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DESIGN OF A LOW COST WINTER STAND-OFF PAD FOR REDUCING NUTRIENT LOSSES TO WATER FROM WINTER FORAGE CROPS GRAZED BY DAIRY COWS

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Abstract

Wintering dairy cows in southern New Zealand most commonly involves grazing brassica crops *in situ*. This system is relatively simple and low-cost compared to alternative wintering systems such as barns and wintering pads, due to: the low cost of the feed, low labour requirement, no structure needed, and no effluent storage required. However, crop grazing at high stocking densities during winter, combined with high winter rainfall and excessively free-draining soils or fine textured soils and sloping land can result in high contaminant losses (N, P, *E.coli*, sediment) to water. This wintering practice is increasingly coming under scrutiny from those who are seeking alternatives to reduce these losses. Current alternatives have large capital cost and require feed to be brought to the animals at further cost. A low-cost stand-off facility that reduces contaminant losses to water, whilst utilising the low cost brassica crop as a feed source, is therefore urgently sought. This trial investigated the feasibility of a portable pad system that consists of an impermeable liner to capture effluent, overlain by a suitable surface for cow comfort and durability. Cows graze the brassica crop *in situ* and return to the portable pad for a proportion of the day. The portable pad can be moved around the farm as the location of the forage crop paddock changes. Minimal effluent storage is required due to the application of the liquid effluent to a neighbouring pasture during winter using low rate and low depth application methods. This paper describes the first stage in the evaluation of this system where the objectives were (i) to determine if a portable pad could be constructed that captured the excreta and rainfall deposited on the pad surface and (ii) to find a readily-available commercial product suitable for the cow comfort layer. Of the 3 surfaces trialled, a geotextile ‘carpet’ was selected as the surface of choice to be used in further trials. The concept of a low-cost plastic liner overlain with a cow comfort layer, and its associated effluent capture, was a success and proved worthy of further investigation.

Introduction

There are two broad types of dairy wintering systems used in Southland: (1) those based on a brassica crop, which is low cost and low input but results in substantial contaminant losses to water (McDowell et al., 2006; Monaghan et al., 2007; Orchiston et al., 2013) , and (2) off-paddock structures which reduce contaminant losses to water by capturing and storing effluent (Beukes et al., 2011; de Klein et al., 2010) but have a high capital cost (Beukes et al., 2011; Newman & Journeaux, 2015) and require feed to be brought to the animals. Additionally there appears to be some conflict between the profitability of winter housing and its ability to reduce nitrogen losses as farmers will often intensify their system to justify the cost of the structure which inadvertently eliminates any reductions in N loss that may have occurred (Newman & Journeaux, 2015) .

Brassica crop paddocks are often located off the milking platform. It is common practice for farmers to have a support block or for sheep and beef farmers to graze dairy cows in winter as an additional source of income. In these situations the purchase of a high-cost wintering structure is not feasible. There is a need for a system that utilises the benefits of both the low-cost brassica system and the high-cost off-paddock systems. An off-paddock structure that is low-cost, captures effluent and is portable so that it can be moved between farms or within a farm and that enables cows to graze brassica crops *in situ* needs to be investigated.

The objectives of this experiment were:

1. Determine if a portable pad can be constructed to capture the excreta and rainfall deposited on the pad surface.
2. Determine if there is an existing, commercially-available surface suitable for cow comfort and outdoor use.

Thus an initial pad was developed to assess proof of concept and answer the question, "Can a plastic liner be used to capture effluent?" The experiment was structured to assess the best cow comfort layer from three options considered. These were a geotextile 'carpet', a rolled rubber and an interlocking mat.

Methods

Trial site

The experiment was established in 2013 on AgResearch's Invermay sheep, beef and deer farm near Mosgiel, Otago, New Zealand (45° 51' S; 170° 24' E). Warepa deep silt loam is the predominant soil type on the trial area. The 30-year (1981-2010) average annual rainfall for Invermay is 817 mm (with an average of 58 mm in June and 71 mm in July) and the average annual air temperature is 10.2 °C (5.8 °C in June and 5.3 °C in July).

Animal Ethics

The experiment was conducted on the AgResearch Invermay farm near Mosgiel during March and April 2013 and had the approval of the AgResearch Invermay Animal Ethics Committee (# 12825). The animals used were non-pregnant dairy heifers (2-years-old, Friesian, average liveweight (LW) of 600 kg).

Approval was for animals to be held on the portable pad for up to 20 hours a day Monday-Friday and to be grazed for 4 hours a day and at weekends for a period of 4 weeks. Permission was also given to attach lying time loggers to the rear leg of each heifer and then remove them again 7 days later. Animals were observed daily and were removed from the pad if there were any concerns regarding their welfare.

Pad design and establishment

A small portable pad was established on the 11th March 2013 (animals didn't go on to the pad until 23rd March). The pad consisted of a 1mm thick impermeable plastic liner (Figure 1, Photo A) and a surface material. Three surface materials were evaluated and are described below. The pad drained effluent generated into a collection sump and the three surfaces were fenced off so that cows remained in three groups. Stocking density was initially set at the equivalent of 1 cow per 4 m^2.

The three surfaces evaluated were:

1. Geotextile carpet (Figure 1, Photo B), a geotextile designed for dairy farm laneway stabilisation. Produced by Geofabrics, formerly Maccaferri (www.geofabrics.co.nz).

2. Interlocking rubber mats (Figure 1, Photo C) designed for bedding areas in dairy barns. (www.numat.co.nz)
3. A rolled rubber matting (Figure 1, Photo D) designed for lining laneways within a dairy barn. (www.numat.co.nz)

The pad was established by topping and rolling the paddock to ensure nothing sharp could puncture the effluent liner. The liner was laid out in one piece (Figure 1, photo A). The cow comfort surfaces were then placed on the top of the liner (Figure 1, Photos: B, C & D). To stop effluent flowing off the sides of the pad, the edge of the liner was laid over a round deer fence post (Figure 1, Photo E) and held down with another fence post. This bunded the edges of the pad. The pad and the three individual surfaces were then fenced off with hotwire. Electric 'gates' were placed at the top of each pad section (Figure 1, Photos: F, G & H). Bale feeders were located at the top of the pad and water troughs at the bottom. Liquid effluent was drained to a concrete water trough (acting as a sump) located at the bottom of the pad and pumped out via a low intensity sprinkler irrigation pod. Excreted solids were hand-scraped daily and then removed by tractor bucket and stored, off-site, on a concrete pad.

Lying time loggers

Lying time loggers were placed on the rear left leg of all cows for a period of 7 days to give an indication of the lying times of the cows. (23rd April – 30th April 2013; Table 1). Due to the timing of the availability of these loggers, they only recorded one full 24-hour period when the cows were on the pad and then five days after the end of the trial when the cows were back on pasture. Onset Pendant G data loggers (http://www.onsetcomp.com/products/data-loggers/ua-004-64) were used to continuously measure the standing and lying times of the cows over the 24-h periods. Data were downloaded using HOBOware Pro software (http://www.onsetcomp.com/support/manuals/12730-MAN-BHW-UG) and converted to daily summaries of lying and standing times, lying bouts and lying duration information using SAS software (http://www.sas.com/en_us/software/analytics/stat.html). The SAS software code was designed for this purpose (Schutz et al., 2015)

Timetable of events

The timing of events during the experiment are summarised in Table 1 below. Site preparation and pad establishment occurred over the period of one week. Cows were held on the pad for the first time on 21st March 2013 and were taken off for the final time on 25th April 2013. The exception to this was the cows on the rolled rubber treatment. They were removed from the pad 6 days after they first went on as there were concerns regarding the suitability of that surface for the purposes being investigated.

Table 1. Timetable of events for the portable pad experiment

Date	**Event**
11/3/13	Site topped and stones removed Plastic liner laid
12/3/13	Cow comfort layers laid
13/3/13-18/3/13	Pad fenced and sides bunded
21/3/13	Cows on to the pad
27/3/13	Cows taken off the rolled rubber treatment
23/4/13	Lying time loggers placed on the cows
24/4/13	One full day of lying time information while animals on pad
25/4/13	Cows taken off the pad for the final time at 9 am
30/4/13	Loggers taken off the cows

Figure 1. Photos of the portable pad experiment. The geotextile, interlocking mats and rolled rubber surfaces are shown in photos B, C, and D, respectively.

Animal management

The cows were held on the pad for 20 hours a day Monday to Friday. For the other 4 hours of each day and also the weekends they grazed a neighbouring pasture paddock. Baleage was fed *ad lib* on the pad in the feeders. All animal handling associated with normal farming practice (moving animals to and from the pad) was carried out by farm staff. Lying time loggers were fitted to the animals by trained animal handlers within the science team. Animals were observed daily by farm staff and science staff, including experienced animal handlers. Careful observations were made so as to identify animal behaviours such as bullying, lying down (or reluctance to do so) and getting back up again, gait when moving to or from the pasture.

ANOVA analysis was conducted using Genstat 17^{th} Edition.

Results

As the cows were reluctant to be near the electric fences that separated the surfaces, the number of cows in each group was reduced from 5 to 3 (rolled rubber) or 4 (geotextile; interlocking mat) to give them more space. Six days into the trial the rolled rubber surface treatment was removed from the trial due to animal welfare concerns. The rolled rubber mat was deemed to be too slippery. There was a noticeable reluctance of the animals to lie down on this surface indicating that cows couldn't get stable footing when getting up again.

The remaining two surfaces remained in the trial for the duration of the 4 weeks. At this point the geotextile carpet was selected as the surface to use in the construction of the pad in the next stage of this work. The reasons for this were: it had better grip when wet than the interlocked mats, it seemed to draw moisture away from the surface and the cost was \$19 m^{-2} compared to \$85 m^{-2} for the interlocking mats. The key features of the three surfaces are summarised in Table 2.

The lying times for cows on the geotextile and interlocking matting on the 24^{th} April were less than 8 hours per day (7.6 hours for the geotextile group and 7.0 hours for the interlocking matting group).

Lying times for both the Geotextile and Interlocking matting mobs once back on pasture were above the minimum recommended value of 8 hours per day (Figure 2, dates 25-29 April). Average lying times of the Geotextile mob were 12.5 hours per day and for Interlocking matting mob 11.5 hours per day; these values were not significantly different ($P = 0.408$).

Table 2: Positive and negative attributes of the different surfaces used as a portable pad surface

Surface	Pros	Cons
Geotextile 	• Non slippery • Easy to roll out • Takes moisture out of dung. • <$20 m^{-2}	• Needs to be secured in place • Questions about cow comfort – lying times • May require a harder surface
Rolled rubber 	• Easy to unroll	• Too slippery for cows – animal welfare issue; not suitable as a surface for this purpose • $59 m^{-2}
Interlocking matting 	• Easy to lock together • Locks become more secure with cow traffic • Liquid flows through cracks to sublayer	• May require a flat surface • $85 m^{-2} • Questions about slipperiness in heavy rain

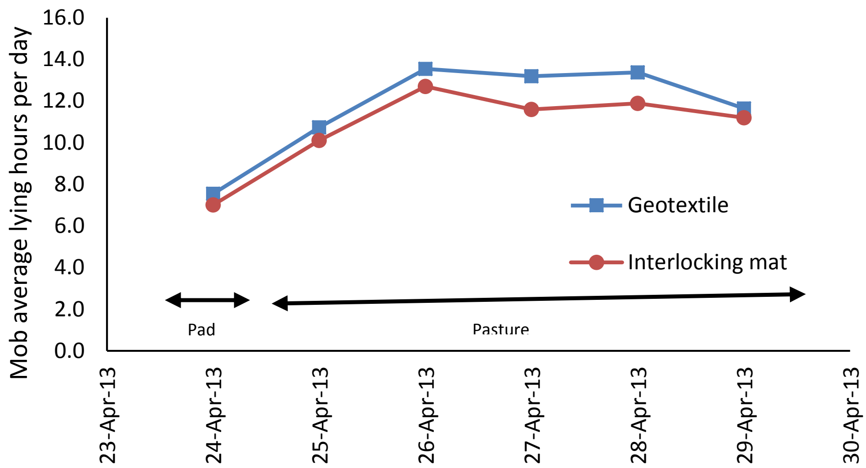

Figure 2: Average daily lying times recorded for cows on the Geotextile and Interlocking matting surfaces. Location of cows (pad = final day after 4 weeks of 20 h/d pad and 4 h/d crop for weekdays and 24 h/d pasture for weekends or pasture = 24 h/d at pasture) is depicted by the double arrowed lines.

Costs of portable pad technology

The cost of a pad using the geotextile surface was calculated. It was assumed that 9 m^2 per cow of plastic liner and geotextile would be required. This was based on an area of 8 m^2 per cow on the pad plus an extra 1 m^2 per cow of material to cover areas such as the bunding of the sides and also overlapping areas for gluing the geotextile strips together. The cost of the geotextile was \$19 m^{-2}, the plastic liner was 6 m^{-2}, the scraper was \$1240 + GST and the water trough was \$400 (1000 litre capacity trough). It was assumed that a cow could potentially produce approximately 25 kg solids per day which would amount to approximately 1.75 m^3 cow^{-1} over a 70 day period. Therefore, an additional 2 m^2 per cow of additional plastic liner to line a solids pit would be required.

For water supply, it was assumed that the maximum number of cows that would be on a pad was 100 and that over and above the cost of the water trough there would be the cost of connecting a water supply to the pad. However, this figure would vary hugely depending on individual situations so it was left out of the analysis.

Earthworks for the pad were valued at \$2000 based on 10 hours work (for a pad large enough to hold 100 cows) at \$200 per hour. It was assumed that there would be a further \$2000 cost to remove the solids at the end of winter. Again, this cost would vary widely depending on the situation and method of removal and subsequent use of the material.

The liquid effluent system for 100 cows was assumed to be 200 m pipe at \$570, one sprinkler at \$80 , a sump at \$1000 and a pump at \$1000. The cost of irrigation would vary depending on the system used, existing infrastructure etc.

Estimates of the cost per cow of the portable pad technology using the geotextile carpet are \$322 cow^{-1} and \$72 cow^{-1} $year^{-1}$ annualised costs (Table 3). This includes: the cost to empty the solids pit (plastic lined pit) annually. This compares to a free-stall barn costing up to \$5,800 cow^{-1} (Newman & Journeaux, 2015) .

Table 3: Cost of portable cow wintering pad technology (assume 9 m^2/cow)

	Cost per cow (\$)	Life Expectancy (years)	Annualised cost (\$ cow^{-1} $year^{-1}$)
Plastic liner	54	3	18
Geotextile carpet	171	8	22.13
Solids pit liner	12	3	4
Low rate irrigation	27	15	1.80
Water trough	4	15	0.27
Earthworks	20	5	4
Solids pit effluent removal	20	1	20
Pad surface scraper	14	10	1.39
TOTAL	**\$322**		**\$72**

Discussion

The concept of a portable pad proved to be successful. The cow comfort layer protected the plastic liner and there were no perforations. The effluent was captured. Bunding the edges of the pad simply by placing a round deer fence post under the plastic liner and securing it worked as a means of keeping the effluent on the pad where it was able to drain to the collection area. Having the pad on a 5 degree slope was enough to drain the liquid down to the collection tank without causing any ponding of liquid on the surface of the pad. The duration of time animals spent on the wet soils was significantly reduced thus potentially protecting soil structure.

The geotextile cow comfort surface was identified as the preferred surface for future investigation. This was based on the surface being non-slippery, appearing to 'wick' water away from the surface, and it was low cost and durable.

There are three main advantages of the portable pad. (1) It is low cost. This is of particular importance in the current economic climate where the dairy payout is low and not forecasted to increase in the near future. (2) It enables farmers to benefit from the use of low-cost brassica crops. (3) It captures effluent and so has the potential to reduce contaminant losses from winter grazed brassica crops. In the current economic climate it could be argued that farmers are better off grazing brassica crops *in situ* as is most common currently. However Regional Councils are increasingly scrutinising nutrient losses from the wintering component of the dairy system.

Disadvantages of the pad are that it requires daily scraping of solid effluent and also either storage or a low rate, low depth application of liquid effluent to land. This winter application of effluent may also require a resource consent. Questions remain regarding the welfare of the animals on the pad. The snap-shot of cow lying times (a common metric of animal welfare) indicate that lying times may be lower on the pad than on pasture and that they may not reach the recommended industry minimum of 8 hours per day (Anon., 2010). This requires further investigation.

Suggested improvements to the portable pad include:

1. Tensioning the cow comfort layer to reduce bunching of the fabric
2. Feeding the supplementary feed on the paddock and not the pad.
3. Developing an efficient and low-cost effluent disposal or storage system.

Areas for further research are:

1. Trialling the pad over a winter and comparing to cows on crop 24 hours a day.
2. Measuring indicators of the welfare of cows wintered on the portable pad (e.g. body condition score, lying time, gait score).
3. Measuring feed intake to determine the optimal time for cows on crop to enable them to harvest enough feed.
4. Measuring volumes of solid and liquid effluent generated.
5. Modelling the system and comparing the nutrient losses to those from a traditional winter grazed brassica system.
6. Developing a system to keep tension on the pad cover.
7. Farm scale implementation of the portable pad concept.

Conclusions

This study showed that the portable pad concept shows merit. It has proven that it is possible to construct a pad using an effluent liner that captures the effluent deposited on the pad. Through this experiment it was determined that the best surface for a cow comfort layer (of the three trialled) was a geotextile fabric. Further investigation into the portable pad concept would be valuable to further assess this system through an entire winter and at a commercial scale.

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