Crowding Your Cows Too Much Costs You Cash

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Take Home Messages

- Many studies exist that document the effects of (short term) overstocking on cow behavior but quantitative measures of overstocking on factors that directly affect cow cash flow (such as milk yield, fertility, lameness) are scarce. Economic analyses of stocking density are therefore hampered by a lack of good performance data.
- Some overstocking is profitable under plausible economic conditions in the U.S. Situations where no overstocking or much overstocking is the most profitable are also easily found. The economically optimum amount of overstocking is quite sensitive to levels of milk and feed prices.
- Stocking density should be reduced when milk sales minus feed cost per cow decreases (low milk prices, high feed prices) to maximize profitability per stall.
- Welfare is reduced above approximately 20% overstocking. There will be a tradeoff between profitability and welfare in some situations.

Introduction

This paper addresses some economic aspects of stocking density of dairy cows housed in pens with freestalls. Stocking density is a quantitative measure of the area occupied by cows. It may be measured by the number of cows per stall in a pen, the surface area available per cow, or the bunk space per cow. In this paper, stocking density is measured as number of cows / number of stalls, unless noted otherwise.

Stocking density may affect the behavior of the cow. Cows are categorized as allelomimetic, meaning that they all want to do the same thing at the same

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time (referenced in Nordlund et al., 2006). When stocking density is (too) high, the behavioral needs of the cow may not be met, for example, the need to lie down or the need to eat when returning from the milking parlor. This can negatively affect her health and performance, such as milk production and reproduction.

On the other hand, high fixed cost of freestall barns makes it sometimes economically attractive to increase the stocking density past the optimal level where cow needs are best met. Indeed, the 2007 Dairy Survey by USDA-NAHMS (2010) showed that 41% of U.S. freestall operations had an average stocking density of ≥ 104% (cows/stall).

In a survey of modernized Wisconsin dairy barns held in 1999, dairy farmers on average reported a stocking rate of 108% (Bewley et al., 2001). Four-row barns had on average higher stocking densities than 6-row barns (111% vs. 104%). Stocking densities from <100% to >130% showed that satisfaction with cow comfort, milk production, and feed intake was consistent across all overcrowding categories (N=157). The authors also found that barn cost per cow was the lowest in barns that were 21 to 30% overcrowded, but barn cost per stall was quite similar.

In this paper, our interest is in the economically optimal stocking density for lactating dairy cows, measured as maximum profit per stall. Secondly, we are interested in how changes in cow performance (milk yield, estrus detection), and prices (milk, fixed costs) affect the economically optimal stocking density. Thirdly, we briefly say something about the welfare implications of economically optimal stocking densities.

To meet these objectives, we will first provide a brief review of some of the literature on the association between stocking density and cow behavior, health, performance, and economics. Next we will provide our own calculations regarding the economics of optimal stocking density.

We will ignore stocking densities for transition cows, where higher stocking densities more severely affect cow performance (Nordlund et al., 2006). We will also not focus on other measures of stocking density, such as feed bunk space, which in some barns could be more limiting than cows per stall and therefore would be better measures of stocking density. For example, Nordlund et al. (2006) "*are of the opinion that bunk space per cow is vastly more important as a risk factor for transition cow ketosis than stall stocking density, and the current focus on stall stocking density frequently misses the most important underlying factor in fresh cow disease – decreased dry matter intake*." Take note.

■ Effects of Stocking Density on Cow Performance

Several studies document the effects of stocking density on some aspect of cow behavior, but few studies provide quantitative relationships between stocking density and cow performance measures that directly affect profitability, such as milk production, milk quality, fertility, or health. For accessible and practical on-line reviews see, for example, Moore (2010), Grant (2011), and Krawczel (2012).

Behavior

A typical daily time budget for a cow, meeting basic behavioral needs, is 3 to 5 hours eating, 10 to 14 hours lying (resting), 2 to 3 hours standing/walking in the alley (grooming, agonistic, estrous activity), and 0.5 hours drinking (Grant, 2011). This leaves 2.5 to 3.5 hours per day for all milkings.

Sufficient rest is important to dairy cows. Grant (2011) reported that significant overcrowding appears to reduce feeding activity, alter resting behavior, and decrease rumination activity. In a review of 8 studies, Krawczel (2012) reported that lying time seemed to start to seriously decrease when the stocking density was greater than 120%. In a designed experiment, Fregonesi et al. (2007) created stocking densities of 100 to 150% and observed a reduction in lying time from 12.9 down to 11.2 hours per day, or about 20 minutes less per 0.1 greater cows/stall.

Cook and Nordlund (2002) have suggested that environments that increase the proportion of cows standing, thus reducing the lying time to less than 10 to 11 hours daily, put cows at risk of developing lameness and other health problems. The relationship between stocking density and lameness is not well quantified, however.

Overstocking also affects feeding behavior. Overstocked cows tend to spend less time eating but total dry matter intake may not be reduced (referenced by Krawczel, 2012).

Milk Production

Bach et al. (2008) studied the effects of stocking density and other non-dietary factors in 47 dairy herds (approximately 3,129 lactating cows) from the northeast of Spain that were offering exactly the same lactating ration. After correction for other non-dietary factors, they found that milk yield (kg/day) was reduced by 7.5 x #stalls/cow, in the range from 0.5 to 1.6 stalls/cow. At 1.0 stall/cow, milk yield was 27.9 kg/day. Expressed in cows/stall, this relationship is not linear. In the range from 0.83 to 1.67 cows/stall, the linear loss in milk yield was 0.52 kg/day per 0.1 cows/stall greater stocking density. Bach et al.

(2008) concluded that overstocking may have negative consequences on milk performance and understocking should have no positive impact on milk yield.

Grant et al. (2011) reported a negative relationship of 1.68 kg/day for each hour of reduced lying time. Combine that with the reduction in lying time due to overcrowding from Fregonesi et al. (2007) and the result is that cows lose about 0.57 kg per 0.1 greater cows/stall. This result is very similar to that found by Bach et al. (2008).

In the survey about modernized Wisconsin dairy barns, Bewley et al. (2001) did not find statistically significant differences in annual rolling herd average milk production and feed intake between stocking densities from <100% to >130%.

The effects of stocking density on milk loss in different lactating groups were not considered in the reports by Bach, Grant, and Bewley cited above. But work by Hill and others (referenced by Krawczel, 2012) showed that first parity cows that were comingled with older cows were much more affected by overstocking than older cows. Similarly, when stocking density was higher, the lame cows in the pen suffered greater losses in milk yield than the healthy cows. It appears that younger and not so healthy cows, when having to compete in a pen with adult and healthy cows, are more negatively affected by overstocking.

Krawczel and Grant (2009) summarized studies that suggest that milk fat was slightly reduced from 3.84% to 3.67% when stocking density increased from 100% to 142%. Somatic cell count tended to increase above a stocking density of 113%. Depending on milk pricing, the value of 1 kg of milk produced in overstocked pens may therefore decrease.

Reproduction

Data on the effects of stocking density on reproductive performance are scarce. Schefers et al. (2010) reported that based on observations in large commercial dairy farms in the Midwest U.S., conception rate decreased by 0.1 percentage point per 1 percentage point overstocking. In other words, in a herd with a 120% stocking density, conception rates were on average 2 percentage points lower (say from 40% to 38%) than in herds that were not overstocked.

Conclusions from the Literature Review

The brief summary of some of the more recent reviews revealed that stocking density affects cow behavior, health, milk production, and reproduction. Many of the described associations do not have clear direct economic

consequences. To be useful for economic analysis, relationships between stocking density and milk production, feed intake, fertility, health disorders, and culling need to be quantified. Further, some studies documented only short term effects (typically designed experiments) and, therefore, did not quantify longer term consequences of overstocking. Thus, the available data for a conclusive economic analysis is weak. Perhaps that is the main reason why we did not find any published studies on the economics of stocking density in dairy cattle.

■ Economic Analyses

Theory of Economic Optimal Stocking Density

Stocking density economics appears to follow the classical law of diminishing marginal returns: this principle states that as more and more of a variable input is combined with a fixed input in short-run production, the marginal value of the variable input eventually declines and becomes negative (http://www.investopedia.com).

In farm terms this means that each additional cow will generate an income (milk sales, calf value, cull income) at a variable cost that varies with the cow (feed, parlor supplies, maybe some labor). Costs that are not affected (fixed cost) by the number of cows in the pen, for example, depreciation and most of the labor cost, are not relevant for the question of optimal stocking density. Every additional cow also reduces the performance of the other cows already in the pen. The economic optimal stocking density is reached when the marginal return of the pen equals the marginal cost of the pen. At this stocking density, the profit per stall is maximized. Add one more cow and the pen's marginal return is less than the marginal cost and profitability per stall decreases.

Spreadsheet to Calculate the Optimal Stocking Density

We developed a spreadsheet of a herd budget that mimics the daily movement of cows through their lactations until they are culled. Some culling happens daily because of known risk factors such as early days in milk, older parities and failure to conceive. Cows get pregnant based on their voluntary waiting period, service rates, and probability of conception. Born calves are valued based on their sex. Lactation curves, and functions for dry matter intake and body weights, with prices for milk, feed and cull cows, further complete the whole herd cash flows. Other factors such as breeding costs, still birth, dystocia costs, and other variable costs are also included. Fixed costs that only vary with the number of stalls, not the number of cows, are entered. The herd budget also calculates many statistics that follow from the chosen inputs, such as annual cull rate, average days open, herd milk

production, and revenues, costs, and profit per stall. An earlier version of this herd budget was used by Lima et al. (2010). We chose our inputs for this paper based on plausible values for U.S. dairy herds during the last several years. Milk price was set at $0.45/kg, fixed costs per stall were $2/day and other variable costs (not including feed cost, breeding cost, and replacement cost) were also $2/day.

In our analysis, stocking density affected milk production and reproduction. The effects linearly increased with stocking density >100%. Milk production was reduced by 0.50, 0.70 or 0.90 kg/day per cow in the pen, per 0.1 greater cows/stall. The 0.70 and 0.90 losses are slightly greater than the 0.52 kg/day reported by Bach et al. (2008), but might include other not well quantified effects such as increased lameness or lower milk quality. Secondly, probability of conception was reduced by 0.1 per 0.1 greater cows/stall in all scenarios, as found by Schefers et al. (2010). Notice that these effects linearly depend on stocking density. Lower milk production reduced dry matter intake and, therefore, reduced feed cost. Lower probabilities of conception resulted in longer days open, increased reproductive culling, and hence the entire herd demographics with its associated revenues and costs. Dry cow performance was not affected. The number of dry cows depended on the number of lactating cows. A sensitivity analysis was carried out to reveal how the optimal stocking density depended on milk loss, milk prices, service rate, and fixed vs. variable cost. Stocking density of lactating cows was varied from 100% to 150%.

Results

Based on these inputs, and with a stocking density of 100%, some key results per milking stall per year were: $5,307 milk sales, $442 cull sales, $167 calf value, $845 heifer enter cost, $2,973 feed cost, and $867 variable other costs. Fixed costs were $730 and profit was therefore $500. Further, annual milk yield was 11,794 kg, daily milk yield per lactating cow was 32.3 kg, pregnancy rate was 19%, and annual cull rate was 37%. These key results may validate our chosen input values to represent a plausible (typical) US dairy herd.

The sensitivity analysis revealed that the optimum stocking density was very sensitive to reasonable changes in the size of the milk loss and prices.

The effects of milk losses of 0.50, 0.70 and 0.90 kg/cow per day on gain in profitability for each 0.1 greater #cows/stall is shown in Figure 1. The figure shows that the level of milk loss has a large effect on the optimal stocking density and the gain in profitability. At a loss of 0.50 kg/cow per day, the maximum profit per milking stall is at a stocking density greater than 150%. The profit per milking stall per year at 150% stocking density is $145 greater than at a 100% stocking density. At a loss of 0.70 kg/cow per day, the optimum stocking density is at 122% and the profit per milking stall per year is

$43 greater than at 100% stocking density. At a loss of 0.90 kg/cow per stall, the optimum stocking density is at 107% and the profit per milking stall per year is only $6 greater than at a 100% stocking density. Annual milk production per stall increased in all 3 cases to more than 15,000 kg/year with stocking density at 150%.

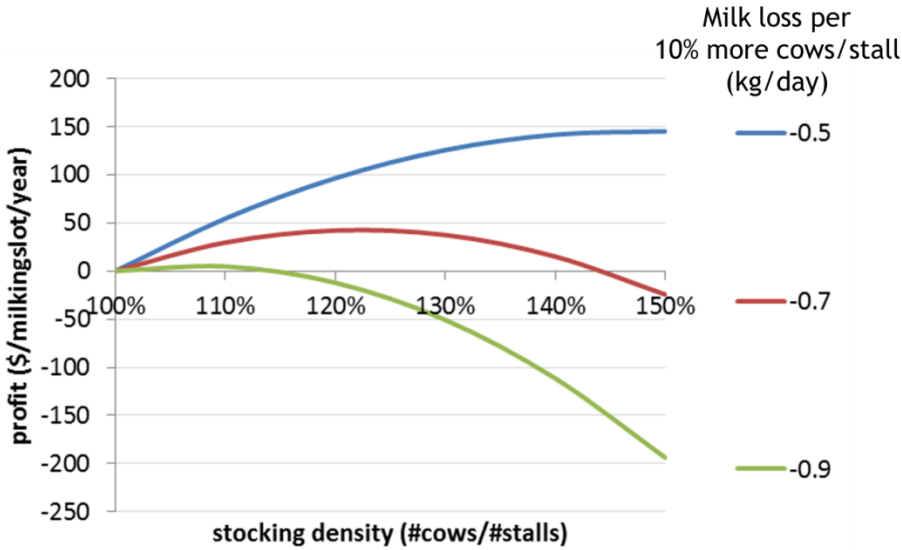

Figure 1. Profit per milking stall per year when stocking density is varied from 100 to 150% for 3 levels of milk loss (-0.5, -0.7, and -0.9 kg/cow per day) per 10% greater stocking density.

Anecdotally, sometimes famers report reducing the stocking density and the total milk yield in the pen stays the same or even increases. To illustrate the loss in milk per cow per stall when 10,000 kg is produced, the example in Figure 2 may be helpful. When stocking density is 120%, annual milk production per cow would be 8,333 kg (a loss of 1,667 kg) which is equivalent to a loss of 4.57 kg/cow per day compared to a 100% stocking density. The 4.57 is much larger than the loss of 2 * 0.52 = 1.04 kg/cow per day from Bach et al. (2008) for 20% overstocking. However, every cow would need to produce only 2.08 kg/cow per day more to reduce the stocking density to 110% to produce the 10,000 kg per stall. The marginal increase in milk per day is smallest at the highest level of stocking density, which means that at high levels of stocking density a smaller increase in milk is sufficient to reduce the economically optimal stocking density.

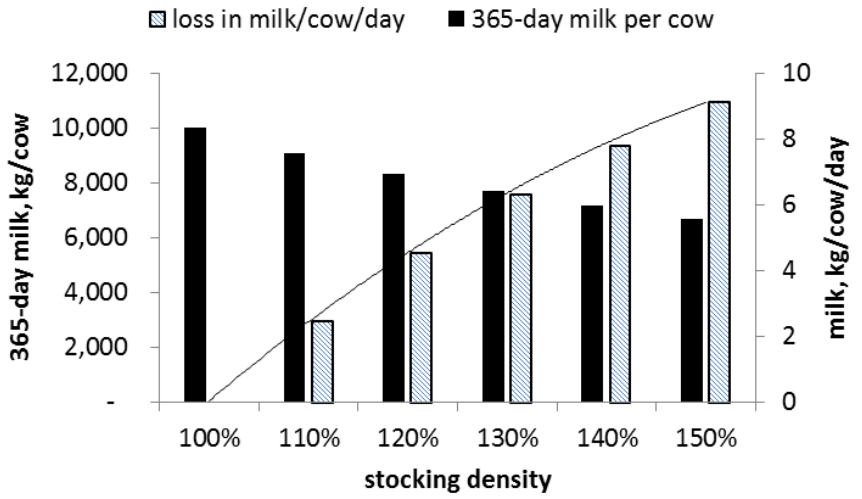

Figure 2. Milk production per year, and loss in milk per day, that is observed per cow when the milk production per stall remains at 10,000 kg for all stocking densities. When stocking density is 120%, annual milk production per cow is 8,333 kg (a loss of 1,667 kg) which is equivalent to a loss of 4.57 kg/cow per day compared to a 100% stocking density.

To continue our herd budget analysis, we varied milk prices from $0.40/kg milk to $0.50 kg ($0.45 was the default). A milk loss of $0.70 kg/cow per day was used. Higher milk prices increase the profitability of each additional cow and, therefore, encourage a greater stocking density. With a $0.50/kg milk price, the optimal stocking density was around 140% with a gain in profit of $180 per stall per year compared to 100% stocking density. The lower milk price of $0.40 reduced the optimal stocking density to 100%. At this milk price, overstocking was not profitable. Profit per milking stall per year with the $0.40/kg milk price was a loss of $89.

This scenario shows that less overstocking is economically better when milk prices are decreased or feed costs are increased. Anecdotally, farmers tend to overstock pens when milk income over feed cost is reduced, perhaps to maintain cash flow from milk sales.

In the scenarios above we assumed $2/day fixed cost per stall and $2/day other variable costs per cow. Fixed cost does not vary with stocking density but other variable costs do vary. It is not always clear if costs, such as labor costs, are fixed or variable. If more costs become variable instead of fixed, then the optimal stocking density will decrease.

Better reproduction through a higher 21-day service rate (estrus detection rate) increased the optimal stocking density, but the effect is not as strong as changes in prices. The optimal stocking density increased from 118% at a 34% 21-day service rate to 128% at a 61% 21-day service rate. Profitability increased from $25 to $55 per stall compared to 100% stocking density.

Many more sensitivity analyses could be performed with prices and effects of stocking density on cow performance. From the limited scenarios shown it is clear that the economically optimal stocking density is very sensitive to reasonable ranges in prices that affect the revenues and costs that vary with the number of cows. On the other hand, the marginal value around the optimal stocking density is very low (a flat curve around the optimum, see Figure 1) which means that profitability per stall is not reduced much when the optimal stocking density is reduced by 10% or 20%.

Welfare Implications

In several realistic scenarios shown above it was economically optimal to overstock pens by up to 50% (given our limited knowledge about how overstocking affects cow performance). In overstocked pens, cow behavior and welfare are compromised. Based on observations of primarily cow behavior, Krawczel and Grant (2009) recommended that stocking density at the free stalls should not exceed 120%. Several measures of welfare are also reduced when stocking density increases past approximately 120% (Moore et al., 2010). Legislation or acceptable animal husbandry practices may prevent (severe) overstocking. Denmark, for example, has strict rules that prevent overstocking at all.

Summary

Various studies concluded that approximately a 120% stocking density is the maximum allowable before cow behavior starts to be significantly affected. Many studies exist that document the effects of (short term) overstocking on cow behavior but quantitative measures of overstocking on factors that affect cow cash flow (such as milk yield, fertility, lameness) are scarce. Economic analyses of stocking density are, therefore, hampered by a lack of good performance data. Some overstocking is profitable under plausible economic conditions in the U.S. Situations where no overstocking or much overstocking is the most profitable are also easily found. The economically optimum amount of overstocking is quite sensitive to levels of milk and feed prices. Stocking density should be reduced when milk sales minus feed cost per cow decreases (low milk prices, high feed prices) to maximize profitability per stall. Welfare is reduced above approximately 20% overstocking. There will be a tradeoff between profitability and welfare in some situations.

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