Available online at www.sciencedirect.com
SCIENCE DIRECT®

Theriogenology

Theriogenology 64 (2005) 589–602
www.journals.elsevierhealth.com/periodicals/the

Cost comparison of natural service sires and artificial insemination for dairy cattle reproductive management

M.W. Overton *

Department of Population Health and Reproduction, Veterinary Medicine Teaching and Research Center, University of California, Davis, 18830 Road 112, Tulare, CA 93274, USA

Abstract

Despite the widespread popularity of artificial insemination, many dairymen still prefer the use of natural service sires due to a variety of reasons, including a common perception that it is easier to manage and less expensive than AI. Little has been done to estimate the explicit and implicit costs, including the probable loss of genetic progress associated with the use of natural service sires in dairy herds. A partial budget approach was used to stochastically model the expected costs and returns of reproductive management options in large, western, Holstein dairies. Option one was natural service sires managed using currently recommended approaches including breeding soundness evaluations, bull vaccination, and a rotational breeding system. Option two was an AI system using a modified Presync-Ovsynch timed AI program in conjunction with estrus detection and inseminations performed by a commercial route breeder. Stochastic variables in the model included the cost of the lactating ration and purchased bulls, as well as the value received for milk, market bulls, and net merit gains. All other variables were treated deterministically. Under the model's assumptions, the use of natural service sires averaged approximately US$ 10 more in cost per cow per year as compared to an AI program. Sixty percent of the time, AI was less expensive than using bulls. However, there was wide variation in expected differences in cost between the two systems with net merit estimates having the largest impact, followed by prices received for milk sold and market bulls.

Keywords: Natural service; Artificial insemination; Economics; Partial budget; Cost of reproduction

* Tel.: +1 559 688 1731x214; fax: +1 559 686 4231.
E-mail address: moverton@vmtrc.ucdavis.edu.

0093-691X/$ – see front matter
doi:10.1016/j.theriogenology.2005.05.015

1. Introduction

Prior to the adoption of artificial insemination (AI), the use of natural service (NS) sires, or breeding bulls, for reproductive management was the default method of reproductive management. Historically, dairies housed bulls in individual pens and hand mated cows by bringing them to the bull. As herds have increased in size and complexity, hand mating of cows and bulls has become rare. Currently, the more popular option is to house one or more bulls with the lactating dairy cows. In this scheme, the bulls assume the roles of both estrus detector and inseminator, reducing labor costs and eliminating human errors associated with estrus detection.

Widespread use of AI has led to rapid genetic improvements and dramatic increases in milk production, relative to using farm raised NS sires. The use of AI allows dairymen to pick a portfolio of bulls with higher reliability and genetic merit as compared to typical natural service sires. The use of AI-proven bulls from major AI organizations results in a gain of US$ 89–101 in value of milk production per year of life by the resulting offspring, as compared to using NS sires [1]. In addition, the use of AI provides known breeding dates that may facilitate improved dry cow management due to improved accuracy of expected calving dates, can help reduce the risk of dystocia in heifers through improved sire mating, reduces the risk of transmission of venereal diseases, and improves worker safety by removing the threat of a bull on the farm.

The Animal Improvement Programs Laboratory (AIPL) publishes comparisons of predicted genetic potential of AI bulls with non-AI bulls of the same age using the concept of Net Merit Dollars (NM$) [2]. Net Merit Dollars is a single number that is designed to mirror the overall economic value of a bull's genetic potential and is defined as the expected lifetime profit as compared to a standard within a breed. It incorporates economic estimates for milk, protein, fat, milk quality, daughter fertility, calving ease, and longevity, as well as accounting for the added cost of marginal feed required to produce the extra milk, fat and protein.

The value of the genetic gain is often hard to conceptualize. Dairymen do not receive a direct payment for the improved genetics, but rather benefit through higher milk production and potentially, through reduced risk of premature culling of the genetically superior offspring. From 1984 to 1998, daughters of AI-proven sires produced 367–441 kg more milk than daughters of NS bulls [1]. However, the benefits associated with genetic improvement, and reproductive changes in general, are delayed while the costs are incurred instantly.

Despite the strong evidence supporting the advantages of AI, many dairy producers still favor the use of natural service sires. Reasons often cited include reduced labor costs, lack of trained labor to manage AI, a reliance by some dairies on the purchase of all replacement heifers instead of rearing their own, and a belief by many that natural service sires are easier to manage and less expensive than using AI.

However, many dairies have become frustrated with the poor reproductive performance or high risk of lameness in bulls that is often seen when NS sires are used for reproductive management, especially in freestall dairies. One strategy suggested to improve the libido and performance of NS sires as well as reduce the risk of lameness is rotational management system [3]. This management system involves maintaining two groups of bulls on the dairy at all times. One set is considered as a ''working group'' and is commingled with the cows. The second set is held in reserve and is referred to as the ''resting group''. The two groups are rotated every 1–4 week. While this management system costs more to implement and use, proponents suggest that the added cost may be offset by improved reproductive performance or lower health costs for the bulls.

There is little published work comparing the cost of natural service sires to AI. Shaw and Dobson assessed the impact of a change from standard bull breeding to on-farm AI in small dairies in the United Kingdom [4]. According to their work, the cost of using natural service beef sires was approximately 76% of the cost of the on-farm AI program, once all of the cash costs were considered. However, by the second and third year, the AI program was more profitable due to the improved reproductive efficiency that resulted in increased milk production and more calves. These differences in cost and profitability were reported without any evaluation in potential benefit from genetic improvement that was likely in the AI program.

Johnston et al. calculated the annual cost associated with maintaining a single herd sire for 2–2.5 years in a 40-cow Wisconsin dairy [5]. Keeping a NS sire for breeding management cost US$ 22.03 per cow in 1987, less expensive than using AI, but the study did not consider the value of the genetic differences between the herd sire and AI sires.

The two previously mentioned studies were based on small dairies and did not evaluate the potential economic advantages associated with genetic merit. Failure to consider the potential value of genetic gains associated with the AI sires may lead to erroneous conclusions regarding costs versus value of reproductive management. The present economic model was designed to compare the predicted costs, within the context of a large, western freestall dairy, between an all AI program and a reproductive management program using 100% natural service sires managed using a rotational system.

2. Materials and methods

An economic model was developed using a partial budget approach in a spreadsheet (Excel 2002, Microsoft® Corporation, Redmond, WA, USA) to compare expected explicit and implicit costs associated with the use of natural service sires with AI. Explicit costs are defined as out-of-pocket or accounting expenses that involve an actual cash payment, such as daily feed consumed. Implicit costs, on the other hand, are the opportunity costs of foregone production and do not involve an actual cash payment. An example of implicit cost in the context of this paper is the value of the genetic merit that producers fail to capture by using inferior sires.

2.1. General assumptions

It was assumed that all heifer calves are retained for replacements in the herd. The model dairy is a typical western freestall commercial unit milking 1000 Holstein cows, and the time horizon is one calendar year. Costs and returns incurred during the current year are reported as unadjusted values while those that are payable in 1 year or more are adjusted to reflect the time value of capital, currently set at 6% per year. Estimates for model inputs such as bull purchase price, costs of vaccines, laboratory testing fees, market cow and bull prices, and feed costs were taken primarily from local Tulare County sources including dairymen, veterinarians, livestock markets, and the local California Animal Health and Food Safety Laboratory. Management details regarding age of bulls at the start of service, culling risk, stocking density, and length of time in-service were taken from unpublished management surveys performed by the author and from work published by Champagne et al. [6]. If sufficient information was available, distributions for specific model components were fit to the data and these variables were then modeled stochastically. Genetic merit estimates were fit from data downloaded from the Animal Improvement Program Laboratory website [2]. Stochastic simulations and fitting of distributions was performed using @RISK 4.5 for Excel (Palisade Corporation, Newfield, NY, USA). @RISK is a risk analysis add-in tool that allows the user to stochastically model various outcomes, based on Monte Carlo sampling techniques from predefined or newly fit distributions. When the range of values was not sufficient to fit a distribution, the variable was treated as a deterministic input with a discrete value. The model reflects current recommendations for managing NS sires on dairies.

2.2. Natural service sire costs

For natural service dairies, it was assumed that bulls are used exclusively for reproductive management and that bulls are managed using a rotational system. Virgin breeding bulls are purchased at 13–15 months of age and put into use immediately after undergoing a standard breeding soundness evaluation and routine health screening for persistent BVD infection. Bulls are maintained in the herd for up to 1 year of service before being sent to the beef market.

There is little in the literature regarding stocking density of bulls in lactating dairy pens, but most advisors recommend 1 bull per 15–25 non-pregnant cows [7,8]. A ratio of 1:20 non-pregnant cows was selected and it was estimated that at any given time, an average of 50% of the total herd would be pregnant, 15% of the total herd would be non-lactating pregnant cows and approximately 12% would be between 1 and 40 days in lactation. Therefore, on average, there would be approximately 465 non-pregnant lactating cows eligible for breeding. As mentioned previously, it was assumed that the bulls would be used in some form of a rotational management system, including a set of working bulls and a set of resting bulls. Therefore, it was estimated that a herd milking 1000 cows would need 24 working bulls at any given time, with another 24 in reserve/resting. If producers replace approximately 25% of the breeding bulls in a year due to lameness, injury, disease, infertility or death (1% risk of mortality), another 12 bulls will need to be purchased during the year.

Using the stocking density of 1:20 non-pregnant cows and a 25% replacement risk, a total of 60 bulls will be purchased per year for a milking herd of 1000 cows. The 60 yearling bulls are purchased for an average of US$ 1000 (±S.D. of US$ 90) and when sold a year later, weigh approximately 820 kg and are sold at approximately US$ 0.10/kg above typical market cow prices. Market cow prices were taken from reported monthly sales figures published by the USDA for good quality cows sold for slaughter and the results were fit to a distribution that was best represented by an extreme value distribution, with a mean of US$ 0.458/kg, a mode of US$ 0.42, and a standard deviation of US$ 0.075, as fit by

@RISK using Chi-square statistic to select the best fit. The bulls that are culled prematurely throughout the year are sold at US$ 0.05/kg above market cow price at an average weight of 600 kg.

Health maintenance cost estimates for bulls include the cost of breeding soundness examinations (BSE), vaccines, and general veterinary care, including hoof trimming. Each bull undergoes a breeding soundness evaluation (BSE) prior to the start of service. In the Tulare area, a general BSE may cost US$ 35–40 per bull, plus another US$ 7–10 for Tritrichomonas foetus testing. Each bull that is selected as a NS sire incurs a cost of US$ 48 in the model for the BSE, which includes the fee for testing for Trichomoniasis. There was no allowance for costs associated with bulls that fail the exam and are then sent to slaughter or returned to the original source farm for replacement.

Each bull is also tested for persistent BVD infection via an ear notch test (immunohistochemistry) at a cost of US$ 6. Bulls are vaccinated with standard four-way modified live virus respiratory vaccine (IBR, BVD, PI3, and BRSV), clostridium seven-way, leptospirosis five-way, and a double dose of vibriosis (Campylobacter fetus) vaccine. Each of these vaccines is repeated in 3–4 weeks and the total cost for all of the vaccines is estimated at US$ 8 per bull, including needles and syringes.

Labor and on-going health maintenance costs were estimated to be US$ 14 per bull per year. With the bull rotational system, it was assumed that a minimum of 1 h every 3 weeks would be required to move bulls from working pens into resting pens. This labor cost is shared equally by all bulls on the dairy. In addition, each bull was assumed to incur miscellaneous health maintenance costs of about US$ 10 per bull per year for the occasional hoof trim or antibiotic injection, or for additional labor to move sick or injured bulls from lactating to hospital pens.

The single largest variable cost for dairies is feed. Predicted dry matter intake for growing beef bulls weighing 590–640 kg is approximately 12.7 kg dry matter [9]. For the purposes of the model, a value of 11.8 kg dry matter feed to more closely represent the "average" intake over the year, accounting for the higher than normal energy density of a lactating ration. In addition, a bull was assumed to spend half of the time with the cows eating the lactating ration and half of the time in a bulls-only pen or dry lot eating a less expensive ration. Consequently, the average cost of the ration would be the average of the two different diets and based on current, typical California feed costs was set at US$ 0.163 and 0.132/kg of dry matter, respectively.

Finally, for NS herds, all cows were assumed to receive one treatment with prostaglandin F2α prior to entering the breeding pen. Many producers have taken the approach of giving one or two prostaglandin injections en masse instead of conducting prebreeding exams. This approach is an attempt to avoid the expense and potential diagnostic errors associated with palpation per rectum in postparturient cows just prior to entering the breeding pens and may aid estrus synchronization. The assigned cost was US$ 3.10 per cow, including labor.

2.3. AI costs

To accurately describe the cost of using NS sires, one must also consider the alternative costs and benefits of using 100% AI. For this portion of the model, it was assumed that the dairy uses a commercial route breeder that visits the dairy once daily in the early morning, performs estrus detection via the tailhead chalking method, and breeds during the same visit. The charges for the estrus detection, inseminations, and semen are typically packaged as a unit charge. This charge may vary depending on the number of cows on the dairy, travel distance, and quality of semen used. A value of US$ 18 per service was used throughout the model.

Based on an unpublished data set by the author containing reproductive data from 90 commercial California dairies, the average services per conception is 3.2–3.3. Within the herd, however, are always cows with unknown breeding outcomes, cows that receive a service and are culled prematurely, and still others that receive numerous services without ever conceiving. In addition, cows may occasionally receive semen on consecutive days, but only have the last service recorded. While the true number of services will vary with the herd's reproductive efficiency and culling risk, 3.6 was chosen as a reasonable estimate of the average number of services that a cow might receive.

Estrus and ovulation synchronization programs have become popular on many western dairies. This model assumed that the dairies were using a modified version of the Presynch/Ovsynch program previously described [10,11]. Under this modified system, cows receive two prostaglandin F2α treatments, spaced 14 days apart, prior to the end of the voluntary waiting period. Cows detected in estrus following the second injection are inseminated as per normal routine. Any cows not detected in estrus over the next 14 days are then enrolled in the Ovsynch protocol and inseminated as per schedule. All cows in the herd incur the cost of the presynch program, which is estimated at US$ 6.20 per cow, including labor. Cows found not pregnant on exam at $\geq$35 days post-breeding are automatically re-enrolled into the Ovsynch program. Under this management routine, approximately 20–25% of all breedings are predicted to occur from the Ovsynch protocol. Additionally, there is a small percentage of cows that are enrolled in the Ovsynch protocol that are detected in estrus and inseminated prior to its completion. To account for the cows that enter the Ovsynch program, but are inseminated prior to its completion, it was assumed that 30% of all breedings would incur the full cost of Ovsynch, which is estimated to be US$ 9.55 per service, including labor.

2.4. AI returns

AI has two major quantifiable benefits as compared to the use of NS sires. These two areas could be presented either as a cost for using NS sires (lost opportunity costs) or as a marginal return for AI. In this model, each of these items is presented as marginal returns for AI.

The first marginal return for AI is the increased rate of genetic improvement. The AIPL Summary of November 2004 Evaluations indicated that proven, active US Holstein AI sires were predicted to have a NM$ value of US$ 378 ($\pm$145 S.D.) while first evaluation young sires have a NM$ value of US$ 354 ($\pm$125 S.D.). For comparison, the NM$ for first evaluation non-AI sires was US$ 161 ($\pm$141 S.D.). The modeled dairy was assumed to use a mix of 25% young sires and 75% proven sires. However, as is the case with most commercial dairies, cost is a big concern. To account for the use of less expensive semen, the modeled dairy does not use any bull from the top 20% of the NM$ distribution due to price. Therefore, the distribution was truncated at the 80th percentile for the proven bulls and the maximum NM$ value possible was 500.

Net Merit Dollars is an estimate of the value of a cow's offspring compared to a standard for that breed. Although all cows may be inseminated with semen from good quality sires, only those cows that conceive, carry the pregnancy to term and deliver a live calf can be expected to benefit from the genetic improvement, ignoring the potential benefits that may be derived as a consequence of using calving ease sires. The heifer calf must also survive calfhood, become pregnant and calve herself before the dairyman can benefit from the potential for higher milk production, improved components, etc., that accompany the genetic gains. To account for each of these factors, it was assumed that on average, 67% of cows that calve once and enter the milking string will calve again, 48% will deliver a non-twin heifer, 92% will be live deliveries, and 88% of the resulting offspring would survive calfhood, conceive, maintain the pregnancy and enter the milking string. The net result is that on average, only 26% of the cows that enter the herd as milking cows and are re-inseminated will deliver a female calf that will later enter the milking herd and potentially exhibit the predicted genetic advantage. Since most dairymen sell the majority of bull calves for the beef or veal market, no additional value was placed on the bull calves born to AI sires. In addition, the dairyman does not see the benefits of improved heifer genetics as soon as the semen is used. Rather, they must wait for the length of gestation and then approximately two more years before calving. Therefore, the genetic merit value is discounted for the delayed returns that begin about 3 years after the purchase of the semen. The current value on a per-lactating-cow basis was derived by multiplying the predicted difference in NM$ as reported above by 26% and then adjusting for a delay in return of 3 years.

The second lost opportunity cost associated with the use of NS sires as opposed to AI that must be considered is the opportunity that a dairyman has to replace NS bulls with lactating cows. This concept is controversial for many producers and advisors. In freestall dairies, assuming that stocking density is maintained at a theoretical maximum carrying capacity, if bulls are eliminated from milking pens, more room will be available for additional cows. Alternatively, if no additional cows are added, the existing cows should have improved access to both feedbunk and freestalls, thus improving marginal feed consumption, reducing the risk of lameness and premature culling, or both. To account for this value, the model adds one additional cow for every two bulls removed as a conservative estimate of the potential benefit that can be derived by replacing NS sires with AI. The economic cost of purchasing these marginal cows was amortized over their expected productive life. Life expectancy was derived by taking the inverse of the average culling rate of 33.5% as reported by Young et al. and as confirmed by review of local dairy herd records [12]. Thus, the annual cost of the purchased animal is estimated at US$ 534 or 1.46/day using a purchase price of US$ 2000 for a replacement primiparous cow, an effective salvage value of US$ 578 once the risk of death is considered, a cost of capital of 6% and an expected productive life of 3 years. In addition, the purchased animals also incur a risk of culling during that lactation and additional cows need to be purchased to replace them. The additional costs associated with replacing the marginal cows are also included in cow purchase costs and the full cost of the culled marginal cows is reflected in the current year.

Marginal costs used in the model for AI include the aforementioned cow purchase costs, as well as daily feed for these marginal cows, which was estimated at 19 kg per cow per day, and the additional veterinary, medical, rBST, breeding, milking supplies and milk marketing/hauling costs for the marginal cows and their milk. Estimates for these costs were taken from South Valley Cost Estimates published by the Dairy Marketing Branch of the California Department of Food and Agriculture [13].

During the 1 year under consideration, primiparous marginal cows were assumed to average approximately 31.8 kg of milk/day. However, over the following year, the cows that successfully become pregnant will enter the non-lactating group and their presence in the herd will then become a negative drain on cash flow. To adjust for the delayed cost, an average of 28 kg of milk per marginal cow per day was used to estimate production for the first year instead of the original 31.8 kg. For milk price, a distribution was fit to the average monthly milk price for California class 4b milk (cheese, non-base milk price) using @RISK. The resulting normal distribution has a mean of US$ 0.286/kg and a standard deviation of US$ 0.067.

3. Results

The final partial budget model is shown in Fig. 1. The model is divided into four major areas: costs associated with use of NS sires, costs associated with the use of an AI program, returns associated with the use of NS sires, and returns associated with the use of an AI program.

The total cost associated with the purchase of the bulls is (US$ 60,000), after the midyear replacement bulls are considered (see Fig. 1, Section 1), and is the single largest cost for using NS sires. The cost associated with health screening and health maintenance, which includes a breeding soundness evaluation, testing for Tritrichomonas fetus and BVD, basic vaccines, and various labor charges totals (US$ 88) per purchased bull, or (US$ 5280) for the herd for the year and is shown in Section 2.

In Section 3, the cost associated with feeding each of these bulls is shown. While 60 bulls are purchased over the course of the year, only 48 are considered to be on-farm at any given time. The average feed intake for each bull over the total year is estimated at 11.8 kg of dry matter, resulting in a cost of (US$ 605) per bull per year, or a whole herd cost of (US$ 29,056).

The final expense for the NS sire program is the cost associated with giving each cow one treatment of prostaglandin F2α. The cost per dose, including the syringe, needle, and labor for administration was estimated at (US$ 3.10) per treatment, for a total cost of (US$ 3100) as shown in Section 4 for Fig. 1.

The total of the costs described in Sections 1–4 is (US$ 97,436) for the milking herd and represents the expected cost of using NS sires for breeding management of a 1000 cow dairy.

The next part of the model is the expected returns associated with the use of NS sires and is shown in Section 5 of Fig. 1. At the end of the year, all bulls are sold (replaced) and the expected market value for a healthy, mature bull is estimated at (US$ 1004) per animal. However, 25% of the original bulls have been replaced at an average salvage value of US$

Natural Service Sire Dairy		AI Dairy	
	Costs:		
1) Bull Procurement Costs	**(Expected Value)**	**6) Breeding Costs**	**(Expected Value)**
Total Bulls Needed to Purchase	60	Commercial Route Breeder (Charge/ Service)	($18.00)
Purchase Price of Bull	($1,000)	Average # Inseminations/ Cow	3.6
Total Cost of Purchasing Bulls	($60,000)	Total Insemination Cost/ Cow	($64.80)
		Total Insemination Cost	($64,800.00)
2) Health Screening/ Maintenance Costs			
Breeding Soundness Exam & Trich Testing	($60.00)	**7) Reproductive Hormones & Management**	
BVD Testing (Ear Notch)	($6.00)	Total Cost for PreSynch Series/ Cow	($6.20)
Vaccines	($8.00)	Total Cost for Presynch (Herd)	($6,200)
Labor and On-going Health Costs	($14.00)		
Subtotal Health Costs/ Bull	($88.00)	Total Cost for OvSynch Series/ Cow	($9.55)
Total Health Costs (All Bulls)	($5,280)	Percent of All Breedings to OvSynch	30%
		Total Cost for OvSynch (Herd)	($10,314)
3) Feed Costs			
		Total Hormone Cost (w/ labor)	($16,514)
Bull Feed Intake/ day	26		
Average Feed Cost/ Bull/ day	($1.66)		
Total Feed Cost/ Bull/ year	($605.33)	Total Reproductive Management Cost	($81,314)
Total Feed Cost/ year (All Bulls)	($29,056)		
		8) Cost of Marginal Cows (Year 1)	
4) Reproductive Hormones		Purchase Cost of Marginal Cows (& Culls)	($12,112.29)
Reproductive Hormones (1 Prostaglandin Tx/Cow)	($3,100)	Feed Cost for Marginal Cows	($13,613.04)
		Marginal Costs of Production (excluding feed)	($2,872.80)
		Total Marginal Cow Costs	($28,598.13)
Total Cost of NS Program	($97,436)	Total Cost of AI Program	($109,912)
	Returns:		
5) Bull Market Returns (Beef)		**9) Marginal Milk Production**	
Expected Market Value in 1 Year (Healthy)	$1,004.47	Initial # of Replacements to Purchase	12
Bull culling risk	24%	Additional Replacements Needed Due to Culling	4
Bull mortality risk	1%	Marginal Milk Income/ Cow/ Day	$8.04
Expected Market Value (Premature Cull)	$673.15	Total Gross Milk Income/ Year	$35,221.33
Net Market Price/ Bull	$832.64		
Net Returns for Marketed Bulls	$49,959	**10) Genetic Merit Estimates**	
		NM$ Young Sires	354
		NM$ Proven Bulls	327
		NM$ Nature Service Sires	163
		Percent of Breedings to Young Sires	25%
		Percent of Breedings to Proven Bulls	75%
		Time Adjusted Difference in NM$ (AI vs NS)	$144
		Percent of Cows Yielding Replacement Heifers	26%
		Predicted NM$ Gain/ Milking Herd	$37,480
Total Return from NS Program	$49,959	Total Return from AI Program	$72,701.50
Net Cost of NS Program	**($47,477)**	**Net Cost of AI Program**	**($37,211)**
Net Cost of NS Program/ Cow in Herd	**($47.48)**	**Net Cost of AI Program/ Cow in Herd**	**($37.21)**
Net Gain or (Loss) for NS as Compared to AI Program	**($10.27)**		

Fig. 1. Partial budget comparing the use of natural service sires to an AI program in a 1000-cow Holstein, western, freestall dairy.

673 per prematurely replaced bull. The net result is that the average return per bull is only US$ 833, resulting in a total net return for the herd of US$ 49,959.

Immediately below Section 5 of Fig. 1 is the net cost of the NS sire program. By adding the total cost of (US$ 97,436) to the total returns of US$ 49,959, the net result is a cost of (US$ 47,477) for the herd, or (US$ 47.48) per lactating cow year.

On the right side of Fig. 1 are the estimated costs and returns associated with using an AI program, as previously described. Section 6 contains the cost estimates of using a commercial route breeder with an average charge of (US$ 18) per cow serviced, including semen, once daily heat detection, and the miscellaneous supplies that are required for breeding management. At an estimated 3.6 services per cow, the total cost for inseminations totals (US$ 64,800) for the herd over a year's time.

Section 7 displays the costs expected with the use of a modified Presynch–Ovsynch program in conjunction with the re-enrollment of any cow found pregnant on pregnancy evaluation. At (US$ 6.20) per cow for Presynch and (US$ 9.55) per Ovsynch breeding, the total cost for reproductive hormones, labor, and management of the program totals (US$ 16,514) for the herd for the year. When added to the insemination costs, the grand total for reproductive management for the herd is (US$ 81,314) for the year.

The final area of cost for an AI program includes the expenses associated with the purchase, feeding and care of the marginal cows previously described. By removing the bulls and using AI, housing and feeding space is created, or crowding is reduced, resulting in either space to add additional cows or more room for existing cows. The model added an initial 12 cows at an amortized cost of (US$ 534) per year over 3 years. Four additional cows were purchased for replacements for the marginal cows added. The culled cows incurred a full purchase cost of (US$ 1425), which is the difference between the replacement cost of (US$ 2000) and the salvage value of US$ 578, during the current year, resulting in a total marginal cow acquisition cost of (US$ 12,112) for the year. These 12 lactating primiparous cows have an estimated feed intake of 19 kg dry matter per cow per day over the first year. At an average cost per kg dry matter of (US$ 0.163), the total feed cost per cow per year is (US$ 1134.42), or (US$ 13,613) for the herd. There are additional marginal expenses that include the veterinary, medical, supplies, and milk marketing costs. These other marginal costs total (US$ 239) per cow per year or (US$ 2873) for all cows. Adding each of these incremental expenses together yields a grand total cost of (US$ 28,598) for the purchase, feeding and care of the marginal cows as shown in Section 8.

Adding each of the costs for Sections 6–8 yields the total expected cost for using an AI program in a 1000 cows milking herd. The whole herd cost is (US$ 109,912) and on a per cow basis, totals (US$ 109.91) for reproductive management for the year.

The lower right area of Fig. 1 contains the expected returns associated with using an AI program. Section 9 contains the estimated value for the milk produced by the marginal cows. At 28 kg of production and an average milk price of US$ 0.286/kg, the daily return from milk is US$ 8.04. Over the course of the year, the total value returned to the herd is estimated to total US$ 35,221.

Immediately below Section 9 is the expected return to be realized due to the genetic progress predicted by using a combination of proven and unproven AI sires instead of NS sires. The net merit advantage of the blend of proven and unproven AI sires has been adjusted for a 3-year delay in return, adjusted for the number of cows that are predicted to yield daughters that enter the milking herd. On a per cow basis, the value is US$ 38.48 and on a whole herd basis, the total value is US$ 38,480, as shown in Section 10.

Adding the returns generated in Sections 9 and 10 yields a grand total return from the AI program of US$ 72,701.50 for the herd, or US$ 72.70 per cow. By adding the total cost from Sections 6–8 (US$ 109,912) to the total expected returns US$ 72,701 we arrive at the net cost of using the AI program. This result is (US$ 37,211) for the herd, or (US$ 37.21) per cow.

Altogether, under the assumptions given in this model, the total explicit costs of using NS sires was estimated to average (US$ 47.48) per lactating cow per year, while the

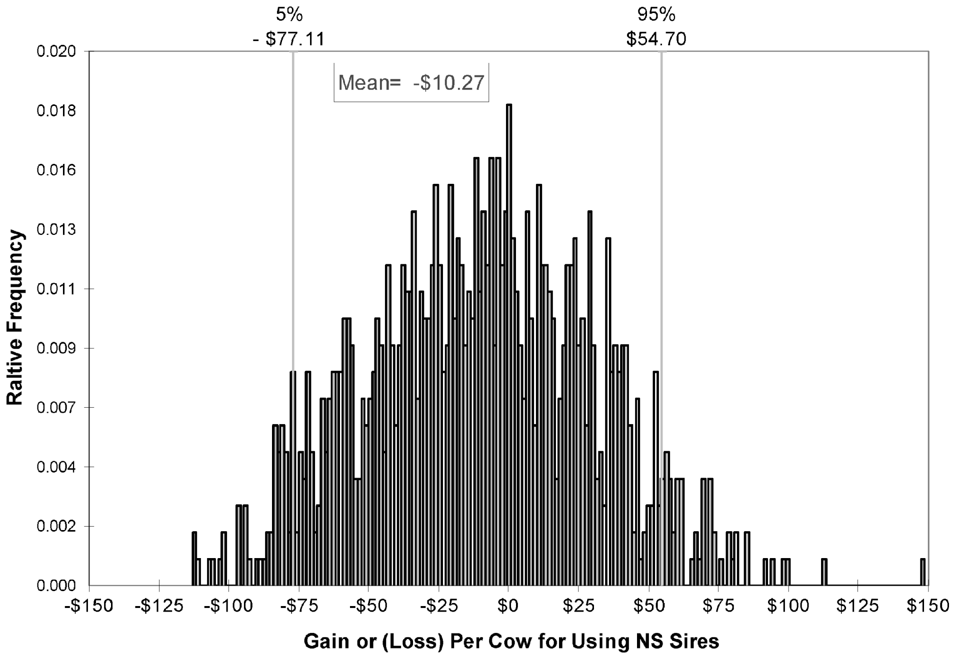

Fig. 2. Expected distribution of the gain or (loss) per cow for using a natural service sire program as compared to an AI program in a 1000-cow Holstein, western, freestall dairy.

average net cost for using AI was (US$ 37.21). Subtraction of the cost of the AI program from the cost of the NS program show that the use of AI results in a savings of US$ 10.27 per cow per year as compared to using NS sires. For a herd of 1000 milking cows, the total cost savings is estimated at US$ 10,270/year.

However, many of the costs and returns fluctuate over time. Some of these variables have been entered as distributions, fit from data over the past 2 or 3 years. Fig. 2 shows the distribution of the predicted difference in cost between the two programs, generated by running 1000 iterations of the model using @RISK. Again, the mean value of the difference in the two programs is (US$ 10.27) in favor of AI, but there is a wide range in expected values, depending on the inputs selected. Approximately 60% of the time, AI is predicted to cost less than using NS sires under the assumptions used in the model. Ninety percent of the time, the true estimate of the difference between these two approaches to reproduction lies between a US$ 77.11 advantage to AI to a US$ 54.70 advantage by using NS sires.

4. Discussion

The purpose of the current study was to compare the estimated costs between an all AI program and a reproductive management program using 100% natural service sires within the context of a large, western, freestall dairy managed using a rotational system. A partial budget approach using stochastic simulation was used to model the impacts of various costs and returns within each management system. While individual costs may vary from region to region, under the assumptions used in this model, and using the expected or mean estimates for each variable, reproductive management using all AI was predicted to be less expensive than using all NS sires.

Using the simulation software, approximately 60% of the time, AI would be less expensive, but there was quite a bit of variation in the projected difference in costs. Sensitivity analyses revealed that the largest variable driving this variation is that of NM$ estimates for AI versus NS bulls. The difference in genetic merit was estimated to be worth approximately US$ 144 per cow in the herd that conceived and delivered a heifer calf that would later join the milking herd. This value was somewhat higher than the US$ 96 per cow increase in annual net income that AIPL scientists estimated would be realized by use of AI in place of NS [14]. Some of the difference between the two estimates may be explained by the older genetic evaluations used in the Norman et al. estimate, which used 1987 genetic estimates, and by the concept that genetic selection intensity is continuing to rapidly increase due to increased sampling of bulls and faster turnaround of daughter production records. In addition, there was no attempt in the current study to include any type of reliability factor, and thus the variation was potentially more extreme.

The second largest impact is the price paid for the milk produced by the marginal cows. When milk price rises, the advantage moves in the favor of AI. However, as milk price declines, the concept of adding additional marginal cows may be less valuable, due to the lower value of the milk relative to the high cost of the purchased animals.

The third largest factor is the price of market cows, and thus, the returns expected for bulls at marketing. When the market price for cull cows and bulls is high, the returns from marketing the used bulls are higher, driving the advantage toward NS sires. This concept is important to remember, especially in light of the current high market cow prices. Historically, market cow prices are typically in the mid to upper US$ 0.30's/kg. Over the last 2 years, the mean market price for good quality slaughter cows was US$ 0.458/kg, providing additional value for the NS program that ordinarily might not be present.

Other factors, such as the cost per insemination and the average number of inseminations per cow likely have very large impacts on the net result, but these factors were not treated stochastically. The cost per service may appear to be low, considering that the cost of semen is also included. However, one must remember that in larger western dairies, labor costs on a per cow basis are likely significantly lower than what may be estimated on small to medium dairies. In large herds, pens containing 200–400 cows each are not uncommon and the majority of these dairies have self-catching stanchions located at the feedbunk. Cows are commonly restrained in this manner following the morning milk and the time required to detect estruses in a large pen of cows using a tailhead-based chalking system is very short.

These results may not accurately describe the cost/benefit of NS sires in dry lot dairies or in dairies that fail to use a bull rotation system. In a dry lot dairy, the value of replacing bulls with marginal cows may be quite different due to the difference in housing styles. Crowding stress and lameness do not appear to be as problematic in dry lot dairies. Certainly, if herds are not using rotational management for their bulls, the projected number of bulls needed on-farm at any given time is reduced, thus reducing the feed cost estimate. However, if herds are not employing a rotational system, the risk of premature culling may be higher and reproductive performance may be hampered.

Based on an unpublished survey of NS management practices performed by the author, most dairies fail to do breeding soundness evaluations or to vaccinate bulls as commonly recommended. Eliminating these costs would reduce the cost advantage of AI down to only US$ 5. However, reproductive performance is likely to be sacrificed, eliminating any possible cost savings.

All of the above results have been reached with the assumption that performance between the two programs was equal. However, based on unpublished work by the author, NS sire herds tend to have lower reproductive success. Getting cows pregnant in a timely manner is extremely valuable and no consideration was given to reproductive efficiency of either program. A well-designed AI program can dramatically impact the reproductive efficiency of a herd and more than offset the additional costs.

One potentially significant cost that was not considered is the cost of veterinary palpation services. This estimate was omitted due to the tremendous variation between herds that exists with palpation schedules, call fees, professional service fees, and farm management routines. Some herds regularly check AI pens once weekly while others may check once every 4 weeks. In addition, some veterinarians or dairy herds incorporate ultrasound early post-breeding, while others may not evaluate for pregnancy until 50–60 days, depending upon the frequency of veterinary visits and skills of the palpator. Clearly, NS herds must palpate more cows per veterinary visit due to the unknown breeding dates, while AI herds usually have very complete breeding records, thus decreasing the number of cows that must be evaluated.

Every attempt was made to include the significant quantifiable variables that affect the cost of reproductive management, but worker safety was not included due to an inability to quantify its value. Safety is a major concern with bulls on dairy farms, partly because cows are handled often, and many dairies lack adequate facilities for proper handling of bulls. Of course, one could estimate the probability of an accident occurring on a NS sire dairy, but who can say what a human life is worth? Attempts to assign costs for use of bulls by considering difference in liability premiums were unsuccessful in that California dairies do not pay additional premiums until an accident occurs.

Cost and benefits of using AI likely differ by farm and the benefits of AI may not be fully realized if replacement animals are purchased instead of raised on-farm. However, under the model presented, AI costs approximately US$ 10 per cow less than NS. Additionally, stochastic simulation shows that AI is less expensive than using NS sires approximately 60% of the time.

Acknowledgements

The author would like to thank the Tulare Sales Yard, the Walter Jensen Cattle Company and Escalon Livestock Market Inc., for their assistance with the estimation of breeder bull and market bull prices.

References

[1] Norman HD, Powell RL, Wright JR, Sattler CG. Timeliness and effectiveness of progeny testing through artificial insemination. J Dairy Sci 2003;86:1513–25.

[2] Animal Improvement Programs Laboratory, USDA, Beltsville, MD. http://www.aipl.arsusda.gov/index.htm 2005.

[3] Overton MW, Risco CA, Dalton JC. Selection and management of natural service sires in dairy herds. Proc Am Assoc Bovine Pract 2003;36:109–17.

[4] Shaw C, Dobson H. Reproductive and financial impact of a do-it-yourself artificial insemination programme compared with keeping a bull. Vet Rec 1996;139:594–7.

[5] Johnston Jr RP, Sendelbach AG, Howard WT. The annual cost of a dairy sire. University of Wisconsin Extension Publication; 1987.

[6] Champagne JD, Kirk JH, Reynolds JP. Bull management practices on California dairies: implications for education and veterinary services. Proceedings of the 15th Annual UC Davis Fall Symposium, 15 September 2002.

[7] Olson TM. Elements of dairying. New York: MacMillan Company, 1950.

[8] Chenoweth PJ, Larsen RE. Selection, use and management of natural service bulls. Large dairy herd management. Am Dairy Sci Assoc 1992;209–18.

[9] NRC. Nutritional Requirements of Beef Cattle, seventh revised ed.; 2000.

[10] Moreira F, Orlandi C, Risco CA, Mattos R, Lopes F, Thatcher WW. Effects of presynchronization and bovine somatotropin on pregnancy rates to a timed artificial insemination protocol in lactating dairy cows. J Dairy Sci 2001;84:1646–59.

[11] Pursley JR, Kosorok MR, Wiltbank MC. Reproductive management of lactating dairy cows using synchronization of ovulation. J Dairy Sci 1997;80:301–6.

[12] Young AJ, Smith SC, Tripp SP. Culling rate and death loss associations with DHI production values. J Dairy Sci 2003;86:54.

[13] California Department of Food and Agriculture. Annual Summary of California Cost of Production. http://www.cdfa.ca.gov/ 2002.

[14] Norman HD, Powell RL, Wright JS. Comparison of occurrence and yields of daughters of progeny test and proven bulls in artificial insemination and natural-service bulls. J Dairy Sci 2002;85(Suppl. 1):325.