Final Report

Sustainable Out-wintering of Beef Cattle on Straw-Bed Corrals

Final report to EBLEX and Environment Agency

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1 Executive Summary

- A straw pad is an open deep bedded enclosure for 'housing' livestock; the majority of straw pads are unlined and the principle of the system is that the depth of bedding provides sufficient absorptive capacity to retain the dung and urine generated by the animals and rainfall over the pad area. However, there is concern about the potential for water pollution from uncontained runoff or drainage to surface and ground water from unlined pads.
- A review was undertaken on the construction, management and distribution of straw pads used for cattle in England. The survey identified 15 farms with straw pads located predominantly in the drier east of England. Of the 15 farms identified, detailed information was collected from 9 farms. The total number of cattle kept on the straw pads at any one time varied between the farms from approximately 50 up to 2500.
- Two of the farms had temporary straw pads which were removed after one year. However, all of the other farms with permanent pads said it would not be feasible for them to move/rotate their pads, citing the 'fixed' infrastructure associated with the pads (i.e. water troughs, concrete feed area, fences etc.).
- All of the farms were positive about the health of the cattle kept on the pads. The majority of farms thought the cattle were as clean outside on the pads as they would have been on a straw yard. None of the farms reported any foot problems or lameness associated with the pads, and 5 farms gave the opinion that cattle kept on straw pads were healthier due to reduced risk of respiratory problems or pneumonia.
- Measurements were carried out on outdoor pads on a commercial farm located in the east of England over the 2012/13 and 2013/14 over-winter periods and compared 2 pads on the same farm – one bedded with straw and one bedded with waste wood-shavings. The measurements included observations of pad condition and livestock performance, drainage water sampling and calculation of over-winter drainage and nitrogen (N) leaching from under the pads.
- Nitrate-N and NH_4-N concentrations in drainage water from both the straw and wood-shavings pads were very high (approximately 60-450 mg/l NO_3-N and approximately 5-35 mg/l NH_4-N), indicating that any effluent draining into the soil from these pads represented a high risk of diffuse N pollution.
- In 2012/13 for the period when the cattle were on the pads (1st October 2012 to mid-March 2013), the estimated drainage volume was 20 mm and 96 kg/ha N was lost via leaching from the straw pad. Drainage occurred during a limited period October 2012 following a period of very heavy rainfall; this highlights the importance of applying sufficient bedding early in the season to allow capacity to absorb effluent following short period of heavy rainfall. In 2013/14 for the period when the cattle were on the pads (23rd September 2013 to late-January 2014), the estimated drainage volume was <1 mm and <1 kg/ha N was lost via leaching from the straw pad.
- Straw bedding recommendations are given for the main beef cattle livestock categories based on the quantity of straw bedding required to absorb the liquid input (excreta and rainfall) to the pad. These recommendations should be used in combination with a visual inspection of the pad and additional straw should be added where required to keep the surface of the pad clean and dry and to ensure there is no 'pooling' of liquid on the pad surface or any seepage of contaminated runoff from the pad.

2 Introduction

2.1 Background

A straw pad is an open deep bedded enclosure for 'housing' livestock, normally cattle, and includes both un-lined corrals and lined out-wintering pads. The bedding used is normally cereal straw, but may also include oilseed rape straw, miscanthus straw or other organic residues such as wood-shavings or sawdust. The majority of straw pads are unlined corrals and the principle of the system is that the depth of bedding provides sufficient absorptive capacity to retain the dung and urine generated by the animals and rainfall over the pad area. Regular additions of bedding are made to the pad during the stocked period to keep the bed clean and dry and to prevent any contaminated runoff from the pad.

Research on woodchip pads for out-wintering cattle (Smith *et al*., 2011) found that use of out-wintering pads can offer many benefits including improved animal health and welfare, less damage to pasture from treading, reduced labour costs, and a cheaper alternative to constructing traditional buildings. Straw pads may offer similar benefits, however as these pads are typically un-lined corrals, there is concern about the potential for water pollution from uncontained runoff or drainage to surface and ground water.

2.2 Aims and objectives

The overall aim of the project is to evaluate key aspects of the design criteria for straw-bed corrals and the need for any refinements of design and management, so as to ensure satisfactory livestock performance and environmental protection.

Specific objectives are:

- To review practical experience of cattle wintering on straw-bedded corrals on commercial farms where these can be located.
- To quantify nitrate leaching losses from beef cattle housed on straw-bedded corrals.
- To quantify the distribution of nitrogen through the soil profile under straw-bedded corrals.
- To draft recommendations on straw-bedded corral design and management based on the findings of the research.

3 Review of existing straw pads

3.1 Introduction

A review was undertaken on the construction, management and distribution of straw pads used for cattle in England. The aim of the review was to identify commercial farms using straw pads to rear cattle and to review practical experience (good and bad).

3.2 Methods

The review identified existing straw pads via:

- EBLEX October 2013 E-new bulletin included a link to an E-survey on out-wintering pads.
- Informal networking approaching using contacts within ADAS, EA, EBLEX and Natural England.

Five farms were identified via the E-survey and a further 10 farms were identified from other contacts.

The EBLEX E-survey included questions on pad location (country), stock type and siting (i.e. on soil/hard core) as well as the option to include further information on pad management and leave contact details. Where contact details were available, contact was made to ask if farmers would be willing to provide further information on their farm practice as part of the review. Of the 15 farms identified, detailed information was collected from 9 farms.

A short questionnaire was drafted to facilitate the collection of key information from the farms via a telephone interview; the farmers were also asked for their comments more generally on their experience on using the pads. All information collected is confidential; it is not possible to identify individual farms, and location details are only used in aggregated form to establish distribution of straw pads across the country.

3.3 Results and observations

3.3.1 Location

The 15 farms identified in the review were located in the east of England from Kent in the south to Northumberland in the north. The survey identified farms with straw pads in the following counties:

Cambridgeshire	1 farm
East Sussex	1 farm
Essex	1 farm
Kent	1 farm
Lincolnshire	2 farms
Norfolk	3 farms
North Yorkshire	2 farms
Northamptonshire	1 farms
Northumberland	2 farms
Nottinghamshire	1 farm

Where more precise location information was available (for 12 of the farms), this was used to identify location specific long term average annual rainfall[1]; the majority (11 of the 12 farms) were located in areas where the long term average annual rainfall is <700 mm.

[1] Average annual rainfall data was sourced from the MANNER-*NPK* postcode based rainfall database (1971 to 2000 average annual rainfall).

Table 1. Location of straw pads according to rainfall bands

Average annual rainfall (mm)	Number of farms	Percentage of farms
<600 mm	2	17 %
600-650 mm	5	42 %
650-700 mm	4	33 %
700-750 mm	0	0 %
750-800 mm	1	8 %

3.3.2 Farm information

Information on the size and type of farms using straw pads (i.e. number of cattle and suckler herd/finishing unit) was available for 14 of the 15 identified farms. Three farms were finishing units only, each finishing more than 1000 cattle per year. Ten farms had suckler herds and information on size was available for 7 of these farms; the smallest farm had 50 cows, 3 farms had 100-200 cows and 3 farms had 1000-1200 cows. Two of the farms with the larger suckler units also finished some of their cattle (between 500 and 1000 per year). The remaining farm used the straw pad to out winter cattle kept for conservation grazing (i.e. grazing that meets nature conservation objectives).

The majority of farms (8 of the 9 farms surveyed in detail) housed cattle on both straw pads and in buildings. The total number of cattle kept on the straw pads at any one time varied between the farms from approximately 50 up to 2500.

Straw pads were located on a variety of different soil types including sandy soils, heavier clay loam soils and soils over rock sub-soil. All of the permanent straw pads were located adjacent to or adjoining (within 500 m) other farm buildings/infrastructure (i.e. farm access tracks, water supply etc.) enabling the farms to utilise this infrastructure for the management of the straw pads. A number of farms had straw pads adjacent to buildings with housed cattle, enabling the management of all the cattle (feeding, bedding etc.) to be carried out together.

3.3.3 Design

Type of straw pad – permanent or temporary

All the 9 farms where we were able to collect detailed information had (or were planning) permanent straw pad facilities; 3 farms had straw pads >10 years old, 5 farms had straw pads 5-10 years old and one farm had a straw pad under construction (not yet in use). Some of the farms with older pads, had also constructed additional newer pads (<5 years old) more recently in order to expand.

Only 2 of the 9 farms also had 'temporary' straw pads used to out-winter cattle (each farm had 50-100 cattle on a single temporary pad) for a single year before being moved; one farm located the temporary pad on an arable stubble field and one used a grassland field.

Straw pad base condition

The 9 farms with permanent straw pads had constructed the pads on a range of different bases:

- Only one farm had sited the straw pad directly on topsoil.
- Two farms had scraped back the topsoil, and sited the straw pads directly on the subsoil.
- The remaining six farms had carried out some sort of additional work to create the base for the pad, including:
    - One farm added a layer of stone over the topsoil

- One farm scraped back the topsoil and added a layer of clay to create a relatively impermeable base (no drainage).
- One farm had removed the topsoil down to clay subsoil and added a layer of rubble/hardcore.
- One farm on impermeable clay soil added drainage (to a lagoon).
- One farm sited the straw pad on a layer of hardcore blinded with chippings (thought to be relatively impermeable, but not drained).
- One farm, which is currently planning the construction of a straw pad, is creating an impermeable base of hardcore and concrete contained by a 500 mm concrete lip; the concrete lip will contain any effluent, which will be absorbed by the bedding (no drainage).

Of the 9 permanent straw pads, only one had installed a drainage system for effluent collection; however, a number of the other farms had created a relatively impermeable base under which drainage of any effluent is likely to be minimal.

The two temporary straw pads were both sited directly on topsoil (one on an arable stubble field and one on a grassland field).

Straw pad size and number of pens

Information on the total area covered by the permanent straw pads was available for 8 of the 9 farms; six of the farms had straw pads covering 1000-3000 m^2 and two of the farms had a larger area covering 12,000-15,000 m^2. All of the farms had more than one pad or a single larger pad area divided into smaller 'pens'. The smallest pads/pens were approximately 200 m^2 and the largest was approximately 2500 m^2. Most of the farms used the multiple pads/pens to separate different livestock categories. The two temporary straw pads each covered an area of <2000 m^2, and one of the temporary straw pads was divided into 4 smaller pens.

3.3.4 Management

Duration of use

Most of the farms used straw pads to over-winter cattle, typically from October/November to March/April, and the pads were empty during the remainder of the year. However, 3 farms stocked their permanent straw pads throughout the year; 2 of the larger finishing units (>1000 cattle finished per year) had cattle on the pads throughout the year, and one of the larger suckler units (*c.*1000 cows) kept some cattle on the straw pad all year, although fewer cattle during the summer.

Stocking rate

Where information on size of straw pads and number of cattle was available, the stocking rate (m^2/animal) was calculated. Stocking rates tended to be lower at approximately 15-20 m^2/animal on the farms where the cattle were fed on-pad. Stocking rates also depended on size of animals; one farm with a suckler herd (cattle fed on-pad) had a higher stocking rate for growing suckler cows (approximately 10 m^2/animal) than for suckler cows (approximately 19 m^2/animal). The lowest stocking rate was 27 m^2/animal (for beef growers 18-24 months).

Where the cattle were fed off-pad[2], stocking rates (excluding the feed area) were 7-13 m^2/animal; with the exception of one farm with a suckler herd which had a higher stocking rate for the young stock (approximately 4 m^2/animal, compared to approximately 8 m^2/animal for suckler cows).

Calving on the pads

Four of the 6 farms with suckler herds calved on the straw pads; one farm used separate 'calving pens' and two farms noted that their pads were near buildings so they could bring the animals in if they needed. Of the 2 farms with suckler herds that didn't calve on the pads, one farm calved outside from April (when the cattle are no longer on the pads), and the other fed 'on-pad' and considered the pads unsuitable for calving because of the more heavily dunged area near the feed stance (the 4 farms that calved on the pads all fed 'off-pad' minimising 'hot-spot' areas of greater dung accumulation).

Management of feed and water

Six of the 9 farms with permanent straw pads fed the cattle 'off-pad' on a concrete feed area. The feed area was scraped, typically once per week, and on all farms the scraped excreta material was managed as solid manure; most farms also added straw to the feed area so the scraped material is a solid manure, and/or the farm scraped the feed area and added the material to straw or an existing FYM heap to create a solid manure.

Three of the permanent straw pads had 'on-pad' feeding. One farm used a ring feeder, which was periodically moved. The 2 other farms fed along one side of the pad, and both had a compacted hardcore base to the feed area which was bedded down with straw. Both of these farms added more bedding to the feed area to try and keep it clean, and both periodically scraped heavily soiled bedding from the feed area and either removed it as solid manure or put it back on the main pad area. The 2 temporary straw pads fed the cattle on-pad using ring feeders/troughs.

The majority of the farms had water troughs on the pads. Only one farm had the water off–pad with the feed. One farm used water bowls rather than troughs; this farm spread straw to the pads with a 'straw blower' and water troughs, if used, would have been contaminated with the 'blown' straw.

Hotspots of greater dung collection

The majority of farms identified the presence of 'hotspot' areas of greater dung collection on the pads, mainly around the water troughs, feed areas or access to off-pad feed areas. Where 'hotspots' were identified, these were managed by a greater quantity/frequency of bedding addition to try and absorb the additional dung/urine and keep the cattle clean. Only two farms, both with off-pad feeding, said that there weren't any hotspot areas of greater dung collection.

3.3.5 Bedding

Bedding materials

The main bedding material used on 8 of the 9 farms was cereal straw; the main bedding material used on the other farm was waste wood-shavings. Five of the farms also used oilseed rape straw (depending on local availability) and 2 farmers gave the opinion that the coarser OSR straw was more effective at keeping cattle clean than cereal straw. One farm had in previous years used woodchip as the base layer on the straw pad.

[2] Off-pad feeding is where access to the feed rail is off the straw pad area via a concrete or hardcore stance adjacent to the pad.

The majority of the farms had to buy in bedding material for the pads. Two farms noted that when available they also used some 'old/weathered' straw unsuitable for other uses.

Frequency of bedding addition

On all farms bedding was added to the pads depending on the surface condition of the pad, generally around twice per week, but up to daily under wetter conditions. Two of the farms used a straw blower to spread straw without driving on the pads. One farm used a purpose made straw spreader, which was driven across the pad and spread the straw evenly. The remaining farms cut the straw bales on the pads (generally positioning the bales on the wetter areas) and either spread the straw manually or with a teleporter, or allowed the cattle to move the straw about themselves.

Total quantity of bedding used

The total quantity of bedding used was dependent on stocking rate, livestock category, whether the cattle are fed on or off the pads and the amount of rainfall. Four of the farms surveyed were able to provide the following information on the total quantity of bedding[3] used on the pads:

- 2 t/animal of straw over a 5 month over-winter period; suckler cows fed off-pad with stocking rate of 13m^2/animal.
- 2 t/animal of straw over a 5 month over-winter period; suckler cows fed off-pad with a stocking rate of 12.5 m^2/animal.
- 1 t/animal of straw for suckler cows (stocking rate 19 m^2/animal) and 0.5-0.75 t/animal of straw for growing suckler cows (stocking rate 10 m^2/animal) over a 4 month over winter period, cattle fed on-pad.
- 1.35 t/animal of wood-shavings *per month* for finishing cattle fed on-pad with a stocking rate of 27 m^2/animal (cattle were on the pad all year).

The other farms were unable to provide information on the total quantity of bedding used on the pads; some farms with cattle on pads and in buildings had information on their *total* straw usage, but not the total quantity used on the pads.

The estimated depth of bedding when the cattle first went on to the pads varied from 10-30 cm (mean approximately 25 cm), and when the cattle came off the pads/prior to mucking out, varied from 50-120 cm (mean approximately 80 cm).

Removal and management of soiled bedding

All of the farms which used straw pads to out-winter cattle, cleared all the soiled bedding from the pads once per year after the cattle were removed from the pads. Of the 3 farms which stocked the pads all year, 2 of them cleared out soiled bedding twice per year and the other cleared out around 4 times per year.

All the farms stacked the soiled bedding after clearing out, either in field heaps or on concrete pads. Most farms then land spread the soiled bedding on to arable or grassland in the autumn; one farm also spread some soiled bedding to maize in the spring. One farm exported all the soiled bedding on a muck for straw arrangement with local farmers.

[3] The total quantity of bedding used includes straw added for the initial 'base' layer plus regular additions of straw whilst the cattle are on the pads.

3.3.6 Condition and health of cattle on the pads

All of the farms felt the cattle performed well on the pads. The majority of farms thought the cattle were as clean on the pads as they would have been on a straw yard; one farm thought the cattle were slightly dirtier, and one farm thought the cattle were cleaner on the pads than in a straw yard. Two of the finishing units noted that the cattle arrived on their farms with a certain level of dirt on them and that the pads didn't make them dirtier.

All farms were positive about the health of the cattle kept on the pads. None of the farms reported any foot problems or lameness associated with the pads, and five farms gave the opinion that the cattle were healthier on the pads due to reduced risk of respiratory problems or pneumonia.

3.3.7 Financial and labour input

A number of the farms commented that one of the main reasons for using straw pads was that they were cheaper to install than building new cattle sheds. However, only 2 of the farms were able to give estimates of installation costs. One farm estimated £60k installation costs for a 3000 m^2 pad area divided into 8 pens with off-pad feeding via a concrete feed area. Another farm estimated £10k installation costs per approximately 2500 m^2 pen with off-pad feeding via a concrete feed area. Most of the farms used their own farm labour and materials available to them to construct the pads, making it difficult to accurately estimate installation costs.

The labour input required for the management of the cattle on the pads varied mainly depending on the size of the pads and number of cattle. Where farms were able to provide details of labour input, this was estimated at between 0.5 and 2 hours per day for feeding and 4-6 hours per week for the management of bedding. A number of the farms commented that the labour input for cattle on the pads was similar to that required for housed cattle, and where farms had both housed cattle and cattle on pads, the feeding and management of bedding was done at the same time for all cattle.

3.4 Summary conclusions/comments

- The review identified 15 farms with straw pads located predominantly in the drier east of England. The 9 farms where detailed management information was collected, covered a range of slightly different 'set-ups' which had been developed to suit the individual farms.
- All of the farms managed the pads with the aim of applying sufficient bedding to absorb the dung and urine from the cattle and the rainfall to the pad area, to prevent any contaminated runoff leaking from the pad. All farms were actively managing the pads to try and keep the surface clean and to ensure clean and healthy cattle.
- One of the main reasons for the farms using straw pads is that they are cheaper to construct than conventional cattle housing. The majority of farms have designed and constructed the straw pads themselves. Some farms had visited other farms with straw pads, but generally farmers had not sought advice or guidance from 'official' sources (i.e. Environment Agency, Natural England/Catchment Sensitive Farming, EBLEX etc.) on pad design and management. Two of the farms noted that they were unsure of whether the pads required planning permission.
- Two of the farms had temporary straw pads which were removed after one year. However, all of the other farms with permanent pads said it would not be feasible for them to move/rotate their pads, citing the 'fixed' infrastructure associated with the pads (i.e. water troughs, concrete feed area, fences etc.). Locating the pads near to farm tracks allows easy access for vehicle deliveries of food and bedding, and near to farm buildings for storage of feed and to enable farmers to easily bring cattle off the pads into the buildings, or to be handled, if needed.

4 Water holding capacity of bedding material

4.1 Introduction

It is essential that for unlined straw pads sufficient bedding is used to absorb the dung, urine and rainfall to the pad area and to ensure there is no uncontained runoff or drainage from the pad. In order to be able to calculate the quantity of bedding required, an estimate of the absorptive capacity of the bedding material is needed.

4.2 Methods

The water holding capacity of different bedding material was determined in a laboratory experiment. The bedding material included the waste wood-shavings (T1) and barley straw[4] (T2) bedding used on the commercial farm where measurements were carried out in 2012/13 and 2013/14 (Section 5), and as a comparison oilseed rape straw (T3) and barley straw (T4) sourced from alternative locations. A further treatment of 'trampled' barley straw (T5) was included (from the same source as T4); the straw was 'mashed' with a wooden post several times during soaking to mimic trampling by cattle, to see if this has an impact on its capacity to absorb water.

There were 3 replicates of each treatment. The material was soaked for 3 days in 25 litre plastic containers. The 'initial' and 'end' dry matter content of each material was determined, and the water holding capacity calculated as a percentage of initial weight.

4.3 Results

The waste wood-shavings sourced from the commercial farm where measurements were carried out were able to absorb just over their own weight in water, whilst the straw used at the farm was able to absorb approximately 3.5 times its own weight in water (Table 2).

The OSR straw was able to absorb approximately 3.0 times its own weight in water and the barley straw was able to absorb approximately 4.5 times its own weight it water. There was little effect of 'trampling' the barley straw on its absorptive capacity (Table 2).

It is possible that the ability of the bedding materials to absorb water under laboratory conditions may be different to the ability of the material to absorb and retain water under pad conditions, where the material is compacted through the treading action of the cattle and by the weight of bedding above it. However, the dry matter content of the waste wood-shavings (T1) and straw (T2) at the end of 'soaking' (18 and 27% DM for straw and wood-shavings, respectively - Table 2) was similar to the dry matter content of the soiled bedding measured when the pads were cleared (18 and 26% DM for straw and wood-shavings, respectively – Section 5, Table 4), which supports the measured water holding capacity as an indicator of the materials ability to retain water under pad conditions.

[4] The commercial farm where measurements were carried out used a mix of barley and wheat straw. The laboratory experiment to determine water holding capacity of bedding material used a sample of the barley straw bedding.

Table 2. Water holding capacity of out-wintering pad bedding material

Treatment number	Bedding material	Initial % DM	End % DM	Water holding capacity (% initial weight)
T1	Waste wood shavings	56	27	108
T2	Barley straw	81	18	348
T3	OSR straw	84	21	301
T4	Barley straw	87	16	458
T5	Barley straw 'mashed'	87	16	434

5 Measurements at an existing straw pad

5.1 Background

Measurements of livestock performance, pad condition, drainage water and calculation of over-winter drainage and nitrogen (N) leaching were carried out at a commercial farm with outdoor pads located in the east of England. The farm is located on sandy-loam topsoil overlying rubbly chalk and the long term average annual rainfall of approximately 640 mm.

Four unlined outdoor pads, each approximately 76m x 36 m, were constructed on the farm in 2008. There was a feed race along one side of the pads, which was on approximately 30 cm of compacted hardcore. The feed area was bedded and the soiled bedding was periodically scraped back onto the main area of the pad. Each pad had a single water trough located roughly at the midpoint on one side of each pad. The pads were empty (left fallow/weedy) for 2 years before the start of measurements; prior to this they had been in use and stocked for 3 years.

The farm finish beef cattle on the outdoor pads and also in adjacent buildings. Cattle are bought in at typically approximately 450-500 kg liveweight and sold after 3-4 months at approximately 600 kg. The outdoor pads were bedded with waste wood-shavings (from a stables) and straw (depending on local availability). The measurements in this study compared two of the outdoor pads – one bedded with straw and one with waste wood-shavings (Figure 1).

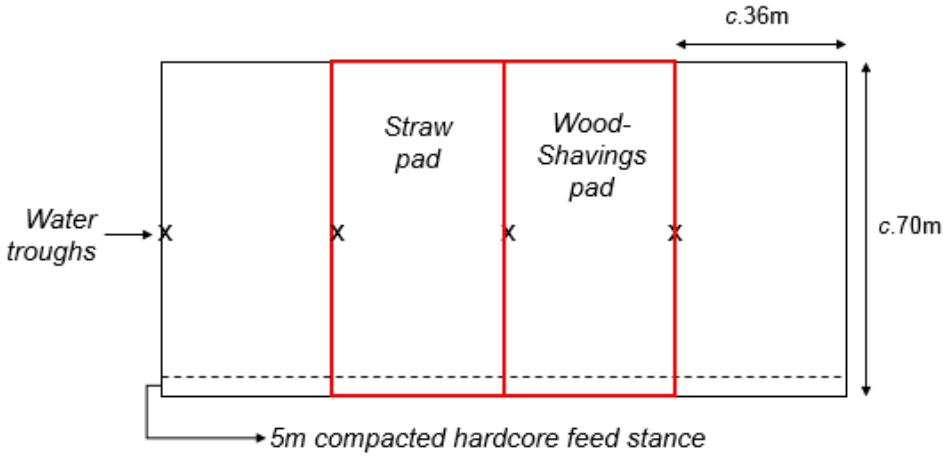

Figure 1. Site plan of the outdoor pads at the commercial farm where monitoring took place (the 2 pads which were monitored are highlighted in red).

5.2 Methods

5.2.1 Pad set up and management

The farm carried out overall management of both the straw and wood-shavings pads and recorded details of quantity of bedding used and the date the bedding was added.

In the first year, the pads were stocked from 1st October 2012 to mid-March 2013. The pads remained empty until the second over-winter measurement period and were stocked again from 23rd September until late January 2014.

The farm regularly added bedding to both pads during the 'stocked' periods and both pads were then completely cleared of bedding in mid-June 2013 (after the 2012/13 over-winter measurements) and in early February 2014 (after the 2013/14 over-winter measurements). Soiled bedding was scrapped back down to the soil using a front loader (Plate 1). The total quantity of bedding removed from both pads at the end of both the 2012/13 and 2013/14 measurement periods was calculated by multiplying the weight of a typical trailer load of soiled straw or wood-shavings bedding by the number of loads removed.

Plate 1. Clearing bedding from the wood-shavings pad (12th June 2013)

The surface condition of both pads was scored for dirt and wetness during the measurement period using a five point scoring system (Table 3 and Table 4). Each pad was divided into quarters, which were scored separately and a mean score for each pad recorded.

Table 3. Scoring of the surface condition of the pads - dirt score

Dirt score	Description
D1.	Surface clean. *No faecal material visible on surface*
D2.	Surface largely clean. *<25% of surface with faecal material visible.*
D3.	Intermediate. Areas of clean and dirty bedding. *25-50% of surface with faecal material visible.*
D4.	Surface largely dirty, but some areas of clean bedding visible. *50-75% of surface with faecal material visible.*
D5.	Surface very dirty. Difficult to see clean areas of bedding. *>75% of surface with faecal material visible.*

Table 4. Scoring of the surface condition of the pads - wetness score

Wetness score	Description
W1.	Surface dry. *Could walk on pad in walking boots.*
W2.	Surface mainly dry, but with some wet patches. *Would need welly boots to walk on some areas of pad.*
W3.	Surface mainly wet, but not boggy *Would need welly boots anywhere on pad.*
W4.	Surface mainly wet, with boggy patches. *Could still walk on pad with welly boots, but noticeable boggy patches.*
W5.	Entire surface very wet with large boggy areas. *Difficult to walk on areas of pad – boots getting stuck in boggy patches.*

5.2.2 Livestock performance

The farm weighed all the cattle on to the pads when they arrived on the farm and when they left the farm for slaughter, enabling calculation of daily live weight gain. In 2013/14, the farm also weighed the cattle housed in the buildings and on the other outdoor pads when they arrived and left the farm, enabling comparison of daily live weight gain between the cattle on the outdoor pads and the cattle housed inside. In 2013/14 feed samples (total mixed ration - TMR) were also taken and analysed.

The cattle on both pads were scored for dirtiness over the measurement periods, using a 5 point scoring system (1=clean; 5=filthy) based on the Meat Hygiene Service classification (FSA, 2007). On each observation date, 15 cattle from each pad were scored and the average score for each pad calculated.

5.2.3 Soil mineral nitrogen

Soil mineral nitrogen (SMN) samples (0-90 cm in 3 depths: 0–30 cm, 30–60 cm and 60–90 cm) were taken from each pad in:

- Mid-October 2012, immediately prior to stocking (following 2 years empty).
- July 2013 following removal of bedding from both pads following the 2012/2013 over-winter period.
- February 2014 following removal of bedding from both pads following the 2013/14 over-winter period.

Each SMN sample consisted of 10 soil cores and each pad was sampled in 3 sections (middle and each end section). Samples were analysed for nitrate (NO_3-N) and ammonium (NH_4-N).

5.2.4 Drainage water sampling

Porous ceramic cups for the measurement of NO_3-N and NH_4-N were installed prior to the start of the 2012/13 and 2013/14 measurement periods (new porous ceramic cups were installed for the second year -2013/14 - due to the risk of damage to the cups during pad emptying). Ten porous ceramic cups were installed at a depth of approximately 45 cm at a 30^o angle in each pad. Tubing from the pots was buried below the bedding, with the location of the porous cups measured out and marked with magnets. Drainage water samples were taken from the porous cups approximately every 2 weeks during the over-winter periods and analysed for NO_3-N and NH_4-N.

In 2012/13 drainage water samples were also taken from a ‘control’ area within each pad. Each control area was 6m x 18m and was fenced off from the main pad to exclude cattle. Bedding was added to the control areas at roughly the same rate of addition as the main pad area, however as cattle were excluded from the control areas the bedding was not compacted and following heavy rainfall it was observed that liquid from the main pad area was seeping into the control area. Consequently the control areas were removed and as an alternative in 2013/14, 5 porous ceramic cups were installed in a nearby winter wheat field (previous crop onions) to provide a comparison with over-winter drainage NO_3-N and NH_4-N concentrations and losses from a more ‘typical’ land-use. Porous ceramic cups were installed in the winter wheat field at a depth of approximately 90 cm at 30^o angle.

5.2.5 Over-winter drainage and nitrogen leaching

Drainage volumes from the pads were estimated using the IRRIGUIDE water balance model (Bailey and Spakman, 1996). The IRRIGUIDE model was modified to take into account the absorptive capacity of the accumulated layer of bedding material (straw or wood-shavings). The model used rainfall recorded at the farm and included an estimate of liquid excretal input from the cattle.

The absorptive capacity of the bedding layer was based on the quantity of bedding and the measured water holding capacity of the bedding material. The water holding capacity of the straw and wood-shavings was determined in a laboratory experiment (Section 4) as 348% and 108%, respectively.

In 2012/13, the straw bedding added to the straw pad included 294 tonnes of 'fresh' baled straw and 158 tonnes of 'old/weathered' straw (approximately 53% DM). The water holding capacity of the 'old/weathered' straw was not measured as part of the laboratory experiment, but was estimated as approximately 230% based on an 'end' dry matter content of 18%[5].

Nitrate-N and NH_4-N concentrations in the porous cups samples were combined with drainage volume estimates to quantify the amounts of NO_3-N and NH_4-N leached (kg/ha) from each pad. Drainage from the winter wheat field was calculated using the IRRIGUIDE model and NO_3-N and NH_4-N leaching losses calculated.

5.3 Results

5.3.1 Pad management

Stocking rate

There were around 100 cattle on each pad with an overall mean stocking rate of 26 m^2/animal (Table 5).

Table 5. Number of cattle and stocking density

	Year	Number of cattle	Stocking rate (m^2/animal)
Straw pad	2012/13	97	27
	2013/14	115	22
Wood-shavings pad	2012/13	93	29
	2013/14	102	26

Note: Stocking rate calculated over the entire pad area including the feed area, which was managed as part of the pad (slurry not scraped and removed). In 2012/13 stocking rate excludes the control areas.

Bedding use

The farm added bedding to both pads as required depending on rainfall and the surface condition of the pads. The quantity of bedding added was recorded and representative samples of straw and wood-shavings bedding material taken for analysis of dry matter, total N and total P (Table 6).

On the straw pad, in both 2012/13 and 2013/14, approximately 50 tonnes of straw was spread to create the initial bed when the cattle went on to the pad, and straw bedding was subsequently added to the pad on average every 1.5 days in 2012/13 and every 2.5 days in 2013/14. In 2012/13, a total of 452 t FW (tonnes fresh weight) of straw was added to the straw pad between 1st October 2012 and mid-March 2013 (Table 6), equivalent to 0.86 t FW/animal/month. This included 294 tonnes of 'fresh' baled straw and 158 tonnes of 'old/weathered' straw (representative samples of each batch of straw were taken). In 2013/14, a total of 223 t FW of straw (fresh baled straw) was added to the pad between 23rd September 2013 and 26th January 2014, equivalent to 0.47 t FW/animal/month.

In 2012/13, 88 tonnes of wood-shavings was spread to create the initial bed, and in 2013/14 64 tonnes of wood-shaving was spread to create the initial bed when the cattle went on to the pad. Wood-shavings were added on average every 3 days in 2012/13 and every 4 days in 2013/14. In 2012/13, a total of 728 t FW of wood-shavings were added to the wood-shavings pad between 1st October 2012 and mid-March

[5] The end dry matter content of the fresh straw at the end of 'soaking' in the laboratory experiment was 18%, and the dry matter content of the soiled straw bedding when the pad was cleared was also 18% (Section 4).

2013, equivalent to 1.45 t FW/animal/month. In 2013/14, a total of 544 t FW of wood-shavings were added to the wood-shavings pad between 23rd September 2013 and 23rd January 2014, equivalent to 1.28 t FW/animal/month.

Table 6. Bedding added to the straw and wood-shavings pads

		Quantity of bedding used (tonnes fresh weight)	Bedding analysis		
			% Dry matter	% total N	% total P
Straw pad	2012/13 01 Oct 12 - 12 Mar 13	452 t of straw, including *292 t fresh straw* *43 t 'old' straw* *72 t 'lightly soiled straw'*	 84 54 52	 0.46 0.74 1.92	 0.58 0.10 0.13
	2013/14 23 Sep 13 – 26 Jan 14	223 t of fresh straw	81	0.65	0.11
Wood-shavings pad	2012/13 01 Oct 12 - 12 Mar 13	728 t of wood shavings	59	0.44	0.31
	2013/14 23 Sep 13 – 23 Jan 14	544 t of wood-shavings	58	0.69	0.09

Bedding was added more frequently to both pads in 2012/13 than in 2013/14 reflecting the very wet October (93 mm rain compared to a long term average of 61mm) and December 2013 (105 mm rain compared to a long term average of 58 mm).

Depth of bedding at the end of the 2012/13 measurement period (on 15th March 2013) averaged 67cm on the straw pad and 87cm on the wood-shavings pad. Depth of bedding at the end of the 2013/14 measurement period (on 27th January 2014) average 45 cm on the straw pad and 70 cm on the wood-shavings pad.

Surface condition of the pads

The surface condition of both the straw and wood-shavings pads was generally good (Plate 2a,c,d,e,f,g,h,k,l). Frequent addition of bedding to both pads usually kept the majority of the surface area clean and dry, although there were 'hot-spots' around the heavily trampled feed stance and water troughs, which were harder to keep clean and dry particularly following heavy rainfall (Plate 2b,i,j). The pads were scored for both dirtiness and wetness; on average the straw pad was slightly dirtier and wetter than the wood-shavings pad (Figure 2).

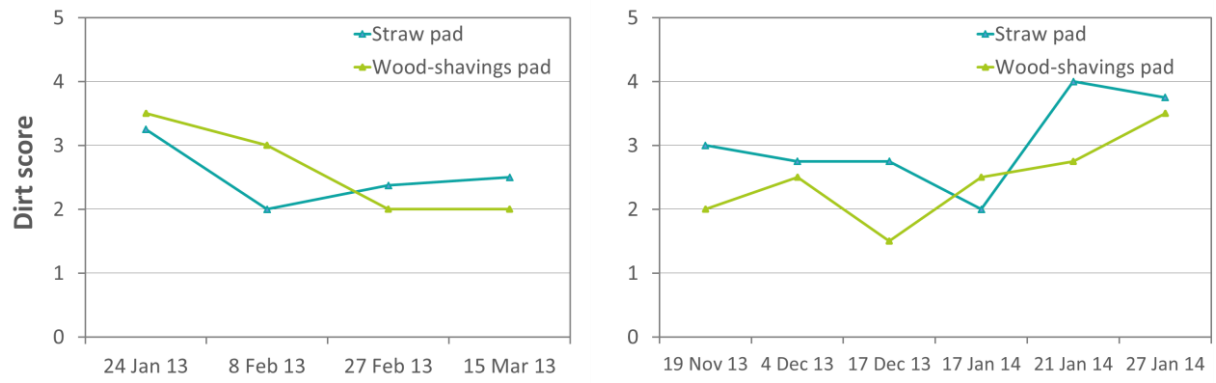

Figure 2.Pad dirtiness score 2012/13 left, and 2013/14 right (1 = surface clean; 5 = surface very dirty)

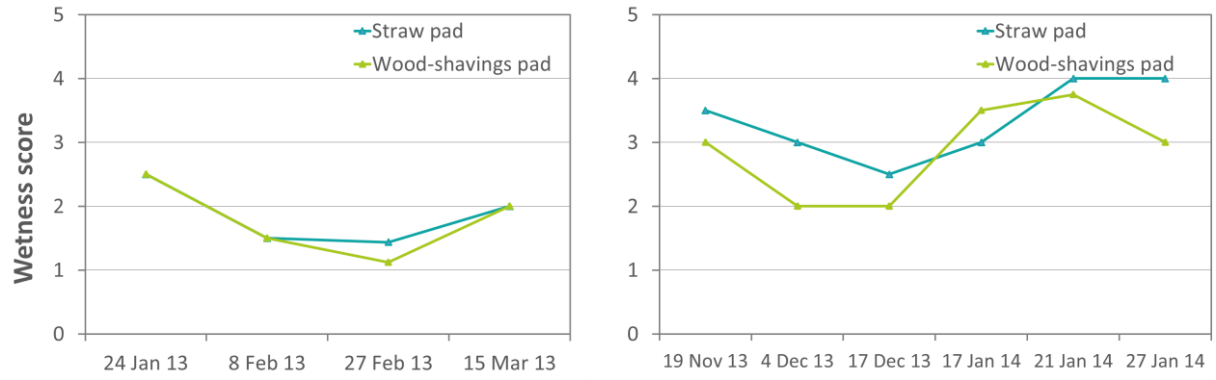

Figure 3. Pad wetness score, 2012/13 left, and 2013/14 right (1 = surface dry; 5 = surface very wet).

a. Straw pad – 24th Jan 2013

b. Straw pad – feed area 24th Jan 2013

c. Straw pad – 4th Dec 2013

d. Wood-shavings pad – 4th Dec 2013

e. Straw pad – 7th Jan 2014

f. *Wood-shavings pad – 7th Jan 2014*

g. Straw pad – 21st Jan 2014

h. *Wood-shavings pad – 21st Jan 2014*

i. *Straw pad – feed area 21st Jan 2014*

j. *Wood-shavings pad – feed area 21st Jan 2014*

k. *Straw pad – 27th Jan 2014*

l. *Wood-shavings pad – 27th Jan 2014 (Water trough visible on left of photo)*

Plate 2. Surface condition of the pads

Soiled bedding

At the end of the 2012/13 over-winter measurement period (in mid-June 2013) 1320 tonnes of bedding was cleared from the straw pad and 1476 tonnes of bedding was cleared from the wood-shavings pad. At the end of the 2013/14 over-winter measurement period (in early February 2014), 712 tonnes of bedding was cleared from the straw pad and 690 tonnes of bedding was cleared from the wood-shavings pad.

The analysis of the soiled bedding is compared to figures for a 'typical' cattle FYM (from Defra's "Fertiliser Manual (RB209)") in Table 7. The dry matter content of the soiled wood-shavings bedding (approximately 26%) was similar to a 'typical' cattle FYM (25% DM), whilst the dry matter content of the soiled straw bedding was wetter (approximately 18% DM) than a 'typical' cattle FYM. Both the soiled straw and wood-shavings bedding had a lower total nutrient (N, P and K) concentration than a 'typical' cattle FYM, reflecting the higher proportion of bedding to excreta on the outdoor pads compared to typical bedding use in a building, and the lower dry matter content of the soiled straw bedding.

Table 7. Analysis of the soiled bedding

	Soiled straw bedding		Soiled wood-shavings bedding		Cattle FYM 'Typical' RB209 figures[1]
	2013	2014	2013	2014	
Dry matter (%)	19	17	27	25	25
Total N (kg/t FW)	4.2	2.4	2.4	2.2	6.0
NH_4-N (kg/t FW)	0.3	0.1	0.7	0.5	0.6
Total P_2O_5 (kg/t FW)	2.0	1.0	2.1	1.2	3.2
Total K_2O (kg/t FW)	7.0	3.7	4.9	3.6	8.0

[1] *Typical figures for Cattle FYM from Defra's "Fertiliser Manual (RB209)" (Anon, 2010)*

5.3.2 Livestock performance

Cattle cleanliness

Cattle on both pads were scored for dirtiness (Figure 4); on average cattle on the straw pad were slightly dirtier than cattle on the wood-shavings pad (by a mean of 0.2 and 0.5 points in 2012/13 and 2013/14, respectively). The majority of cattle on both pads scored either 2 ('light contamination with dung') or 3 ('significant contamination with dung') using the Meat Hygiene Service 5 point classification (Plate 3). Although in the first year on the first observation date (24-01-13) a third of cattle from both pads scored

a 4 ('heavily contaminated with dung'), and in the second year on the final observation date (27-01-14) around half of cattle from the straw pad scored a 4. On both occasions the dirtier cattle reflected the wetter, dirtier pad surface condition following heavy rain.

The farm noted that generally the cattle arrived on the unit with some contamination of the legs and belly, and that there is generally little difference in the level of contamination between cattle housed inside and cattle housed on the outdoor pads. The farm clip the cattle to remove dung contamination prior to slaughter.

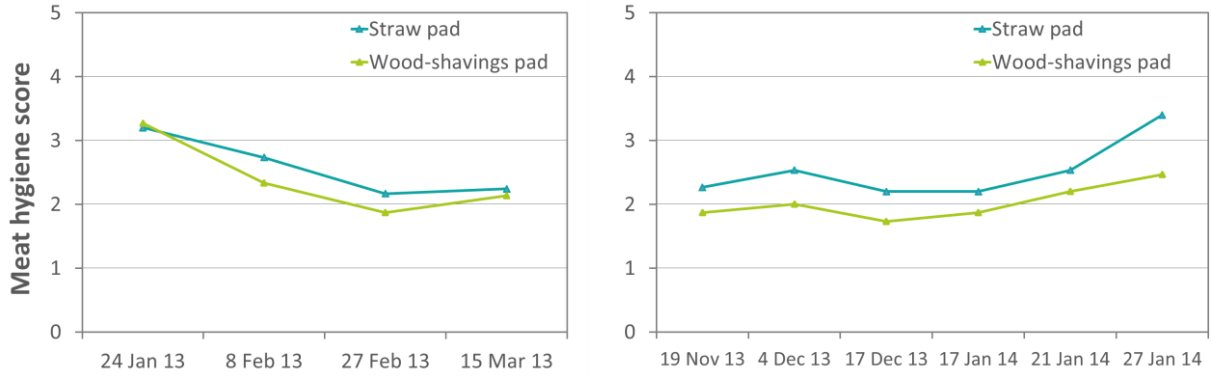

Figure 4. Meat hygiene dirt scores, 2012/13 left, and 2013/14 right (1 = clean; 5 = filthy)

Straw pad – 25th Oct 2013

Straw pad – 4th Dec 2013

Wood-shavings pad – 7th Jan 2014

Wood-shavings pad – 27th Jan 2014

Plate 3. Photos illustrating levels of cattle cleanliness on the straw and wood-shavings pads

Daily live-weight gain

In 2012, the cattle averaged approximately 470 kg live weight when they arrived on the farm and went onto the pads and approximately 670 kg in mid-late March when they were weighed off the pads for slaughter. Mean daily live-weight gain (LWG) for 2012/13 was similar between the pads at 1.36 kg/head/day on the straw pad and 1.28 kg/head/day on the wood-shavings pad (Table 8).

In 2013, the cattle averaged approximately 445 kg when they arrived on the farm and went onto the pads and approximately 605 kg when they were weighed off the pads for slaughter. Mean daily live-weight gain for 2013/14 across both pads was slightly less than 2012/13 at 1.16 kg/head/day on the straw pad and 1.22 kg/head/day on the wood-shavings pad (Table 9).

Table 8. 2012-13 cattle live-weight gain

	Straw pad	***Wood-shavings pad***
Mean live weight on	492 kg	446 kg
Mean live weight off	706 kg	627 kg
Average duration[1]	157 days	140 days
Mean daily LWG (kg/head/day)	1.36	1.28
Number of data	*n=93*	*n=114*
Total number of cattle[2]	*97*	*115*

[1] Average length of time the cattle were on the straw pads.

[2]. Accurate information on live weight on and off the pads was not available for all animals, so the total number of cattle on the pads was greater than the number of data available.

Table 9. 2013-14 cattle live-weight gain

	Straw pad	***Wood-shavings pad***	**All cattle on outdoor pads**	**All cattle in buildings**
Mean live weight on	445 kg	446 kg	445 kg	516 kg
Mean live weight off	609 kg	603 kg	599 kg	634 kg
Average duration[1]	143 days	129 days	122 days	86 days
Mean daily LWG (kg/head/day)	1.16	1.22	1.18	1.32
Number of data	*n=90*	*n=100*	*n=302*	*n=209*
Total number of cattle[2]	*93*	*102*	*497*	*365*

[1] Average length of time the cattle were on the straw pads.

[2]. Accurate information on live weight on and off the pads was not available for all animals, so the total number of cattle on the pads was greater than the number of data available.

The difference in daily LWG between the 2 pads was relatively small (<0.1 kg/head/day) for both years and there was not a consistent effect of bedding type on daily LWG; in 2012/13 daily LWG was greater (P<0.05) on the straw pad, but in 2013/14 daily live-weight gain was greater (P=0.07) on the wood-shavings pad[6].

In 2013/14 cattle weight information was available from the farm for the majority of cattle on the outside pads and in the buildings, enabling comparisons of the performance of the cattle. The mean daily LWG of cattle inside (1.32 kg/head/day) was greater (P<0.01) than the cattle on the outdoor pads (1.18 kg/head/day). The cattle inside were heavier when they arrived on the farm (approximately 516 kg inside

[6] Note – the cattle were allocated to the two pads by the farm and there was no randomisation of cattle onto the pads as part of this study.

compared with approximately 445 kg on the outdoor pads) and were finished quicker (mean finishing period of 86 days) than the cattle on the outdoor pads (mean finishing period of 122 days).

All cattle on the farm are fed a total mixed ration (TMR) (Table 10) based on 2 t roots (potatoes/parsnips), 1 t brewer's grain, 0.5 t blend, 0.25 t citrus, 0.25 t chips and 0.3 t of straw fed through a TMR wagon.

Table 10. TMR analysis (wet-chemistry)

Analysis	Units	Mean value
Dry matter content	%	28.2
pH		4.4
Acid Detergent Fibre	% dry matter	20.4
Metabolisable energy	MJ/kg DM	11.9
Neutral Detergent Fibre	% dry matter	53.8
Crude Protein	% dry matter	15.6
Ash	% dry matter	8.7
Total Oil	% dry matter	8.4
Starch	% dry matter	14.5
NCGD	% dry matter	70.0

Note: replicate samples taken on 21/01/14, 27/01/14 and 06/02/14.

5.3.3 Soil mineral nitrogen

Background SMN (0-90 cm) in mid-October 2012, before the cattle went back onto the pads, was relatively high at approximately 290 kg/ha on the straw pad and approximately 180 kg/ha on the wood-shavings pad (Figure 5). These relatively high SMN levels are likely to reflect the past use of the land as outdoor pads for keeping cattle.

Soil mineral N samples were taken again from both pads following 'mucking-out' after the 2012/13 winter period (in July 2013) and again after the 2013/14 winter period (in February 2014) (Figure 5).

On the straw pad, SMN levels in July 2013 (approximately 280 kg/ha) and February 2014 (approximately 250 kg/ha) remained similar to background SMN levels measured in mid-October 2012 (approximately 290 kg/ha). This is consistent with the low estimated drainage from the straw pad in both years (20 mm and <1 mm over the 2012/13 and 2013/14 over-winter stocked period, respectively).

In contrast, on the wood-shavings pad, there was a large increase in SMN during the 2012/13 over-winter period (to approximately 450 kg/ha), reflecting the movement of NO_3-N and NH_4-N in drainage (151 mm drainage) from the bedding layer into the topsoil. However, there was little subsequent change in SMN levels over the 2013/14 over-winter period; SMN levels measured in February 2014 (approximately 465 kg/ha) were similar to levels measured in July 2013, reflecting the lower drainage volume over the 2013/14 winter period (60 mm).

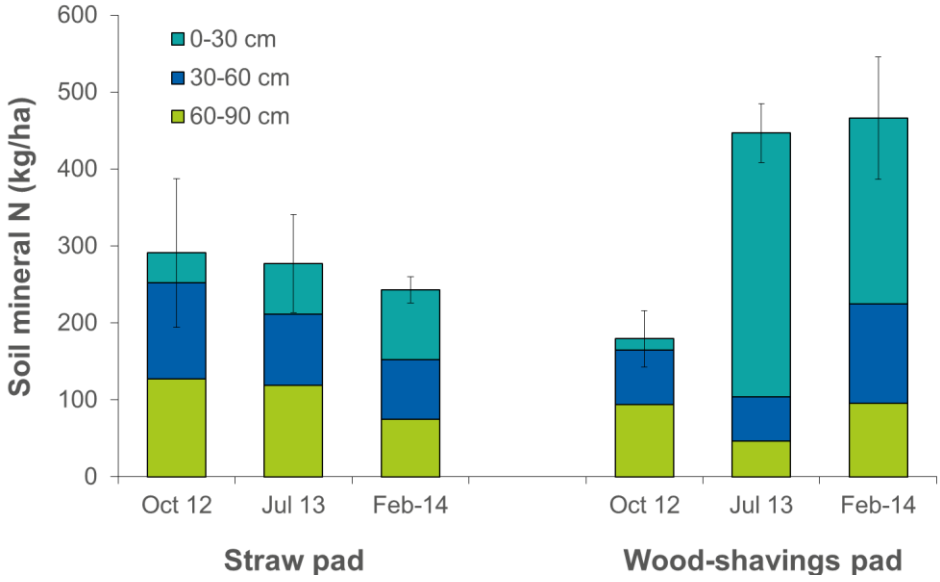

Figure 5. Soil mineral nitrogen (0-90 cm) sampled October 2012, July 2013 and February 2014

5.3.4 Drainage water NO_3-N and NH_4-N concentrations

Drainage water NO_3-N concentrations

In 2012/13, Nitrate-N concentrations in drainage water from the straw pad were high, averaging between 450 mg/l NO_3-N in early December 2012 (at the start of measurements) and 200 mg/l NO_3-N in mid-March 2013 (at the end of measurements). Nitrate-N concentrations in drainage water from the wood-shavings pad were lower than from the straw pad, although still high, averaging between 210 mg/l NO_3-N in early December 2012 (at the start of measurements) and 130 mg/l NO_3-N in mid-March 2012 (at the end of measurements) (Figure 6). The higher NO_3-N concentrations in drainage water in 2012/13 from the straw pad reflect the higher background SMN levels (approximately 290 kg/ha SMN) compared to the wood-shavings pad (approximately 180 kg/ha SMN), and possibly also a dilution effect of the greater drainage volume from the wood-shavings compared to the straw pad (section 5.3.5)

In 2013/14, NO_3-N concentrations in drainage water from the straw pad were approximately 90 mg/l NO_3-N at the start of sampling in mid-November 2013, and fell to approximately 60 mg/l NO_3-N by the end of sampling in late January 2014. These NO_3-N concentrations are notably lower than were measured from the straw pad over the 2012/13 winter period (approximately 200-450 mg/l NO_3-N). In contrast, NO_3-N concentrations in drainage water from the wood-shavings pad averaged between 200-240 mg/l NO_3-N (Figure 7); approximately 2-3 times greater than concentrations measured from the straw pad, and similar to concentrations measured from the wood-shavings pad over the 2012/13 winter period (approximately 130-210 mg/l).

Measured NO_3-N concentrations in drainage water from the nearby winter wheat field in 2013/14 were approximately 45-65 mg/l – approximately 25 mg/l lower than from the straw pad and approximately 160 mg/l lower than from the wood-shavings pad. Nitrate-N concentrations in drainage water from both pads and from the winter wheat field exceeded the EC Nitrates Directive limit of 11.3 mg/l NO_3-N.

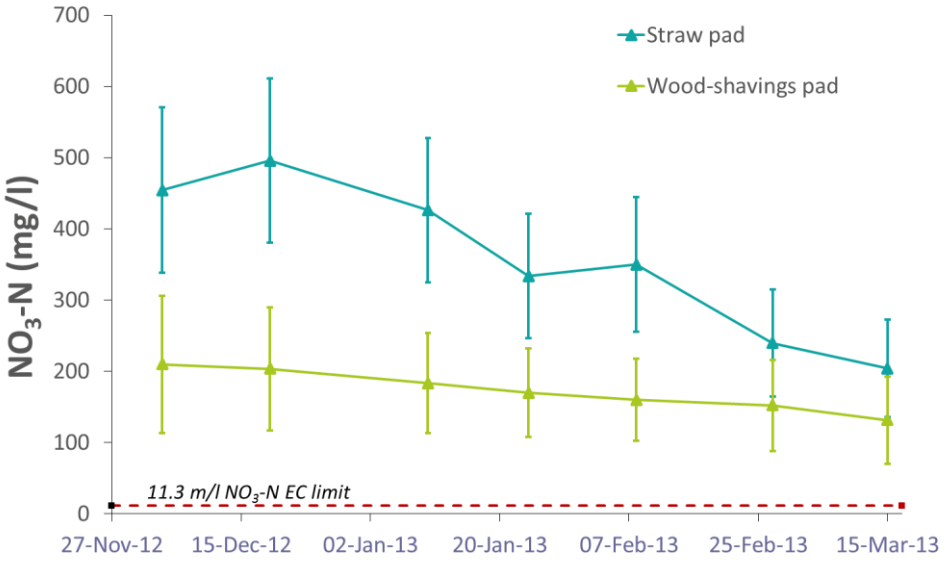

Figure 6. Nitrate-N concentrations in drainage water (2012/13)

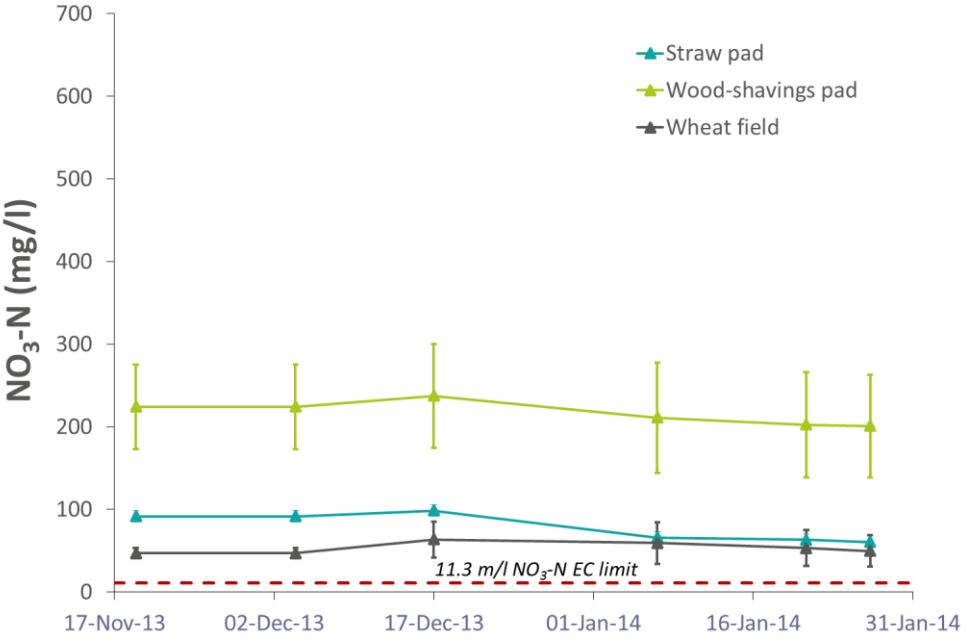

Figure 7. Nitrate concentrations in drainage water (2013/14)

Drainage water NH_4-N concentrations

Ammonium-N concentrations in drainage water measured from both pads in both years were high and very variable (Figure 8 and Figure 9). In 2012/13, mean NH_4-N concentrations in drainage water were similar between the 2 pads at approximately 20-30 mg/l NH_4-N (Figure 8). Maximum NH_4-N concentrations of 111 and 153 mg/l NH_4-N were measured from the straw and wood-shavings pads, respectively.

In 2013/14, NH_4-N concentrations were greatest from the wood-shavings pad, averaging approximately 30 mg/l NH_4-N, with a maximum concentration of 246 mg/l NH_4-N. Ammonium-N concentrations from the straw pad were lower, averaging approximately 5 mg/l NH_4-N, with a maximum concentration of 31 mg/l NH_4-N (Figure 9). Ammonium-N concentrations from the wood-shavings pad were similar to those measured over the 2012/13 winter period, whilst NH_4-N concentrations from the straw pad were lower than those measured over the 2012/13 winter period.

Mean NH_4-N concentrations from both pads in both years were significantly greater than the EC Freshwater Fish Directives limit of 0.78 mg/l NH_4-N. In contrast, NH_4-N concentrations in measured in drainage water from the nearby winter wheat in 2013/14 field were very low, averaging <0.1 mg/l with a maximum concentration of 0.3 mg/l NH_4-N (Figure 9).

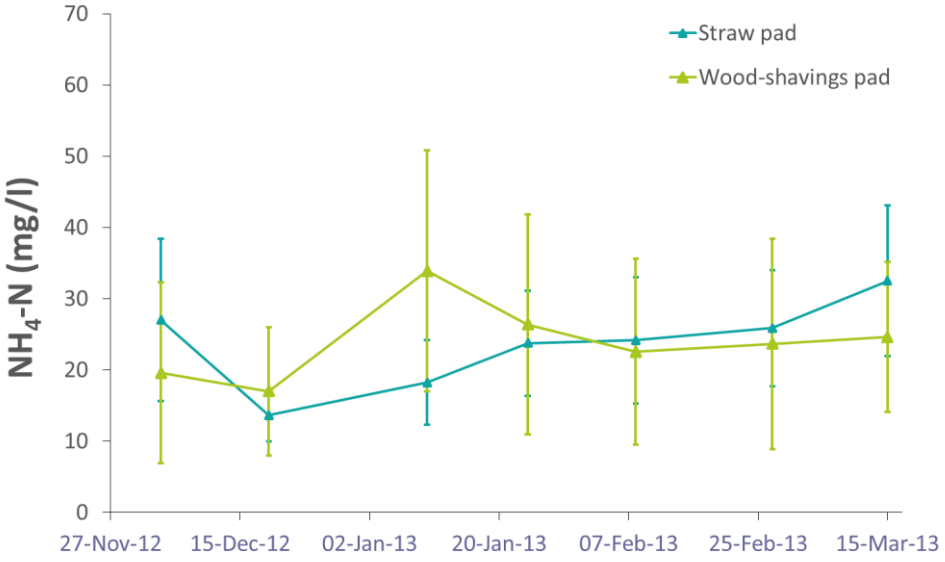

Figure 8. Ammonium-N concentrations in drainage water (2012/13)

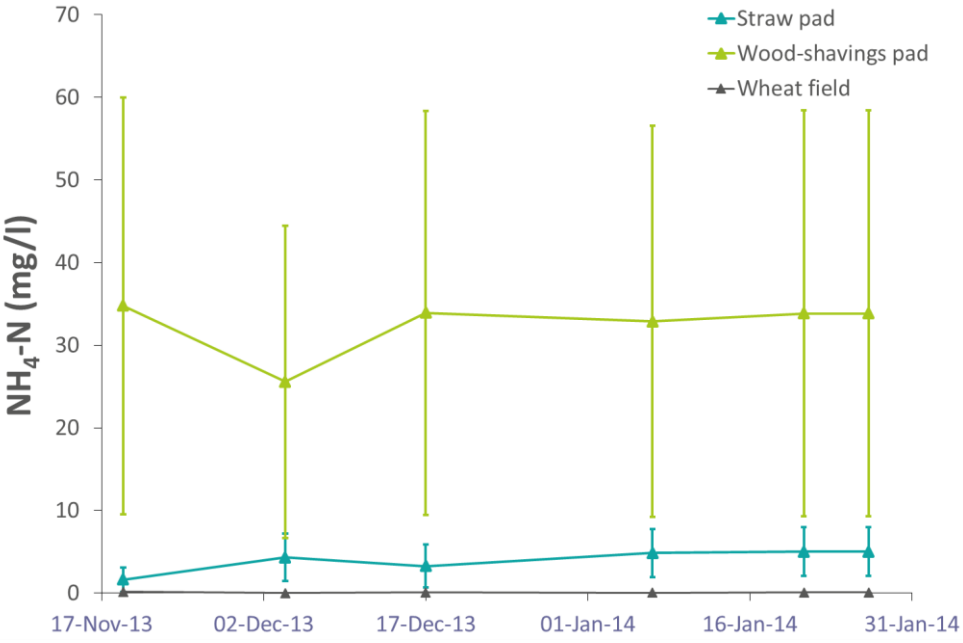

Figure 9. Ammonium-N concentrations in drainage water (2013/14)

5.3.5 Over-winter drainage volume and nitrogen leaching

2012/13 over-winter drainage

For the period when the cattle were on the pads (1st October 2012 to mid-March 2013), the estimated drainage volumes were 20 mm from the straw pad and 151 mm from the wood-shavings pad. In contrast, drainage volume from bare soil (without the bedding) was estimated as 281 mm. The lower estimated drainage volume from the straw pad reflected the higher water holding capacity of the straw bedding compared to the wood-shavings.

For the straw pad, the greatest risk of drainage was early in the season when the quantity of bedding may not be sufficient to absorb the rainfall and excreta during periods of above average rainfall. The 2012/13 over-winter period represents a 'worst case scenario' as the wet summer and early autumn period meant that the soils were at field capacity at the start of the stocking period and October and December 2012 were >50% wetter than average (Table 11). Our estimates suggest that drainage only occurred over an 11 day period (22/10/12 to 01/11/12) on the straw pad (Figure 10). In contrast, drainage occurred intermittently over the majority of the measurement period on wood-shavings pad (Figure 11).

Table 11. Rainfall during the 2012/13 and 2013/14 out-wintering periods compared to long term (30 year) average

	Oct	Nov	Dec	Jan	Feb	Mar
30 year average (mm)	***61***	***61***	***58***	***55***	***44***	***49***
2012/13 (mm)	93	59	105	56	30	25
2013/14 (mm)	90	55	42	48	-	-

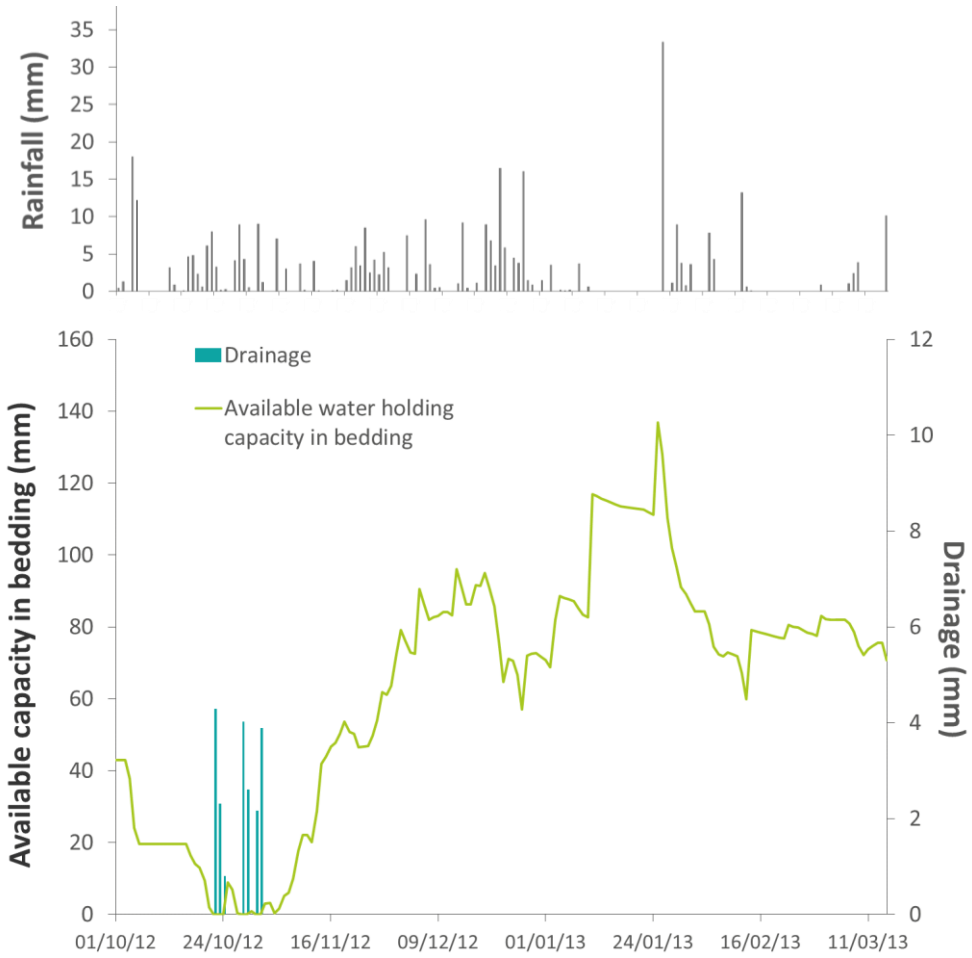

Figure 10. Straw pad (2012/13) – rainfall distribution (top) and remaining water holding capacity of bedding and drainage from pad (bottom)

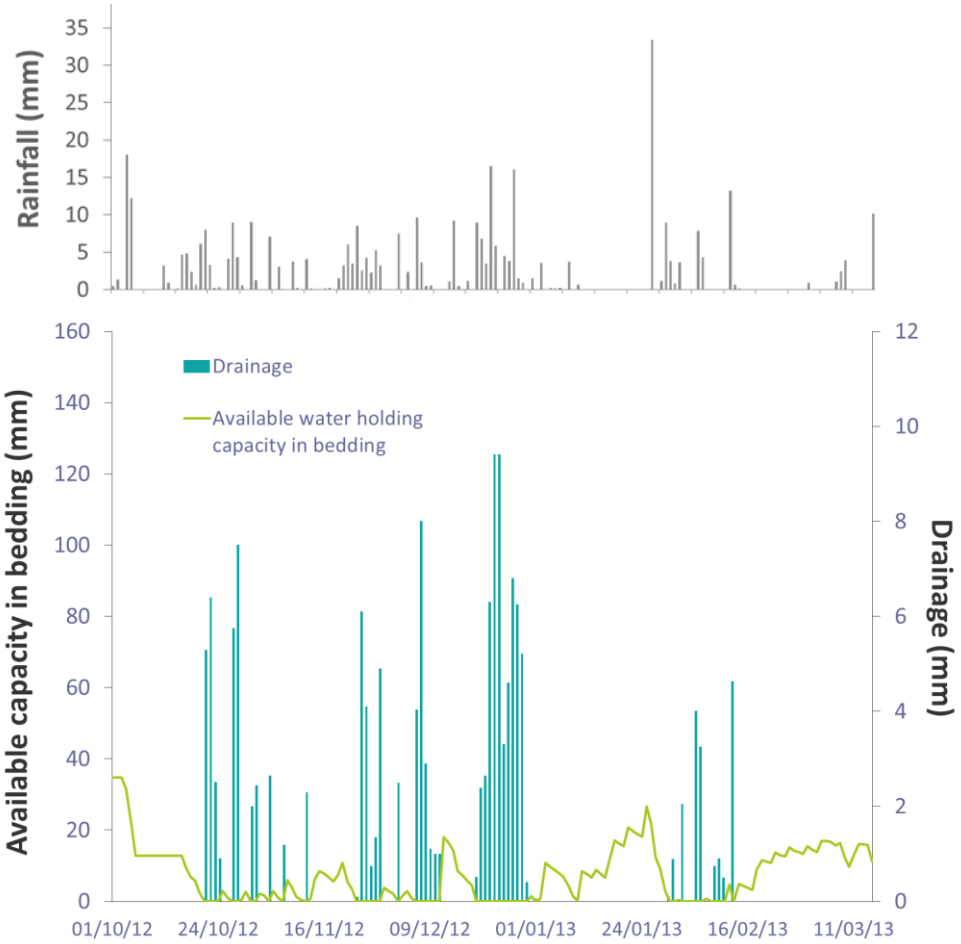

Figure 11. Wood-shavings pad (2012/13) - rainfall distribution (top) and remaining water holding capacity of bedding and drainage from pad (bottom)

2012/13 Nitrate-N and ammonium-N leaching losses

Nitrate-N and NH_4-N leaching losses were calculated from the measured drainage water NO_3-N and NH_4-N concentrations and estimated drainage volumes. Total NO_3-N and NH_4-N leaching losses were 96 kg/ha N from the straw pad (91 kg/ha NO_3-N and 5 kg/ha NH_4-N) and 322 kg/ha N from the wood-shavings pad (299 kg/ha NO_3-N and 33 kg/ha NH_4-N). *Note* - because the 'control' areas in 2012/13 were unsuccessful, there is no background comparison of leaching losses from an un-stocked area.

2013/14 over-winter drainage

For the period when the cattle were on the pads (23rd September 2013 to late-January 2014), the estimated drainage volumes were <1mm from the straw pad (0.3 mm on 23/10/13) and 60 mm from the wood-shavings pad. In contrast, the drainage volume from bare soil (without the bedding) for the same period was estimated as 170 mm.

The straw pad reached 'capacity' (i.e. it was unable to absorb additional water) on one occasion in late October 2013, however additional bedding was added to the pad before significant drainage occurred (<1 mm drainage on 23/10/13) (Figure 12). In contrast, and as also observed in 2012/13, drainage from the wood-shavings pad occurred intermittently over the majority of the measurement period (Figure 13).

The lower estimated drainage volume from the straw pad reflected the higher water holding capacity of the straw bedding compared to the wood-shavings. The lower drainage volumes measured in 2013/14 reflect a combination of the shorter measurement period (approximately 4.5 months in 2013/14 compared to approximately 5.5 months in 2012/13) and drier over-winter period (Table 11).

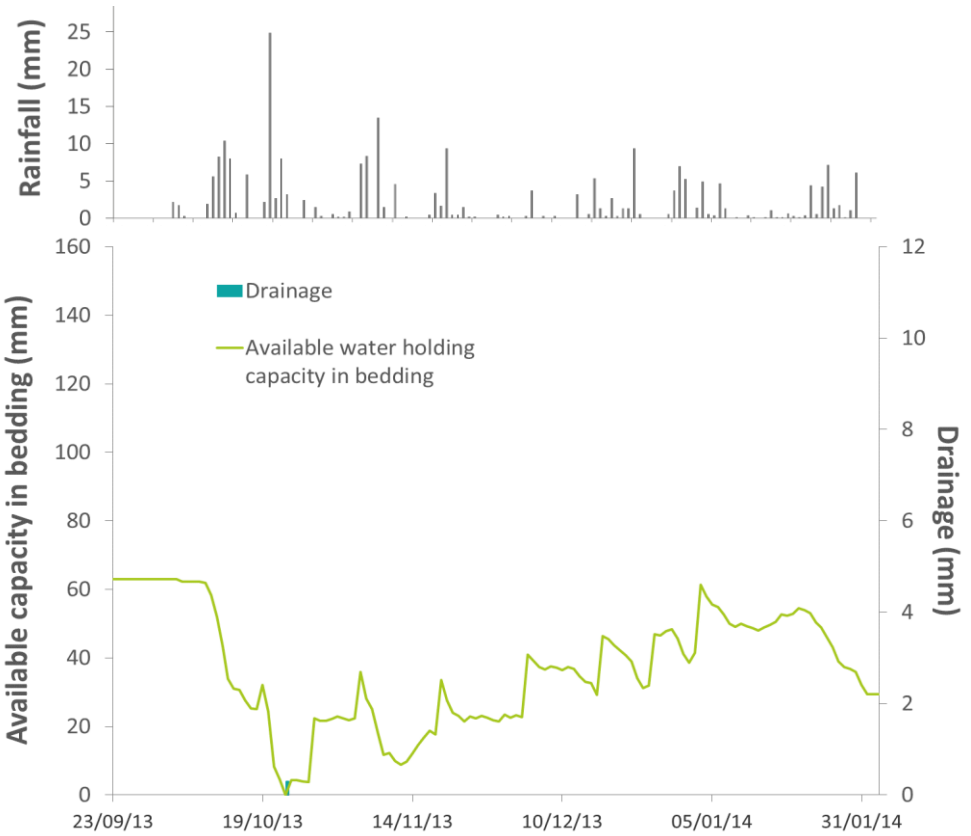

Figure 12 Straw pad (2013/14) - rainfall distribution (top) and remaining water holding capacity of bedding and drainage from pad (bottom)

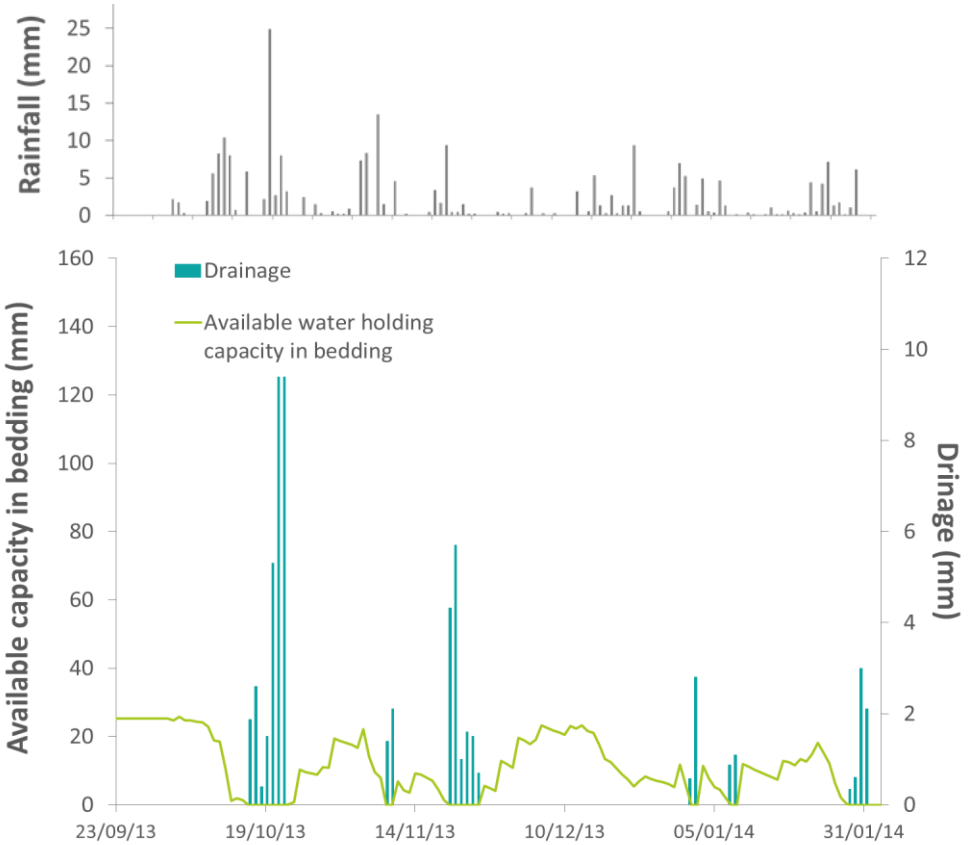

Figure 13 Wood-shavings pad (2013/14) - rainfall distribution (top) and remaining water holding capacity of bedding and drainage from pad (bottom)

2013/14 Nitrate-N and ammonium-N leaching losses

Nitrate-N and NH_4-N leaching losses were calculated from the measured drainage water NO_3-N and NH_4-N concentrations and estimated drainage volumes from the straw pad, wood-shavings pad and the winter wheat field. Nitrogen leaching losses were <1 kg/ha from the straw pad (reflecting the low estimated drainage of < 1mm), 153 kg/ha from the wood-shavings pad (133 kg/ha NO_3-N and 20 kg/ha NH_4-N) and 47 kg/ha from the winter wheat field (47 kg/ha NO_3-N and <0.1 kg/ha NH_4-N).

5.4 Summary

- The surface condition of both the straw and wood-shavings pads was generally good. Frequent addition of bedding to both pads usually kept the majority of the surface area clean and dry, although there were 'hot-spots' around the heavily trampled feed stance and water troughs, which were harder to keep clean and dry particularly following heavy rainfall.
- Bedding use was higher and bedding was added more frequently to both pads in 2012/13 than in 2013/14, reflecting the wetter 2012/13 over-winter period. Straw bedding was added on average every 1.5 days in 2012/13 and on average every 2.5 days in 2013/14. Wood-shavings were added on average every 3 days in 2012/13 and on average every 4 days in 2013/14.
- Bedding use on the straw pad was equivalent to 0.86 t FW/animal/month in 2012/13 compared to 0.47 t FW/animal/month in 2013/14; bedding use on the wood-shavings pad was 1.45 t FW/animal/month in 2012/13 compared to 1.28 t FW/animal/month in 2013/14.
- Laboratory studies showed that fresh straw and soiled wood-shavings were able to absorb 3.5 and 1.1 times their initial weight in water, respectively. The water holding capacity of 'old/weathered' straw is likely to be lower than new-season straw, and was estimated at approximately 2.3 times its initial weight.
- In 2012/13 for the period when the cattle were on the pads (1st October 2012 to mid-March 2013), the estimated drainage volumes were 20 mm from the straw pad and 151 mm from the wood-shavings pad (compared to an estimated 281 mm drainage from bare soil), reflecting a wetter than average winter period.
- In 2013/14 for the period when the cattle were on the pads (23rd September 2013 to late-January 2014), the estimated drainage volumes were <1mm from the straw pad (0.3 mm on 23/10/13) and 60 mm from the wood-shavings pad (compared to an estimated 170 mm from bare soil).
- Bedding use on the wood-shavings pad was insufficient to absorb the rainfall, dung and urine, and drainage occurred intermittently during the stocked period in both years.
- Drainage occurred during a limited period in October 2012 from the straw pad following a period of very heavy rainfall; this highlights the importance of applying sufficient bedding early in the season to allow capacity to absorb effluent following short period of heavy rainfall.
- Nitrate-N and NH_4-N concentrations in drainage water from both the straw and wood-shavings pads were very high (approximately 60-450 mg/l NO_3-N and approximately 5-35 mg/l NH_4-N), indicating that any effluent draining into the soil represents a high risk of diffuse N pollution.
- In 2012/13 N leaching losses were 96 kg/ha N from the straw pad and 322 kg/ha N from the wood-shavings pad. In 2013/14 N leaching losses were <1 kg/ha N from the straw pad and 153 kg/ha N from the wood-shavings pad, compared to 47 kg/ha N from a nearby winter wheat field. The lower leaching losses in 2013/14 reflected the lower drainage volumes compared with 2012/13.

6 Bedding recommendations for straw pads

6.1 Introduction

The review (section 3) found that the majority of straw pads are unlined corrals; the principle of the system is that the depth of bedding provides sufficient absorptive capacity to retain the dung and urine generated by the animals and rainfall over the pad area. Any effluent draining from the pad is likely to have high concentrations of NO_3-N, NH_4-N, phosphorus and faecal pathogens, representing a high risk of diffuse pollution. It is essential that on unlined straw pads sufficient bedding is used to absorb the total excretal input and rainfall to the pad.

The quantity of bedding required to absorb all the excreta and rainfall can be calculated based on the absorbency of the bedding and the volume of liquid added to the pad, which can be calculated based on stocking rates, rainfall and evaporation.

The review suggests that most farms with straw pads base their bedding use on a visual inspection of the pad and apply bedding regularly to ensure a clean dry surface. It is essential that farmers are able to base their bedding use on both the calculated volume of bedding required to absorb all the liquid effluent and a visual inspection of the pad to ensure a clean dry surface.

6.2 Methodology for calculating bedding requirements for straw pads

6.2.1 Bedding absorbency

The water holding capacity of different out-wintering pad bedding materials was determined in a laboratory experiment, including an OSR straw and 2 cereal straws (Section 4). The OSR straw had a water holding capacity of approximately 300% and the 2 cereal straws had water holding capacities of approximately 350% and approximately 450%. More than half of the farms in our review used a combination of cereal and OSR straw on the pads, depending on local availability. Two farms also noted that, when available they also used some ‘old/weathered’ straw. The water holding capacity of ‘old/weathered’ straw is likely to be lower, reflecting a lower initial dry matter content; the water holding capacity of ‘old/weathered’ straw used in the first season of the experimental work was estimated as approximately 230% (Section 5.2.5).

Calculations for bedding requirements here have been based on an overall bedding absorbency of 300% to reflect the lower end of the range of absorbencies of straw materials typically used on pads.

6.2.2 Excreta input

Typical figures for the volume of excreta produced by different livestock types are included in the NVZ Regulations (SI, 2015). The straw bedding should absorb the liquid portion of the excreta (i.e. faeces and urine); ‘neat’ (i.e. undiluted) excreta is typically 90% water and 10% dry matter. Consequently in the calculations here, it is assumed that the liquid excretal input to the pads is 90% of the total excreta produced (Table 12).

Where there is no concrete feed area (i.e. cattle are fed ‘on-pad’) it is assumed that the cattle spend 24 hours per day on the pad and that all excreta is deposited on the pad. Where the cattle are fed ‘off-pad’ on a concrete feed stance, a portion of the excreta will be deposited on the feed stance and scraped away from the pad. For pads with a concrete feed area, it is assumed that the cattle spend 66% of their time on

the pad and 33% of their time on the feed stance[7] and the excretal input is reduced accordingly (to 66% of liquid excreta produced) (Table 12).

Table 12. Excreta input to pads from different livestock categories

Livestock type	Total excreta[1] volume m^3/month/animal	Volume of liquid excreta[2]	
		On-pad feeding m^3/month/animal	Off-pad feeding[3] m^3/month/animal
1 beef animal between 2-12 months of age	0.6	0.54	0.36
1 beef animal between 12-24 months of age	0.78	0.70	0.46
1 beef animal for slaughter older than 24 months of age	0.96	0.86	0.57
1 female for breeding 24 months of age and over weighing up to 500 kg LW	0.96	0.86	0.57
1 female for breeding 24 months of age and over weighing over 500 kg LW	1.35	1.22	0.80

1. Standard figures for livestock excreta (i.e. faeces and urine) production from NVZ Regulations
2. Liquid excreta input to pad is assumed to be 90% of total excreta volume (based on a dry matter content of 10%)
3. For off-pad feeding estimates based on 33% of time on the feed stance and 66% of time on pad area.

6.2.3 Rainfall

Rainfall will vary depending on location and between years. The review (Section 3) identified 15 farms using straw pads located in the east of England and the majority were in areas where the long term average annual rainfall (1971-2000) is <700 mm.

Bedding requirements have been calculated for 3 rainfall areas: 550 mm, 650 mm and 750 mm average annual rainfall. It is assumed that rainfall is distributed evenly throughout the year and bedding requirements are given in tonnes per month.

The calculated bedding requirements are a guide based on long term average annual rainfall and farmers should be prepared to add more bedding where actual rainfall is higher than normal.

6.2.4 Evaporation

The liquid excreta and rainfall input will be reduced by evaporative losses. Evaporative losses were estimated using the IRRIGUIDE water balance model (Bailey and Spakman, 1996), modified to reflect the surface characteristics of the straw (i.e. using bulk density and water holding capacity of straw).

The IRRIGUIDE model was used to estimate evaporative losses based on 20 years of climate data for 3 locations, broadly reflecting the extent of the distribution of straw pads in the UK:

- Thetford, Norfolk (approximately 600mm average annual rainfall)

[7] Research on woodchip pads for out-wintering cattle has shown that cattle spend approximately one third of their time on the concrete feed stance (Anon, 2007; Smith *et al*., 2011).

- Melton Mowbray, Leicestershire (approximately 750 mm average annual rainfall)
- Moulton, North Yorkshire (approximately 900 mm average annual rainfall).

Estimated evaporative losses varied over the year, but were very similar between the 3 locations (Figure 14). The calculations for bedding requirements are based on a single mean evaporative loss figure of 17 mm/month over the winter period (October to March) and 42 mm/month over the summer period (April to September).

Two thirds of farms contacted as part of the review (Section 3) used straw pads to over-winter cattle, typically from October/November to March/April, with the other farms stocking the straw pads throughout the year. Where straw pads are used throughout the year, bedding use in the summer will be lower reflecting the higher summer evaporative losses.

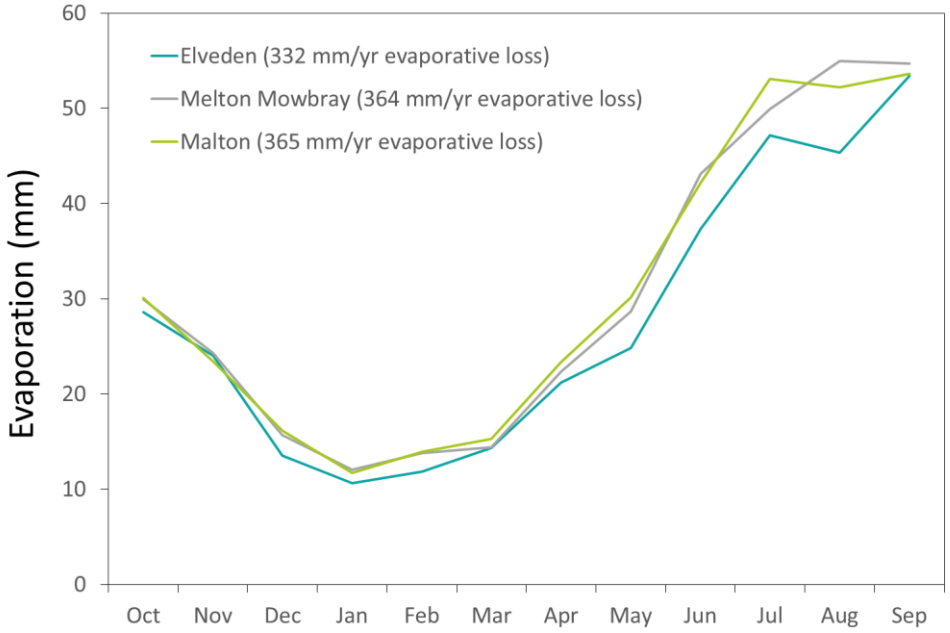

Figure 14. Estimated monthly evaporative loss from straw pads located across the East of England

6.2.5 Stocking density

Calculations for bedding requirements have been based on stocking rates of between 8 and 28 m^2/animal, reflecting the range of stocking rates observed in the review (Section 3). Bedding requirements are given in tonnes per animal per month, and increase on a per animal basis as the stocking rate reduces, reflecting the increased surface area per animal and greater volume of rainfall to absorb per animal.

6.3 Bedding requirements

Bedding recommendations have been calculated for the following livestock categories:

- 1 beef animal between 2-12 months of age (Table 13)
- 1 beef animal between 12-24 months of age (Table 14)
- 1 beef animal for slaughter older than 24 months of age (Table 15)
- 1 female for breeding 24 months of age and over weighing up to 500 kg LW (Table 15)
- 1 female for breeding 25 months of age and over weighing over 500 kg LW (Table 16)

The bedding recommendations are based on the quantity of bedding required to absorb the liquid input (excreta and rainfall) to the pad. These recommendations should be used in combination with a visual

inspection of the pad and additional straw should be added where required to keep the surface of the pad clean and dry and to ensure there is no 'pooling' of liquid on the pad surface or any seepage of effluent from the pad.

In addition, it is important to consider the timing of bedding application and in particular to ensure sufficient bedding is added early in the stocking period to ensure the straw pad has the capacity to absorb the effluent produced following short periods of heavy rainfall, i.e. a greater proportion of the total bedding requirement should be added early on to ensure sufficient initial depth of bedding. The straw bedding requirements given here are total bedding requirements and include straw added initially and then regularly to keep the surface clean.

Table 13.Straw bedding requirement (tonnes of straw per animal per month) - 1 beef animal between 2-12 months of age

Average annual rainfall	Season	Stocking rate (m^2/animal)[1]										
		8	10	12	14	16	18	20	22	24	26	28
Cattle fed off-pad												
550 mm	Winter (Oct to Mar)	0.20	0.21	0.23	0.25	0.27	0.29	0.31	0.33	0.35	0.37	0.39
	Summer (Apr to Sep)	0.13	0.13	0.13	0.14	0.14	0.14	0.14	0.15	0.15	0.15	0.15
650 mm	Winter (Oct to Mar)	0.22	0.24	0.27	0.29	0.32	0.34	0.37	0.39	0.42	0.44	0.47
	Summer (Apr to Sep)	0.15	0.16	0.17	0.18	0.18	0.19	0.20	0.21	0.22	0.22	0.23
750 mm	Winter (Oct to Mar)	0.24	0.27	0.30	0.33	0.36	0.39	0.42	0.45	0.48	0.51	0.54
	Summer (Apr to Sep)	0.17	0.19	0.20	0.21	0.23	0.24	0.26	0.27	0.28	0.30	0.31
Cattle fed on-pad												
550 mm	Winter (Oct to Mar)	0.26	0.28	0.30	0.31	0.33	0.35	0.37	0.39	0.41	0.43	0.45
	Summer (Apr to Sep)	0.19	0.19	0.20	0.20	0.20	0.20	0.21	0.21	0.21	0.21	0.22
650 mm	Winter (Oct to Mar)	0.28	0.30	0.33	0.35	0.38	0.40	0.43	0.45	0.48	0.50	0.53
	Summer (Apr to Sep)	0.21	0.22	0.23	0.24	0.24	0.25	0.26	0.27	0.28	0.29	0.29
750 mm	Winter (Oct to Mar)	0.30	0.33	0.36	0.39	0.42	0.45	0.48	0.51	0.54	0.57	0.60
	Summer (Apr to Sep)	0.23	0.25	0.26	0.28	0.29	0.30	0.32	0.33	0.34	0.36	0.37

[1]. For cattle fed off-pad, the stocking rate excludes the feed area.

Table 14. Straw bedding requirement (tonnes of straw per animal per month) - 1 beef animal between 12-24 months of age

Average annual rainfall	Season	Stocking rate (m^2/animal)[1]										
		8	10	12	14	16	18	20	22	24	26	28
Cattle fed off-pad												
550 mm	Winter (Oct to Mar)	0.23	0.25	0.27	0.29	0.31	0.33	0.35	0.37	0.39	0.40	0.42
	Summer (Apr to Sep)	0.16	0.17	0.17	0.17	0.17	0.18	0.18	0.18	0.19	0.19	0.19
650 mm	Winter (Oct to Mar)	0.25	0.28	0.30	0.33	0.35	0.38	0.40	0.43	0.45	0.48	0.50
	Summer (Apr to Sep)	0.19	0.19	0.20	0.21	0.22	0.23	0.24	0.24	0.25	0.26	0.27
750 mm	Winter (Oct to Mar)	0.28	0.31	0.34	0.37	0.40	0.43	0.46	0.49	0.52	0.55	0.58
	Summer (Apr to Sep)	0.21	0.22	0.24	0.25	0.26	0.28	0.29	0.30	0.32	0.33	0.35
Cattle fed on-pad												
550 mm	Winter (Oct to Mar)	0.31	0.33	0.35	0.37	0.39	0.41	0.43	0.45	0.46	0.48	0.50
	Summer (Apr to Sep)	0.24	0.25	0.25	0.25	0.25	0.26	0.26	0.26	0.26	0.27	0.27
650 mm	Winter (Oct to Mar)	0.33	0.36	0.38	0.41	0.43	0.46	0.48	0.51	0.53	0.56	0.58
	Summer (Apr to Sep)	0.27	0.27	0.28	0.29	0.30	0.31	0.32	0.32	0.33	0.34	0.35
750 mm	Winter (Oct to Mar)	0.36	0.39	0.42	0.45	0.48	0.51	0.54	0.57	0.60	0.63	0.66
	Summer (Apr to Sep)	0.29	0.30	0.32	0.33	0.34	0.36	0.37	0.38	0.40	0.41	0.43

[1]. For cattle fed off-pad, the stocking rate excludes the feed area.

Table 15. Straw bedding requirement (tonnes of straw per animal per month) - 1 beef animal for slaughter older than 24 months of age, OR 1 female for breeding 24 months of age and over weighing up to 500 kg LW

Average annual rainfall	Season	Stocking rate (m^2/animal)[1]										
		8	10	12	14	16	18	20	22	24	26	28
Cattle fed off-pad												
550 mm	Winter (Oct to Mar)	0.27	0.29	0.31	0.32	0.34	0.36	0.38	0.40	0.42	0.44	0.46
	Summer (Apr to Sep)	0.20	0.20	0.21	0.21	0.21	0.21	0.22	0.22	0.22	0.22	0.23
650 mm	Winter (Oct to Mar)	0.29	0.31	0.34	0.36	0.39	0.41	0.44	0.46	0.49	0.51	0.54
	Summer (Apr to Sep)	0.22	0.23	0.24	0.25	0.25	0.26	0.27	0.28	0.29	0.30	0.30
750 mm	Winter (Oct to Mar)	0.31	0.34	0.37	0.40	0.43	0.46	0.49	0.52	0.55	0.58	0.61
	Summer (Apr to Sep)	0.24	0.26	0.27	0.29	0.30	0.31	0.33	0.34	0.35	0.37	0.38
Cattle fed on-pad												
550 mm	Winter (Oct to Mar)	0.36	0.38	0.40	0.42	0.44	0.46	0.48	0.50	0.52	0.54	0.56
	Summer (Apr to Sep)	0.30	0.30	0.30	0.31	0.31	0.31	0.31	0.32	0.32	0.32	0.32
650 mm	Winter (Oct to Mar)	0.39	0.41	0.44	0.46	0.49	0.51	0.54	0.56	0.59	0.61	0.63
	Summer (Apr to Sep)	0.32	0.33	0.34	0.34	0.35	0.36	0.37	0.38	0.39	0.39	0.40
750 mm	Winter (Oct to Mar)	0.41	0.44	0.47	0.50	0.53	0.56	0.59	0.62	0.65	0.68	0.71
	Summer (Apr to Sep)	0.34	0.36	0.37	0.38	0.40	0.41	0.42	0.44	0.45	0.47	0.48

[1]. For cattle fed off-pad, the stocking rate excludes the feed area.

Table 16. Straw bedding requirement (tonnes of straw per animal per month) - 1 female for breeding 25 months of age and over weighing over 500 kg LW

Average annual rainfall	Season	Stocking rate (m^2/animal)[1]										
		8	10	12	14	16	18	20	22	24	26	28
Cattle fed off-pad												
550 mm	Winter (Oct to Mar)	0.34	0.36	0.38	0.40	0.42	0.44	0.46	0.48	0.50	0.52	0.54
	Summer (Apr to Sep)	0.28	0.28	0.28	0.29	0.29	0.29	0.29	0.30	0.30	0.30	0.30
650 mm	Winter (Oct to Mar)	0.37	0.39	0.42	0.44	0.47	0.49	0.52	0.54	0.56	0.59	0.61
	Summer (Apr to Sep)	0.30	0.31	0.32	0.32	0.33	0.34	0.35	0.36	0.36	0.37	0.38
750 mm	Winter (Oct to Mar)	0.39	0.42	0.45	0.48	0.51	0.54	0.57	0.60	0.63	0.66	0.69
	Summer (Apr to Sep)	0.32	0.34	0.35	0.36	0.38	0.39	0.40	0.42	0.43	0.44	0.46
Cattle fed on-pad												
550 mm	Winter (Oct to Mar)	0.48	0.50	0.52	0.54	0.56	0.58	0.60	0.62	0.64	0.65	0.67
	Summer (Apr to Sep)	0.42	0.42	0.42	0.42	0.43	0.43	0.43	0.43	0.44	0.44	0.44
650 mm	Winter (Oct to Mar)	0.50	0.53	0.55	0.58	0.60	0.63	0.65	0.68	0.70	0.73	0.75
	Summer (Apr to Sep)	0.44	0.45	0.45	0.46	0.47	0.48	0.49	0.49	0.50	0.51	0.52
750 mm	Winter (Oct to Mar)	0.53	0.56	0.59	0.62	0.65	0.68	0.71	0.74	0.77	0.80	0.83
	Summer (Apr to Sep)	0.46	0.47	0.49	0.50	0.51	0.53	0.54	0.56	0.57	0.58	0.60

[1]. For cattle fed off-pad, the stocking rate excludes the feed area.

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