

GPS technology as a tool to aid pasture management on dairy farms

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Abstract

This research determined the accuracy and precision of Global Positioning System (GPS) enabled devices as a potential tool to automate the recording of on-farm grazing events, which can be used to indicate productivity of paddocks (with number of grazings per year), or, when combined with other farm data, estimate energy harvested. Static tests were initially conducted to determine the devices' accuracy (location error) and precision (Circular Error Probability; CEP). Based on 11 Agtech and 22 mOOvement devices tested, the mean location error was 5.4 m and 34.2 m, respectively. The 95% CEP was 13.9 m and 77.6 m, respectively. In the subsequent on-farm study, 11 cows in a 400-cow milking herd were fitted with an Agtech and mOOvement ear tag and two with digitanimal collars. Data were analysed for the AM and PM grazing periods for four days. The digitanimal collars recorded 62.3% of total observations in the correct paddock, instead of adjacent paddocks or races, compared with 52.5% for the Agtech devices and 45.2% for the mOOvement ear tags. These results suggested that GPS technology is feasible for the automated recording of grazing events. However, a longer-term study is required to demonstrate the value this technology could have for farmers.

Keywords: Grazing records, low-power wide-area networks (LPWAN), Internet of Things (IoT), dairy farming

Introduction

In countries with temperate climates, such as New Zealand and Ireland, grazed pasture is crucial in underpinning dairy production and farm profitability (Hanrahan et al., 2018; Neal and Roche 2020). Pasture growth occurs year-round in these climates with a seasonal pattern, making pasture a low-cost, high-quality feed source if well managed, and reduces reliance on purchased feeds with higher cost and environmental footprint (Belflower 2010; Rotz et al., 2020).

Maximising pasture productivity and utilisation requires accurate grazing records and information on individual paddock performance. Unfortunately, measuring and recording paddock performance and grazing information is time-consuming and so is not common practice on many farms (Anderson and

McNaughton 2018). For example, in New Zealand, although some farmers record pasture cover estimates and paddocks grazed during weekly farm walks to make feeding and farm management decisions, many do not (Anderson and McNaughton 2018; Eastwood et al., 2020). Furthermore, after the immediate decisions have been made, the data is not always retained (Stevens and Knowles 2011). By contrast, in Ireland, farmers are encouraged to use PastureBase Ireland (PBI), a national grassland management decision support database tool, to record paddock grazing events and other land management actions such as reseeding and fertiliser application (Hanrahan et al., 2017). This provides valuable data for research and benchmarking purposes (O'Donovan et al., 2022).

Recent studies have focused on the feasibility and value of automated remote sensing technologies (e.g., satellite imagery and unmanned aerial vehicles) to promote the routine collection and application of paddock performance and grazing information (Li et al., 2020; Aquilani et al., 2022). Dairy cows may be fitted with Global Positioning System (GPS) capable devices to record paddock grazing events and help estimate pasture mass in near-real-time (Haultain 2014; Woodward et al., 2019). The number of devices required is farm specific, depending on factors such as milking frequency and time spent grazing each paddock. If these devices can be used to record grazings or grazing events automatically, they will provide a simple way for farmers to record and analyse individual paddock performance (e.g., number of grazings per paddock) and provide an alternative to the time-consuming manual methods currently used, such as pen and paper or mobile apps. In the future, this system could potentially be integrated with data from other on-farm monitoring systems (e.g., milk monitoring) to provide estimates of feed intake and pasture harvested. However, at present, the use of GPS technology, such as cow collars and ear tags, has not yet been widely adopted on-farm, possibly due to the high cost of existing GPS devices and lack of integration with farm management software tools.

The rise of the Internet of Things (IoT) has driven the development of new low-power wide-area networks (LPWAN) such as LoRa and SigFox (Mekki et al., 2019). Older networks (e.g., cellular) were unsuited for many IoT applications, which require low power consumption, low data rate and the ability to transmit

data over long distances (Mekki et al., 2019; Dos Reis et al., 2021). Recently, several companies have released LPWAN GPS capable devices (e.g., solar-powered ear tags) suitable for use on cattle, including mOOvement and Agtech. Both companies are based in Brisbane, Queensland, Australia and have packages starting from around \$95 NZD per tag and \$1,500 NZD for a LoRa base station for the mOOvement option (mOOvement 2021a) and \$95 NZD per tag and \$2,000 NZD for a LoRa base station for the Agtech product (Pers. comm. C. Brand, Agtech). This development motivates revisiting the earlier work of Haultain (2014) and Woodward et al. (2019) to assess whether GPS location data from these newer devices can be used to accurately determine paddocks grazed on a commercial dairy farm.

This paper presents the results from (1) a static test study to establish the accuracy and precision of commercially available GPS devices suitable for use on cattle and (2) an on-farm study to determine whether the GPS devices could be used to determine the paddocks grazed on a commercial dairy farm. The accuracy of the devices was assessed and compared, and options for integrating this information into grazing management decisions are discussed.

Materials and Methods

Devices

The trial compared the performance of LPWAN GPS devices in static tests and attached to cows on a commercial dairy farm. Three GPS device types were evaluated; Agtech and mOOvement solar-powered ear tags and digitanimal cow collars. Agtech and mOOvement ear tags are reusable, lightweight (30-37 g) solar-powered devices with an estimated lifespan of approximately five years (Meat and Livestock Australia 2019; mOOvement 2021b). The digitanimal collars are specifically designed for animals, including cattle, and provide activity tracking and animal location data. They are lightweight devices weighing 265 g and measuring 10.4 x 7.6 x 4.8 cm (digitanimal 2021).

The Agtech and mOOvement devices use the LoRa network (data from the GPS devices to the base station) and cellular/Wi-Fi data (data from the base station to the cloud). They were configured to acquire a GPS position hourly (Agtech) or two-hourly (mOOvement) as per the manufacturer's default settings before sending that information to the cloud. In contrast, the digitanimal collars used the Sigfox network and acquired a GPS position once per hour, which was later sent to the cloud.

Static testing

In the first part of the trial, static GPS tests were carried out on the Agtech and mOOvement devices to determine

their accuracy relative to their known position. The digitanimal devices could not be statically tested as they were already on animals as part of an existing trial. For static testing, the devices were attached to a fence at DairyNZ's Scott Farm, Newstead, New Zealand (37.76861° S, 175.3664° E) for one week in March 2021. The devices were attached to a wooden board situated on top of two wooden posts forming a part of a conventional electric fence (Figure 1). To minimise any possibility of interference between each device, they were placed at 10 cm intervals onto the wooden board. All devices were installed and tested in a single location on Scott Farm to reduce spatial variability in terms of precision and accuracy and satellite visibility affecting the results. A total of 22 mOOvement devices and 11 Agtech devices were tested.

The individual data points of each GPS unit were then compared to their actual position using the following two-step process. First, a Real-Time Kinematic device (Model: Trimble R6 RTK) with an accuracy of 3 cm was used to identify the GPS coordinates for the start and end of the wooden board. Then, each device's GPS coordinates (i.e., latitude and longitude) were calculated from these two points. All statistical analyses were undertaken using R software (v4.2.0; R Core Team 2021). The distance between the true and logged points (i.e., the location error and accuracy calculation) was calculated using the `distHaversine` function in the `geosphere` package for R (v1.5.10; Hijmans et al., 2019). Meanwhile, the CEP (precision calculation) was calculated using the `getCEP` function in the `shotGroups` package for R (v0.8.1; Wollschlaeger 2022) at the 50% and 95% levels. The CEP was a circular radius containing a stated percentile of points around an actual location (GPS device's proper location) (Turner et al., 2000; Morris and Conner 2017).

On-farm testing

In the second part of the trial, on-farm testing of the Agtech and mOOvement ear tags and digitanimal collars was conducted on a 400-cow dairy farm in Fernside, Canterbury, New Zealand (43.345° S, 172.5549° E). The trial property was situated at 38 m above sea level and consisted of 115 hectares (110 hectares effective) subdivided into forty-five paddocks ranging from 1.7 to 3.4 hectares. During the period of interest, the farm milked cows twice daily.

Data collection

Eleven cows (~2.8% of the milking herd) were randomly selected and fitted with an Agtech and a mOOvement solar-powered GPS ear tag (one in each ear). In addition, two of the eleven cows (0.5% of the milking herd) were fitted with a digitanimal cow collar as part of an existing trial (Figure 2). The GPS devices



Figure 1 GPS devices during static testing. Agtech tags are shown on the left and mOOvement on the right.

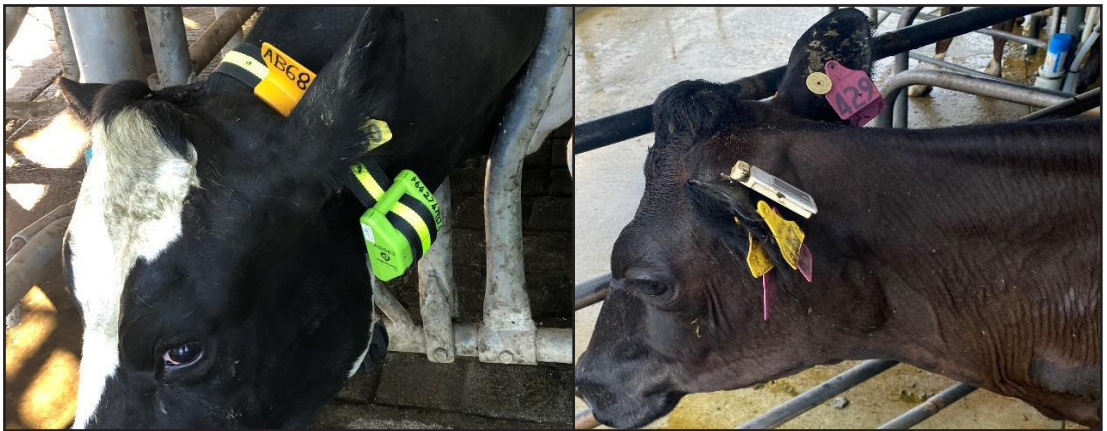


Figure 2 GPS devices on cows during the trial period. A digitanimal collar is shown on the left, and an Agtech ear tag is on the right (white ear tag).

remained fitted to the same cows throughout the trial, regardless of whether they remained in the milking herd or were drafted out into a secondary herd for medical treatment or another purpose. The farmer participants manually recorded the grazing records during the trial period. The LoRa base stations required for the Agtech and mOOvement devices were installed near the cowshed for convenience and easy access. Essential information collected by the on-cow devices included the position (latitude and longitude), date and time of each observation, temperature, and battery condition.

Using a digital farm map of the property (Figure 3), it was possible to interpret the GPS data recorded by the devices to create a record of the recently grazed paddocks. In conjunction with the digital farm map of the paddock boundaries, the `st_join` function (from the `sf` package (v1.0.6; Pebesma 2018)) in R was used to identify which GPS points were recorded in the allocated paddock and which were recorded elsewhere, e.g., at the cowshed or on the farm laneways. The

data were then grouped by grazing break (either AM, between 6 am and 3 pm, or PM between 3 pm and 6 am of the following day) and analysed for four days from the 5th to the 8th of April 2021.

Results and Discussion

Static test

The Agtech devices returned a mean location error (MLE), the difference between the true and projected location, of 5.4 m (SE (standard error) 0.2 m; Table 1), a median location error of 4.0 m, and a range of 0.3–166.8 m. Percentage-wise, 65% of all the observations were within 5 m of the true position, 90% within 10 m and 98% within 20 m. In comparison, the mOOvement devices recorded a MLE of 34.2 m (SE 0.9 m), a median location error of 24.5 m and a range of 0.3–213.2 m. Nine percent of all observations were within 5 m of the true position, 24% within 10 m, 44% within 20 m and 57% within 30 m. The difference in MLE was statistically significant ($P < 0.001$) between the Agtech

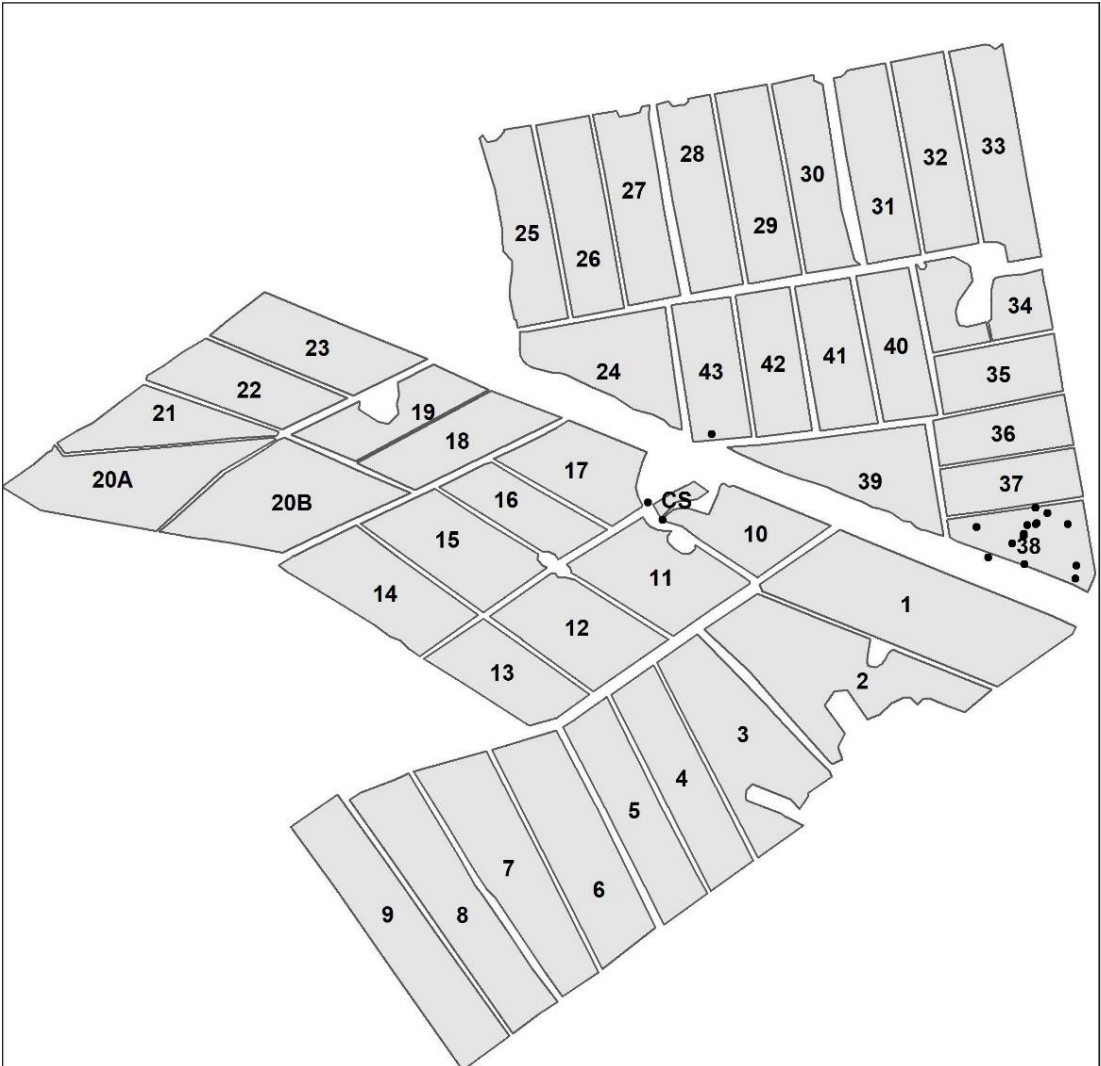


Figure 3 Trial property outline and example of GPS location fixes recorded by two digital animal devices for one grazing period (5/4/2021 between 6 am and 3 pm). CS indicates the cowshed.

and mOOvement groups (unequal variances t-test).

The Agtech devices returned a mean 50% and 95% CEP of 6.1 m (SE 0.7 m) and 13.9 m (SE 2.2 m), respectively. In contrast, the mOOvement devices recorded a mean 50% and 95% CEP of 35.4 m (SE 1.5 m) and 77.6 m (SE 3.6 m), respectively. The difference between the device groups was again statistically

significant ($P < 0.001$) for both the 50% and 95% CEP (unequal variances t-test).

On-farm test

In the on-farm study, 619 observations were recorded from 11 Agtech devices during the four days analysed. From these observations, 345 (55.7% of total

Table 1 Mean, standard error (SE), lower quartile (LQ), median (Med), and upper quartile (UQ) of location error (m) from two brands of GPS devices in the static test.

Device	Mean	SE	LQ	Med	UQ	No. Devices	NO. Obs
Agtech	5.4	0.2	2.6	4.0	6.4	11	1,109
mOOvement	34.2	0.9	10.6	24.5	49.5	22	1,208

observations) were recorded in the allocated paddock and 94 (15.2%) at the cowshed. The remaining 180 observations (29.1%) were recorded either on the laneways or in an incorrect paddock.

During the four days, the 11 mOOvement devices recorded 364 observations. One hundred and sixty observations (44%) were recorded in the allocated paddock, with another 28 (7.6%) recorded at the cowshed. The remaining 176 (48.4%) observations were recorded on the farm laneways or in an incorrect paddock. The percentage of GPS observations in the correct paddock ranged from 32.4% to 57.1% of the total observations recorded during that grazing period.

The two digitanimal devices recorded 158 observations in total over the four days. Of these 158 observations, 100 (63.3%) were recorded in the actual paddock grazed by the dairy herd and six (3.8%) were recorded at the cowshed. The remaining 52 observations (32.9%) were recorded on the farm laneways or in the incorrect paddock. The allocated paddock observations ranged from 50% to 76.5% of the total observations for individual paddocks.

The percentage of GPS observations in the allocated paddock for all devices ranged from 34.9% to 71.6% of total observations recorded while the dairy herd was in each paddock and varied between both the AM and PM grazing periods. However, there was no consistent trend favouring a particular grazing period, either AM or PM, for the percentage of grazing observations recorded in the allocated paddock.

In line with the static test results, paddock identification was better with the Agtech devices than the mOOvement devices. Paddock identification with the digitanimal devices was the best of all three device types tested.

Discussion

The results of this study showed that it is possible to automate the recording of paddocks grazed on a commercial dairy farm using the current generation of GPS devices. This could be highly valuable to help farmers optimise grazing management and feed planning. The GPS device accuracy and precision required to identify paddocks grazed on-farm depended on farm-specific factors, such as paddock size, herd size, grazing duration and distance to the milking shed. As paddock size decreased, higher accuracy and precision was required. For example, Haultain (2014) suggested that for farms with small paddocks (*i.e.*, less than 1.5 ha), a 95% CEP of ~6 m was required compared with a 95% CEP of ~9 m if paddocks are greater than 1.5 ha. The 95% CEP recommended by Haultain (2014) was lower than that reported by the Agtech and mOOvement devices used in the current study.

Given the current costs of implementing such a

system on-farm, the results suggested that, if the aim was to identify the grazed paddock, it was sufficient for approximately 1% of the herd size to be fitted with GPS devices. However, in small herds of less than 300 cows, a minimum of three devices per herd should be used, as suggested by Haultain (2014) and McGranahan et al., (2018), to provide a buffer if animals are drafted out for assorted reasons, such as mating and animal health. There is always the possibility that a GPS collar or ear tag may fall off or the batteries go flat. Finally, on farms covering a large area, the milking herd may spend up to a third of the day either at the milking shed or walking to and from it, thus reducing the time spent in the allocated grazing area. In these situations, the likelihood of identifying the paddock were likely decrease if only 1% of the herd (< 300 cows) are fitted with GPS devices.

This study considered using GPS devices to record grazing events for a farming system that operated one main herd plus a treatment herd and offered one paddock per grazing period. In practice, farms may use other systems, such as multiple herds on-farm or offering several paddocks (or parts of paddocks) during each grazing period. Additionally, cows may be offered crops or supplements on a feed pad at certain times of the year, reducing the time available to graze the allocated paddock or paddocks. Similarly, a change in milking frequency from twice daily to once daily or sixteen hourly could alter the time spent in the allocated paddock. Where grazing time is reduced, more devices or a higher fix rate, the frequency at which a capable device records a GPS position, are needed to provide sufficient confidence of the area grazed.

Using devices with a higher fix rate, such as a half-hourly fix rate (*i.e.*, one observation every thirty minutes), means that more GPS observations will be recorded, therefore likely providing greater certainty that the identified paddock is correct. A half-hourly fix rate effectively doubles the number of observations for the Agtech and digitanimal devices and quadruples the observations for the mOOvement devices. Although increasing the fix rate will increase paddock accuracy due to more observations, the combination of solar availability and battery capacity may mean this is not sustainable for the devices tested in the current study. A future study will assess the optimum trade-off between fix rate and battery life.

The information gained by accurately recording paddocks grazed can be used to infer which paddocks are performing best (*i.e.*, growing more forage) since these paddocks can be grazed more often. Such paddock-by-paddock information is valuable for grazing management (rotation length, which paddock to graze), feed planning and farm management decisions such as pasture renewal and fertiliser usage.

This information could be used as a data feed to other programmes which rely on grazing information, such as feed budgeting software like Minda Land and Feed and Pasture Coach (Hammond 2017). Finally, linking paddocks grazed to cow performance data (e.g., milk produced in the shed, which is usually recorded by milk monitoring systems installed at the cowshed) would further increase the value of the GPS paddock data.

Conclusions

This preliminary investigation showed that it is feasible to fit a small proportion of a dairy herd (i.e., 1% of cows, or at least three cows per herd) with GPS devices to automatically record the grazed paddocks. Further work, including a longer-term on-farm study, is required to prove this technology for on-farm practice and to develop a value proposition for farmers showing the benefits of this technology and the advantages of recording grazing events. Nevertheless, with the focus on maximising pasture utilisation on dairy farms and the increasing range and decreasing cost of LPWAN GPS devices, there is likely to be more interest in this technology in the future.

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