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Role of Digital Technologies in Livestock Management

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Abstract
Farm and farmers' characteristics associated with digital technology adoption in cow, buffalo and goat farming were assessed using regression analysis. The effects for the implemented and new technologies in farm houses in Jalgaon district slightly differed. The regression analyses showed that the type of production (organic or conventional), the working time (full- or part-time business) and the agricultural area were not related to the adoption of digital technologies in ruminant farming in study area. However, farmers with larger numbers of livestock units were more likely to adopt both types of technologies than farmers keeping fewer livestock. On the other hand, age was negatively and significantly correlated to the adoption of new digital technologies: farmers were less likely to adopt this type of technology with increasing age. The zone, the main farm type, the region, the enterprise and the barn system mattered for adoption. More specifically, compared with the base category river valley, a small negative effect on the adoption of implemented digital technologies could be found for hill and mountain zones and a strong negative effect on the adoption of new technologies for the mountain zone. Farmers with animals in tie stall barns and farmers who had a combination of loose housing and tie stall systems were less likely to have implemented technologies compared with the base category loose housing. Dairy biotechnology related to cross-breeding technology, increasing disease resistance in livestock, scientific feeding of cows, embryo transmit technology, artificial insemination, development of new molecules and vaccines for prevention and disease management of animals, dairy enzymes/proteins/probiotics, food-grade bio-preservatives, etc. have perspective role livestock management in Jalgaon district and Maharashtra in special and India in general. Lack of good indigenous software, lack of management awareness, lack of computer awareness and cost of the digital technology are the factors that affect process of incorporation of technology in livestock rearing and management.

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I. Introduction

Since the inception of human civilization, animal husbandry and dairying activities, along with agriculture, continue to be an integral part of human life. These activities have contributed not only to the food basket and draught animal power but also by maintaining ecological balance. Owing to conducive climate and topography, Animal husbandry and Dairying Sectors have played prominent socio-economic role in India. Traditional, cultural and religious beliefs have also contributed in the continuance of these activities. They also play a significant role in generating gainful employment in the rural sector, particularly among the landless, small and marginal farmers and women, besides providing cheap and nutritious food to millions of people.

Growing population, changing lifestyles, expanding urbanization and accelerated climate changes are creating new challenges in Bovine breeding systems. In the past, the challenge was to ample feed, but now it is to provide essential nutrients to promote health especially reproductive health; and in the future, the challenge would be to provide optimal nutrients based on an animal's genetic profile and productivity. Fortunately, along with challenges, the developments in science are creating new avenues for tackling the challenges.

Further, biodiversity of livestock, which is so crucial for sustaining long-term productivity, is also under jeopardy. The genetically uniform systems are vulnerable to external shocks under extreme weather conditions, emerging diseases and pathogens. In livestock sector, due to continued focus on exotic germplasm based cross breeding, the number of indigenous breeds with better adaptability, disease-resistance and feed efficiency ratio is declining. The situation is made worse by unregulated blood levels in the crossbred progeny, in attempts to increase milk yield indiscriminately. Hence it is the need of the hour to conserve and improve the productivity of Indian indigenous breeds. For accomplishing this task, the department is now therefore focusing on 100 percent Artificial Insemination coverage along with the application of advanced cutting-edge reproductive technology developments.

In this context, India is blessed with a huge biodiversity of 43 indigenous cattle breeds and 13 Buffalo breeds which have survived over last hundreds of years in respect of their suitability for specific purposes in the concerned local environment. The Department's strategy is thus to enhance the average productivity of milk of select breeds from the overall available breed types (e.g. Gir for high milk productivity) from the present level of 4.85 kg per day to 6.77 kg per day per indigenous animal.

As per 19th Livestock census, there are 88 million In-Milk animals whose records are unavailable on an annual basis even. Records of those in breeding stage, their productivity, treatment and vaccination are also not properly maintained by State Animal Husbandry Departments (SAHD). This is because the system for maintaining records on the above aspects has not yet evolved in complete shape due to lack of prioritization. Impediments like lack of animal identification and traceability, inability to meet sanitary and phyto sanitary conditions also need to be addressed in this connection. In this context, an initiative has been taken namely, "E-PashuHaat", the e-market portal for bovine germplasm which provides real time data on availability of high quality germplasm along with identification and traceability of germplasm sold through e-market, connecting breeders, State agencies and stake holders. A modern technology like sexing of semen is being taken up to regulate the sex ratio and to produce large number of progenies with one sex. In advanced dairy nations, female sex sorted semen is made available to farmers to produce more number of high genetic merit heifers to increase milk production and profitability of dairy farming

The increased world population is demanding more reliable quality livestock products the number of farms is decreasing but the number of animals for per farm and animal production is increasing. In addition to this trend livestock production problems also increasing. The solution of these problems comes from multidisciplinary studies from very different fields such as technology. In large enterprises it is not possible to obtain the expected performance without using technology and automation systems from animals with very high genetic values. Daily work on livestock farming is simple in and standard application routinely Data monitoring in the modern dairy farm enables the ongoing control of production, animal health, and welfare (Ipema et al,2012). However, as the number of animals increases, error burden and work load increase. Successful livestock farmers will be capable of rapidly adapting their infrastructures to exploit changes in technology for better production. Mechanism and automation systems offer options in front of the user in intense competition for convenience. Currently, most data is extracted manually, yet manual observation is gradually being replaced by many milking systems by automated recording (milk yield, milk conductivity, activity recording and body weight measurements) leading to better data, both in quantity and quality. The number of farms automation systems has increased rapidly since 1980. Almost any medium- to large-sized farmers can benefit from enhanced automation (Thornton, 2010). There are many opportunities for facilities in automation technologies and systems. Today livestock farmers increasingly use robots on production or algorithms to optimize their farm management decisions. Technological developments are creating a new automation system in which smarter and more flexible work possibilities in livestock production (Kearney, 2017). The automation of animal husbandry and integration of on-farm systems and processes have a key role to play in facilitating the process of meeting each of important challenges for competitive market (Cornou, 2009). The main technologies are electronic recording, milking, heat detection auto-weighing, auto-drafting, genetic improvement, feeding, barn optimization, and health monitoring, livestock housing and equipment designs. These technologies provide to dairyman many opportunities to make easier and more convenient their decisions about dairy future plans.

The potential of India's huge livestock resources is grossly under utilized, necessitating more rapid progress towards boosting per unit productivity, quality of products and exports. Whereas, the demand for, and production of livestock and livestock products in less developed countries (LDCs) is expected to double over the next 20 years (Delgado et al.,1999). The overall growth rate in livestock sector is steady and is around 6% and this has been achieved despite the fact that investment in this sector was not substantial (Bhat and Das, 2002). But in terms of productivity, India's huge livestock resources are one of the poorest in the world. For instance, the milk yield of a cow in India is 900 kg, which is about 20% of the world average (Birthal and Jha, 2005).

According to Department of Animal Husbandry, Dairying and Fishery (DAHDF), the milk productivity per lactation is only 987 kg in India as against world average of 2,038 kg. Thus, the poor productivity as well as the quality of production and products remains a cause of concern in Indian livestock sector. For productivity improvement, technology generation (Research), technology dissemination (extension), technology users (farmers) and support mechanisms (inputs supply, market credit etc) have to be geared up. The functioning of various livestock development agencies especially the State Departments of Animal Husbandry (SDAH) in relation to the extension education activities performed by them need to be analyzed so as to ascertain a paradigm for livestock extension service suitable to India. To this end, it would be pertinent to review various extension mechanisms currently in operation in India and their role in delivering livestock related information to the farmers and feedback from them.

The Animal Husbandry Department (AHD) at the state level is the major stakeholder as far as livestock development is concerned. The AHD with its huge infrastructure, however, is primarily involved in treatment of animals for which it has a clear mandate. With more effective control of serious diseases such as rinderpest (now eradicated from India) and Newcastle disease and more easily available treatment for many other conditions, animal health constraints are gradually being overcome (Morton and Matthewman 1996). But the demand for information on different aspects of livestock production is growing; as also the great numbers of livestock are now kept by people without traditional background causes distinct pressure on AHD to educate the owners. It is expected that farmers' education and extension contacts enable them to acquire, receive and decode new information to evaluate benefits of alternative sources of economically useful information and to have earlier access to such information (Duraisamy, 1992; Adeokun and Akinyemi, 2003). This necessitates a system through which farmer can receive desired information. However, there is no organized system of providing extension messages to the farmers especially with regard to improved animal husbandry. The activities relating to livestock extension are sporadic and spread over time and space and do not meet the requirements of a vast majority of farmers (Lehmann et al. 1994). The problem is further compounded with the neglect of policy makers and by researchers towards livestock production extension (Morton and Matthewman, 1996; Sen, 2003; GOI 2002) since the animal health extension gets precedence over production extension in India.

II. Material And Methods

Data collection

The design of experiment was done with specific objective to assess the current state of mechanisation and automation used in cattle farms located in Jalgaon district of Maharashtra. For this purpose, specific questionnaires for 12 different types of cattle farms were visited during the study period. The questionnaires contained different numbers of questions and answer options, which are relevant to use of technology in animal farm and dairy bussiness. Because our study focused on digital technology adoption on livestock farms, questionnaires were related to dairy cattle specifically buffaloes, cows and goats. For most questions, multiple answers were possible. The answer options included various sensors and applications from the thematic areas of feeding, animal behaviour and activity, animal monitoring and identification and, if applicable, milking technologies. To better understand the adoption process, farm and farmers'characteristics related to the adoption of digital technologies in Jalgaon district farming were examined. Relevant farm variables linked to the respective farms from the questionnaires. The following variables were considered for further analyses: the continuous variables 'age', 'agricultural area' and 'number of livestock units', the dichotomous variables 'gender (male/female)', 'production system (conventional/organic)' and 'on-farm working time (part-time/full-time)'. Furthermore, the barn systems 'loose housing' and 'tie stall' were included in the analyses as well as 'both' if both systems were in use on the farm.

Statistical analysis

In the first part, frequencies of digital technology adoption were calculated for all livestock-related farm house. In the second part, farm and farmers' characteristics associated with digital technology adoption in catlle farming were assessed using regression analyses to better understand the adoption process.

Based on the results from the first part, the digital technologies were divided into implemented ones that have been already proven in practice and new ones that make farmers pioneers in their use. Thus, three categories were created: The category of implemented technologies includes all technologies used by at least 10% of the farmers surveyed. The category of new technologies includes all technologies used by less than 10%. Because multiple answers were possible, individual farmers can occur in both groups. The third group comprises the non-adopters.

Two binary regression analyses were done to evaluate correlations between farm and farmers' characteristics and the adoption of implemented and new digital technologies, each compared with the group of non-adopters. For both cases, the dependent variable was the adoption decision (0/1) and the independent variables included the farm and farmers' characteristics. Estimated marginal changes (dF/dx) in the regression results indicate the change in the probability of adoption when the respective independent variable (clustered at the enterprise level) changes by one unit while keeping all other variables at their averages. The livestock units and age variables are presented in standardised form that is, expressed in standard deviation differences from the overall sample mean. This presentation allows a meaningful interpretation because the variables contain comparatively large numeric values, so that single unit changes represent only incrementally small changes compared with the overall spread of the distribution. Results were analysed with the statistical software R Version 4.0.5 using the package 'mfx' (Fernihough, 2019).

III. Results

The farm and farmers' characteristics were described for all respondents and for ruminants including cows, buffaloes, and goat farming in Table 1.1. The farmers were on average 40 years old and predominantly male.

Table 1.1 Animal Farm and farmers' characteristics non-respondents and all livestock respondents and of respondents to ruminant farming in Jalgaon district.

Variable	Non-respondents (livestock)	All respondents (livestock)	Respondents to ruminant farming
Number (n)	986	1589	674
Age (Mean ± SE)	40 ± 4	40 ± 6	41
Total agricultural area (ha) (Mean ± SE)	18± 2	22 ± 4	21± 3
Livestock units total (Mean ± SE)	24± 3	32 ± 3	35± 4
Gender : Male (0)	972	1545	642
Female (1)	14	44	32
Production system: Conventional (0)	879	1385	589
Organic (1)	107	204	85
Working time Part-time (0)	69	176	58
Full-time (1)	917	1413	616
Zone: River valley	489	978	387
Hill	35	176	158
Mountain	462	435	129
Main farm types: Specialist field crops	12	22	8
Specialist permanent crops	4	8	5
Specialist ruminant livestock	668	1174	547
Mixed cropping	14	17	10
Mixed livestock	176	237	48
Mixed crops-livestock	112	131	56
Enterprise: Dairy Cows	302	481	192
Dairy Buffaloes	485	898	380
Dairy Goats	199	210	102
Husbandry system* Loose housing	-	-	559
Tie stall	-	-	78
Both	-	-	37

Mean values ± SD are shown for numeric variables and total numbers are shown for categorical variables. *Information from questionnaires. SE = standard error.

All respondents had an average agricultural area of 20 ha and on average 32 livestock units per farm but with high deviations from the mean values. The majority of all respondents managed the farm conventionally and full-time. About half of the farms were located in the villages belonging to tehsil viz, Chopda, Yawal, Raver, Muktainagar of Jalgaon district along the footsteps of mountains and hills of Satpuda ranges at the border of Maharashtra and Madhya Pradesh. The characteristics of farmers with ruminants differed only slightly from those of all farmers: most of the ruminant farms were located in the mountains, followed by river valley and hills. Whereas most of the cattle farmers (559) kept their animals in loose housing systems, 78 kept them in tie stall barns and 37 had both husbandry systems.

As a result of survey of dairy farm houses offline and online, it was noted that some of the technologies (Figure 1.1 to 1.4) are already in practice in Maharashtra and rest of the India, albeit the adoption is still quite low while many others are yet to penetrate the industry. Nevertheless, there is no doubt that technology is playing a key role in modernising the Indian dairy industry. Let's take a look at some key new-age dairy technologies:

Health Tracking Devices for Cattle

Health disorders reduce the productivity, longevity and reproductivity of cattle. Every year, farmers cough up huge amounts of money on their cattle's health and wellness. However, thanks to wearable animal gadgets which are akin to human fitness trackers, farmers can track, monitor and manage cattle's health, nutrition, behaviour, pregnancy, milking frequency, milk production anomaly and activity level in real-time. These smart animal trackers can be implanted in the cattle's ears, tail, legs, neck or any part of the body.Last year, Maharashtra government had implanted GPS-enabled digital chips in the ears of 56 lakh animals across the state to track their health and early diagnosis of medical condition. Some of the companies that have developed smart cattle health tracking devices are SmaXtec, Cowlar, Moocall, Smartbow, Stellapps, etc.

Figure 1.1 Cowlar, a wearable that can be attached to cows on a collar and used to better manage a herd of dairy bovines.

Instead of helping to improve a cow's health via exercise, the Cowlar tracks metrics such as eating, sleeping, mating and even its temperature. All of these aspects are important to farmers hoping to increase how much milk each cow produces, how long it will live and its mating patterns. The Cowlar sends this information to solar-powered base station up to four kilometres away where it can then be relayed to the farmer in a number of ways. They can receive a SMS alert, an automated phone call.

Robotic Milking Machines

Traditionally, cows have always been milked manually by hands. This is not only a time-consuming activity but also has labour cost associated with, thereby increasing the price of milk. Robotic milking machines are enabling farmers toeliminate the pressure on physical labour, maintain a hygienic milking process, milk the cows anytime of the day instead of following a fixed schedule and improve the milk production.

The robotic milking machines have arms or cups with sensors that can be attached individually to cows' teats. The sensors can detect whether the cow or which of its teat is ready for milking or not. Once the milking starts, the machines can also identify impurities, colour and quality of milk. If the milk is not fit for human consumption, it is diverted to a separate container. The machines can also automatically clean and sanitize the teats once the task is over.

Figure 1.2 Automation in Diary cows in Jalgaon district of Maharashtra

Raghava Gowda from India has developed a low-cost, non-electric milking machine for cows. Some other startups which have introduced automated milking systems are miRobot, GEA, DeLaval, Fullwood Packo and Lely among many others.

Figure 1.3 The miRobot used as milking machine in diary cattle farming in Jalgaon district of Maharashtra

The miRobot is developing the next-generation automatic robotic milking system for cost-effective, high-performance milking in medium and large dairy farms (150 to >1,000 cows). Designed as an add-on to conventional milking parlor equipment, miRobot's system comprises fully automatic robotic arms installed in each milking stall. The robotic arms perform cleaning, stimulating, attaching the milking cluster, and post-milking routines to enable a milking procedure that is very high quality and uniform.

The miRobot multi-stall system will allow farmers to –

- Establish big data infrastructure in the milking parlor
- Milk dozens of cows simultaneously with only one supervisor, compared to current operations, which requires three to six operators

Cattle Monitoring Drones

Farmers are required to keep a manual vigilance whenever the livestock moves out of the farm for grazing. There are high chances of the cattle getting lost, stolen or being attacked by other animals. The cattle monitoring drones can keep track of the cattle and herd them back from fields to barns. Some drones are equipped with thermal sensing technology, which helps to track the cattle from the heat of their bodies. Drones can also capture the pictures of pasture areas and relay information as to whether these are suitable for cattle grazing.
A number of companies such as TRITHI Robotics, Dronitech, Sagar Defence Engineering, DJI Enterprise and Sunbirds have made headway in building commercial drones for various purposes, including for agriculture and livestock management.

Figure 1.4 Use of GPS and cattle monitoring system in Dairy farms of Jalgaon district of Maharashtra

Product Traceability for Customers through Blockchain

These days, customers like to know the journey of their dairy products from farm to table. This calls for end-to-end supply chain transparency to enhance the trust of customers. An increasing number of dairy manufacturers, suppliers and other stakeholders are leveraging blockchain technology to give real-time data about their products to customers. This is done by putting a QR code on the packaging which customers can scan on their mobile devices to get information on the origin of the milk – how and where it was collected and packed, how old it is, what kind of transportation and cold milk chain facilities were used, etc.

The Maharashtra and Kerala government in India is leveraging blockchain technology to streamline purchase and distribution of milk, fish and vegetable in the state. The international food giant Nestle has tied-up with Australian startup OpenSC to deploy blockchain technology in to improve its dairy supply chain. French supermarket Carrefour sells its micro-filtered full-fat milk in bottles with a QR code. Some of the startups operating in food biotech are StaTwig, Ripe, AgriLedger, TE-Food and Foodcoin.

Milk Freshness

Milk is a highly perishable product. In spite of treating it with pasteurization, freezing and preservation processes, it has a tendency to go stale. Millions of tons of milk turns stale before timely consumption and goes waste. Efforts are also being consistently made to increase the shelf life of milk without adding additives or preservatives.

Technology is now making it possible to detect the freshness of milk and store it for a longer period of time. Australia-based food technology company Naturo has developed a technology that can keep natural milk fresh in the refrigerator for at least 60 days without using any additives or preservatives. US scientists have pioneered a new pasteurization technique which increases shelf life of fresh milk from 13 days to 40 days without changing its taste or nutritional value. Back home in India, IIT Guwahati scientists have developed a smartphone-app aided paper sensor kit that can test the freshness of milk and inform how well it has been pasteurized. This kit can come quite handy in large kitchens, milk collection centres and milk bars.

Figure 1.5 Milk fresher technology in dairy farm of Jalgaon district.

Automated Cattle Traffic Management

It can be an extremely tedious task to manage and move cattle to milking stalls and back to barns. There is also a risk of injuries to the cattle. Automated cattle traffic management system has computer-controlled gates which opens and closes electronically. These gates can sort the livestock on the basis of their readiness to milk. The livestock ready to be milked is moved to the milking area while the others are either put in the waiting area or returned to the barns. Companies like Delmer, Bump Gates, Fullwood Packo and Lely are known for their automatic cattle traffic systems.

Feed Management

The feed requirement of cattle depends on their health and weather. For example, a sick or pregnant cow may need more nutrition. Hot and humid weather means that cattle need more glucose in their feed.There are a number of feed technologies that produce formulated feed additives, supplements, premixes and base mixes to maintain optimal milk production throughout the year. For example, the National Dairy Development Board (NDDB) has developed bypass protein technology to produce specially treated protein supplements that can be fed to cattle to increase milk yield and quality.

Then, there are also digital feed monitoring solutions which can help farmers detect the quality of feed, manage feed inventory and understand cattle's feeding pattern. In fact, feed monitoring solution can help design customized diet for each cow based on the assessment of their body weight, milk quality and yield, and thereby improve fertility and productivity per cow. Some of the companies providing feed management solutions are Godrej Agrovat, DeLaval, Dairy Margin Tracker, etc.

Ecommerce Market places
Several online B2B marketplaces such as AgroStar and Gold Farm have been launched in India to make modern equipment and advisory services available at the doorstep to farmers and dairy manufacturers on their smartphones. Many B2C platforms such as FreshVnF, WayCool and FarmLink have also emerged at a rapid pace – they pick fresh produce from farms and deliver them at the doorstep of retail customers, hotels, restaurants and cafes.

Supply Chain Technology
The Indian dairy industry supply chain is quite complex owing to its dependency on a number of factors such as storage temperature, cold chains availability, weather, perishability/shelf life, first and last-mile distance, packaging, etc. The fact that the Indian dairy industry is unorganized and fragmented also adds to the supply chain woes. However, a number of technological innovations are taking place in the dairy supply chain in India. Take, for example, India-based supply chain startups such as Stellapps, MilkManApps and Trinetra Wireless.
Under supply chain, cold chain technology is expected to progress by leaps and bounds. The coming years will witness the rise of energy-efficient and cost-effective cold chain warehouses, cold boxes, Phase Changing Material (PCM) pads, temperature-controlled cold chain packing, refrigerated vehicles, cold chain pallet shippers, and other advanced cooling technologies. Tessol and Warehouse-India startups are making their mark in cold chain infrastructure in India.

Farm Management Technology
From accounting, finance and labour management to livestock and supply chain management, a dairy farm has to ensure that all its operations run seamlessly. Farm management software can help automate and digitize end-to-end production and operations activities. It can give a holistic view of all farm activities, manage records, generate reports and detect inefficiencies. Stellapps, Milc Group, My Dairy Dashboard and Nedap are some of the smart farm management solutions that exist currently.

Frequencies of digital technology adoption in ruminant farming
Dairy farms located in various tehsils of Jalgaon district were surveyed through personal visits and based on the information obtained Table 1.2 shows the three questions concerning the adoption of technologies related to:
(1) Electronic sensors measuring devices namely Pasture growing measurement, Roughage intake, Animal tracking systems, Rumination sensors, Activity sensors, Electronic ear tags, Electronic weighing system, Camera monitoring ,Milk conductivity sensor,Concentrate feed intake, Milk temperature sensor, Transponder collar, Milk flow sensor and Digital milk meter used in diary farming (2) Electronic controls like Automatic feeding system, Selection gates, Automatic calf feeder and Concentrate feeding station used in animal farming and (3) Electronic data-processing options like Body condition scoring with camera system, Pasture management, Disease detection, Feed ration planning, Oestrous detection, Data transfer into herd management systems, Concentrate feed allocation depending on milk yield are adopted. Compared with farmers in all other cattle farm houses, farmers with dairy buffalo used digital technologies the most, which is illustrated by the answer option 'none' being ticked by 35.7%, 31.3% and 47.3% for electronic sensor measuring devices, electronic controls and electronic data-processing options used respectively.

Table1.2 Frequencies (%) of adoption of electronic sensors and measuring devices, electronic controls and data-processing options in cattle farms of Jalgaon district in Maharashtra

Electronic sensors and measuring devices used	Dairy Cow (n = 347)	Dairy Buffalo (n = 553)	Dairy Goat (n = 210)	Percentage total
None	112	159	98	35.7
Others	4	8	3	2.9
Pasture growing measurement	1	2	0	2
Roughage intake	2	4	1	3
Animal tracking systems	2	7	1	4
Rumination sensors	1	2	0	2
Activity sensors	3	5	0	4
Electronic ear tags	2	6	2	5
Electronic weighing system	4	6	1	5

Camera monitoring	15	54	4	24
Milk conductivity sensor	4	12	NA	7
Concentrate feed intake	6	18	1	8
Milk temperature sensor	2	8	NA	5
Transponder collar	8	24	2	11
Milk flow sensor	12	42	0	18
Digital milk meter	18	47	NA	22
Electronic controls Used	Dairy Cow	Dairy Buffalo	Dairy Goat	
	(n = 325)	(n = 527)	(n = 198)	Percentage total
None	102	128	78	31.3
Others	4	7	5	5
Automatic feeding system	2	6	1	3
Selection gates	2	8	1	5
Automatic calf feeder	8	14	NA	7
Concentrate feeding station	12	24	1	12
Electronic data-processing options adopted	Dairy Cow	Dairy Buffalo	Dairy Goat	
	(n = 296)	(n = 489)	(n = 178)	Percentage total
None	156	178	97	47.3
Others	3	0	2	2
Body condition scoring with camera system	2	2	NA	3
Pasture management	1	3	NA	1
Disease detection	1	5	NA	2
Feed ration planning	3	6	0	3
Oestrous detection	10	15	1	8
Data transfer into herd management systems	5	12	0	5
Concentrate feed allocation depending on milk yield	2	8	NA	3

NA = not applicable.

Dairy cattle farmers most commonly applied easy-to-use digital technologies related to the milking process. For example, digital milk meter was the most frequently used technology in dairy buffalo, with 47%, followed by 18% in dairy cow farms. Likewise, transponder collar, milk flow sensor and concentrate feed intake were ticked by more than 18% of the dairy cattle farmers. Digital milk meters were also the most frequently used sensors for dairy cow and buffalo but most of the dairy goat farms are without the same technology. The surveillance by digital cameras were the most likely adopted electronic system by dairy goat with 4% followed by dairy cow with 15% and its highest percentage (54%) was found in dairy buffalo. Electronic controls in the form of Automatic feeding system, Selection gates, Automatic calf feeder and Concentrate feeding station were adopted by Dairy cow and buffalo farms with significant percentage.

Expert autoamatic feeding system, dairy goat farms also had Selection gates, Automatic calf feeder and Concentrate feeding station. In relation to electronic data processing system, dairy cow and buffalo farms located in various tehsils of Jalgaon district adopted statistically significant Body condition scoring with camera system, Pasture management, Disease detection, Feed ration planning, Oestrous detection, Data transfer into herd management systems, Concentrate feed allocation depending on milk yield.

Farm and farmers' characteristics associated with digital technology adoption in cow, buffalo and goat farming were assessed using regression analyses. The effects for the implemented and new technologies in farm houses in Jalgaon district slightly differed. The regression analyses showed that the type of production (organic or conventional), the working time (full- or part-time business) and the agricultural area were not related to the adoption of digital technologies in ruminant farming in study area. However, farmers with larger numbers of livestock units were more likely to adopt both types of technologies than farmers keeping fewer livestock. On the other hand, age was negatively and significantly correlated to the adoption of new digital technologies: farmers were less likely to adopt this type of technology with increasing age. Furthermore, the results indicated that female farmers were less likely to adopt any type of digital technology compared with male farmers. The zone, the main farm type, the region, the enterprise and the barn system mattered for adoption. More specifically, compared with the base category river valley, a small negative effect on the adoption of implemented digital technologies could be found for hill and mountain zones and a strong negative effect on the adoption of new technologies for the mountain zone. Farmers with animals in tie stall barns and farmers who had a combination of loose housing and tie stall systems were less likely to have implemented technologies compared with the base category loose housing.

IV. Discussion

In the past few years, the Indian dairy industry has received a tremendous boost through technology-driven products, services and solutions, the credit for which deservingly goes to agricultural and dairy startups. The differences in adoption pattern between the animal species show that there are areas and production branches in which the use of digital technologies is already commer cially implemented. This is mainly the case in the dairy sector. Compared with other livestock sectors, the dairy cattle sector has by far more digital technologies available (Stachowicz and Umstätter, 2020). The milking process is time-consuming and related to a high physical workload, so that the expected advantage of using digital technologies quickly becomes apparent. User-friendly technologies that are integrated for example, in the milking parlour have higher adoption rates in practice than technologies that collect additional data on the animal or in the barn, for example, for disease detection and that may be bought separately. An exception is the electronic data processing options data transfer into herd management systems, which was ticked by more than 10% of the farmers in each of the groups. However, the usage has a direct benefit because many animal-related parameters have to be recorded in general for quality assurance and documentation purposes and are therefore essential for economically viable production. It can be therefore concluded that political incentives can also lead to increased adoption.

Results of the present study confirmed the results from other countries for which the use of digital technologies in dairy production has been investigated. A study from New Zealand showed that technologies related to the milking process itself are used more than information collection technologies for example, for disease detection or heat detection (Edwards et al., 2015). Gargiulo et al. (2018) evaluated different adoption patterns according to herd sizes among Australian farmers and found that larger farms adopt more precision dairy technologies than smaller ones. In our study, the number of livestock units was also positively correlated to the adoption of digital technologies

However, results moted in the present study also show that there are still dairy farms that are managed almost without or with sporadic use of digital technologies. This is especially the case for agricultural enterprises that have a low production value per se or where the workload per livestock unit is comparatively low. But even in the dairy sector a considerable share of farmers did not use digital technologies at all. With regard to the high workload for milking, this is a surprising result for a country where dairy farming is very widespread. On the other hand, it is also possible that farmers stated using none of the surveyed technologies but that certain technologies are automatically integrated, for example, into the milking parlour, so that it is not always an active decision to have them and use them.

Barkema et al. (2015) investigated the worldwide commercial implementation of milking robots in a comparative study. Their results showed that the use of milking robots varies between 5% in Canada and over 20% in Sweden and Denmark. Almost 4% of the surveyed farmers used a milking robot in present study, thus Jalgaon district is in the lower international range here. Nevertheless, milking robots are not stand-alone units because they contain a large number of sensors and measuring systems that automatically record and connect data, even if the farmer may not use all available information (Ordolff, 2001). However, the share of farmers using robots on their farms is still very small and mainly limited to dairy farming.

None of the participating farmers in our study indicated using pasture growth measurements, and only 1% stated using data-processing options for pasture management. Also, Gargiulo et al. (2018) found low adoption rates for automated pasture measurement in Australia, possibly because it is very time-consuming and difficult to apply. An international survey regarding the use of precision livestock farming technologies in dairying showed that mastitis, nutrition and reproduction were high-priority research topics, whereas goat farming and grassland management ranked as lower priority (Palczynski, 2016). Animal diseases generate a wide range of biophysical and socio-economic impacts that may be both direct and indirect, and may vary from localized to global. The economic impacts of diseases are increasingly difficult to quantify, largely because of the complexity of the effects that they may have, but they may be enormous: the total costs of foot-and-mouth disease in the UK may have amounted to \$18–25 billion between 1999 and 2002 (Bio-Era 2008).

In the developing world, there have been relatively few changes in the distribution, prevalence and impact of many epidemic and endemic diseases of livestock over the last two decades, particularly in Africa, with a few exceptions such as the global eradication of rinderpest. Over this time, there has also been a general decline in the quality of veterinary services. A difficulty in assessing the changing disease status in much of the developing world is the lack of data, a critical area where progress needs to be made if disease diagnostics, monitoring and impact assessment are to be made effective and sustainable. Globally, the direct impacts of livestock diseases are decreasing, but the total impacts may actually be increasing, because in a globalized and highly interconnected world, the effects of disease extend far beyond animal sickness and mortality (Perry and Sones, 2009).

Ryan and Wilson (1991) reported that, the 'National Disease Control Information System' (NDCIS) of New Zealand, consists of a set of independent computers database on animal diseases such as tuberculosis and brucellosis, which is a good example of possible applications of digital technologises in improving the animal health. Jalvingh et al. (1995) and Sanson et al. (1999) reported that, because of their economic importance, contagious animal disease outbreaks require rapid identification and elimination of all virus sources. For managing the vast amount of data and for help in setting the correct priorities, the use of computerized decision support systems (DSS) seems to be promising.

However, worldwide comparison or ranking of adoption rates for digital technologies is difficult because there is no uniform survey method and almost no representative study. For example, several studies used voluntary online surveys with the selection bias that participants may be relatively technically inclined farmers who use computers and the Internet in general (Gargiulo et al., 2018). Furthermore, the sampling procedure should be representative and cover as far as possible all size classes of farms in order not to over esti mate or underestimate the adoption rate. As an example, in a multidisciplinary study by Gargiulo et al. (2018), an online questionnaire was distributed using a snowball method among industry contacts and their network. Although 301 questionnaires were received, there were no selection criteria for the survey sample. In our study, we considered almost all Swiss farms for random sampling and stratified the sample for each farm type to ensure that farms of different size classes were addressed. This approach makes this study more significant and representative than most available studies.

Overall, our findings show that production-intensive livestock farming enterprises such as dairy cattle, breeding pigs or poultry often use digital technologies, even if it is not possible to deduce the entire adoption from example technologies for pigs and poultry. However, although only example technologies were surveyed for these two enterprises, trends can still be identified. Considerably more farmers used electronic ear tags for breeding pigs than for fattening pigs. This difference could be due to the different production systems. Breeding pigs are very labour intensive and require a higher level of management, whereas pig fattening involves fewer work processes.

Farm and farmers'characteristics in Jalgaon district

In the present study, an increase in age was associated with a decrease in the likelihood to adopt new technologies, whereas no correlation could be found for technologies already implemented. The number of livestock units as proxy for farm size was positively correlated with both types of technologies even though the effect was stronger for implemented than for new technologies. The agricultural area did not matter for adoption. These findings confirm the inconsistent results from the literature for age and farm size. For example, age and farm size were not associated to the adoption of electronic identification tools for gaot, whereas the likelihood of adoption of nutrient abatement technologies increased with increasing farm sizes and decreased for older farmers (Lima et al., 2018; Konrad et al., 2019). Furthermore, a recent study investigated the adoption of digital technologies among crop, dairy and livestock producers in the USA with the results that size (expressed as hectares and numbers of animals) was positively correlated with Internet access and level of usage and gender (women), farm income and education level (Drewry et al., 2019). In our study, however, female farmers were less likely than male farmers to adopt digital technologies, but the sample included only very few female farmers. Interestingly, our results further showed that farmers using tie stall barns adopted less technology, both implemented and new, compared to farmers using loose housing systems, likely because many technologies do not bring an added value in tie stall barns, where cows cannot express their behavior freely.

The finding that the zone correlated with technology adoption was to be expected and confirms the results of a recent study on the adoption of precision agricultural technologies on Swiss crop farms (Groher et al., 2020). Mountain farms in particular often generate less income (FSO, 2019b) and have to cope with difficult production conditions, which may explain the strong negative correlation on new technology adoption. However, small and inexpensive technologies can also support these farms. For example, activity sensors, electronic identification tools or animal tracking can be used to remotely monitor animal behaviour or location. Moreover, precise pasture management could help to use existing resources more efficiently. Apart from the many opportunities that the use of digital technologies offers, some studies have explored the barriers in the adoption of digital technologies in agriculture (Wathes et al., 2008; Drewry et al., 2019). For instance, a major challenge is the interpretation of the recorded data because the time-varying and individual behaviour of each animal makes an interpretation difficult (Palczynski, 2016).

An additional barrier in the adoption of technologies can be the insufficient robustness of sensors (Wathes et al. , 2008). Additionally, systems of different manufacturers may be incompatible and a combination of data received from different sensors must be transformed into usable information (Van Hertem et al., 2017). Certainly, the financial advantage is one of the major determinants in the adoption decision (Reichardt and Jürgens, 2009; Pathak et al., 2019). The farmers' view seems to be that the use of modern technologies and smart farming is very expensive and only profitable for larger farms, maybe due to the perception of high costs and the complexity. However, there are other technologies that are inexpensive, easy to use and do not entail enormous costs (Schrijver et al., 2016). Interestingly, Lima et al. (2018) found that users of digital technologies are more likely to see the technologies as useful and practical than non-adopters showing that farmers' perceptions and beliefs are also important determinants in technology adoption.

Role of Biotechnology in cattle dairy farming

Biotechnology is a relatively emerging field in the dairy industry. However, it is being touted as one of the most disrupting dairy technology of the future. The potential of dairy biotechnology lies in the areas such as cross-breeding technology, increasing disease resistance in livestock, scientific feeding of cows, embryo transmit technology, artificial insemination, development of new molecules and vaccines for prevention and disease management of animals, dairy enzymes/proteins/probiotics, food-grade bio-preservatives, etc.

Breeds in animal husbandry has changed a lot with the use of breeding and gene technology. Till 1980s livestock products demands have been met by breed substitution, cross-breeding, and within-breed selection. But these demand in future is to be met using new techniques such as such as artificial insemination and more specific selection techniques. Genomic selection provides more possibilities for the higher rate of genetic gain in the livestock sector. After all genomic breeding values will be calculated from the genetic marker, rather than from pedigree and phenotypic information in near future. The genome maps for poultry and cattle is completed and these developments provide new opportunities for animal breeding and animal models (Lewin, 2009). Leakey (2009) reported that DNA-based tests for genes or markers affecting traits that are difficult to measure currently, such as meat quality and disease resistance, will be particularly useful. But genetic resources still important for helping livestock adapt to changing the climate (Thornton, 2010). Native breeds are to genetic insurance against future challenges. In combination with modem reproductive technologies, there is potential to use frozen and stored germplasm (genetic resource banks) to support conservation measures for the maintenance of genetic diversity in threatened species. Besides the direct application of technologically advanced reproductive procedures, modern approaches to non-invasive endocrine monitoring play an important role in optimizing the success of natural breeding programs (Holt and Pickard, 1999). A separate progeny-test category may be developed for farms that collect all data electronically and have those data monitored closely. Automated data collection along with parentage verification offers substantial opportunities for genetic improvement of overall economic merit. Nowadays biological samples are sent laboratory for genetic analysis to identify the relevant genes responsible for productive parameters. Also, selective breeding can reduce the need for alternative methods.

Some of other examples of dairy biotechnology products that have made headlines are animal-free ice cream by Perfect Day, livestock disease diagnostic tools by Advanced Animal Diagnostics, bovine genetics breeding by Genus ABS India, etc. The above mentioned list of technologies is inclusive but not exhaustive. Currently, most dairy technologies face adoption barriers in India because a large percentage of the Indian dairy industry still comprises of small-scale and unorganised players who lack financial means, accessibility and expertise to deploy the technology. The good news is that dairy technological revolution has already begun in India, and it's only a matter of time that these technologies become common.

Factors affecting technology adoption specifically in Maharashtra and in India as whole:

a) Lack of good indigenous software: Absence of commercially available software with technical support, local terminology and availability in regional languages is the single foremost factor which has prevented the large-scale usage of herd management software in India.

b) Lack of management awareness: In most dairy farms, the only parameter in which the owner is interested is the total milk yield produced by the herd every day; individual management records are rarely maintained. Motivation to the farmers to take up computerized farm recording would be a major challenge.

c) Lack of computer awareness: With the computer becoming omnipresent from primary schools to financial institutions, this factor is not such an insurmountable one, especially given the fact that most modern dairy farms are located in peri-urban areas.

d) Cost factor: A dust-free room and stable power with adequate backup are essential that are not affordable for every farm owner.

Limitations and benefits of automation in dairy farms

The main focus of this study was to assess the state of automation and mechanisation in diary farms of Jalgaon district of Maharashtra. Therefore, questions related to digitalization in agriculture were only one of many parts of the survey with limited scope. The selection of technologies were based on a literature research, always with regard to technologies that were known to be relevant for India. Although we thoroughly chose these technologies based on these criteria, it is of course possible that some technologies were missed on the list. Furthermore, personal motives to investigate the farmers' perceptions and possible barriers to adoption of technology were not surveyed and are therefore a possible subject of future research, to further understand the adoption process. The presented results are mainly in line with the existing literature and low adoption rates are as expected, which we now evidenced by research data. The present study extends the adoption literature by deriving knowledge from survey data combining a representative random sampling procedure with a considerably large response rate, which provides us a representative picture of the overall farming population in Switzerland. Technology adoption, especially of digital technologies, is evolving over time. Therefore, it is beneficial to study the overall adoption rate in different countries or regions to get an up-to-date view on current developments that can be used to derive knowledge on determinants for technology uptake.

V. Conclusion

The adoption of digital technologies in livestock farming in Maharashtra in general and Jalgaon district in special varies strongly between different agricultural groups and is most common on large specialist ruminant livestock farms. The industrial revolution has made a radical change in the production method and systems throughout the world. The net result has been the more comfortable animal, higher production, and decreased labor. The rapid penetration of these new age technologies will provide a further layer of sophistication of farm work and new strategies in animal production. Future disease trends are likely to be heavily modified by disease surveillance and control technologies.

In general, easy-to-use sensors and measuring devices, for example, integrated in the milking automated system is more widespread than data-processing technologies. The husbandry system also determines the use of digital technologies, with the result that farmers with tie stall barns are less likely to use digital technologies than farmers with loose housing systems. Studies of farmers' personal determinants of adoption and prospects of implementation can help identify further barriers to the adoption of digital technologies. Since most of the dairy farms are located in peri-urban areas, the economical status is main constrains for most of livestock of farm owners.

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