and GPS. Red are dung patches that are marked by GPS but missed by drone, GPS non-match. Blue are dung patches identified by drone and not by GPS, drone miss-match.

Validation

Table 1 compares the total number of dung patches per ha identified using the GPS, compared to those identified in the image taken by the drone. The number of patches measured by the GPS ranged from 1104 to 5092/ha, with a mean of 2727/ha and standard deviation (SD) of 1103/ha. The number of patches identified by the image taken by the drone ranged from 856 to 4041/ha, with a mean of 1805/ha and SD of 1090/ha. The GPS non-match with the drone derived patch measures ranged from 194 to 1529/ha, with a mean of 1125/ha and SD of 342/ha. The number of drone miss matches with no GPS patches ranged from 33 to 772/ha, with a mean of 202/ha and SD of 243/ha. The percentage of GPS and drone matches ranged from 36 to 82% with a mean of 57% and SD of 15%. The percentage of GPS non-match with drone patches ranged from 18 to 65%, with a mean of 44% and SD of 15%.

A number of factors affected the accuracy of dung patch measurement, including pasture height, amount of bare soil and trees. The height of the pasture reduced the ability of the drone camera to capture dung patches. Long pasture hides the dung as well as causing shadows which looks like dung patches, which also increase the number of drone miss matches. Bare wet soil and soil damaged by treading affects the number of dung patches that can be measured by limiting the colour contrast between the soil, dung and green pasture. Cows are more likely to tread the dung into wet soil which makes them harder to locate. The last factor affecting the drone method accuracy in the present study was the shelterbelt of trees along the side of the paddock. Tree branches cover the grass below the height the drone is flown, making it difficult to identify dung patches in the images.

Table 1: The number of dung patches marked using the GPS and identified from the image taken from the drone and the validation accuracy of each method.

Treatment	**GPS/ha (Trimble)**	**Drone/ ha**	**GPS Non-match/ha (Missed dung patched)**	**Drone miss match/ha (non-dung)**	**Drone accuracy to GPS percentage**	**GPS non-match percentage**
Adaptive	1104	1560	194	649	82	18
Adaptive	1983	856	1186	59	40	60
Adaptive	2089	1293	943	146	55	45
Adaptive	2242	1083	1192	33	47	53
Adaptive	4257	3871	1158	772	73	27
Adaptive	3385	1975	1451	41	57	43
Adaptive	3245	2245	1151	151	65	35
Adaptive	5092	4041	1184	133	77	23
Mean	**2925**	**2116**	**1058**	**248**	**62**	**38**
SD	**1318**	**1223**	**375**	**291**	**15**	**15**
Control	1882	857	1134	109	40	60
Control	2450	1542	975	67	60	40
Control	2387	1017	1529	160	36	65
Control	2612	1314	1405	107	46	54
Mean	**2333**	**1183**	**1261**	**111**	**46**	**55**
SD	**315**	**305**	**252**	**38**	**11**	**11**
Mean overall	**2727**	**1805**	**1125**	**202**	**57**	**44**
SD overall	**1103**	**1090**	**342**	**243**	**15**	**15**

The comparison of dung distribution between the adaptive and control grazing is still currently being processed.

Conclusion

The research shows that an image taken by a drone can be used to identify and locate dung patches. Drone-based technology had the ability to correctly identify dung patches with an average accuracy of 57% (range 36% to 82%) across 12 grazed cells. Accuracy was influenced by factors such as pasture height which caused shading of the dung, bare soil causing colour contrast issues and shading of dung patches by tree branches.

Future research aims to validate the drone-based method under a wider range of climatic conditions and diverse pasture treatments to understand what conditions best suit the use of technology and to further understand the limitations of the method. There is also an opportunity to use drones for other purposes such as locating and estimating the area of bare soil and waterways.

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