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Technology Adoption and Impact in Dairy Farming

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Abstract: Dairy farming necessitates daily decision-making and a holistic approach to ensure profitability, consumer well-being, environmental responsibility, and product quality. This study examined the adoption of precision dairy technologies using a mixed-method approach focusing on milking efficiency. It covers motivations for investment, anticipated benefits, and maintenance practices. Conducted across 20 dairy farms in Anand and Vadodara districts the survey involved 80 respondents. Data analysis, performed using Excel, categorized responses into agree, neutral, and disagree to address response skewness. Findings revealed that labour savings and simplifying milking processes were key motivations for adopting precision technologies. While most farm owners were satisfied with technical support and training, challenges such as system data integration persisted. Many users relied on the technology for data entry, alert monitoring, and training but noted underutilization of advanced system functionalities, underscoring a need for improved user guidance. In developing countries like India, precision dairy farming is still emerging but offers significant potential for improving individual animal and herd management by enhancing animal health, welfare, and environmental sustainability, precision farming supports long-term sustainability goals in livestock management.

Keywords: Precision dairy farming, Productivity, adoption, sustainability

INTRODUCTION

Dairy farming requires constant decision-making and a comprehensive approach to sustain profitability while ensuring consumer trust, environmental stewardship, and high product quality. The challenge of narrow profit margins has heightened the focus on improving efficiency and productivity in the dairy sector. According to estimates from the Food and Agriculture Organization (FAO, 2022), India is expected to contribute 54% of the global increase in demand for milk and fresh dairy products. To meet this demand, the country's dairy producers will need to increase milk production by 56 million tons annually by 2026, a 40% rise compared to 2014 levels. Achieving this growth while meeting the nutritional needs of a growing population necessitates adopting advanced real-time monitoring technologies. Effective dairy farm management increasingly prioritizes individual animal care alongside traditional herd or group management strategies. As highlighted by Maltz (2000), the foundation of dairy production lies in managing each individual cow, the smallest production unit. Precision agriculture, and specifically precision dairying, seeks to optimize the productivity of each cow to unlock its full potential.

Future growth in production and profitability within dairy farming systems may be constrained by the availability of skilled labor and the complexities associated with managing larger herds (Dairy Australia, 2015b). For farmers considering expanding their operations, it is crucial to implement best

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practices in herd management, operational efficiency, financial planning, human resource management, and strategic decision-making (Hadley et al., 2002). As dairy farms scale up, the complexity of monitoring and managing individual animals increases, requiring farmers to develop more advanced management skills and approaches (Edwards et al., 2015; Bewley, 2016). To manage the challenges of larger herds, farmers are increasingly adopting automation and sensor systems, collectively known as precision technology. These innovations help reduce labor demands while improving herd management (Bewley, 2010; Eastwood et al., 2012, 2016a). Technologies such as automated cup removers, sorting gates, calf feeders, post-milking disinfection systems, and milk plant wash systems can significantly ease labor pressures or increase efficiency, especially on larger farms (Edwards et al., 2015). Additionally, precision technologies that capture data are being used to monitor individual cow metrics, with the goal of improving production efficiency and farm performance. These include systems for automatic estrus detection, inline milk meters, electronic cow identification, and herd management software.

Despite the potential benefits, the adoption of data-capturing technologies in dairy farming remains limited globally, with only a small percentage of farms implementing these tools (Bewley, 2010; Rutten et al., 2013; Borchers and Bewley, 2015; Edwards et al., 2015). In the dairy sector, a wide range of service providers, including agronomists, veterinarians, nutritionists, consultants, researchers, and technicians, play a vital role. These professionals, from both private and public sectors, are integral to the support network for dairy farmers and have a significant impact on the decision-making processes within the industry (Klerkx and Jansen, 2010; Eastwood et al., 2012; Murphy et al., 2013). Service providers have the potential to incorporate precision technologies into their services and interactions with farmers. For example, they could offer tailored reports on areas such as animal health or nutrition (Eastwood et al., 2016a, b). While prior studies in various countries have investigated the adoption of precision technology on dairy farms (Watson, 2009; Khanal et al., 2010; Dharma et al., 2012; Borchers and Bewley, 2015; Edwards et al., 2015), there is limited understanding on a global scale about how herd size impacts farmers' decisions to invest in on-farm precision technologies. Furthermore, there has been little exploration of the views of service providers, even though they play a significant role in influencing many farmers' decisions (Eastwood et al., 2016b).

To address this gap in understanding, we conducted a survey aimed at exploring the connection between herd size and the adoption of technologies on dairy farms. The results of this study could help improve the strategies of commercial companies, research programs, and dairy policy organizations in the development and promotion of new precision technologies.

MATERIAL AND METHODS

A mixed-method approach was utilized to gather detailed information about the use of precision technologies, with a focus on milking efficiency (Edwards et al., 2012). The survey, designed to investigate various aspects of precision technology usage, was informed by previous research in precision dairy farming (Yule and Eastwood, 2011; Eastwood et al., 2012). It included questions centered on critical themes such as motivations for adopting technology, expected advantages, maintenance and operational routines, the effects of technology implementation, and the perceived benefits experienced by farmers.

During the survey, respondents were asked to rate various statements using specific scales. The majority of the questions employed a 5-point scale, where 1 represented 'strongly disagree,' 5 indicated 'strongly agree,' and 3 signified a neutral stance. One question, however, used a different 5-point scale ranging from 'Not useful' to 'Highly useful,' while another featured a 4-point scale that spanned from 'none' to 'a lot.'

STATISTICAL ANALYSES

The data were systematically organized and analyzed using Excel. Structured survey responses included farmer feedback gathered during discussion sessions held at farm

locations, where participants shared their experiences and observations about the changes brought about by adopting the technology. Data are primarily presented as counts and percentages. For responses collected on a 5-point scale, categories were consolidated into agree (combining 'strongly agree' and 'agree'), neutral, and disagree (combining 'strongly disagree' and 'disagree') in the Results section. This method of reporting was preferred over using averages to minimize the influence of skewed or varied responses to individual items (Clason and Dormody, 1994).

PARTICIPANTS

The survey included 80 respondents from 20 dairy farms. Participants identified their roles as Farm Owners, Farm Managers, Milkers, or Farm Workers. Farm Owners were analyzed separately to account for their critical role in making strategic decisions for the farm. This distinction allowed for a deeper exploration of differences in perceptions between decision-makers, who have a thorough understanding of the farm business and technology investments, and the other respondents.

The farms involved in the study ranged in size, with herd numbers spanning from 50 to more than 200 cows. Six different milking equipment manufacturers were represented among the participants. Farms were selected based on their use of essential precision technologies, such as INAPH Tagging, milk meters, RFID systems, and herd management systems (HMS). Additionally, some farms utilized advanced technologies like auto drafting, in-bail feeding, automated heat detection, and walk-over-weigh scales.

RESULTS

Reasons for Investing in Technology

Among the 20 farm owners who participated, the primary motivations for adopting technology were 'reducing labour requirements' and 'simplifying the milking process' (Table 1). Approximately 45% cited 'more efficient feeding' as a significant reason, while attracting and retaining staff were key considerations for 40% and 45%, respectively. Other reasons, such as identifying cow health issues or detecting oestrus cows, were important to less than 40% of owners.

There were some differences between farm owners and other respondents, particularly regarding staff attraction and retention, as well as the use of technology for identifying health concerns. About half of the farm owners felt that the learning support provided met their expectations (Table 2). Most were aware prior to purchase that data exchange between systems might present challenges. Regarding satisfaction with technology performance, 68% of owners agreed that its actual performance aligned with their initial expectations.

Table 1: Reasons for adopting precision dairy technologies (selected from a predefined list) presented as the percentage of responses within the categories of 'all respondents' and 'farm owners.'

Reasons for Investment	*All (%)*	*Owners(%)*
Labour saving	**80**	**90**
Make milking easier	**65**	**70**
To attract staff	**45**	**40**
To retain staff	**35**	**45**
More efficient feeding	**30**	**45**
Identify cow health issues	25	20
Identify oestrus cows	25	32

Table 2: Respondents' initial expectations of precision dairy technologies, shown as percentages for the categories of 'all respondents' and 'farm owners'

Statement	*Pre-Purchase expectations oftechnology performance matchedreality*		*Knew there may beissues moving data between software systems*		*Learning support received fromretailer was what I expected*	
	All	*Owner*	*All*	*Owner*	*All*	*Owner*
Strongly agree (%)	20	24	20	29	21	20
Agree (%)	48	47	53	50	32	32
Neutral (%)	18	8	20	14	26	22
Disagree (%)	10	13	3	0	16	15
Strongly disagree (%)	4	8	4	7	5	11

Use of Technology and Perceived Benefits

Respondents rated several statements regarding the advantages of precision technologies using a 5-point scale (Table 3). Among all participants, there was a strong consensus that these technologies were a valuable investment, with 91% agreeing, and 84% expressing willingness

to install them again. Participants also evaluated the perceived usefulness of their precision technologies (Table 4). The highest usefulness was reported for labor-saving during milking, with 92% of respondents identifying the technologies as 'highly useful.'

Table 3: The perceived advantages of precision dairy technologies presented as percentages of responses within the 'all respondents' and 'farm owners' categories

statement	*Investment in technologies was worthwhile*		*Those technologies have savedme time*		*I would definitely install these technologies again*		*It is simple touse the information in my decisionmaking*		*People on thefarm find herdmanagement easier*	
	All	*Owner*	*All*	*Owner*	*All*	*Owner*	*All*	*Owner*	*All*	*Owner*
Stronglyagree (%)	70	79	60	66	70	76	50	48	44	40
Agree(%)	21	10	27	16	14	16	36	38	34	33
Neutral(%)	4	8	5	10	5	3	9	7	14	17
Disagree(%)	0	0	0	0	5	2	2	2	4	5
StronglyDisagree(%)	5	3	8	8	2	7	3	5	4	5

Table 4: The perceived utility of precision dairy technologies represented as percentages of responses in the categories of 'all respondents' and 'farm owners'

statement	*Managing cow health*		*Making right Decision atthe right time*		*Saving onlabour during milking*		*Making milking andherd management more enjoyable*		*Helps to attract andretain peopleon farm*	
	All	*Owner*	*All*	*Owner*	*All*	*Owner*	*All*	*Owner*	*All*	*Owner*
Strongly agree (%)	35	30	33	35	70	65	50	54	30	32
Agree(%)	42	46	48	46	20	30	42	44	32	38
Neutral(%)	20	20	15	15	4	2	4	2	16	8
Disagree(%)	4	4	4	4	5	2	2	0	16	21
Strongly Disagree(%)	0	0	0	0	1	0	2	0	6	0

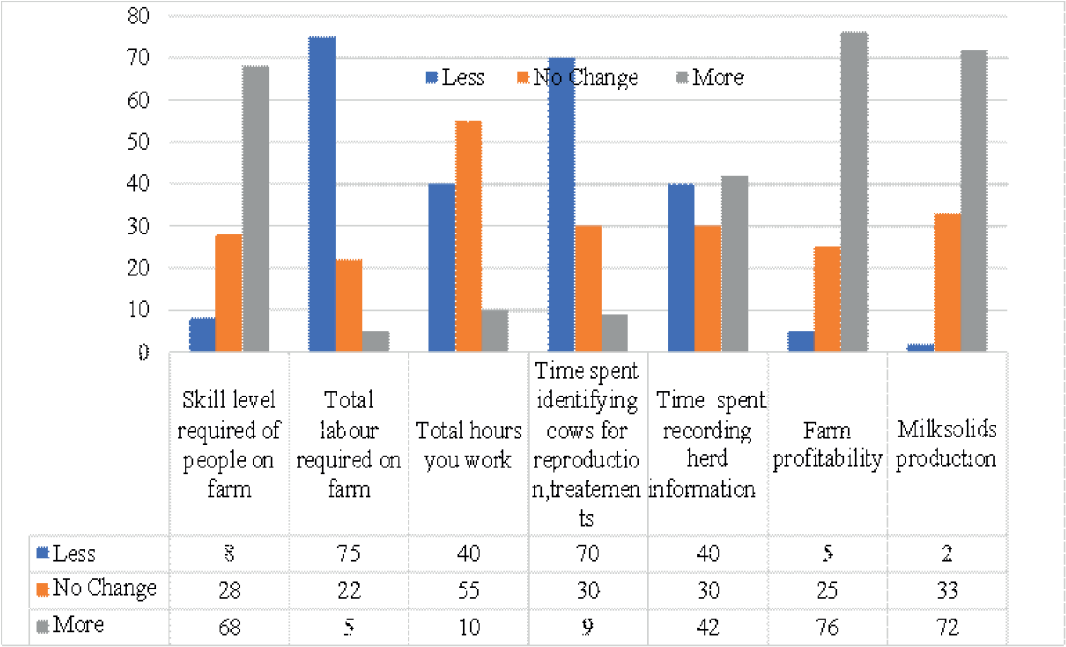

Fig. 1: Respondents' views on the relative effects of investing in precision technology on farm production, profitability, workforce skills, and routines (% of all respondents)

There was minimal difference in the views of all respondents compared to farm owners. Many respondents believed that the technology had enhanced farm profitability and milk solids production (Fig. 1). A significant proportion also noted a reduction in time spent identifying cows for reproduction and treatments (70%) and a decrease in labor requirements on the farm (75%). However, they felt that a higher skill level was necessary among the farm workforce (68%). Regarding the effect on total working hours, 40% reported a reduction in their own working hours, while 30% observed no change since the technology was introduced. Respondents had varied opinions on the amount of time spent recording herd information.

Maintenance of Technology and Adaptation of Work Routines

Participants were asked about their use of technology, with a focus on data entry and analysis, alert monitoring, training, as well as maintenance and calibration procedures. Notably, about one-third of respondents reported never calibrating their milk meters, and a quarter stated that they never calibrated their walk-over weighing systems. Regarding manually entered data, such as cow health treatments, calving dates, and insemination records, most respondents updated this information daily. More than half of the farms (54%) involved multiple individuals in the data entry process, while farms with a dedicated person assigned to the task entrusted them with all related responsibilities.

DISCUSSION

Precision dairying (PD) marks a major development in dairy farm management, characterized by the rising adoption of dairy Information and Communication Technologies (ICT) (Jago et al., 2013; Edwards et al., 2015). The implementation of precision technologies by PD farmers brings about particular challenges in learning to use and fully optimize these new tools on their farms. This group of farmers is expanding, presenting a unique challenge for farm advisory and support services.

The integration of precision technologies into farm management is considered a "high challenge" approach, demanding that farmers engage in a significant learning process (Eastwood, 2013). This transition often requires a shift in farmers' management approaches, from relying on tacit knowledge to developing a more explicit understanding (Eastwood and Kenny, 2009). The feedback from participants in this study provides valuable insights into the specific needs of PD farmers, particularly in terms of training, technical support, and potential areas for future technology advancements.

The main reason farmers in this study adopted precision technologies was to reduce labor requirements and simplify the milking process, which aligns with findings from other studies (Eastwood et al., 2012; Bewley, 2013). Although the majority of farmers expressed satisfaction with their investment and indicated they would install the technologies again, about half of the respondents reported no change in their total working hours. This suggests that time within the business was reallocated, or savings were made in labor costs.

While most farmers acknowledged the time-saving and herd management benefits of the technologies, they also recognized a gap between their current use and the full potential of the systems. They estimated around 20% of the functionality remained unused, possibly due to the software being designed for international markets and specific to housed farming systems. The challenge for farmers lies in obtaining better information to understand which aspects of this unused functionality are worth investing time and learning. Additionally, some features may be considered unnecessary or lacking sufficient value, highlighting the need to address these concerns to improve the effective use of precision technologies in dairy farming.

The benefits perceived by precision farmers are largely based on anecdotal evidence, which presents challenges in obtaining measurable data within commercial farming environments. To help farmers make informed decisions about future investments, there is a clear need for more independent, comprehensive information regarding the usage and advantages of precision technologies. The survey also revealed that a significant number of farms do not regularly

calibrate these technologies, raising concerns about farmers potentially making critical decisions based on inaccurate data. Moreover, if such data are incorporated into national databases, there could be wider implications for the industry. To address these issues, it is essential to increase awareness among farmers and their networks about the importance of proper maintenance and calibration of tools like milk meters and walk-over-weigh scales. Enhancing this awareness will help ensure the reliability and accuracy of data, leading to more effective decision-making at both the individual farm level and within the larger dairy industry.

CONCLUSION

Farmers involved in this study acknowledged the positive impacts of precision technology adoption, particularly in terms of increased profitability and improved labor efficiency. However, many questions remain about how to maximize the use of these technologies and the data they generate. Specifically, farmers remain uncertain about the potential benefits of in-bail individual feeding, how to effectively integrate different technologies and data systems, and the appropriate level of support required. To tackle these issues, technology suppliers should shift their focus toward after-sales services, offering support programs tailored to various stages of farmers' learning progress. Creating a strong value proposition will be crucial in encouraging farmers to invest in and pay for these services. Peer-to-peer learning among farmers should also be promoted as an effective way to share knowledge within the farming community. There is a pressing need for independent information to help farmers make well-informed decisions before committing to precision dairy technologies. This guidance should include advice on selecting the right technologies and optimizing their use. The collection of on-farm data presents significant opportunities for individual farmers and the dairy industry, helping with performance management and enabling quicker adaptation to changes in farm systems. Dairy organizations must take a leadership role in guiding the development of new technologies that meet the needs of farmers. This approach will help reduce the uncertainties surrounding precision dairy innovations and ensure that advancements are relevant and effective. In countries like India, where precision dairy farming is still emerging, there is considerable potential to improve animal and herd management aligning with sustainability goals, emphasizing animal health, welfare, and environmental conservation in livestock farming. Further research is necessary to explore the adoption process, overcome challenges, and ensure the successful implementation of these technologies.

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