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Economic evaluation of stall stocking density of lactating dairy cows

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ABSTRACT

An increase in stall stocking density (SSD), as measured by the number of lactating cows per stall in a freestall barn, reduces cow performance, such as milk yield and fertility, but may increase farm profitability. Our objectives were to calculate effects of varying SSD on profit per stall for a range of effects on cow performances and external farm factors and store results in regression metamodels. The literature on quantified effects of SSD on cow performance that directly affects cash flow was found to be weak. We assumed effects of SSD on milk yield, probability of conception, and probability of culling. External farm factors were probability of insemination, feed price, and milk price. A herd budget-simulation model was used which mimics the performance of cows in a herd and calculates profit per stall per year and other results. The SSD varied from 100 (no overstocking) to 150% (severe overstocking) in steps of 10%. Sensitivity analyses for effects of SSD on cow performance and effects of external farm factors were performed. Three regression metamodels were developed. The first metamodel accurately predicted profitability at 100% SSD for all variations in the external farm factors. Optimal SSD varied from 100 to 150% SSD, depending on the combination of inputs, and was very sensitive to changes in the size of the milk loss and milk and feed prices. Average optimal SSD of all 2,187 combinations of inputs was 120% SSD and average maximum increase in profit was $99/stall per year. Of the 2,187 combinations of inputs, 18% were ascending (maximum increase in profit >150% SSD), 33% were descending (maximum profit at 100% SSD), and 50% had a maximum increase in profit between 100 and 150% SSD. The second metamodel accurately captured changes in profit for all combinations of biological and external inputs and SSD. A third metamodel captured breakeven daily milk losses which would result in the same profit as at 100% SSD given the same external farm factors. In conclusion, overstocking was profitable under plausible economic conditions in the United States. The 3 metamodels accurately captured the results for a wide range of values of the input variables. A tradeoff will occur between economically optimal SSD and animal welfare in some situations.

Key words: overcrowding, stocking density, profit, economics

INTRODUCTION

Stocking density on dairy farms is a quantitative measure of the concentration of dairy animals. It may be measured by the surface area per cow, feed bunk space per cow, or the number of cows per stall in a freestall barn [stall stocking density (**SSD**)]. In the current study we focus on the economics of SSD of lactating dairy cows because the literature on effects of SSD on cow performance appears to be stronger than the literature on other measures of stocking density. Overstocking in this context occurs when SSD >100%.

Cows are categorized as allelomimetic, meaning they want to express the same behavior at the same time (Barrows, 2001). This behavior includes the need to lie down or the need to eat when returning from the milking parlor. When stocking density is (too) high, the behavioral needs of the cow may not be met because other cows are in the way. This can negatively affect her health and performance and, hence, her economic performance. For example, Grant (2011) reported that significant overcrowding reduces feeding activity, alters resting behavior, and decreases rumination activity. In a review of 8 studies, Krawczel (2012) reported that lying time seemed to seriously decrease when the SSD was greater than 120%. In a designed experiment, Fregonesi et al. (2007) observed a reduction in lying time from 12.9 down to 11.2 h/d when SSD increased from 100 to 150%. Cook (2002) suggested that environments that increase the proportion of cows standing, and thus reducing the lying time to less than 10 to 11 h daily, put cows at risk of developing lameness and other health problems.

Significant overcrowding reduces milk production (Bach et al., 2008; Grant, 2011). Krawczel (2012) reported a study that found that first-parity cows

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comingled with older cows were more affected by overstocking than older cows. Also, in that study, the lame cows in the pen suffered greater losses in milk yield than the healthy cows when SSD increased. In a survey on modernized Wisconsin dairy barns, Bewley et al. (2001) did not find statistically significant differences in annual rolling average milk production and feed intake between different stocking densities. Krawczel and Grant (2009) summarized studies that suggested milk fat slightly reduced whereas SCC tended to increase with greater SSD. Schefers et al. (2010) reported that, based on observations in large commercial dairy farms in the Midwest United States, fertility decreased with increased stocking densities.

The fixed costs of freestall barns may make it economically attractive to increase the stocking density past the level where cow behavioral needs are best met. In a survey of modernized Wisconsin dairy barns conducted in 1999, the average SSD was 108% (Bewley et al., 2001). Four-row barns had, on average, greater SSD than 6-row barns (111 vs. 104%). Farmer satisfaction with cow comfort, milk production, and feed intake was consistent across all overcrowding categories. That study also found that barn costs per cow were the lowest in barns that had 121 to 130% SSD, but barn costs per stall were quite similar. The 2007 Dairy Survey (USDA-NAHMS, 2010) showed that 41% of US freestall operations had an average SSD ≥104%. In a survey of cow comfort of high-producing Holstein dairy cows in 121 North American freestall dairy farms, von Keyserlingk et al. (2012) reported that 60% of dairy farms had a SSD >100% (range = 71–197%); hence, overstocking of dairy cows is not uncommon. Lusk and Norwood (2011) illustrated the tradeoffs between farm profitability and animal welfare at different stocking densities for laying hens. We did not find economic evaluations of SSD in dairy freestall barns.

Stocking density economics follow the classical law of diminishing marginal returns (Lusk and Norwood, 2011). This means that each additional cow will generate revenues (milk sales, calf value, cull sales) at costs that vary with the cow (variable costs: costs for feed, some parlor supplies, maybe some labor). Costs that are not affected (fixed costs) by the number of cows in the pen (e.g., depreciation and most of the labor costs when SSD varies moderately) do not affect the economically optimal SSD. Every additional cow also reduces the performance of the other cows already in the pen. The economic optimal SSD is reached when the marginal returns of the pen equal the marginal costs of the pen. At this SSD, the profit per stall is maximized. Adding another cow to the pen past the optimal SSD implies that the pen's marginal returns are less than its marginal costs and profit per stall decreases.

Optimal economic SSD may be calculated with an economic simulation model. Results will depend on several input variables with varying values, such as prices and assumed effects of SSD on cow performance. In sensitivity analysis, often one-factor-at-a-time designs are used to vary single inputs while holding other inputs constant. Such designs greatly limit the number of evaluated scenarios that can be reported. A larger number of combinations of inputs may be of interest (e.g., because effects of SSD on cow performance are somewhat uncertain), but reporting all results in tables or figures is not feasible. Metamodels are models of models that aim to simplify the relationship between the inputs and outputs of a simulation model (Friedman, 1996; Jalal et al., 2013). Examples of metamodels using regression applied to livestock science models include Vonk Noordegraaf et al. (2003), who modeled prevalence of infectious bovine rhinotracheitis for different control strategies, and Kristensen et al. (2008), who modeled gross margin as a function of technical performance indicators of dairy herds. These metamodels are then easily applied without the need for making the original simulation model available.

Our first objective was to evaluate the effects of SSD of lactating dairy cows on farm profitability. This includes finding the economically optimal SSD for a variety of different effects of SSD on cow performances (milk yield, probability of conception, culling). The economically optimal SSD may also depend on external farm factors, such as milk or feed prices. A second objective was to capture the results of many combinations of inputs with regression metamodels such that these results can be easily approximated without the simulation model used in the current study.

MATERIALS AND METHODS

Herd Budget Model

We updated and expanded an existing herd budget model (Lima et al., 2010) for our economic analyses. Briefly, the herd budget model mimics the technical and economic performance of a herd of young stock and cows. Animal flow through the herd is modeled by Markov chains, which determine the daily probability an animal is in a state characterized by parity, days since calving, and days pregnant. Approximately 732,000 states for cows are possible, depending on the length of the insemination period. Transition from state to state is calculated by the probabilities of culling, conception, abortion, and calving. Technical performance in a state is determined by technical inputs such as milk production curves, feed intake functions, BW, probabilities of insemination, conception, abortion, and culling, as well