

Article

# Utilization of Common Reed (*Phragmites australis*) as Bedding for Housed Suckler Cows: Practical and Economic Aspects for Farmers

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**Abstract:** The common reed (*Phragmites australis*) has long been used in wetlands of the French Atlantic coast as fodder and bedding or roof thatching, among other uses. This article explores the practical and economic aspects of utilizing common reed for housing suckler cows compared to straw. Based on a study conducted over two years on a research farm of the French National Research Institute for Agriculture, Food and the Environment (INRAE), located in the marshes of Rochefort-sur-Mer, we show that reed is a good alternative to cereal straw and its cost is quite competitive compared to straw; the closer the reed bed is to the farm, the more competitive it is. By mobilizing the concept of restoration of natural capital, we lay the foundations for a debate on a possible revival of this ancient practice, with the idea that ecological restoration of reed beds can benefit biodiversity and the economy of wetlands farms.

**Keywords:** mixed crop-livestock farms; bedding; restoration of natural capital; reed beds; wetlands; bioeconomy

## 1. Introduction

In 2019, approximately half of the 17.3 million tons of cereal straw produced in France was used as bedding for livestock [1]. Many livestock or mixed crop-livestock farms are not independent in terms of straw for housing their animals. Yet straw is an agricultural resource that in some years can be rare and therefore expensive. Droughts, like the one that occurred in 2011, or more recently in 2019, have impacted straw harvests. The forecasted climate change therefore risks harming straw production in years to come, especially in the event of drought, which would trigger new price increases. Farmers with limited independence are therefore forced to purchase straw, which makes them vulnerable to variations in its price as well as problems in supply, especially during periods of high demand. Developing the autonomy in bedding resources of these farms would represent an economic advantage, while allowing farmers to adjust to the consequences of climate change more gradually.

On cattle farms, cereal straw is the primary source of bedding [2], but livestock farmers are looking for substitute beddings, mainly to reduce their expenses. Through collaboration with research and development organizations, some alternatives have been successfully tested over the last decade, e.g., miscanthus, woodchips, sand, or box compost [3–5]. Saint Laurent de la Prée research farm is an INRAE's experimental site dedicated to these types of experiments. Since 2009, this farm has been operating an agroecological transition (see [6,7] on the foundations of agroecology), emphasizing the conservation of biodiversity and increasing the independence of its production system in terms of feed, bedding, and the system's nitrogen needs. It operates in the context of the marshes of the French

Atlantic coast [8]. The farm has been operating almost completely free of inputs [9], except for straw, which must be purchased externally at an elevated price (as high as €120/t). To avoid this form of dependence, this organic farm is currently exploring other sources of bedding, seeking to remain strictly in line with agroecological principles, and particularly prioritizing the use of local natural resources as much as possible. What natural resource present in marshlands could address this lack of autonomy in livestock bedding on farms?

Looking at historical practices in wetlands, the common reed (*Phragmites australis*), a tall grass of the Poaceae family, could be a good option. Since ancient times, it has been harvested for various uses, e.g., as a material for industry, a source of biofuel, or for water treatment processes, including agricultural uses [10]. In France, it used to be utilized as a bedding material for cows, and less commonly as coarse fodder. In fact, it was called “the bedding of the marshes” or “the straw of the marshes” [11]. Nowadays, it is marginally used by livestock farms in certain wetland areas [12]. In the French *département* of Charente-Maritime where the experimental farm is located, reed is relatively common (total surface area of 1800 ha), and in certain areas it makes up extensive reed beds [13]. However, it is not utilized or is only very rarely used. We therefore posit that reeds could have a role in livestock farms, particularly organic farms that wish to make better use of natural resources whilst also preserving them. The possibility of developing reed use could thus be beneficial for these marsh areas in their attempt to achieve more bedding independence.

Considering the lack of scientific knowledge on the use of reeds in livestock farming (see however [10]), the purpose of this study was therefore to test whether reeds could be used as bedding for suckler cows. In addition to the relevant practical aspects to consider, e.g., the feasibility of harvesting and of distributing reeds during mulching, we wanted to explore if it is economically viable for a farm to develop reed use. To do so, an experiment comparing different types of bedding material was conducted on the Saint Laurent de la Prée research farm over two successive years (autumn-winter 2018–2019 and 2019–2020). This included analyzing the fertilizer properties of the composts made from these beddings. The specific goals were: (i) to produce scientific knowledge on reed bedding, compared to a more traditional bedding made from cereal straw or a “reed + straw” mixture; and (ii) to analyze the practical and economic aspects of this use. We finalize this assessment by discussing the likelihood of developing the use of reed beds with regard to environmental and agricultural aspects.

## 2. Materials and Methods

### 2.1. Study Site

The Saint Laurent de la Prée research farm is testing an organic mixed crop-livestock farming system in the Rochefort-sur-Mer marshes (45°58′52″ N, 0°02′28″ W, Charente-Maritime *département*). The farm spans 160 ha and includes 115 ha of fodder areas, with 103 ha of wet grasslands and 45 ha of crops. It runs a suckler cow herd consisting of 60 Maraîchine breed cattle and replacement heifers that graze grasslands from early April to early November and are housed for the rest of the year (free stalling). This type of housing requires large amounts of straw, about 120–130 t per year, but the quantity cannot be reduced according to the herdsperson and professionals on the farm, since it is essential for the animals’ well-being. The straw generally comes from the cultivation of cereals, e.g., wheat, triticale, barley, in the crop rotation system and from purchases of straw “behind the harvester” from neighboring farms.

### 2.2. Practical Aspects of Reed Harvesting

Reed harvesting used to be a traditional practice in the Charente-Maritime wetlands but has since been largely forgotten by farmers in these marshes. We found no existing reference to the contemporary equipment to be used for mowing and harvesting it. A prerequisite for the study therefore consisted in finding out about the most suitable equipment for these two operations. Following the advice of

an agricultural contractor we tested a mower conditioner (CLAAS rear mower, model DISCO 3000 Flapgrouper—Harsewinkel, Germany), which proved to be suitable for mowing. On 6 September 2018, a 1.3 ha reed bed was harvested off the farm, on the hunting and wildlife reserve of Cabane de Moins, 10 km from the farm. The cut reeds were swathed, and after a week of sun drying, bundling was carried out with a round-baller (a KRONE, model Comprima CV 150 XC—Spelle, Germany) equipped with a “rotocut”, an essential device to be able to condition the reed in 30–40 cm strands and thus facilitate its subsequent distribution to the straw blower. In total, 20.4 t of reeds were harvested (53 bales of 1.40 m diameter; average bale weight: 385 kg).

In the second year, a 1.1 ha reed bed, located 37 km from the farm in the Val de Trézence, was mowed on 13 September 2019. It was less uniform in terms of vegetation than the previous one, with part of the surface composed of common reed (*Phragmites australis*), but also large sedges (*Carex* sp.) and false reed (*Phalaris arundinacea*). Another type of mower was used (KRONE front mower, model EasyCut, without conditioner—Spelle, Germany) which proved to be slightly less efficient. The drying process again was sun drying. A total of 16.1 t of reeds were harvested (43 bales; 1.40 m diameter; average bale weight: 375 kg). At the time of baling, the bales consisting mainly of common reed were distinguished from other “false reed” bales.

The reed bed production was estimated from the biomass obtained from each harvest. It was 15.7 t/ha and 14.6 t/ha for the first and second reed bed, respectively. Their management were: one third of the surface area of the Cabane de Moins reed bed is mowed every year, whereas the reed bed in the Val de Trézence is generally mowed every 2–3 years.

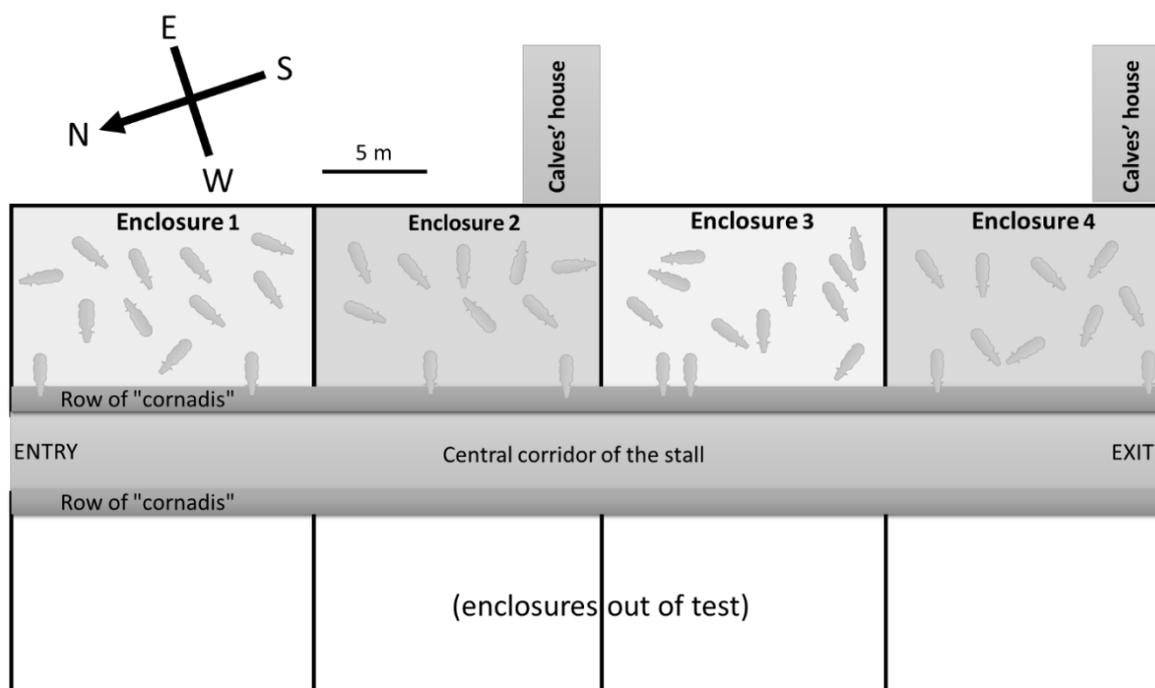
### 2.3. Testing Reed as a Bedding Material

The experiment took place at the experimental farm’s sheds over the course of three periods of 36, 39, and 27 days each (Trials 1, 2 and 3, respectively), from November 2018 to February 2019, and an additional period of 43 days (Trial 4), from October to December 2019. The trials started in the days following cows housing, so that they were at the same level of cleanliness at the time of the first observations. The three types of bedding material were tested on 4 herds of cows in 4 enclosures with the same area (about 75 m<sup>2</sup> each). As the 4 groups were not composed of the same type of animals (cows with or without calves), the following enclosures were compared 2 by 2 (Figure 1):

- enclosures 1 and 3, each with a batch of 12 cows without calves (spring calving),
- enclosures 2 and 4, each with a batch of 10 cows with calves (autumn calving). The calves stayed with their dam for the morning and evening feedings, but were kept in the calf enclosures the rest of the time. A bull was introduced into each of these two enclosures, on 4 December 2018 and 20 November 2019, for reproduction purposes.

The average weight of the cows (weighed in 2018 and 2019, a few days following housing) was not significantly different between enclosure 1 and 3 (Mann-Whitney tests:  $U = 44$ ,  $p = 0.11$  for 2018 and  $U = 34$ ,  $p = 0.23$  for 2019) or between enclosure 2 and 4 ( $U = 49$ ,  $p = 0.67$  for 2018 and  $U = 30$ ,  $p = 0.13$  for 2019). The following groups were thus compared: “straw” vs. “reed”; “straw” vs. “straw + reed” for year 1 and “straw” vs. “reed”; “straw” vs. “false reed” for year 2 (see Table 1).

The mulching of the enclosures was done three times a week (by adding clean bedding, using a straw blower). Different types of straw were used in the different trials: a relatively brittle barley straw (Trial 1) and a better-quality wheat straw with only one year of storage (Trials 2 and 3). Trial 4 was conducted with wheat straw (harvested in summer 2019). Similar amounts of bedding were distributed in each enclosure. Since the amount of bedding distributed in the first two trials was not sufficient to keep the animals clean enough, the quantities were doubled from Trial 3 onwards: approximately 185 kg of straw and 192 kg of reed per enclosure were used for Trials 1 and 2, compared to 370 kg and 385 kg for Trial 3 or 330 kg and 375 kg for Trial 4, respectively. The average weight of straw bales in year 1 was 185 kg, compared to 165 kg in year 2, while the reed bales weighed an average of 385 kg in year 1 and 375 kg in year 2.



**Figure 1.** Layout of the 4 enclosures used in the experiment in the sheds.

**Table 1.** Trial conditions in the 2 years of the study. S = straw; R = reed; FR = false reed.

	Year 1			Year 2
	Trial 1	Trial 2	Trial 3	Trial 4
Period	12 Nov.–17 Dec. 2018	21 Dec. 2018–28 Jan. 2019	1 Feb.–27 Feb. 2019	21 Oct.–2 Dec. 2019
Number of days	36	39	27	43
Encl. 1 & 3	S vs. R	S vs. R	S vs. R	R vs. S
Encl. 2 & 4	S vs. R + S	S vs. R + S	S vs. R + S	FR vs. S
Cows per encl.	12 (encl. 1, 3) 10 <sup>1</sup> (encl. 2, 4)	12 (encl. 1, 3) 10 <sup>1</sup> (encl. 2, 4)	12 <sup>2</sup> (encl. 1, 3) 10 <sup>1</sup> (encl. 2, 4)	12 <sup>3</sup> (encl. 1, 3) 10 (encl. 2, 4)
Quantity of bedding per mulching	1 bale of straw or 1/2 bale of reed	1 bale of straw or 1/2 bale of reed	2 bales of straw or 1 bale of reed	2 bales of straw or 1 bale of reed
Type of straw used	Barley straw (brittle, 2 years of storage)	Wheat straw (good quality, 1 year of storage)	Wheat straw (good quality, 1 year of storage)	Wheat straw (good quality, harvested in 2019)

<sup>1</sup> Enclosure 4 had 11 animals instead of 10; <sup>2</sup> One cow was taken out of enclosure 1 at the beginning of Trial 3; <sup>3</sup> On 15 November 2019, 2 cows were taken out of each of the enclosures, 1 and 3.

Assessments of animals' cleanliness were undertaken early in the morning, twice a week, using a chart with 4 photos of cows with increasing levels of dirtiness classified in categories as described in [14]. Scores were given for the lower legs, upper legs, flank and the belly (up to the sternum) by one trained observer. Categories ranged from "clean": no manure/dirt or only trace amounts of dirt; "slightly dirty": only lower half of the thigh and lower half of the belly and sternum covered with dirt; "dirty": the upper thigh to the front of the sternum covered with dirt; "very dirty": from the hip to the tip of the shoulder covered with dirt. We however added intermediate categories, thus 7 in total: "clean", "slightly dirty −", "slightly dirty", "slightly dirty +/Dirty −", "Dirty", "Dirty +", "Very dirty"; see Figures in the Results section). Temperature and humidity in the sheds were measured using two sensors (brand: TFA Dostmann, Klimalogg pro—Wertheim, Germany) situated at a height of about 3 m (the first was placed between enclosures 1 and 2, and the second between enclosures 3 and 4). The temperature of bedding was also verified with a thermometer probe (brand: Testo, 104-IR, SE & Co KGaA—Lenzkirch, Germany) taken at mid-height of the bedding layer, i.e., at about a

5–10 cm depth). In each enclosure, 6 spatially distributed readings were taken and the 6 values were averaged to give a mean temperature per enclosure. Finally, the level of soiling of the bedding was noted: the observer generated a visual estimate of the percentage of mulched surface of the enclosure still containing clean bedding. We considered the bedding to be soiled as soon as it lost its yellow color and turned “black” because of the animals’ excrements.

#### *2.4. Composition and Temperature of the Composts Obtained from Bedding*

Between trials, the manure from the experimental enclosures was stored in the shed for manure of the farm. Straw and reed manure were separated from each other to allow for separate subsequent sampling. However, the manure from the “reed + straw” enclosure was mixed with the reed manure. At the end of May 2019, the manure was transported to the field for composting, again keeping the two types of manure separate. This composting was achieved by two windrow turning operations in mid-June and early July (22 days apart). The temperature of the composts was measured every 1–2 days using a probe (brand: Dramiński Hm—Olsztyn, Poland), from 30 May to 18 July 2019. The measurement was taken at 3 locations in the windrow, in the upper, middle and lower part of the windrow, at a depth of about 40 cm. Finally, on 25 July 2019, three samples of each type of compost were taken just before spreading. The samples were then analyzed for their content (moisture, organic matter, minerals) at the Auréa AgroSciences laboratory in La Rochelle.

#### *2.5. Calculation of the Actual Cost of Reed*

The cost of operations related to the reed harvest was calculated based on invoices provided by the contractor we used during the two-year period. Only the cost of transporting the bales that we made in the first year was estimated on the basis of fuel consumption for the 3 return trips (a 10-km route between the reed bed and the farm, without taking into account the “labor” cost related to this expense). The reference price for the purchase of straw was set at (i) €100/t, “delivered in the yard”, according to average local prices indicated in the local agricultural press in Charente-Maritime or at (ii) €60/t for straw purchased “behind the harvester” (a cost of €35/t for straw + mechanization charges).

#### *2.6. Data Analyses*

Most of the analyses consisted of comparisons of means, using non-parametric tests when sample sizes were <30. Kruskal-Wallis tests were used to test for possible differences in temperature and the general condition of the bedding. Given the non-independence of the observations in relation to each other, an ANOVA for repeated measures (=days of cleanliness observations) was used to explore whether animal cleanliness was different from one enclosure to another. For this purpose, a score was assigned to each cleanliness category: from a score of 7 for “clean” to a score of 1 for “very dirty”. Based on the percentage of animals in a batch in each of the 7 categories, we obtained an overall cleanliness score per batch of animals and per date of observation, which was then used in the ANOVA. Finally, Mann-Whitney tests were run on the mineral content and fertilizer value of the composts, while their mean temperature was compared with repeated ANOVA measurements. The analyses were performed with Statistica (version 7.1, StatSoft Inc., Tulsa, OK, USA) and R (version 3.6.1, R Foundation for Statistical Computing, Vienna, Austria) with a significance threshold set at 5%.

### **3. Results**

#### *3.1. Results of Year 1: Trials 1 to 3*

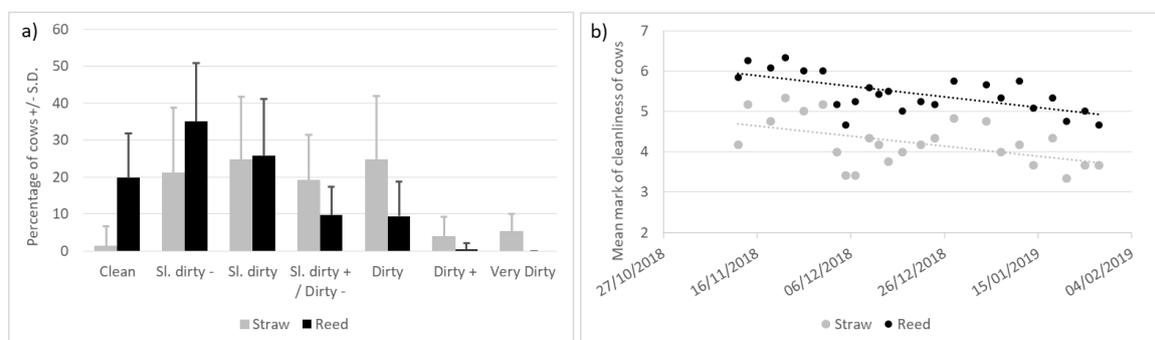
The three successive trials took place under housing conditions in which the room temperature taken in the morning was on average between 8 °C and 10 °C, with a relative humidity of 85 to 90%. Large variations in temperatures were nonetheless observed during the trials (min; max range: 1.7 °C; 15.4 °C) however the air relative humidity did not vary as much (min; max range: 78; 94%).

The bedding temperature remained stable, averaging between 20 °C and 26 °C (Table 2; little difference from one enclosure to another, with the exception of the temperature of enclosure 2, which was slightly higher than that of enclosure 1). During Trial 3, the temperature gradient between beddings was negative and statistically significant, ranging from approximately 34 °C to 25 °C from enclosures 1 to 4. Enclosure 1 was the first exposed to direct sun radiation in the morning; it is very likely that this phenomenon is due to the location of the enclosures in the shed. The fact that this difference in temperature was observed only during Trial 3 is likely due to: (i) the change in the sun’s position in the sky as the winter season approached; and (ii) the doubled amount of bedding distributed during Trial 3.

**Table 2.** Average temperature (°C) ± standard deviation of bedding measured in the different enclosures during the 4 trials (during years 1 and 2) and results of statistical tests. Encl. = enclosure.

Year	Trial Number	Encl. 1	Encl. 2	Encl. 3	Encl. 4	Measurements	Kruskal-Wallis Test
		Straw	Straw	Reed	Reed + Straw		
Year 1 (2018–2019)	1	22.8 ± 5.4	25.8 ± 3.8	23.0 ± 4.2	23.0 ± 2.7	9	H = 8.44 p = 0.037
	2	22.7 ± 6.9	21.9 ± 5.2	19.7 ± 4.4	19.6 ± 4.9	11	H = 7.52 p = 0.056
	3	33.6 ± 8.9	29.8 ± 5.6	26.6 ± 6.4	25.0 ± 5.3	9	H = 11.27 p = 0.01
Year 2 (2019–2020)	4	Reed	False reed	Straw	Straw	12	H = 17.73 p = 0.0001

For Trials 1 and 2, we observed significant proportions of animals housed on reed bedding in the categories “slightly dirty–” and “slightly dirty”, whereas for straw, this distribution is clearly skewed towards the dirtiest categories “slightly dirty”, “dirty”, or even “very dirty” (Figure 2a). Graphically, the cows housed on reed did better. We obtained the same type of distribution for Trial 3 (graph not provided). Once converted into a global cleanliness score for batches of animals, this data confirmed that the cows on reed bedding had a score that was 1.3 points greater (during Trials 1 and 2;  $F = 250.3$ ,  $df = 1$ ,  $p \leq 0.001$ ; Figure 2b) and 0.7 points greater (during Trial 3;  $F = 18.56$ ,  $df = 1$ ,  $p \leq 0.05$ ) than those housed on straw. However, the condition of the bedding expressed as a percentage of mulched surface containing clean bedding did not show any statistically significant difference from one enclosure to another, with a maximum of 10–15% (Trials 1 and 2;  $U = 209$ ,  $p = 0.31$ ) and 30–35% (Trial 3;  $U = 38$ ,  $p = 0.82$ ) of the bedding remaining clean.



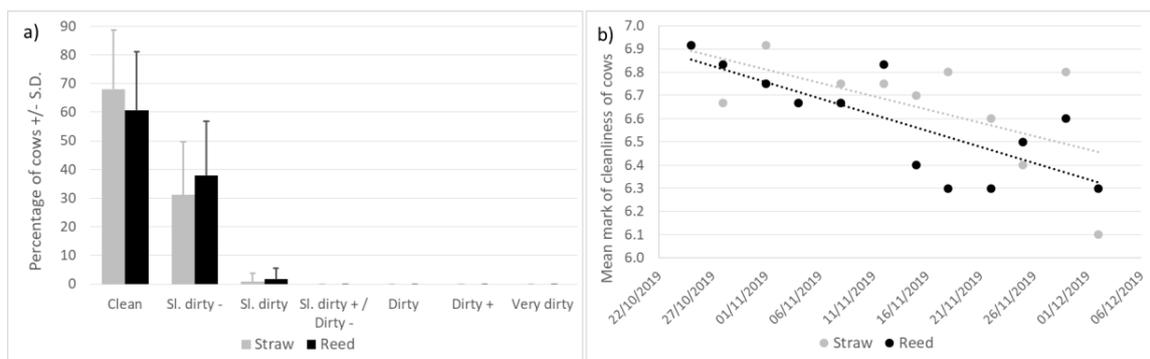
**Figure 2.** (a) State of cleanliness of cows in the “Straw” and “Reed” enclosures (1 and 3, respectively) in Trials 1 and 2; (b) dynamics of mean marks of cleanliness of cows over time. Sl. means “slightly”.

During Trials 1 and 2, cows housed on straw had an average score that was statistically 0.7 points greater than those of the “straw + reed” enclosure ( $F = 58.82$ ,  $df = 1$ ,  $p \leq 0.001$ ). By contrast, during Trial 3, none of the types of bedding was advantageous compared to the other ( $F = 0.006$ ,  $df = 1$ ,  $p = 0.94$ ). There was no statistically significant difference in the condition of the bedding from one enclosure to another (Trials 1 and 2:  $U = 177$ ,  $p = 0.14$ ; Trial 3:  $U = 38.5$ ,  $p = 0.85$ ).

### 3.2. Results of Year 2: Trial 4

The average room temperature was 11 °C and humidity was 89% (min; max range: 4.8 °C; 17.6 °C and 85; 92%). Enclosure 1 mulched with reed and enclosure 3 mulched with straw had an average temperature that was significantly higher than that of false reed ( $H = 17.73$ ,  $p \leq 0.0001$ ; Table 2). Bedding temperatures during Trial 4 in year 2 were approximately 13 °C higher than those of year 1 ( $F = 212.6$ ,  $p \leq 0.001$ ). This result must be considered in light of the greater amount of bedding (double) distributed to maintain animal cleanliness during the second year.

In general, animals were maintained cleaner than during year 1 (see Figures 2 and 3). Animal cleanliness levels were identical between the “reed” and “straw” enclosures ( $F = 1.21$ ,  $df = 1$ ,  $p = 0.31$ ). This result also applied to the comparison between the “straw” and “false reed” enclosures ( $F = 1.95$ ,  $df = 1$ ,  $p = 0.21$ ), especially since the general condition of the bedding itself was not significantly different (straw vs. reed:  $U = 25.5$ ,  $p = 0.06$ ; straw vs. false reed:  $U = 50.5$ ,  $p = 0.51$ ).



**Figure 3.** (a) State of cleanliness of cows in the “Straw” and “Reed” enclosures (3 and 1, respectively) in Trial 4; (b) mean mark of cleanliness of cows. Sl. means “slightly”.

### 3.3. Composition and Temperature of Composts

There was no statistically significant difference between the mineral content of the two composts (Table 3). The only significant differences were found with respect to phosphorus and potassium, which revealed to be slightly lower in reed compost (15.9 and 75.2 g per kg of dry weight, respectively) compared to straw compost (17.1 and 87.0 g per kg of dry weight). C/N ratios, approximately 11, did not show statistically significant differences.

The temperatures taken in the field during the months of June–July 2019 in the two types of compost varied from 28 °C to 71 °C. The temperature increase in reed compost was 5 °C greater ( $F = 11.15$ ,  $df = 1$ ,  $p \leq 0.01$ ) than that of the straw compost.

**Table 3.** Mineral element composition of reed and straw composts (3 samples of each).

	Straw Compost (n = 3)	Reed Compost (n = 3)	Mann-Whitney U Test
Moisture (% gross product)	58.2 ± 8.4	52.1 ± 2.0	U = 2.0; p = NS
Organic matter (% gross product)	26.3 ± 5.5	30.5 ± 1.5	U = 2.0; p = NS
Minerals (% gross product)	15.5 ± 2.9	17.4 ± 0.6	U = 2.5; p = NS
N total (g/kg dry weight)	28.5 ± 0.3	28.2 ± 0.9	U = 4.0; p = NS
Phosphorus (g/kg dry weight)	17.1 ± 0.4	15.9 ± 0.3	U = 0.00; p ≤ 0.05
Potassium (g/kg dry weight)	87.0 ± 3.1	75.2 ± 1.5	U = 0.00; p ≤ 0.05
C/N ratio	11.0 ± 0.2	11.3 ± 0.4	U = 2.5; p = NS

### 3.4. Cost Price of Reed Bedding

The cost price of reed bedding was €53/t, including the cost of transportation over the 10 km between the reed bed and the farm, and €92/t, respectively, for the first and second years (Table 4). This difference is due to: (i) a longer mowing time during year 2, i.e., 5 h vs. 3 h, due to a mower model less suitable for mowing reed; (ii) higher material transportation costs, i.e., 1 additional hour of round-trip travel x two trips; and (iii) higher reed transportation costs during year 2.

**Table 4.** Reed use costs (€) in 2018 and 2019 and cost price (€/t).

	Cabane de Moins Reed Bed (1.3 ha, 10 km from the Farm)	Val de Trézence Reed Bed (1.1 ha, 37 km from the Farm)
	2018	2019
Mowing costs	€420	€640
Baling costs	€604	€584
Transport costs	€50 <sup>1</sup>	€250
Total costs	€1074	€1474
Yield	20.4 t	16.1 t
Cost price	€53/t	€92/t

<sup>1</sup> Estimated (€50); based on the fuel costs for transporting the reed from the reed bed to the farm (3 round trips).

## 4. Discussion

This study has shown that under the same mulching conditions (frequency and amount of bedding distributed) reed gives similar results to cereal straw and the same performance in terms of the fertilizing value of the compost as cereal straw. It is also competitive since its cost price varies from 53 to 92 €/t depending on the distance from the reed bed to the farm and the agricultural equipment used. This makes it at best half as expensive, at worst about the same as buying straw “delivered in the yard”. Monitoring of animal health did not reveal any specific pathology in any of the enclosures. The best technical performances of reed obtained in Trials 1 and 2 must be nuanced by experimental artifacts. We found that in these trials, cows housed on reed were significantly less dirty than those on straw. This result supporting the use of reed can be partly explained by the use in Trial 1 of a poor quality barley straw that had been stored for two years and was quite brittle. The over-soiling of the “straw” enclosure was due to a cow that was lapping water from the drinking trough, spreading a lot of water over part of the enclosure and contributing to the accelerated soiling of the straw. We therefore feel that straw was somehow “penalized” during these initial tests.

This experiment also made it possible to readjust the mulching. Once the cow with atypical behavior was removed from the batch in Trial 3, and after doubling the quantities of bedding distributed to the mulch (2 bales of straw or 1 bale of reed), the animals’ cleanliness scores improved (without catching up with those of reed). This result suggests that the amounts of bedding distributed in the first two trials were not sufficient to maintain proper cleanliness of the 10–12 cows per enclosure. Under our conditions, these quantities of bedding should be about 5 kg/m<sup>2</sup> of bedding at each mulching, with 3 mulchings per week.

The increase in the amount of bedding mulch in Trials 3 and 4 is likely responsible for the observed increase in bedding temperatures. This is a phenomenon well known by breeders: the temperature of the bedding increases with the quantity of straw applied to the mulch. While the average temperature of the bedding during Trials 1 and 2 was 20 °C to 26 °C, with very little difference from one enclosure to another, it was around 40 °C in Trial 4. The false reed bedding was at 32 °C and appears to have fermented less than straw or reed. The temperature of the straw bed is a parameter to be monitored in relation to the critical threshold of 40 °C not to be exceeded, to avoid the proliferation of mastitis-causing germs, established in dairy cattle farming [15,16]. Knowing that measuring bedding temperature is a useful indicator for optimizing bedding inputs [17], it seems that the 5 kg/m<sup>2</sup> of bedding proposed above should not be exceeded during mulching.

Examination of the composts made from these beddings showed that the temperature of the reeds tended to rise slightly more than the straw (on average, 5 °C difference), despite the fact that visually it tended to lose less volume compared to the straw compost windrow (A. Tricheur, personal observation). Towards the end of the compost maturation period, the temperature reached 55–65 °C, which allowed for good hygienization of the effluent. In general, the fertilizing value of the two types of compost and their mineral content were close. Only phosphorus and potassium were slightly less abundant, 7% and 13.6% respectively, in the reed compost compared to straw. The C/N ratios were about 11 for both types of compost, which is not very high (the optimum being 15–30), but suggests an identical level of “field” degradability once applied.

Under the conditions in which this study was carried out, i.e., mulching frequency, amount of bedding distributed per mulching, number of cows per enclosure, etc., reeds have therefore proved to be a good alternative to cereal straw. It can be used alone or mixed with straw even if the results of the “straw + reed” enclosures seemed a little less convincing than straw alone (this result seems to be due more to experimental artifacts—a problem with a bowl that leaked during a trial—than to the nature of the beddings themselves). False reed can also be used but seems to be more sensitive to trampling than straw, especially if it is a batch of cows with calves (D. Durant, personal observation).

These results confirm the enthusiasm generally observed among the few farmers who use reed for bedding. Reed bedding allows for the same levels of animal cleanliness as does straw. It meets requirement criteria that are generally listed by farmers: (i) animal welfare and cleanliness, sanitary issues; (ii) feasibility of harvesting and physical properties of the bedding; (iii) cost; and (iv) the farmers’ workload. Its cost is competitive (€53/t in the first year), i.e., it is 50% cheaper than purchasing straw at the reference price of €100/t, which may even be greater during periods of shortage and high demand. The greater cost in the second year (€92/t) shows that the distance between the reed bed and the farm is a crucial factor to take into account in the “profitability” of the operation (reduced costs for moving machinery and transporting bales). The fact that a farmer owns the equipment for mowing and bundling the reed also reduces the associated costs. Finally, tests of the mower and round baler models used in this study allowed us to clarify and update the technical aspects related to this practice and the know-how on the utilization of this plant resource.

### *Implications of This Study*

In the Charente-Maritime *département*, the vast majority of marshland farms do not use the reeds. Like in many other rural areas in France and Europe, the modernization of livestock farms has contributed to the disappearance of the know-how related to regional particularities. Livestock farmers have been convinced that reed beds are not productive and therefore that there is no need to maintain them in the landscape, which has contributed to their regression (among other factors [18]). A recent inventory estimated that the current total area of reed beds in Charente-Maritime is 1800 ha [13], but it has largely decreased over time. This study however contributes to demonstrating the benefits that these natural resources can have for livestock farming in wetlands. It has confirmed two findings. Firstly, a reed bed is a highly productive habitat. Biomasses of 14.6 and 15.7 t/ha were found for both reed beds, which is consistent with the literature figures which suggest average production levels of

12.5 t/ha (range 5–25 t/ha; [19]) or 13 t/ha (from 5 to 36 t/ha; [11]), see also [10]. The second finding concerns the interest that reed can have in contributing to the proper functioning of wetland farms. Indeed, reed production on farms in marches seems very promising for many of them, to reach or at least to contribute to autonomy in bedding material supply. It is unlikely that a farm will have enough reed beds to cover all its bedding needs, but even a small area of 1 or 2 ha would provide additional bedding and reduce the dependence of livestock farms on buying straw off-farm. It is also possible that, in certain difficult years, e.g., because of a drought, these areas may constitute “flexibility zones” by compensating for the shortage of straw and the rise in prices linked to climate change. Demonstrating the usefulness of this natural material for livestock farming could thus be a means of rehabilitating—here, we mean extending or re-creating—these reed beds, with a twofold objective: (i) an environmental objective, since reed beds provide many ecosystem services, e.g., nesting sites and food resources for certain bird species, e.g., reed bed passerines, participation in the purification of marsh water, typical habitat of wetland landscapes [10,20]; and (ii) an agricultural objective, by economically valuing these typical marsh habitats that can be a source of bedding for animals. This is indeed what the concept of restoration of natural capital is about [21]. It considers that there is a close link between, on the one hand, the restoration of degraded environments and their functions, along with the conservation of biodiversity, which often go together, and, on the other hand, local economic and social concerns [22]. The underlying idea is that ecological restoration often benefits the local economy [23]. Thus, the restoration of the ‘reed capital’ on marshland farms, via the creation of reed beds or the development/expansion of an area with reeds, e.g., [24], could benefit farmers who would save on straw purchases or receive payments for environmental services [25], and thus the economy of marshland farms can be improved.

In this study, these promising initial results thus led to a debate on the ecological restoration of reed beds and its benefit for biodiversity and the economy of farms in marshes. Could mulching with reed once again be part of the practices of today’s farmers? Can we imagine a change in marshes towards more utilization of reed biomass in livestock systems, contributing to their agroecological transition? This also raises various questions about the potential contribution of the utilization of reed by farmers in the bioeconomy of a whole territory, i.e., a marshland. Could reed become an essential resource for shaping the bioeconomy of wetlands? This refers to socio-economic benefits of wetlands producing biomass to meet major challenges and objectives pursued by the bioeconomy, e.g., increasing the use of biological resources, mitigating climate change or ensuring food security [26]. Here, reed seems promising in order to reach autonomy in bedding supply (or at least to enhance it) and we can imagine that some fluxes or exchanges of reeds between farmers with differences in their capacity to produce reed can be organized and managed, i.e., a cooperation between farmers to overcome the cost of straw and the reliability of its supply. Managers of protected areas, nature reserve for instance, could also be involved, as they sometimes need to cut reed beds to maintain them in good conditions and so, providing suitable habitats for wildlife. We thus believe that reed may provide opportunities for developing the bioeconomy in marshes, with reference to the bio-ecology vision described by Bugge et al. [27], but this finding evidently requires further study. Thus, the policy implications of this study appear quite clear. It suggests the importance of the adoption of this farming practice by farmers, which we know depends on many factors [28]. Investigating the role of farmers’ behavioral factors in the adoption process has been investigated in a few studies, e.g., [29]. For instance, their adoption of reed as bedding can be influenced by the extent to which they consider the regression of reed beds to be a problem. Thus, this study suggests further enhancing farmers’ knowledge of reed as bedding, but also potential policy options for encouraging farmers to adopt this kind of environmentally sustainable practices. The most likely short-term solution would be to launch specific economic incentives policies, such as subsidies, to promote its utilization on farms. Finally, there is one last aspect that should not be overlooked. The exploitation of reed beds must respect the biological cycle of the plant and harvesting late in the season enables them to retain their role as a habitat for

many animal species [20]. The challenge therefore remains to adopt a management adapted to the reed's biological cycle as well as that of other related animal species [30].

## 5. Conclusions

We have shown that reeds make good bedding material for suckler cows, at a lower cost than purchasing straw. This plant species could find a place in marshland farms, particularly those in organic farming, which seek to make better use of the natural resources of the environment, while preserving them. The trend that has been underway for several years for this type of agriculture, occupying increasing agricultural areas, raises questions about the new resources that need to be mobilized for this type of agriculture to produce sufficiently and sustainably. This study shows the advantages that this natural resource could have for the successful operation of marsh livestock agriculture, provided that the reeds are managed sustainably. The next step would be to make the utilization of reed as bedding better known by a population of farmers, i.e., those operating in marshes. This seems essential to make the implementation and adoption of this 'updated' practice by farmers possible.

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