Use of Technologies in Reproductive Management: Economics of Automated Activity Monitoring Systems for Detection of Estrus

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Take Home Messages

- Automated activity monitoring systems (**AAM**) can be incorporated as a tool to replace visual observation of estrus.

- General considerations before an AAM system acquisition include: current estrus detection (**ED**) efficiency, system cost, visual observations cost, and system life expectancy. Purchasing a system with a life expectancy of at least 5 years would be critical under all conditions.

- Improvement in ED efficiency necessary to breakeven or improve profitability largely depends on the: (1) baseline proportion of cows inseminated in estrus with the current ED program; (2) life expectancy of the AAM system and its cost: and (3) cost of the program for visual observation of estrus.

- AAM systems may be a feasible and economically beneficial solution for dairy farms with limitations to conduct an efficient ED program or dairy farms that prefer to allocate personnel to other activities.

Introduction

Insemination of cows based on estrual behavior continues to be a widespread strategy to service lactating dairy cows in a vast majority of dairy farms in the U.S. and elsewhere (Caraviello et al., 2006; Ferguson and Skidmore, 2013). Therefore, dairy farmers that rely on detection of estrus should strive to develop and maintain a successful estrus-detection (**ED**) program that leads to excellent reproductive performance and maximizes profitability. Success of any ED program will depend, at least in part, on the ability of cows to display estrus, which is affected by a myriad of physiological and management factors that either favor or suppress estrus expression (Roelofs et al., 2005; Wiltbank et al., 2006; Palmer et al., 2010). Another critical factor to the success of the program is the ability of farm personnel to identify cows in estrus. Such endeavor requires a significant effort and dedication by farm personnel that many farms fail to maintain, whereas others may prefer to avoid altogether. In this regard, adopting new technologies such as automated activity monitoring (**AAM**) systems may be a viable alternative to dairy farms that either struggle with their ED program or prefer to allocate their resources and time to other activities.

Although numerous devices and technologies with different levels of complexity have been developed and are available to dairy farms to either replace or aid with ED in dairy farms (Nebel et al., 2000; Firk et al., 2002; Hockey et al., 2010; Valenza et al., 2012; Chanvallon et al., 2014), the interest and adoption by dairy farms of the new generation of AAM systems has increased in recent years. Indeed, to date at least 7 to 10 different AAM systems are available to dairy farms in the U.S. These systems can be integrated with other technologies or installed as a stand-alone system for detection of estrus. Details on how AAM systems work are beyond the scope of this paper and can be found elsewhere (Firk et al., 2002; Valenza et al., 2012; Michaelis et al., 2014). Likely this trend for adoption of technologies will continue as better, more cost-effective, and user-friendly technologies become available for dairy farms. Nevertheless, like for any other capital investment, farms incur in a substantial upfront cost to cover the purchase, installation, and maintenance of AAM systems. Therefore, the potential benefits to farm management of incorporating an AAM system should be weighed in with the cost of adopting this new technology for detection of estrus. To this date very few studies have thoroughly evaluated the economics of adding an AAM system for ED in dairy farms and those available were focused on very particular research scenarios (Larson, 2007; Fricke et al., 2014).

Thus, the objective of this paper was to evaluate the economic implications of incorporating an AAM system for detection of estrus in a dairy herd. Different reproductive management scenarios and economic aspects of purchasing an AAM system were considered to represent the conditions of commercial dairy farms evaluating the adoption of this technology for detection of estrus.

Activity Monitors for Detection of Estrus

In recent years several research studies have been conducted around the world to evaluate the performance of the new generation of AAM systems on commercial dairy farms under more intensive confinement (Neves et al., 2012; Valenza et al., 2012; Chanvallon et al., 2014; Fricke et al., 2014; Michaelis et al., 2014; Stevenson et al., 2014) or pasture-based conditions (Hockey et al., 2010; Aungier et al., 2012).

The majority of the recent studies performed in North America (Neves et al., 2012; Valenza et al., 2012; Fricke et al., 2014; Stevenson et al., 2014) seem to indicate that AAM systems can be successfully used by dairy farmers to inseminate cows based on activity. Nevertheless, due to physiological limitations presented by lactating dairy cows (Valenza et al., 2012; Stevenson et al., 2014) or technical limitations of these systems that lead to inaccuracy of detection of estrus (Hockey et al., 2010; Holman et al., 2011; Chanvallon et al., 2014; Stevenson et al., 2014), it seems clear that AAM systems should be used in combination with synchronization of estrus and ovulation protocols before TAI. Induction of estrus with 1 or more prostaglandin $F_{2\alpha}$ (PGF) injections maximizes the proportion of cows that are inseminated immediately after the end of the VWP or non-pregnancy diagnosis (Fricke et al., 2014; Giordano et al., 2014; Stevenson et al., 2014), whereas inclusion of a TAI protocol ensures timely AI of cows that are not detected with increased activity after the end of the VWP (Fricke et al., 2014; Stevenson et al., 2014) or after failing to conceive to a previous AI service (Giordano et al., 2014). Whether estrus synchronization with PGF is used and the time interval at which the TAI protocol is initiated depends on the known or expected success of the farm to identify cows displaying estrus and the resulting fertility of AI services based on activity. Farms able to achieve average or above average ED efficiency without estrus synchronization could avoid it altogether and potentially consider delaying the initiation of the TAI program. Conversely, farms that struggle with ED should consider favoring estrus expression with the use of estrus inducing agents and avoid overextending the period until initiation of the TAI protocol to have better control of the timing of insemination.

Economic Assessment of Automated Activity Monitoring Systems

Based on the research results discussed and observations from commercial dairy farms that employ AAM systems, it is clear that AAM systems can be used to perform ED on a dairy farm, and that in general, AAM systems must be combined with a TAI program to achieve maximal reproductive performance.
These systems can be an alternative for dairy farms that:

1-struggle to maintain an efficient and consistent ED program,

2-farms that prefer to automate ED in order to reduce the number of activities performed by certain personnel at the farm (i.e., owner, herd managers, herdspersons, AI technician, or milkers).

Numerous biological and management factors obviously affect the performance of an AAM system on a particular dairy farm and because they are very specific, a myriad of scenarios could be explored. Some general questions, however, apply to the majority of farms and should be addressed before making the decision of incorporating an AAM system for detection of estrus. Specifically, it is relevant to determine:

1-the economic impact of adding the AAM system according to the current reproductive performance

2-labor efficiency of the ED program in place at the farm

3-impact of the AAM system cost on the profitability of the farm reproductive program.

Thus, the specific objectives of this simulation study were to explore the following concepts:

(1) what is the economic value of incorporating an AAM system when a farm has varying levels of ED efficiency (poor vs. average)

(2) what is the impact of the AAM system life expectancy and upfront cost on its economic value?

(3) what is the economic value of incorporating an AAM system with varying levels of labor efficiency and cost of performing visual ED?

A simulation study was performed to evaluate several scenarios that would reflect the conditions of a commercial dairy farm considering incorporation of an AAM system. All analyses were created and

run using the UWCU-Repro$ decision support system. This software tool has the capability of comparing multiple scenarios for a current versus and alternative reproductive management program for a dairy farm. Details about the simulation model used to create the software tool are not described herein because they can be found elsewhere (Giordano et al., 2012). Development of this software tool was the result of research collaboration between Dr. Victor Cabrera's laboratory at the University of Wisconsin-Madison and Dr. Giordano at Cornell University. The tool is available to users at no cost at:
http://ansci.cals.cornell.edu/extension-outreach/adult-extension/dairy-management/wisconsin-cornell-dairy-repro-giordano and
http://dairymgt.uwex.edu/tools.php.

It is important to note that the following analysis is <u>strictly limited to detection of estrus</u> which excludes the potential benefits that some of the new AAM systems may include. For example, some systems can integrate automated monitoring of biological traits indicative of health status (i.e., rumination, body temperature), parlor identification, daily milk weights, milk components, etc. Assuming that the information generated by these systems is reliable and can be utilized by dairy farms to make management decisions beyond ED, potential economic added value was not all accounted for in this analysis and should be considered at the time making a purchase.

Farm Description and General Economic Input Measures

The conditions simulated were for a typical commercial confined dairy herd in the Northeast U.S. with 1,000 milking cows. Cows were housed in freestall barns with headlocks at the feed line that could be used to facilitate AI. Milk production was based on lactation curves extracted from a 1,100 milking cow herd in NY producing approximately 28,000 lb of milk per cow-yr, involuntary culling rate of 28%, mortality rate at 5%, and stillbirth rate at 5%.

General economic measures included: milk price of $22.80 per cwt (all milk price from USDA National Agricultural Statistics Service for last 12 months), cost of feeding lactating cows of $0.14 lb of DM, and cost of feeding dry cows at $0.10 lb of DM, female and male calf value at $175 and $25, respectively, heifer replacement cost at $1,750, and salvage value of cows at $0.90 per lb of live weight. Cost of insemination was set at $10 per AI (including semen and labor), pregnancy testing at $110 per hour, whereas GnRH and PGF for synchronization of ovulation were set at $2.50 per dose.

Comparison of Reproductive Programs

Baseline reproductive management program consisted of a combination of ED and TAI for all inseminations. For first postpartum AI service cows were eligible to be inseminated if detected in estrus from the end of the VWP at 50 days until 75 days when the Ovsynch-56 (Brusveen et al., 2008) protocol (GnRH-7 d-PGF-56 hours - GnRH-16 hours TAI) was initiated for cows not yet detected in estrus and AI (Figure 1). After their first AI service cows were eligible to receive AI if detected in estrus. If not inseminated in estrus by 32 days after a previous insemination cows were enrolled in an ovulation-resynchronization protocol (GnRH-7 d-PGF-56 hours - GnRH-16 hours TAI) to receive TAI 10 days later (Figure 1). Non-pregnancy diagnosis was performed at 39 d after AI by palpation per rectum of uterine contents (at the time of the PGF injection of the protocol). For programs that used ED it was assumed that it was performed by VO by an experienced technician at a cost of $12.5 dollars per hour of labor.

For scenarios that used an AAM system the cost was set at $8,000 for installation of hardware including antennas, PC, and software, whereas cost per activity tag was set at $90 or 120 per tag depending on the scenarios evaluated. A total of $1,500 per year was included to account for maintenance and lost tags (i.e., 2%). A salvage value of 10% of the initial equipment cost was included. It was assumed that 50% of the cows in the herd were fitted with monitors from the end of the VWP until reconfirmation of pregnancy at 67 days after AI.

Using the reproductive management program described previously as baseline, different hypothetical scenarios were generated.

Scenario 1. Determine the economic value of improving detection of estrus in a scenario of *current poor ED efficiency* (30% of cows EDAI as baseline). In this case, numerous scenarios were simulated to include improvements in ED efficiency that result in 10-percentage point increments of cows EDAI up to a maximum of 80% of the cows. In this case, the assumption was that installing the AAM system would improve ED efficiency. Thus, the percentage of cows EDAI from the end of the VWP to the beginning of Ovsynch for first TAI or in between TAI services varied from 30 to 80% (Figure 1). It was assumed that no change to the insemination outcome (P/AI) would occur for cows receiving EDAI, whereas a 1% reduction for every 10-percentage point increment in cows EDAI for cows receiving TAI was included (baseline P/AI was 35% for first service and 33% for subsequent AI services when 30% of cows received EDAI) to account for the change in the population of cows reaching TAI (i.e., more anovular, metabolically challenged, unhealthy cows). A second dimension to the analysis was added by including variation to the AAM system cost and the labor effort to perform ED by VO. To evaluate different AAM system cost scenarios the life expectancy (i.e., number of years that the system was functional) and cost of activity tags varied. The system life expectancy was set at 3, 5, and 7 years to reflect a wide variation in system lifespan, whereas cost of activity monitors was set at either $90 or $120 per tag. Likewise, to evaluate the impact of labor efficiency for VO of estrus, the amount of hours performing ED by farm personnel was set at 2 (30 min per pen for 4 pens) or 3 hours (45 min per pen for 4 pens) per day.

Scenario 2. A second set of scenarios was created to simulate the conditions of a dairy farm that presented *current average ED efficiency* (60% of cows EDAI as baseline). In this case it was assumed that the farm had acceptable performance of VO of estrus and that the AAM system could only improve the percentage of cows EDAI by 10- or 20-percentage points to reach a maximum of 80% of the cows receiving EDAI. As for the previous set of scenarios with poor ED efficiency, impact of the AAM system cost and labor efficiency for ED was included. In both cases all other variables remain unchanged.

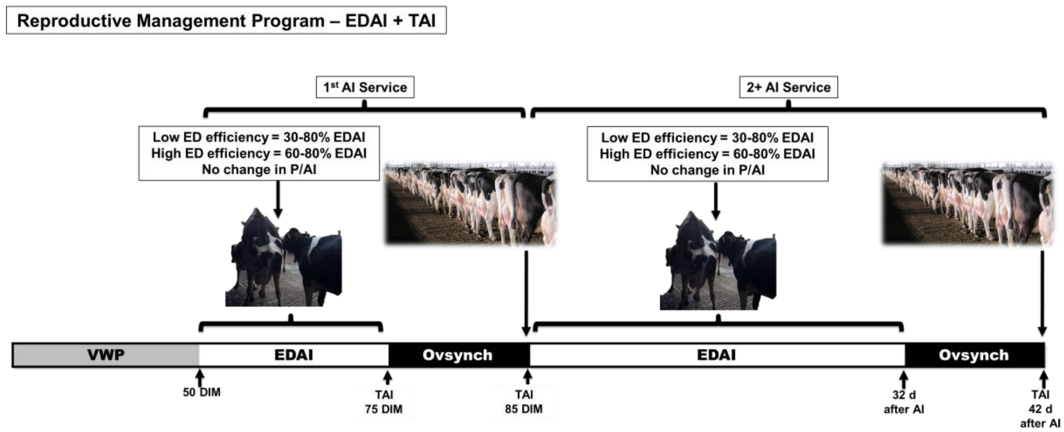


Figure 1. Schematic representation of baseline reproductive program simulated to assess the economics of adopting an automated activity monitoring system. EDAI = cows inseminated after estrus detected by visual observation or by increased physical activity; TAI = timed AI; ED = estrus detection; VWP = voluntary waiting period; P/AI = pregnancy per AI (conception risk).

Results and Discussion

Numerous economic scenarios were modeled to gain insight into some general questions that should be addressed by most dairy operations considering the integration of an AAM system to replace VO of estrus. It was assumed that the dairy of interest would prioritize a reproductive management program with reduced hormonal intervention, thereby synchronizing ovulation with the Ovsynch protocol was included only to ensure AI of cows not detected in estrus. No attempts were made to simulate conditions that would include more sophisticated synchronization protocols (e.g., Double-Ovsynch, Presynch-Ovsynch, G-6-G, etc.) known to improve the fertility of AI services in lactating dairy cows.

Current Poor-Estrus Detection Efficiency. Results for the scenarios simulated for a 1,000 cow herd with current poor ED efficiency (30% of the cows EDAI) are summarized (Figures 2 and 3). As expected, because of the concurrent evaluation of increases in the proportion of cows EDAI (from 30 to 80% in 10-percentage point increments), life expectancy (3, 5, or 7 years), and activity tag cost ($90 vs $120) for the AAM system, and the cost associated with different labor efficiency for VO (1 person at 2 or 3 hours per day), a wide range of results were obtained. Because the most likely current price for activity tags is $120, the results obtained for that base price will be discussed and only contrasted to those results for a tag price of $90. For this particular set of scenarios that assumed poor ED efficiency for the baseline program, incorporating the AAM system was associated with losses ($-17 to $-1 per cow-year), no change, or positive economic benefits ($1 to $39 per cow-year) depending on the increment in the proportion of cows EDAI and cost of the system. Economic impact of incorporating the AAM system at different levels of ED efficiency was dramatically affected by the life expectancy of the AAM system. For example, when the system life was set at 3 years, it would be necessary to increase the proportion of cows EDAI from 30 to 70% of the cows for the new program to be profitable ($6 cow per year; Figure 2A). Conversely, a 20- and 10-percentage point increment of cows EDAI would be necessary to breakeven or generate a $5 per cow-year gain in favor of the AAM system when the life expectancy was set at 5 and 7 years, respectively (Figure 2A). Impact of improving ED efficiency was anticipated because increasing the proportion of cows EDAI with no change in P/AI for cows EDAI would improve overall reproductive performance and reduce cost. As expected, a reduction in activity tag cost from $120 to $90 per tag would benefit programs that used the AAM system at all levels of longevity. In this case the increment in the proportion of cows EDAI to outperform the VO program was reduced by 10-percentage points for each one of the life expectancy scenarios evaluated. For example, for a life expectancy of 5 years, it was necessary to increase the proportion of cows EDAI from 30 to 50% when tag cost was $120 versus an increment from 30 to 40% cows EDAI when tag cost was set at $90 (Figure 2A and 2B).

Predicting the exact increase in ED efficiency for a particular dairy farm may not be possible because of the numerous intrinsic factors that affect the ability to inseminate cows in estrus. Nevertheless, because in most cases the major cause of poor ED efficiency is human error or insufficient resources (i.e., personnel and time) allocated to ED, it is possible to speculate that incorporating the AAM system could improve the percentage of cows EDAI by at least 20 to 30 percentage points. Under these circumstances and a tag cost of $120, the AAM system must remain functional for at least 5 years to breakeven and could generate as much as $13/cow per year in extra profits when life expectancy is 7 years (Figure 2A; 60% of cows EDAI). Assuming a similar improvement in proportion of cows EDAI (20 to 30%) and a tag cost of $90, the farm would benefit at all levels of life expectancy with improvements in profitability of $4, $12, and $16 per cow-year at each level of life expectancy (Figure 2B). Whether the farm can achieve above average ED efficiency with the AAM system to inseminate up to 70 and 80% of the cows in estrus will likely depend on providing the most optimal conditions for cows to display estrus (and increased activity) so that the system can maximize detection. Achieving such high level of ED efficiency, which would result in profits of as much as $21 to $31per cow-year (70 to 80% EDAI and LE of 7 years and $120 per tag), is unlikely to be observed for a majority of commercial dairy farms under confinement conditions; however, it may be observed in some very well managed dairy herds (Ferguson and Skidmore, 2013; Fricke et al., 2014).

Obviously numerous alternatives (e.g., induction of estrus with hormonal treatments, delaying the initiation of the TAI program) are available to maximize ED efficiency with an AAM system; however, the economic value of such programs was beyond the scope of this paper and were not evaluated because reproductive management scenarios to minimize the use of reproductive hormones were prioritized. Those interested in evaluating other programs that rely more heavily on TAI may use software tools such as the UWCU-Repro$ to evaluate their specific program of interests.

When cost for VO of estrus was greater because labor efficiency for ED was lower (3 hours per day), the same patterns were observed compared with the greater labor efficiency scenarios. In fact, for each of the scenarios simulated the difference with the high labor efficiency (2 hours per day) was exactly $6 per cow-year, which represents the extra cost for ED (Figure 3A). Because in this case VO of estrus was more expensive, the economic benefits of incorporating the AAM system were realized with smaller increments in the proportion of cows EDAI for the different life expectancy values. For example, an increment of 30 percentage points (from 30 to 60%) for cows EDAI at a tag cost of $120 would render the AAM system more profitable than VO by $4 per cow-year at a life expectancy of 3 years. In addition, under these conditions of greater VO cost, the AAM system would reach breakeven costs with a life expectancy of 5 years and could generate as much as $27 to 37 per cow-year in extra profits if 70 to 80% of cows are EDAI at a life expectancy of 7 years. Even more favorable conditions would be accrued when the tag cost was reduced to $90 and labor efficiency of VO was poor (< 50%). The AAM system would be more profitable than the VO program with no increase in the proportion of cows EDAI if life expectancy is at least 5 years and an increment in 20 percentage points for cows EDAI would make it profitable at a life expectancy of 3 years (Figure 3B). Under these conditions, the AAM system also could generate the greatest profitability observed in this study with $39 per cow-year with at least 80% of cows EDAI (Figure 3B).

When evaluated individually, the effect of changing the life expectancy of the AAM system was dramatic and consistent for the different cases of labor efficiency for VO of estrus. Although a relatively small increase (from 30 to 40%) in the proportion of cows EDAI was sufficient for the AAM system to be more profitable than the VO program at life expectancy of 7 years (Figure 2A), when the life expectancy was only 3 years the AAM system needed to increase the proportion of cows EDAI by 40 percentage points (Figure 2A), which may not be achievable for all dairy farms. As expected, more favorable conditions for the AAM system were observed when the efficiency of the VO program was lower and therefore VO cost was greater (Figure 3B). Under these conditions, at no change in the proportion of cows EDAI the AAM system would breakeven when life expectancy was 5 years and would be $5 per cow-year more profitable than VO when life expectancy was 7 years. When the tag cost was reduced to $90 the life expectancy of the system still caused major changes in profitability. The negative correlation between tag cost and profitability reduced the need to increment the proportion of cows EDAI to exceed the profitability of the VO program. Taken together, the results for scenarios of both low and high labor efficiency of VO of estrus, high and low tag cost, and different increments in the proportion of cows EDAI indicate that under most circumstances the LE of the AAM system should be at least 5 years. On the contrary, major improvements in ED efficiency are necessary to justify economically the incorporation of the AAM system when the life expectancy was 3 years. The impact of an AAM system LE on the differences in profitability between programs is, as for the increment in ED efficiency, not surprising because a longer life expectancy of the system significantly reduced the fixed costs of purchase and installation. Magnitude of the effect of a life expectancy of 3 versus 5 years, or 3 versus 7 years, on profitability was 1.8 and 2.7 times greater than that of a reduction in purchase price of $30 per tag. Therefore, producers may benefit more by acquiring a system that remains functional by a longer period of time rather than by paying less for activity tags. To the best of the author's knowledge, no published information is available regarding the LE of AAM systems. According to claims from some of the companies that market AAM systems in the U.S., life expectancy is projected to be 6 to 10 years.
(http://www.trackacowus.com/Heat_Detection_Faq.html,
http://www.microdairylogic.com/flash/heatime.swf).
Very likely, the timespan that an AAM system will remain functional will depend on the quality of the product as well as the care and maintenance provided by the farm.

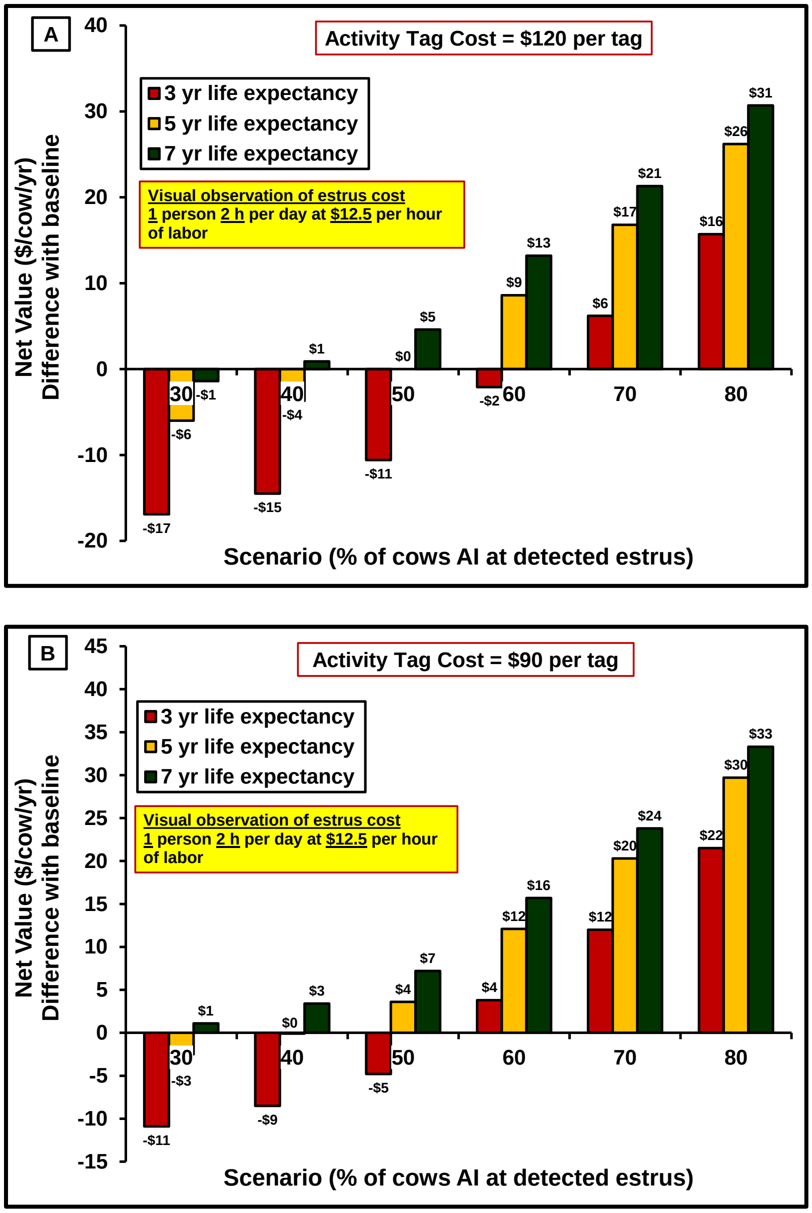


Figure 2. Net value differences ($ per cow-year) between a baseline program with poor estrus detection efficiency based on visual observation of estrus versus a program that uses activity monitors. Differences among programs reflect the change in profitability when visual observation is replaced by an automated activity monitoring system for detection of estrus. The scenarios represented a situation of high labor efficiency (2 hours per day) for visual observation of estrus and activity tag cost of $120 (A) or $90 (B) per tag.

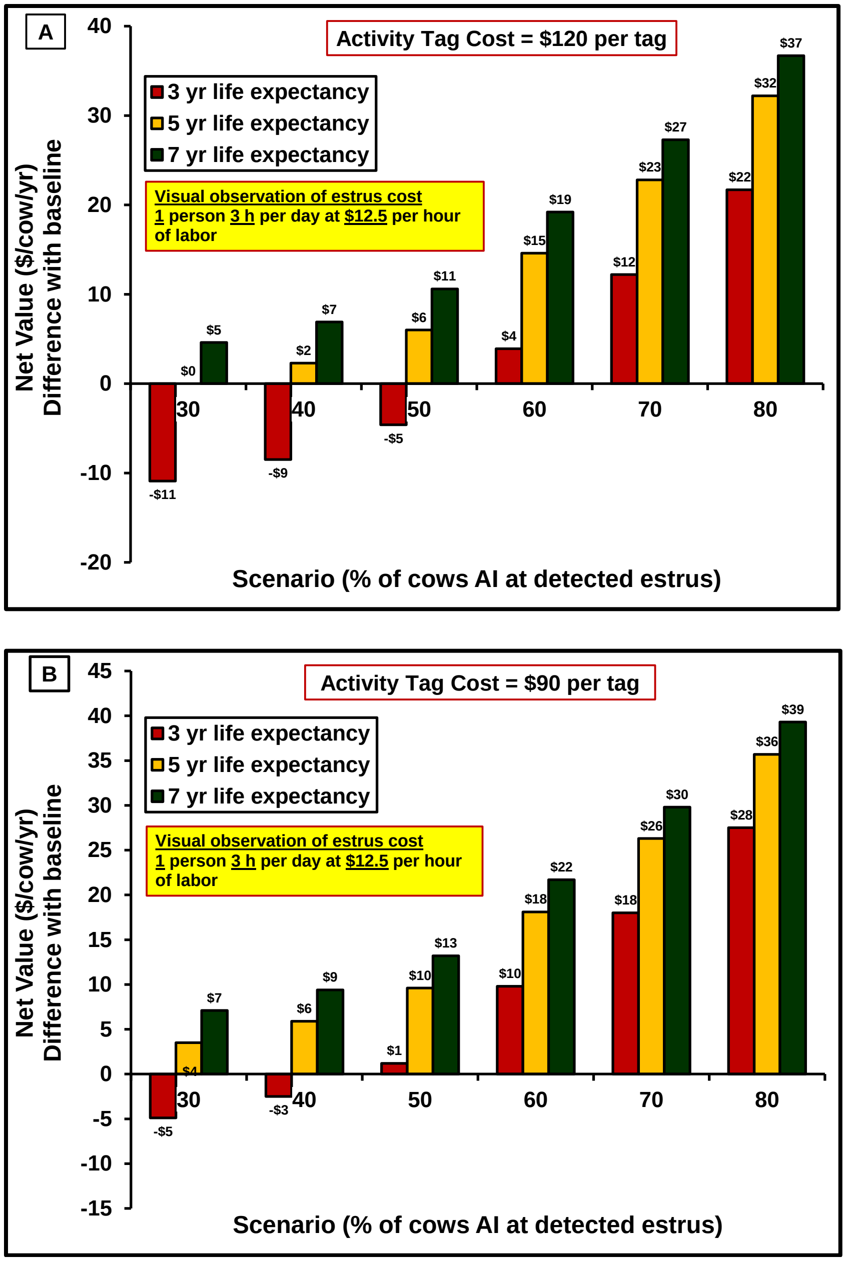


Figure 3. Net value differences ($ per cow-year) between a baseline program with poor estrus detection efficiency based on visual observation of estrus versus a program that uses activity monitors. Differences between programs reflect the change in profitability when visual observation is replaced by an automated activity monitoring system for detection of estrus. The scenarios represented a situation of poor labor efficiency (3 hours per day) for visual observation of estrus and activity tag cost of $120 (A) or $90 (B) per tag.

Current Average-Estrus Detection Efficiency. Unlike previous scenarios used to represent a farm with current poor ED efficiency, it is possible that farms with an effective ED program already in place may consider incorporating an AAM system to replace VO of estrus. Under such conditions the economic implications will likely differ because the farm may not experience major increments in the proportion of cows EDAI.

Indeed, when compared with the high labor efficiency scenarios for VO of estrus (2 hours per day) and life expectancy set at 3 years, the AAM system needed to increase the proportion of cows EDAI to the maximum of 80% (unlikely for a vast a majority of farms) to be marginally profitable even with a tag price of $90 (Figure 4A and B). Conversely, a 10 percentage point increment in cows EDAI was required to make the AAM system slightly more profitable than the VO program with high labor efficiency. In this case, $2 and 7 per cow-year could be obtained when life expectancy of the system was 5 and 7 years, respectively (Figure 4A). Reducing the cost of tags to $90 made the AAM system profitable when life expectancy was 7 years, despite no increase in the proportion of cows EDAI, but it did not dramatically change the profitability of the programs using AAM systems with a maximum difference of $6 per cow-year (Figure 4B).

Further, when compared with a program with lower labor efficiency for VO of estrus (3 hours per day) the scenarios were more favorable to the AAM system. Even with no change in the proportion of cows EDAI, a life expectancy of 5 years generated an almost negligible disadvantage of $1 per cow-year. When the minimum life expectancy of 5 years and the greatest success of the AAM system (80% cows EDAI) were assumed, the gains attainable by the AAM system were in the range of $22 to 25 per cow-year when tag cost was $120 and $90, respectively (Figure 5A and B). Although such gains are significant, they represent a reduction in additional profits of as much as 40 to 48% compared with similar scenarios for the baseline program with poor ED efficiency. In fact, reductions of more than 100% could be observed compared with the scenarios comparing the AAM system with a VO program with poor ED efficiency regardless of labor cost.

Taken together, these results indicate that for dairy farms with an efficient and consistent ED program that allows insemination of approximately 60% of the cows in estrus with acceptable fertility, the AAM system's minimum life expectancy should be at least 5 years, and at least 10% more cows should be EDAI. In general, relatively smaller gains in profitability will be accrued unless that the AAM system is capable of increasing the proportion of cows EDAI up to 80%.

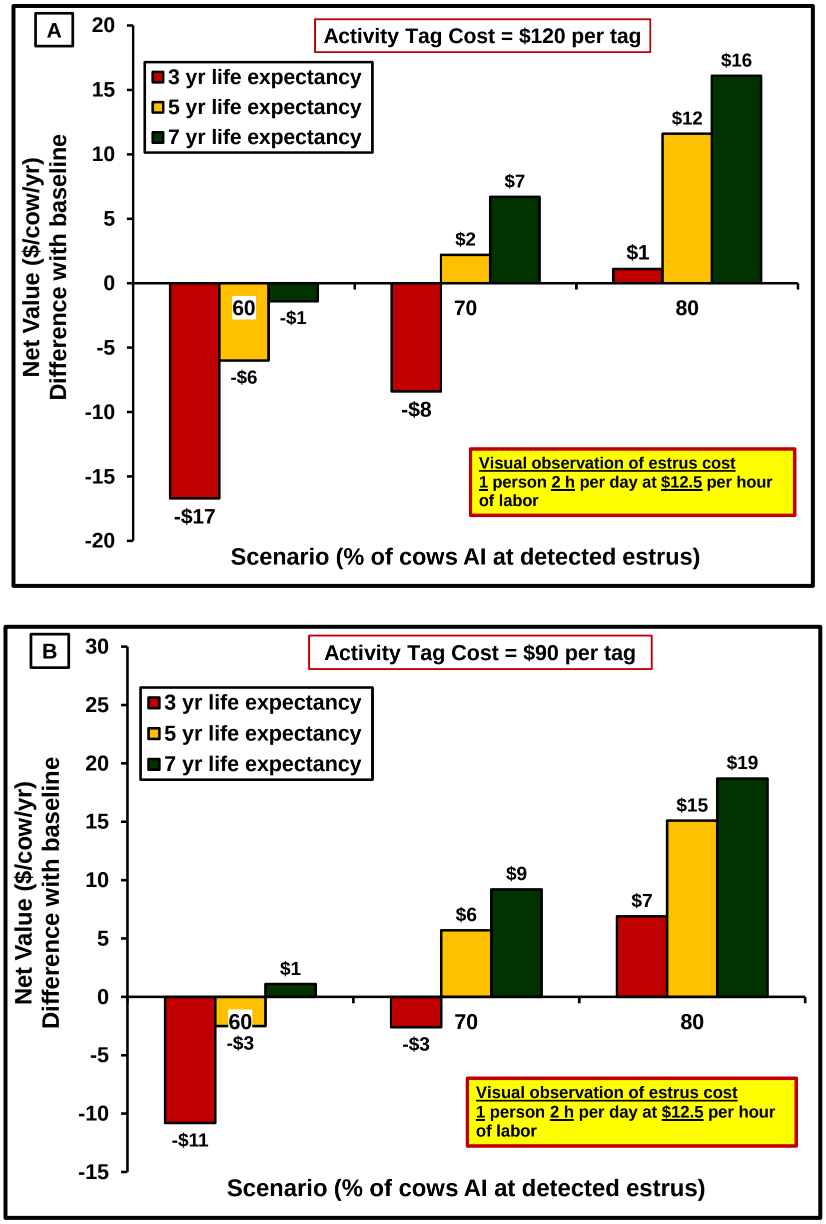
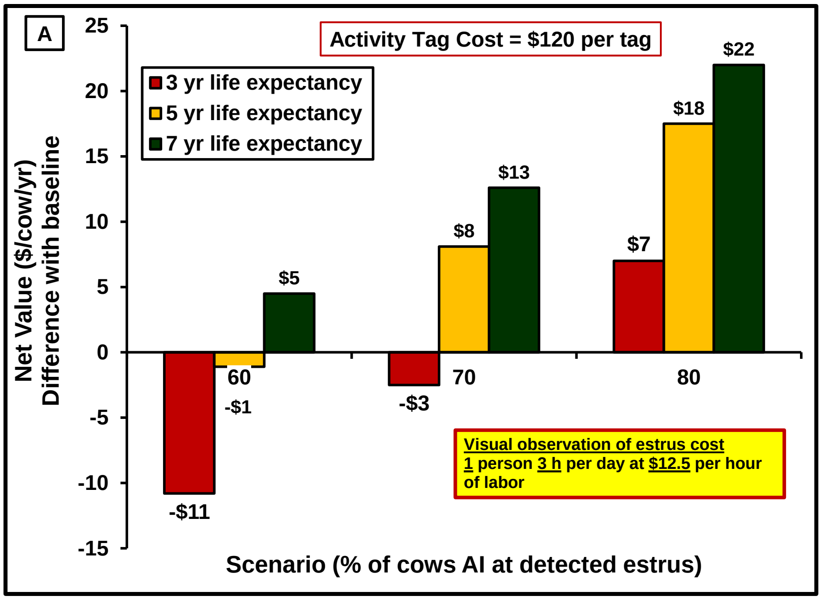


Figure 4. Net value differences ($ per cow-year) between a baseline program with high estrus detection efficiency based on visual observation of estrus versus a program that uses activity monitors. Differences between programs reflect the change in profitability when visual observation is replaced by an automated activity monitoring system for detection of estrus. The scenarios represented a situation of high labor efficiency (2 hours per day) for visual observation of estrus and activity tag cost of $120 (A) or $90 (B) per tag.



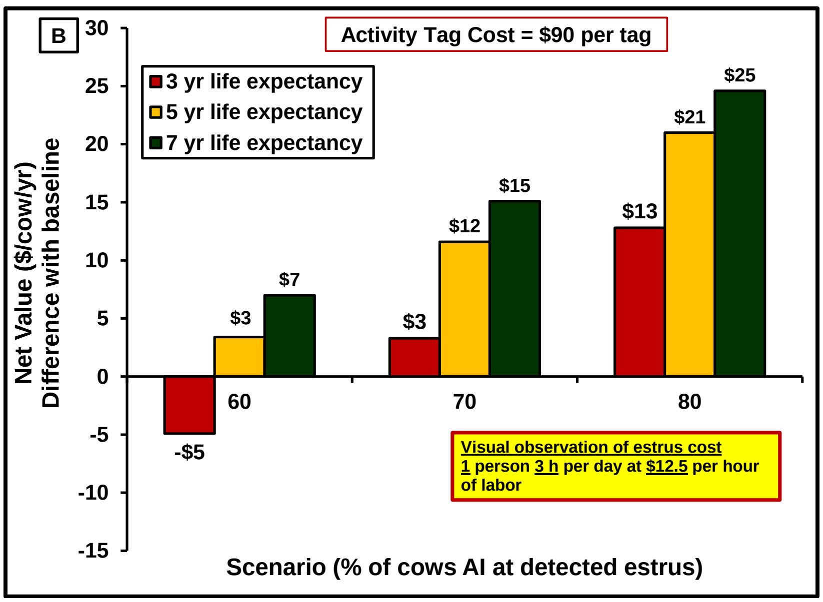


Figure 5. Net value differences ($ per cow-year) between a baseline program with high estrus detection efficiency based on visual observation of estrus versus a program that uses activity monitors. Differences between programs reflect the change in profitability when the farm replaces visual observation by an automated activity monitoring system for detection of estrus. The scenarios represented a situation of low labor efficiency (3 hours per day) for visual observation of estrus and activity tag cost of $120 (A) or $90 (B) per tag.

Impact of Reducing Fertility of Cows Inseminated in Estrus. A caveat of this simulation study is that for simplification purposes it was assumed that the fertility (P/AI) of cows that are inseminated based on detected estrus would not change regardless of the proportion of cows inseminated in estrus. Conversely, the P/AI of cows that reached TAI was reduced by 1 percentage point for every 10 percentage point increment in cows EDAI. This adjustment was included to reflect the change in the population of cows reaching the TAI after a majority was EDAI. Although it is certainly possible that same fertility for cows EDAI could be maintained as the proportion of cows EDAI increased, it would also be possible to observe a reduction in P/AI of cows EDAI because more cows may be inseminated at the wrong time or based on false positive alerts from the AAM system. Thus, the impact of reducing the fertility of cows EDAI when more cows are inseminated in estrus was briefly explored by reevaluating some of the extreme scenarios initially discussed. As expected, the reduction in profitability was dramatic. For example, when the proportion of cows EDAI increased from 30 to 80% in a scenario of high labor efficiency and activity tag cost of $120 (Figure 3A) reducing P/AI of cows EDAI to 30% for first AI and to 28% for second and subsequent AI (reductions assumed for TAI services) the change in profitability in favor of the AAM system was reduced from $31 to $4 per cow-year when life expectancy was 7 years and from $26 to a loss of $0.60 per cow-year when life expectancy was 5 years.

Although it is difficult to predict the reduction in P/AI as the proportion of cows EDAI increases, these results indicate that dairy farms should strive to maintain good fertility after inseminations based on activity to achieve good reproductive performance and maximize profitability. Otherwise, all the added benefits of the AAM system to profitability may vanish and incorporating the system could become less profitable.

Conclusions

Automated activity monitoring systems can be incorporated as a tool to replace visual observation (**VO**) of estrus. Although the decision to purchase these systems is farm specific, some general considerations should be made before its acquisition. Purchasing a system with a life expectancy of at least 5 years would be critical under all conditions. In addition, improvement in ED efficiency necessary to breakeven or improve profitability largely depends on the: (1) baseline proportion of cows inseminated in estrus with the current ED program; (2) life expectancy of the AAM system and its cost: and (3) cost of the program for VO of estrus. Automated activity monitoring systems may be a feasible and economically beneficial solution for dairy farms with limitations to conduct an efficient ED program or dairy farms that prefer to allocate personnel to other activities.

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