



T.R.
ONDOKUZ MAYIS UNIVERSITY
INSTITUTE OF GRADUATE STUDIES
DEPARTMENT OF AGRICULTURAL ECONOMICS

EFFICIENCY ANALYSIS AND INNOVATION ADOPTION
AMONG THE DAIRY FARMS OF PUNJAB, PAKISTAN

Ph.D. Thesis

Umer bin KHALID

Supervisor
Prof. Dr. İsmet BOZ

SAMSUN
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ACCEPTANCE AND APPROVAL OF THE THESIS

The study entitled “EFFICIENCY ANALYSIS AND INNOVATION ADOPTION AMONG THE DAIRY FARMS OF PUNJAB, PAKISTAN” prepared by **Umer bin KHALID**, and supervised by **Prof. Dr. İsmet BOZ**, was found successful and unanimously accepted by committee members as Ph.D. thesis, following the examination on the date 8.4.2022

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Head of Institute of Graduate Studies

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I hereby declare and undertake that I complied with scientific ethics and academic rules in all stages of my Ph. D. Thesis, that I have referred to each quotation that I use directly or indirectly in the study and that the works I have used consist of those shown in the sources, that it was written in accordance with the institute writing guide and that the situations stated in the article 3, section 9 of the Regulation for TÜBİTAK Research and Publication Ethics Board were not violated.

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19/07/ 2022

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AMONG THE DAIRY FARMS OF PUNJAB, PAKISTAN

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ÖZET

PAKISTAN'IN PUNJAB İLİNDE FAALİYET GÖSTEREN SÜT İŞLETMELERİNDE ETKİNLİK ANALIZI VE YENİLİKLERİN BENİMSENMESİ

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Tarım Ekonomisi Ana Bilim Dalı
Doktora, Ağustos /2022
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Bu çalışmanın amacı, Pakistan'ın Pencap ilindeki süt işletmelerinde verimlilik analizi ve yeniliklerin benimsenmesini incelemektir. Araştırmanın ana materyali rastgele örnekleme tekniği ile Cochran formülüne dayalı olarak 300 süt işletmesi ile yapılan anketlerden sağlanan verilerden oluşturulmuştur. Süt işletmelerinin aylık ortalama brüt kar marjı 114220.67 Rs olmuştur. Süt üreticilerinin ortalama teknik etkinlik düzeyi 0.907, ortalama tahsis etkinlik düzeyi 0.66 ve ekonomik etkinlik düzeyi 0.60 olmuştur. Çiftçinin eğitim düzeyi, ana gelir kaynağı olarak süt, sağım makinesi, aşılama, parazit tedavisi, mısır silajı, mineral ve tuz, internet, sosyal medya ve kesif yem kullanma değişkenleri, süt çiftçilerinin teknik etkinliği ile pozitif ve anlamlı bir ilişkiye sahiptir. Tahsis etkinliği durumunda eğitim düzeyi, sağım makinesi, süt soğutma, mısır silajı, sosyal medya ve internet ile kesif yem arasında pozitif ve anlamlı ilişki bulunmuştur. Ekonomik etkinlik durumunda açıklayıcı değişkenler; süt üreticilerinin eğitim düzeyi, sağım makinesi, süt soğutma, aşılama, mineral ve tuz, mobil internet üzerinden sosyal medya ve kesif yem arasında pozitif ve anlamlı ilişki bulunmuştur. Etkinlik düzeyleri ve sosyoekonomik özelliklerin, yenilik sürdürülebilirlik indeksi arasındaki ilişkiler incelendiğinde; teknik, tahsis ve ekonomik etkinlikler, hayvan başına süt verimi ve eğitim seviyesinin yenilik sürdürülebilirlik indeksi ile pozitif korelasyon gösterdiği görülmüştür.. Çalışmanın altıncı amacı ikili lojistik model kullanılarak gerçekleştirilmiştir. Çiftlikte yaş, aile büyüklüğü, kredi hizmeti ve işe alınan emek, benimseme düzeyini olumsuz etkilemiştir. Yaş ile benimseme düzeyi arasında anlamlı negatif bir ilişki bulunmuştur. Çiftçilik deneyimi, sağılan hayvan sayısı, sürüdeki inek yüzdesi, veterinerlik hizmetleri, çiftlikteki egzotik ırklar ve sosyal medya kullanımı benimseme düzeyi ile pozitif ve anlamlı bir ilişkiye sahiptir. Hükümet, güncel bir şekilde teknolojileri sübvansetmeli ve ekonominin bu hareketli sektörünü desteklemek için düzenli yayım ve eğitim programları uygulamalıdır.

Anahtar Sözcükler : Süt İşletmeciliği, Etkinlik Düzeyi, Yeniliklerin Benimsenmesi, Toplam Bilgi Puanı, Yenilik Sürdürülebilirlik Endeksi,

ABSTRACT

EFFICIENCY ANALYSIS AND INNOVATION ADOPTION AMONG THE DAIRY FARMS OF PUNJAB, PAKISTAN

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The purpose of this study was to determine the efficiency analysis and innovation adoption among the dairy farms in Punjab, Pakistan. The main data source for this investigation was questionnaires conducted with 300 dairy farmers based on Cochran's formula through random sampling technique. The mean monthly gross margin of the dairy farms was 114220.67 Rs. The mean technical efficiency, allocative efficiency, and economic efficiency of dairy farms in the research area was 0.907, 0.66, and 0.60, respectively. Education level, milking herd size of the farmer, dairy as main income source, owning milking machine, vaccination, using maize silage, using minerals and salt, using the internet and social media, and using concentrate feeds had positive and significant association with the technical efficiency of dairy farmers. In case of allocative efficiency, education level, milking machine, milk refrigeration, maize silage, social media and internet, and association membership had positive and significant relationship. In case of economic efficiency, the explanatory variables like; education level of dairy farmers, milking machine, milk refrigeration, vaccination, mineral and salt, social media through mobile interne, maize silage and assocation membership had positive and significant association. The technical, allocative and economic efficiency positively correlated with innovation sustainability index, and total information score, milk yield per animal area under forage crops, milking animals and number of cows at dairy farm also correlated with the index. The innovation and management practices were determined to fulfil the fifth objective of the study. The vaccination is most commonly adopted innovation practice among the low and high level adopters followed by social media through mobile internet. The sixth objective of the study fulfilled by using binary logistic model. Age, family size, credit service and hired labor at farm negatively affected the adoption level. Farming experience, number of milking animals, percentage of cow in the herd, veterinary services, exotic breeds at farm and social media use had positive and significant association with the adoption level. Government should subsidize the diary technology and improve the veterinary services at gross root level through regular interaction and regular training programs to support the vibrant sector of the economy.

Keywords: Dairy Farming, Efficiency Level, Innovation Adoption, Total Information Score, Innovation Sustainability Index

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SYMBOLES AND ABBRIVATIONS

DEA	: Data Envelopment Analysis
SPF	: Stochastic Frontier Analysis
CRS	: Constant Return to Scale
VRS	: Variable Return to Scale
ISI	: Innovation Sustainability Index
TE	: Technical Efficiency
AE	: Allocative Efficiency
EE	: Economic Efficiency
GOP	: Government of Pakistan
TL	: Turkish Lira

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1. INTRODUCTION

1.1. An Overview of Agriculture Sector in Pakistan

The development of agriculture sector is crucial to Pakistan's macroeconomic goals because of its forward and backward ties with other sectors of the economy. Accelerated agricultural expansion contributes immediately to poverty reduction and meeting the food demands of low-income group. Agriculture accounts for 20.9% of Pakistan's GDP and employs 43.5% of the workforce, with 60% of the rural population relying on it. Agriculture and agriculture-based processed products account for 70% of overall exports in the country (GOP, 2020).

1.2. Performance of Agriculture Sector During 2020-21

In Pakistan, there are two farming seasons. The "Kharif" sowing season lasts from April to June and harvested between October and December. The important crops are wheat, rice, maize, sugarcane, and cotton. Rice, sugarcane, cotton, maize, moong, mash, bajra, and jowar are among the "kharif" crops. The second sowing season, known as "Rabi," runs from October to December and harvested from April to May. "Rabi" crops include wheat, gram, lentil (masoor), tobacco, rapeseed, barley, and mustard. The water availability is critical in this season for decent production.

Table 1.1. Growth in Agriculture sector (% , Base=2005-06)

Sector	FY 2017	FY 2018	FY 2019	FY 2020	FY 2021
Agriculture	0.15	2.18	4.00	0.58	2.77
Crops	-5.27	1.22	4.69	-4.96	2.47
i) Important Crops	-5.86	2.60	3.56	-7.68	4.65
ii) Other Crops	0.40	-2.51	6.26	2.59	1.41
iii) Cotton Ginning	-22.12	5.58	8.80	-12.74	-15.58
Livestock	3.36	2.99	3.70	3.82	3.06
Forestry	14.31	-2.33	2.58	7.87	1.42
Fishing	3.25	1.23	1.62	0.80	0.73

Source: Pakistan Bureau of Statistics

About 3% growth rate experienced in the overall crop sector due to the timely availability of quality inputs (canal water, certified seed, certified pesticides, certified chemicals and timely disbursement of credit) despite of poor fertilizer application methods and dosages. The most significant crop in Rabi season is wheat, increased production by 8.1% to a record-breaking 27.293 million tonnes from 25.248 million

tonnes the previous year. Due to a boost in the production of vegetables, fruits, fodders, and other crops, which make up 2.24% of the GDP and 11.69% of agriculture value addition, indicated a growth of 1.41%. The production of cotton crop declined, and this resulted in a 15.58% decline in cotton ginning. Livestock contributed an increase of 3.06%, which accounts for 11.53% of the GDP and 60.07% of agriculture. Fishing sector had growth of 0.73%, while forestry sector had growth of 1.42% while having overall contribution of 2.10% in agriculture sector and 0.40% in GDP.

Agriculture consists of both dairy sector and crop production. Over time, the livestock subsector has eclipsed the crop subsector as the leading provider to agricultural value addition. Throughout 0.75 billion people around the world work in the livestock market to supplement their income and address food security and poverty reduction challenges. Cows provide for around 81% of global milk output, followed by buffalos at 15% and goat, sheep, and camels at 4%. The milk production of the world intensified from 0.52 billion tons in 1987 to 0.838 billion tons in the 2019 with a capacity of 0.37 billion tons and 745 million dairy animals, the South Asian region is a major contributor to global milk production, accounting for 21% of global milk output. In Pakistan, the milk production escalated by 3.2% in recent years by improving the livestock population and marketing facilities for dairy producers despite having low milk yield per animal. Buffalo milk accounts for 60% of total milk production in Pakistan's dairy industry, followed by cow milk accounting for 36% and goat, sheep, and camel milk accounting for only 4% of total milk output. Pakistan (FAO, 2020). Pakistan has the fourth largest dairy herd in the world with a number of 0.196 billion with a growth rate of 4.2% annually. Pakistan is the fourth largest raw milk producer and ninth largest meat producer in the world (Shahbaz et al., 2020). Milk is a valuable dairy product that regarded as "white gold" by dairy farmers in Pakistan. Around 8 million families indulge in dairy farming practices having dairy holding of 30 million cattle, 27 million buffalo, 54 million goats, 27 million sheep, and 1 million camels in Pakistan (Rehman et al., 2017). It will contribute 60.6% of total agricultural and 11.7% of GDP in 2019-20. The gross value addition of livestock increased by 2.5% from Rs 1,430 billion in 2018-19 to Rs 1,466 billion in 2019-20. Pakistan, despite being the fourth largest milk production and herd size, imported raw milk worth 0.74 billion dollars in three years, beginning in 2014 (Shahzad, 2022).

Table 1.2. Population of livestock in Pakistan

Species	Estimation population of livestock (Million Nos.)				
	2016-17	2017-18	2018-19	2019-20	2020-21
Cattle	44.4	46.1	47.8	49.6	51.5
Buffalo	37.7	38.8	40.0	41.2	42.4
Sheep	30.1	30.5	30.9	31.2	31.6
Goat	72.2	74.1	76.1	78.2	80.3
Camels	1.1	1.1	1.1	1.1	1.1
Horses	0.4	0.4	0.4	0.4	0.4
Asses	5.2	5.3	5.4	5.5	5.6
Mules	0.2	0.2	0.2	0.2	0.2

Source: Ministry of National Food Security and Research, Pakistan

The dairy business has a considerable economic impact in the country but is the least commercialized business in the country. The dairy population categorized into dairy farms depending on milk production and herd size. Table 1.3 indicates that small dairy farmers hold around 70% of dairy herds in the country. Small farmers hold above 90% of the dairy animals and are the game changer of the dairy industry. Majority of the small farmers are landless farmers and rear animals to fulfil the liquid milk demand of their families with a capacity of 4-7 liters daily milk at farm level. The excess sold to nearby families or milkman at local rate or used in dairy by product like ghee, cheese or butter for family use (Ashraf et al., 2013; Khan et al., 2013; Shahzad, 2022).

Table 1.3. Herd size of households

Number of dairy animals	Household ownership percentage
1-2	27.32
3-4	23.73
5-6	14.32
7-10	13.68
11-15	6.29
16-20	2.65
21-30	2.58
31-50	2.71
51 or more	6.72
Total	100

Source: Pakistan livestock census, 2006

They have poor access to green fodder throughout the year and discard their dry animals on regular basis to address the fodder shortage problem and mitigate the family requirements and needs as well. Sometimes quality cattle slaughtered on

religious festivals though it contribute major portion of their income. There is a clear lack of management methods and it is difficult to explore the potential of milking animals at this level, which makes up the majority of the livestock industry at stake.

Second category of the farms are those who have animals holding above 25 dairy animals, use dairy, and operate at semi commercial level. They kept local and imported breeds together with peak milk yield of 25 liter daily and average of 12-20 liter milk yield, often obtained from commercial farms and are not involved in import of quality animals directly for their farms. They make only the 5% of total dairy farm at nationwide. The feed stuff used by these farms are green fodder and concentrate and is unaware about the total mixed ration and all weather shed for dairy animals and proper heating and cooling system at farm. However, they earn a reasonable profit from their animal but unfortunately do not explore the full potential of their milking animals (Farooq, 2016; Rehman et al., 2017; Tahir et al., 2019).

Only 16 Cooperate dairy farms are running countrywide and fully modernized, with a capacity of 2000–6000 imported dairy cows (Holstein Friesian, Jersey, and Freisian Jersey Cross) with a daily milk production capability of 30–40 liters. They have their own milk processing plants at their farms and reaping a handsome profit from dairy business by providing milk in packing farm directly to final customers with their on point shops near and local markets. They have efficient feed management by using total mixed ration as feed and well-trained staff with complete veterinary facilities at farm level (Farooq, 2016; Rehman et al., 2017; Tahir et al., 2019).

1.3. Handling of Livestock Animals at Dairy Farms

Major portion of small and medium level farms, which is more than 70% of the total dairy farming community are not traceable and are illiterate about the management practices and technology adoption to extract the full potential of dairy animals (Zaid et al., 2019). Poor tagging, absence of milking and reproductive records, poor management of quality animals, and lack of information leads to risky and laborious dairy farms at small-scale level (Khan et al., 2013 and Chhachhar et al., 2014). Small farmers purchased different semen form unknown sources and inseminate their quality animals to increase their milk production. The unrecorded and unauthentic practices results poor quality animals at farm with less milk potential deteriorate the local breeds as well (Khan et al., 2013 and Marshal, 2014). On contrary, the commercial farms are operating with fully equipped technologies with proper

records of individual dairy animal at farm. Maintain lifecycle records, proper traceability, and full feed artificial insemination management system and proper pedigree of farm animals, with proper information and sanitation facilities at farm (Adam et al., 2016).

Herd surveillance, distinguishing dairy animals based on production and reproduction potentials, well-maintained records are the helpful tool for feed and disease management of dairy farms but are expensive techniques to install on dairy farms. The fully functional herd management system (HMS) which includes insemination data, vaccination reports, daily milk production records, and a day-to-day action plan for feeding operations, is useful for converting information into action plans for dairy farm management and a new management technique for dairy enterprise (Antanaitis et al., 2015). Mostly large dairy farmers in Pakistan use HMS to collect information about their dairy farms to transfer that information into farm operations. Sometime it is hard to transform the data in meaningful information and efficient farm operations due to lack of skill staff, language and social barriers and poor training levels of farm staff (Shahzad, 2022). Sensor based monitoring of individual dairy animal integrated with cell phone through reminder and email using radio frequency. This technology is helpful in understanding the daily activity and feeding behavior of individual animal, control disease, milk production and health management of dairy animals, which combine the success of dairy farms with the animal welfare (Bucek et al., 2015 and Knight, 2020). Adoption of this technique level make it easy handling of large herd size with less labor force but fewer dairy farms at country level due to high-level installation and handling cost adopt this technology.

1.4. Milk Status in Pakistan

Around 150 million families around the world produce milk, with 363 million milking cows and buffalos. About 8.5 million Pakistani households rely on livestock for their income, with 5 million milking cows and buffalos having production of 40 billion liters of milk each year, with a 3.89% annual growth rate. The buffalo milk has highest percentage of fat, crude protein and lactose level and is most demanding among all the dairy animals due to its unique taste followed by the indigenous cows as healthy percentage of total solid in milk is supportive to desi ghee, butter, cream, and dairy sweets (Khoya). The imported animals have high milk potential but have low fat, crude protein and lactose level.

Table 1.4. Raw dairy milk composition

Parameters	Buffalo	Indigenous cow	Imported cow
Total solids	15.6	12.1	12.2
Solids not fat	10.2	8.3	8.7
Fat	5.40	3.88	3.5
Crude protein	4.16	3.73	3.1
Lactose	5.30	3.84	4.9
Total ash	0.75	0.69	0.70

Source: Jensen, 2002 and Tahir et al., 2019.

In Pakistan, 35 million people associated with the livestock industry, and deriving 30- 40% of their income from livestock sector. Only 31.76 billion liters (80%) is available for human use. In terms of value addition, milk is the single most important commodity in the livestock sectors. The cash embedded by the milk sale in the rural economy at TL 5.73 per liter (lower bound estimate) during 2019-20 is TL 166.47 billion per year or TL 0.45 billion per day. Due to a lack of efficient cooling, storage, transportation and road infrastructure, 15% of sold milk wasted on route to market (Fakhar and Walker, 2006). Meat is the second largest product of livestock sector, but Pakistan's meat export is only 1.95% of its total meat production (GOP, 2019). The overall livestock development strategy revolves around encouraging "private sector-led development with the public sector providing healthy and economic environment through policy interventions

Table 1.5. Situation of Milk and Meat production in Pakistan

Estimated milk and meat production					(000 tons)
Species	2016-17	2017-18	2018-19	2019-20	2020-21
Overall Production of milk	56,080	57,890	59,759	61,690	63,684
Cow	20,143	20,903	21,691	22,508	23,357
Buffalo	34,122	35,136	36,180	37,256	38,363
Sheep	39	40	40	41	41
Goat	891	915	940	965	991
Camel	885	896	908	920	932
Milk (Human Consumption)	45,227	46,682	48,185	49,737	51,340
Cow	16,115	16,722	17,353	18,007	18,686
Buffalo	27,298	28,109	28,944	29,805	30,691
Sheep	39	40	40	41	41
Goat	891	915	940	965	991
Camel	885	896	908	920	932
Meat	4,061	4,262	4,478	4,708	4,955
Beef	2,085	2,155	2,227	2,303	2,380
Mutton	701	717	732	748	765
Poultry meat	1,276	1,391	1,518	1,657	1,809

Source: Ministry of National Food Security and Research

1.5. Milk Management System in Pakistan

Despite contributing a healthy percentage in GDP of the country, dairy sector is the least commercial sector of the economy. Nearly 40% of this sold, with the remaining 60% consumed by rural households. Rural areas produce 80% of the total milk sold, with the remaining 20% coming from urban and peri-urban farms. About 90% of milk produced in the country, sold through informal routes (such as the milkman or direct to the consumer), with only 10% going to the professional processing industry (Zia, 2009 and Kamal et al., 2022).

Small and medium level farmers are using manual record system and prefer manual milking at their dairy farms because of limited resources and poor understanding of milking parlors technology. This is serious threat to health of dairy animal as hygienic conditions and udder health is highly compromised. The manual milking practices is more labor intensive and time-consuming job, for the reason there is always a labor problem at dairy farms. In manual procedure, it is hard to segregate the healthy animals from the sick one with no information about the milk contents and production. In manual record system, there is no chance to access the potential deviation of milk quality, as is no milking meter facility. Milking parlors used in the

country's cooperative sector to milk dairy animals, which is a precise technology for understanding the milk dynamics of dairy farms. This technique aids in the improvement of udder health, dairy animal immunity, and the keeping of accurate milk records on a regular basis, which is helpful in farm decision-making. It is helpful to segregate the sick animals from healthy animals ensuring the hygiene conditions at farm (Shahzad, 2022).

1.6. Feed Management Practices by the Dairy Farms

1.6.1. Dairy Feed in Pakistan

There are conventional and non-conventional feedstuff used as dairy diet in Pakistan. Conventional feedstuff includes the green fodder and dry forages used traditionally at farm. Maize, sorghum, millet, barley, berseem, oat, Alfa Alfa, moath and mung are main fodders in Pakistan and are healthy source of dry matter, crude protein and crude fiber in the dairy feed. Green and dry fodder are the feedstuff that have high level of crude fiber and low percentage of digestible nutrients. Dairy farms usually prepared hay from Lucerne, sorghum, oats and green grasses and used in dry period as source of diet. Among the green fodders, range grass has the largest percentage of dry matter (35.7%). With 22.5% crude protein, alfalfa, also known as Lucerne, has the highest percentage of crude protein. With a proportion of 36.7%, range grass had the highest percentage of crude fiber. Barseem and Lucerne are the most widely utilized fodder in the nation for dairy animals because they have a healthy amount of dry matter, crude protein, and crude fiber. Contrarily, silage is a feed that is made from a variety of fodder crops or a combination of fodders that has a high protein content and a low soluble carbohydrate content. When molasses mixed with silage it lowered the PH level and improve the lactic acid content in feed (Garipoglu et al., 2020).

Table 1.6. Parameter of green fodder used in Pakistan

Fodders	Dry matter (%)	Crude protein (%)	Crude fiber(%)
Maize	23.7	9.8	27.1
Sorghum	33.4	6.8	31.8
Millet	25.0	4.4	32.6
Barley	19.8	13.3	21.9
Berseem	15.2	18.9	15.8
Oat	17.2	13.5	23.0
Lucerne	18.2	22.5	24.0
Sugarcane	27.2	6.2	31.2
Guar	21.7	19.2	14.0
Bajra-Napier	23.7	15.3	28.3
Hybrid Napier grass	28.8	16.3	26.1
Range grass	35.7	5.1	36.7
Moth	24.5	1.1	31.3
Mung	23.1	14.5	32.2

Source: Younis and Yaqoob, 2005

Forages are edible parts of plants, other than separated grain, that can provide feed for grazing animals, or that can harvested for feeding includes browse, herbage, and mast. Wheat straw, rice straw, maize stove, maize stove, hay of range grass, mung straw, chickpea straw, and sugarcane straw are the most popular forages utilized on dairy farms. Mung straw forages have the highest percentages of dry matter and crude protein, and sugarcane straw has the highest percentage of crude fiber among all the forages. These feed has a high dry matter contents but a low protein and mineral contents, as well as a low digestion level, making it a poor quality feed for dairy animals.

Table 1.7. Parameter of dry forages used in Pakistan

Dry forages	Dry matter (%)	Crude protein (%)	Crude fiber (%)
Wheat straw	90.5	3.0	41.8
Rice straw	90.5	4.1	31.9
Maize stoves	95.2	5.5	38.0
Sorghum stoves	94.5	3.5	40.5
Range grass hay	91.1	3.1	40.6
Mung straw	95.5	8.4	37.8
Chickpea straw	95.2	5.5	44.2
Sugarcane straw	92.3	2.1	47.8

Source: Younis and Yaqoob, 2005

Concentrates are the portion of feed that have high percentage of protein and energy level with low fiber content and has high digestibility level. Concentrate

categorized as protein rich concentrate used as protein supplement and energy rich concentrate used as energy supplement in dairy animals. Energy rich concentrates are wheat bran, sugar beat pulp, and molasses and rice polish and are by product of cereal grains and sugarcane industries.

Table 1.8. Parameters of concentrates used by dairy farms

Concentrates	Dry matter (%)	Crude protein (%)	Crude fiber (%)
Mustard seed cake	91.7	32.4	19.8
Cottonseed cake	91.9	23.4	27.4
Maize oilcake	94.6	16.5	9.3
Wheat bran	89.7	14.5	8.8
Rice bran	89.7	8.2	13.0
Wheat bread	89.7	14.9	8.8
Maize gluten feed	87.9	12.5	12.7
Cottonseed meal	92.2	36.7	15.4
Guar meal	93.2	44.3	12.2
Soybean meal	91.8	48.4	7.2
Sunflower meal	91.1	35.5	19.1
Rapeseed meal	96.7	35.7	12.4
Fish meal	90.7	56.3	0.9
Blood meal	92.1	54.5	0.9

Source: Younis and Yaqoob, 2005

Molasses contains carbohydrates and some important minerals and most commonly used by the local dairy farms as cheap source of energy. Some farmers mix it directly in the feedstuff and some offer them in form of feed block for licking as it improves the consumption level of dry forages. Protein base concentrates has high protein level usually prepared at industrial level and is the byproduct of oil industries. Guar meal has the highest portion of dry matter among all the concentrates. Protein is important feed component and is helpful in tissue repairs, synthesis of hormones in the body along with milk synthesis in dairy animals. Although fishmeal contains the highest quantity of crude protein, not frequently used in the dairy industry. Contrarily, a widely used concentration at national level is cotton seed cake, which has a lower percentage of crude protein. Plant-based concentrate has a lower crude protein content than animal-based concentrate; however, animals based concentrates (fishmeal and blood meal) are not commonly available therefore the majority of concentrate derived from crop and industrial leftovers. The nutritionists in Pakistan suggested that the daily concentrate requirement is 3.5 to 4 kg for the animal having milking capacity up to 10

liter per day. Normally this is half portion of the total milk produced by the dairy animal on single day (Iqbal et al., 2015).

Table 1.9. Ingredient percentage in concentrate used by dairy farms

Ingredients of concentrate	Ratio Percentage
Sunflower cake	10-13
Cotton seed Cake	20-25
Rape seed cake	10-13
Peanut cake	20-25
Cotton seed meal	15-20
Soybean meal	10-15
Rapeseed meal	15-20
Rice polishing	18-20
Wheat bran	23-25
Wheat grains	15-20
Maize gluten 60%	5-10
Molasses	10-15
Urea	1-2
Oil	2-3
Common salt	1-2
Mineral mixture	2

Source: Iqbal et al., 2015

The nutritional requirement of dairy animals cannot be met by a concentrate containing all ingredients from plant origin due to its low crude percentage content, a balanced combination of different ingredients from plant and animal origin can be used to meet the diet requirements of milking animals in cost efficient way. A buffalo (400 kg body weight) producing 10 liter per day required 7 kg of grains to fulfill his requirement (Habib et al., 2007). Inferior quality forages along with single ingredient of concentrate, which are a very common practices by majority of the farmers. Dairy animals cannot maintain a good body score with these practices because this disturb the protein carbohydrate level of dairy feed results poor milk production at farm level.

The cost of concentrate and high-quality feeds like silage or hay are not subject to any sort of check and balance system. A large portion of the dairy farming population having smallholdings causes poor production of dairy animals. They are focusing less on a balanced diet due to the high expense and do not provide concentrates; the shortfalls in dry matter, energy, and crude protein are around 21%, 29%, and 33%, respectively (Hasnain and Usmani, 2006). A well-balanced diet promotes rumen efficiency, a stronger immune system, healthier dairy animals, and

enough milk production. Balanced diet management improves the nutritional condition of dairy animals and serves as a guidance for dairy farmers who want to sow high-nutrition fodder crops to increase milk output in a cost-effective manner. Water is essential in the daily routine of dairy animals for the proper functioning of their metabolism and is a low-cost nutrition source. Dairy animals meet their water needs by drinking from water tanks, eating feed, and drinking water created by metabolic activity in the body.

Normal size dairy animal intake dry matter up to 2-3 percent of body weight during a day. Energy is important component for smooth functioning of body and protein and carbohydrates along with fat are main energy components. Major portion of energy fulfilled through carbohydrates as it is the cheap and economic energy source for dairy animals. Protein is important energy source but considered as five time more expensive as compare to carbohydrates. Fat content in feed provides 2.25-time high energy as compared to carbohydrates (Mlay et al., 2006 and Iqbal et al., 2015).

1.7. Milk Marketing in Pakistan

Buffalos and cows generate a substantial part of milk in Pakistan, with Punjab having the most buffalos (64%) and cows (48%) among the other provinces. The national average per capita milk consumption is 190 liters, with Sindh province having the greatest per capita milk consumption (246 kg), followed by Punjab (132 kg), and Baluchistan (108 kg) having the lowest per capita milk consumption among the four provinces of the country. Inflation and poverty are the primary drivers of raw milk consumption in the country, as people are increasingly price aware. Milk producers, milk collectors, milk processors, milk retailers, and milk consumers are the main players in the milk market. Dairy farmers are milk producers who live in rural, peri-urban, and urban sections of the country. Milk collectors are milkmen that collect milk directly from dairy farmers at milk collection stations in rural, peri-urban, and metropolitan settings. Milk processors include individuals involved in UHT milk processing plants, as well as local processors who convert milk into dairy confectionaries such as desi ghee, cream, butter, and dairy sweet products (Khoya). Milk shops are places where milk gathered from milkmen or milk contractors and farmers and provide to final customers. Final stakeholders are the milk consumers used formal and informal channel to get milk for family use (Ishaq et al., 2016).

The formal and informal market systems are the two marketing channels used by market stakeholders to ensure the supply chain of milk. Informal market system deals with the marketing of milk and confectionaries without license issued by the concerned authorities. This segment of milk market is handling 90% of the total milk production from different parts (Zia, 2009). Mostly farmers sold milk to milkman and milkman handed over to the milk shop followed by the purchase for final consumption. Sometime milkman collected milk from dairy farms and handed over to traditional processors and processor handover the dairy confectionaries to milk shop and they sell this processed stuff in the form of butter, desi ghee, cream and dairy sweets (Khoya) to final customer.

The formal sector deals with the dairy marketing operations like UHT treatment, handling, processing and packing under the license and regulations of dairy department at district level. They collect milk from collection centers, contractors, large dairy farmers and middleman and convert them in yogurt, skimmed milk, butter, desi ghee, cheese, ice-cream and dairy sweets. They have setup collection spots at different areas and those MCC interlinked with the processing plants. After proper testing and chemical analysis recommended by food safety authority, handover milk for final processing and packing to plants but still have a very small market share of 6%. Some companies have setup their own outlets to reach final consumers and reaping handsome profit from their processed products and some sell them to local shops after processing which later on purchased by the final customer for daily use with less profit margins (Ishaq et al., 2016).

1.8. Veterinary Services Setup in Pakistan

The primary goal of the country's veterinary services is to solve livestock issues and to improve the health, welfare, and standards of dairy animals and dairy products on a national and international scale with the objectives of disease control, risk management and animal welfare improvement. National program launched in 2006 to control the Foot and Mouth Disease (FMD), Peste des Petits Ruminants (PPR), Brucellosis and Haemorrhagic Septicaemia disease control in the country.

Table 1.10. Veterinary services at provincial and national level

Region	Research/vaccination Production centers	Veterinary Hospitals	Veterinary Dispensaries	Centers	Labs
Punjab	1	530	1213	1713	28
Sindh	2	119	60	608	7
KPK	1	98	363	218	7
Baluchistan	1	116	783	-	15
Northern Areas	-	12	165	-	7
Federally Administered Tribal Areas	-	25	212	207	1
Islamabad Capital Territory	1	4	7	-	1
Azad Jammu and Kashmir	-	59	66	129	6

Source: Afzal, 2009

Pakistani animals and meat transported to neighboring countries through informal channels without quarantine practices, which is basic standard procedure for the trade of dairy animals as public sector in the country is using obsolete technical practices with lack of funds and poor infrastructure facilities and vaccination facilities. Punjab being the largest dairy holders has the better level of veterinary, labs and diagnostic lab facilities in comparison to rest of the provinces and federal territories of country. Basic purpose of these setups and infrastructure are disease eradication, quality control of vaccines, proper drugs licensing, quality food supply, and timely vaccination. Procedures and improve the animals and products quality to earn a reason foreign exchange form this sector (Afzal, 2009)

The regulatory measures aim to improve the adoption of innovation for the improvement in the productivity of livestock animals, health coverage of dairy animals, management practices at farm level, milk refrigeration, quality animal breeding practices, artificial insemination services, the balance use of total mix ration, and the control of livestock diseases and marketing channels for milk and meat. The goal is to capitalize on the livestock industry's potential for economic growth, food security, and rural economic uplift of rural families.

1.9. Challenges of Dairy Sector in Pakistan

Pakistan is the sixth largest populous country in the world, and it will become the third most populous country by 2050. Due to rapid population growth, the demand for the necessities (food, clothes, shelter) are on increasing side. A well-designed food supply chain mechanism, required to fulfil the daily nutritious requirement of

population. Majority portion of the population living in the rural areas of country at subsistent level and the price hike posing a serious threat on subsistent livelihood. With poor efficiency and production level in different sector of economy especially the agriculture sector, it will be difficult for a large portion of population to sustain their livelihood in near future.

Dairy sector is the more prominent contributor in the agriculture sector. Inadequate availability of quality inputs e.g. total mixed ration(TMR), poor canal water availability for fodder crops, poor quality feed concentrate in the market, high markup rate for dairy credit, absence of farm mechanization, poor training facilities at local level, absence of all-weather infrastructure and poor marketing channels have suppressed the investment in the dairy sector of the country.

Poor literacy rate and skill development, inadequate milk collection centers, low milk price at farm level and limited marketing channel in the rural area of the country made this industry less attractive. High animal's mortality rate and due to lack of technical knowledge and poor coordination with the veterinary doctors and staff results serious loses to the dairy farmers. Most of the milk (80%) comes from the rural area of the country but marketing channels are available in the urban area of the country. Therefore, this business become more labor and capital intensive with the passage of time. Milk and meat production is labor intensive in rural area of the country rather than mechanized and technology oriented. More labor and poor production of dairy animal reduce the profit margins of dairy farmers. High inputs costs of fertilizers, irrigations and concentrates is not suitable for the farmers that has limited resources for their farm activities. Expensive milking machines, lack of credit facilities in the rural areas and inadequate marketing system facilities are some other common challenges of the dairy farms (Saifullah and Zulfqar, 2006).

1.10. Research Problem

The scientific knowledge, dissemination of information about the management's issues, diffusion of technologies at small-scale level and dairy products marketing strategies not only improve the economic status of the livestock families but also the production potential and health status of the animals. Nowadays it is obligatory to adopt the scientific innovations for the efficient animal's production in accordance with dairy sector needs (Abou-Tahoon, 1993). The adoption of innovations in any sector of agriculture depends upon the socio-economics status of the families directly

involved, understanding about the necessary scientific knowledge of modern technologies and the availability of technologies in the area. The understanding level varies from person to person at farm level due to education level and socio-economic differences. The technology innovations suitability varies at each level of the dairy business from production to marketing levels (Singh et al., 1993) There is a significant gap in many developing countries between available farm technology and what farmers practice on their farms. Adoption of technology is a difficult and time-consuming process due to a lack of scientific knowledge, inadequate extension agents and local government training programs, and the resistance provided by local norms in rural communities (Sofranko and Fliegel, 1984). Strong extension system at grass root level in the rural area of the country is convenient to improve the adoption of innovations through proper training, information system and dissemination of scientific agriculture knowledge among farmers (Salam, 1992). Agriculture based economies can improve the level of economic development and national income by transferring the modern agriculture technology at small level. These efforts at national level will drive the production potential, economic efficiency of small farmers (large portion of economy) and purchasing power of the domestic consumers (Omar, 1992).

In recent years, government has exercised extensive efforts to improve the production potential of livestock sector by allowing the imports of quality semen's (654.5 thousand doses) and embryos (Holstein-Friesian and Jersey) to improve the genetic potential of local animals. Quality semen of imported animals are available at district level veterinary hospitals at affordable prices for the local dairy farmers. Government also permits the imports of macro and micro feed ingredients for quality feeds in excess of the dairy farmers (220.2 metric tonnes, 120.6 metric tonnes milk replacer and feed premix). Free of cost vaccinations against the major diseases (Foot and Mouth Disease, Peste des petits ruminants, Transboundary Animal Diseases) are available at district hospitals. In addition, milking machines, meat processing machines and silage machineries are available in market at subsidized rates for the promotion of value added industry in the country. Around 53 thousand tonnes of meat and meat products exported during the fiscal year 2019-20. Import duty of 45% imposed on powdered skimmed milk to protect the subsistent livestock farmers in the country (GOP, 2020)

Despite of all the efforts and facilities at district level made by the government to boost the livestock sector of the country, the adoption rate among the livestock farmers are not up to the standards and is still very poor among the livestock farmers. It is necessary to investigate the key reasons for poor or non-adoption for innovative technologies in the dairy sector of the country. A few articles found during research, on the topic of dairy efficiency analysis in Pakistan and no research available on the issue of relationship between efficiency analysis and innovations adoption in dairy sector of the country. Keeping in mind the above-mentioned issues, no study found on the topic of efficiency analysis and innovation adoption even at country level. A micro level study conducted to explore the efficiency level of dairy farmers and relationship of efficiency levels with the innovation adoptions in the Punjab province, Pakistan. Procedures and improve the animals and products quality to earn a reason foreign exchange form this sector (Afzal, 2009)

The regulatory measures aim to improve the adoption of innovation for the improvement in the productivity of livestock animals, health coverage of dairy animals, management practices at farm level, milk refrigeration, quality animal breeding practices, artificial insemination services, the use of total balance diet, and the control of livestock diseases and marketing channels for milk and meat.

The goal is to capitalize on the livestock industry's potential for economic growth, food security, and rural economic uplift of rural families.

1.11. Major Research Questions

These questions were helpful for the researcher to develop association between the literature review, variable used and analysis methods for the completion of research study.

1. What are the socio-economic characteristic of the dairy farmers in the research area?
2. What approach of the dairy farmers towards the adoption of innovation?
3. What are key factors affecting the revenue of the dairy farmers?
4. What are the factors affecting the milk production at farm?
5. What types of facilities are available at farm level for the dairy animals?
6. What types of innovation adopted by the dairy farmers?
7. What are the constraints for the adoption of innovations?

8. Frequency of interactions with veterinary professionals and knowledgeable individuals.

1.12. Research Hypotheses

The analysis of research hypotheses planned to be the part of study and defined below

1. The socio-economic characteristic of dairy farmers like age, education level of the farmer, number of family members, farm and off farm income, total land possession influence the efficiency level.
2. The socio-economic characteristic of dairy farmers influence the adoption of innovations.
3. There is a relationship between the efficiency level and adoption of innovations.

1.13. Objectives of the Study

The estimation of dairy farms efficiency and factors influencing innovation adoption were the major objectives of the study. More specifically this study was aimed to achieve the following objectives:

1. To determine the socio-economic characteristics of dairy farmers.
2. To determine the profitability of dairy farmers.
3. To determine the efficiency level of the dairy farmers.
4. To determine the factors affecting the efficiency level of dairy farmers.
5. To identify which type of innovations and management practices adopted by dairy farmers.
6. To determine is relationship between efficiency level and innovation adoption.
7. To determine the factor affecting the adoption level of dairy farmers.
8. To develop recommendations for the dairy farmers based on their efficiency scores.

1.14. Limitations of Study

There are some major constraints to conducting this research in Pakistan's, province of Punjab. The majority of research studies in social science established on

primary data sources based on the response of the selected respondents. The level of awareness and understanding about the modern technologies and treatment methods is not up to mark in the rural area of the country. Key limitation to these primary data studies is the respondents' unwillingness, inability to provide accurate information and record the accurate response to the questions put on in the questionnaire. Necessary measures incorporated to prevent the error, inherent in social surveys but cannot eliminate. The selected dairy respondents have poor dairy records for their animals regarding the milk production, age of the animals, peak-milking capacity of animal, liters of milk across complete lactation length, seasonal vaccinations against the diseases, daily routine farm expense, fodder availability per animal, fodder composition, duration of dry period of milking animals, mineral mixture concentration in daily feed etc. Most of the dairy farmers in the selected research area are reluctant to provide the information about their total family income, scheduled business activities other than dairy sector, total income generated by the sale of dairy animals and the profit margins by different agriculture activities at farm. The accuracy of all the informations regarding the socio-economic characteristics and adoption level mentioned above is up to the honesty and dedication of the researcher.

The documentation of milk and meat records for small units, sale and purchase records, availability of silage at farm level, quality of veterinary services village or city level and limited information sharing across the provinces are limitation at institutional level. Limitations at grass root levels are that there is no uniform training facilities available regarding animals cares under harsh climatic conditions, total mixed ration availability, nutrition value of different available feed, all weathered infrastructure and uniform market structures under different weather conditions across country may pose limitation to this study to be applicable across the country.

All these limitations mentioned above at different levels are due to shortage of budget, time shortage to cover all these aspects, poor understanding about modern dairy practices and lack of innovations adoption rate and high interest rates loans for dairy business. Agriculture sector in the developing countries are continuously facing these problems over the decades due to poor climatic conditions, lack of understanding about the modern agriculture system. Key reason for these problems are depletion of nature resources (range lands and forest), poor adoption rate of technology at farm

level and absence of large portion of farming population (small farmers) in marketing activities, value addition supply chain mechanism (Bezabih and Chambwera, 2010).

1.15. Scope of Study

Dairy sector plays a vital role in achieving the development of the country by providing employment opportunities, reduction of poverty in the agriculture sector of developing economies and ensuring food security in the vast area of the country. The adoption of modern innovations play a vital role in successful dairy business these days, which is more technology oriented rather than labor intensive.

This study's results will be helpful for the large number of subsistent dairy producers by providing beneficial information regarding their production cost, management cost, marketing cost, gross margins and suggests suitable measure to reduce their problems. Those dairy producers, operating at conventional level can reduces cost of doing business, and improve their efficiency level through adoption of modern technologies. The improvement in milk production at small-scale level not only fulfil the ever-increasing demand of the milk in the country but also the income level of the farmers and save foreign reserves of the country.

The findings of this study will serve as reference material and will open up the research area for academicians, research institutions, and the government. Nexus of these institutions will improve the well-being of farmers through publications, capacity-building training programs, and policy regulations to meet the country's ever-increasing milk demand through adoption of innovations at gross root level in the country.

1.16. Thesis Structure

The units for the composition of thesis are as comply of five sections:

- I. Introduction: This section covered performance of agriculture sector, status of milk and meat production, challenges in dairy sector in Pakistan, research problem, major questions and objectives of the study, hypothesis of the research, broad and specific objective of the study with scope and limitations.
- II. Review of literature: In this section, the primary segment is about the efficiency concepts and the second section contains the efficiency calculation methods within the field of agriculture and livestock sector.

The third section of this chapter contains the innovation adoption methods in agriculture and livestock sector.

- III. **Material and Methods:** This section contains the primary data and the methods and procedure for detail investigation of variables in the study. This unit composed of three parts; area for the research, sampling techniques and questionnaire for the collection of data and analysis procedure for the specific objectives.
- IV. **Results and Discussion:** This section encompass the socio-economic characteristics of the dairy farmers, their technical, allocative and economic efficiencies level, level of innovation adoptions, relationships of socio-economics variables with the efficiency level of the farmers and relationship between innovation adoption and efficiency level of the dairy farmers.
- V. **Conclusions and recommendations.** This section entangles the descriptive analysis referring the hypothesis and objective of the studies based on statistical method used to reach some solid conclusion and suggest recommendation based on evidence.

2. REVIEW OF LITERATURE

Appropriate review of literature is valuable to pinpoint the knowledge gaps in the recent studies, save time and resources to avoid the research, already done in the specific field to carry on from the point where the other field specialists have already reached and getting in touch with the invaluable knowledge and sources. It provides researcher in-depth knowledge, important works, new skill sets, relevant information, intellectual context and suitable methods to meet the objective of the research. This chapter contains three sections with the concept of efficiency, method to measuring efficiency and innovation adoptions.

2.1. Literature on Efficiency Concept

The economic efficiency concept, first introduced by Farewell in 1957. He disposed of the absolute efficiency measurement concept based on ideally pre-defined calculations. He suggested that in genuine sense of efficiency could measure by calculating the degree as deviation from the best peer bunch. He also separated technical and allocative efficiency concept.

2.2. The Concept of Economic Efficiency

Economic efficiency is to attain the maximum amount of output by the firm by using limited resources and cost. Meireles et al. (2008) efficiency as variation between the actual output level produced by the firm and expected output level for given a set of inputs level (output efficiency) whereas the difference between the actual level of inputs used by the firm and expected level of inputs to be used for the certain level of output (input efficiency). Economic efficiency is actually the maximum level of output produced by the firm by using limited amount of available resources with least cost. Economic efficiency is analogy to production efficiency in some studies (Mugambi et al., 2017).

2.3. The Concept of Technical Efficiency

Technical efficiency is the maximization of output with specific available inputs and technology (Battese and Coelli, 1988). Farrell (1957) suggest that there are two approaches for the calculation of technical efficiency. These are input oriented approach. and output oriented approach. In input oriented approach, researchers actually investigate the decrease in the number of inputs in proportion without

disturbing the amount of output level of firm. In case of output-oriented approach, they determine the increase in the output amount without disturbing the inputs level of firm.

2.4. The Concept of Allocative Efficiency

Allocative efficiency, which is actually a price efficiency of a firm, is selection of optimal proportion by the firms. It is actually a ratio between the costs of producing a unit of output in efficient way using relative input amounts to ratio of costs of producing technical efficient unit of output relative to optimal inputs amounts (Masuku et al., 2014). A firm is said to be operating at allocative efficient level if it operates at the least cost combination. The success of right combination of inputs competed with profit maximization in pure competition condition where the marginal value of the product is equal to unit cost of the desired product (Chukwuji et al., 2006). Byerlee (1987) divided allocative efficiency calculation in two cases based on constraint and unconstraint assumptions. Constraint base allocative efficiency calculated when cost factor remain constant during the inputs reallocation because of information and scale lack. Unconstraint based allocative efficiency calculated when marginal expense return is equal to capital cost on expansion path because of imperfection in market, constraints in the cash and risk averse attitude.

2.5. Methods for the Calculation of Efficiency Measurements

There are two methods to analyze the efficiency. The parametric method first defined by Aigner et al. (1977), and Meeusen and Broeck (1977); and the non-parametric method for the estimation of efficiency was developed by Charnes et al. (1978).

2.6. Concept of Parametric Method for Efficiency Analysis

In this method, Stochastic Frontier Analysis (SFA) used for the estimation of efficiency in various agriculture related studies calculate the error and statistical noise, which differentiate the random noise from the efficiency level. Kumbhakar and Heshmati (1995) used translog functional form with SFA for the estimation of technical efficiency. Ahmad and Bravo-Ureta (1996) used simple translog and Cobb-Douglas functional form for the estimation of technical efficiency. Jaforullah and Devlin (1996) used stochastic frontier analysis with trans-log functional form and revenue of farm output variable for the estimation of technical efficiency. Reinhard et al. (1999) used SFA with trans-log functional form for the calculation of input based

efficiency. Reinhard et al. (2000) used SFA along DEA using simplified trans-log functional form for the estimation of input oriented efficiency. Brummer and Loy (2000) use trans-log functional form for the estimation of comparing technical efficiency in North Germany. It not only grants hypothesis testing but also allow inefficiency effect estimation during the analysis by providing the score of every individual involved in the study. Necessary intervention required by the individuals and the prime reason of inefficiency (Kumbhakar and Lovell, 2003). Jaforullah and Premachandra (2003) used SFA and DEA with Cobb-Douglas functional form for the estimation of technical efficiency. Hailu et al. (2005) used SCF with trans-log for the estimation of cost efficiency in Canada. Jiang and Sharp (2008) used SFA with trans-log functional form for the estimation of technical efficiency. Alvarez et al. (2008) used SCF using trans-log functional form for the estimation of cost efficiency. Moreira and Bravo-Ureta (2010) used SMFA with trans-log function form the estimation of technical efficiency across three countries. Oladunni et al. (2013) used stochastic frontier to calculate the efficiency of maize in Nigeria. The efficiency level found as 0.758 and variable like seed rate, fertilizer dose, and chemical dose and farm size found significant relationship with maize production using regression analysis. Ibrahim et al. (2014) used SFA for the calculation of groundnuts and sesame crop in Kordofan, Sudan. Technical efficiency score for groundnuts found to be 0.40 and technical efficiency score for sesame was 0.84, respectively. Amount of seed used, sufficient rainfall in the area, total number of weeding, fertilizer dose, and labor days significantly affect the production of sesame and groundnut.

2.7. Concept of Non-parametric Method for Efficiency Analysis

In this method, DEA is used for the estimation of efficiency, which actually compare the every individual involved with most efficient counterpart (Kirigia et al., 2007). Being more popular in agriculture sector studies, DEA is a mathematical programming system for the calculation of multi-input and multi-output measures. Technical efficiency and allocative efficiency constitutes economic efficiency (Farrell, 1957). Shah (1995) used profit function for the estimation of technical and allocative efficiency and found that farmers were the profit maximizer in India. Schmidt and Lovell (1979) used cost minimization approach for the calculation of efficiency. Kumbhakar (1987) found in their study that farmers in India were operating at technically at inefficient level.. Reinhard et al. (2000) used two different methods for

the calculation of environmental efficiency of dairy animals in Holland. Stochastic frontier analysis, the efficiency level found 89% and the DEA score was 78%, respectively. He also mentioned the strength and weaknesses of both models in his study. Jafforrullah and Whiteman (1999) employed the DEA using primary data of 264 dairy farms in Holland. They found a maximum efficiency score of 83%, and minimum efficiency score of 39%, respectively. Manjunatha et al. (2009) used the DEA to calculate water use efficiency across water buyers, water seller, controlled farmers group, and found that water buyer group was more efficient among these groups. The efficiency level of water buyer was 0.77 and 0.84 under the assumptions.

2.8. Efficiency Analysis in Agriculture and Livestock Sector

A large number of studies conducted to calculate the level of technical and allocative efficiency in the agriculture sector, but only a few of them based on the economic efficiency of dairy farmers. Muller and Shapiro (1977) used probabilistic linear approach for the calculation of technical efficiency of cotton in Tanzania and found 34% inefficiency level among the farmers in the selected area. Belbase et al. (1984) used ordinary least square method for the calculation of efficiency and found 20% inefficiency level across whole farm in Nepal using income level, education status, nutrition level of farmers and experience years as explanatory variables. Flinn and Mubarik (1986) investigated the Basmati rice inefficiency level and found an inefficiency level of 50% among the farmers in Pakistan. Jin et al. (2005) used single as well as multiple output cost function for the calculation of economic efficiency of new maize and wheat varieties. Strong relationship reported between the new varieties of maize and wheat with the economies of scale and positive relationship between education status, cost efficiency, and outsourcing of genetic materials. Rahman and Umar (2009) suggested that land redistribution among the farmers and subsidized fertilizer should be encouraged to improve the efficiency level of crops in Nigeria. Ogunniyi and Ajao (2011) found that suitable farm size, appropriate seed quantity and suitable dose of fertilizer can improve the efficiency level of the farmers. Efficiency score obtained by using the DEA is less than the score by using the SFA model. Oladeebo and Oluwaranti (2012) suggested that family size of the farmer, amount of credit available for farm operation, and dose of chemical improve the profit efficiency of cassava in Nigeria. Donkor and Owusu (2014) explained that the farmers operating at their own land are more efficient than those operating on shared and rented land;

and marital status of farmer, extension contacts in community, and social media involvement are the factors reduce the inefficiency level of the rice farmers. Abdulkareem and Isgin (2016) suggested that poor efficiency level among the male and female farmers can improve through relevant trainings of extension staff, setup proper farmer field schools in the area, demonstration about the modern agriculture technologies, quality seeds and appropriate value chain system. Rukhsana et al. (2017) recommended that microcredit facilities, higher education level, and farming experience can improve the efficiency level of the farmer by improving the income, purchasing power, and food supply.

Mbaga et al. (2003) calculated technical efficiency, using cross-sectional data of 1143 dairy specialized farms in Quebec State, Canada by using common functions (Cobb-Douglas production function, Translog function and generalized Leontief). Production function calculation by DEA used as alternative approach in this study. The farms categorized on maize and non-maize region based on soil and climatic condition within state. Milk yield per cattle used as dependent variable with concentrate quantity, forage consumption, labor hours, capital and cattle average weight used as explanatory variables. The efficiency scores using DEA were 0.950 and 0.9215 with respect to maize and non-maize region. DEA model highlighted that 66% of the selected farmers were operating at efficiency level above 90%, while 10% of the selected respondent falls under this category using (GL) function for estimation with no efficiency correlation. The DEA model score in maize region was alike to GL function and score were found lower for the non-maize region in the Quebec state. The discrepancy found in the scores obtained from parametric and non-parametric methods for efficiency estimation.

Jeffrey et al. (1996) investigated the relationship between the milk cost of production with total herd size, total milk yield, and technical efficiency of dairy producers at farm level in state of Alberta, Canada. They defined the relationship of efficiency level of the farm with management characteristics of farm and cost of production in the research area. The variables used in this study were herd size, farmer's age, allocation of ration, milk yield, breeding type, and veterinary expenses. The result indicated that of appropriate herd size and better management practices at farm level can boost the milk production in the state.

Candemir and Koyubenbe (2006) calculated the production efficiency of the dairy farms in izmir province, Turkey. The cross sectional data of 80 farmers form the year 2003 used in this study. Total number of output varibales were three (milk value, number of animals at farm, and value appricaition of dairy animal). Input variable numbers were total seven in number (dairy labor, stable capacity of dairy farm, continuous capital inflows, total number of cows, concentrate used as feed, fodder feed in ration, and other miscellaneous expenditures at dairy farm). Random sampling technique through personal interviews used for data collection. The DEA technique used for the determination of scale efficiency level with the assumptions of CRS and VRS. Average technical efficiency score level under CRS was 0.83 and umder VRS this number was 0.890 with overall scale efficiency score of 0.97 with respect to three outputs. Under the CRS assumption, only 49% of the selected farmers were operating at technical efficient level. Under the VRS assumption, the percentage level was 58 for technical efficient farmers.

Jalil et al. (2009) analyzed the peri-urban market structure, milk production per dairy animal (buffalo and cow) and the sources through which milk entered in market in Lahore, Pakistan. Simple random sampling used across 120 farmers and 60 milk shops and collection centers. The result showed that demand of milk in the area was very high and malpractices used to meet the demand. Milk processing was not possible without the well-organized contribution of dairy and livestock department in the area due to poor facilities, transportation services, poor dairy related education, and poor training facilities. Widely scattered milk producers, small processing percentage, and large number of small-scale producers directly threatens the profits and economies of scale.

Kavoi et al. (2010) used stochastic frontier analysis by considering translog cost function for the estimation of economic efficiency across 285 dairy farms by using random sampling technique in the district of Machakos and Makueni, Kenya. The study found that the cost inefficiency of Ayrshire breed was 24.36%. The cost inefficiency of Hostile Friesian breed was found to be 25.08% followed by Jersey breed as 25.54% and Sahiwal breed as 28.43%, respectively. Quality infrastructure, extension services availability, and credit availability in the area reduced the cost inefficiency

Parlakay et al. (2015) calculated the technical efficiency, using DEA across 138 dairy farms in Hatay, Turkey. The key variables in this study were annual production of milk, concentrate used at farm, total veterinary cost, and labor involved in dairy activities. Inefficiency causes were determined by using Tobit model in this study. Efficiency score of the farmers operation at CRS was found to be 0.64 and efficiency score of those who were operating at VRS was 0.65, respectively. Efficiency level was positively associated with the variables of feed to concentrate ratio, farming experience of the farmers, and size of the herd. Profitability can be augmented by improving herd size and concentrate ratio in the feed of dairy animals.

Aydın and Unakıtan (2018) conducted a research across different agriculture enterprises in the province of Edirne, Turkey. Stratified sampling technique used across 169 respondents in this study. The selected population divided in three strata (1-50 decares, 50-200 decares and 201 decares) with respect to land size in the region of Thrace. The average land size in this study was 117.49 decares. The average capital for the enterprise was found to be 621052.29 TL. Vegetative crop revenue was 32929.42 TL. Revenue for the livestock enterprise was 23895.80 TL. Fixed cost across the enterprises was 30288.35 TL while variable cost was found to be 20331.77 TL. Technical, allocative and economic efficiency scores were higher for the third group than the other two groups. Average technical efficiency score for the enterprise was 0.66. Average pure technical efficiency score was 0.84. Average scale efficiency score for enterprises was 0.78. Average allocative efficiency score was 0.89 and average economic efficiency found 0.75, respectively. Tobit model used to determine the effect of socio-economic factor on the economic efficiency level. Education period, family size, non-farm income and number of agriculture enterprises have negative impact on the economic efficiency level where as size of land, livestock entity at farm and amount of irrigation water had positive relationship with the efficiency level.

Silva¹ et al. (2018) calculated the technical efficiency of dairy farms using secondary data from agriculture association (AASM, n.p.) across 91 dairy farms in Azeros, Portugal. They categorized the farms in two groups; for which the criteria was part time farmer and full time farmer. Among 91 dairy farmers, only 9.8% of farms belonged to part time category and 90.2% of farms belonged to full time farmer's category. Non-parametric method (DEA) was used for the calculation of technical efficiency with two assumptions (CRS and VRS) across two groups. Sale of milk,

subsidies availed by the farmers and sales of other produces were used as output variables in this study. Total number of cows at farm, total size of land (Hectors) and total cost incurred (Euros) including fixed and variable cost, used as input variables in the study. Under the CRS assumption, technical efficiency score was 0.679 for group one, and 0.689 for group two, respectively. One member from group one and six members of group 2 found efficient under this assumption. Under the VRS assumption the technical efficiency score for group 1 was 0.787, for the group 2 this score was 0.818, and one member from group one and thirteen members from group 2 were operating at technical efficient level. Regarding scale efficiency, this score was 0.855, and 0.845, respectively; with one member from first group, and six members from second group were operating at efficient level. Group of farmers appeared to more efficient, who's income come from agriculture activities rather than part time farmers.

Yilmaz et al. (2020) analyzed the technical efficiency across 92 dairy farms using cross-sectional data in Burdur province, Turkey. The technical efficiency score was calculated by using Cobb-Douglass function. Range of efficiency found between 30-90% with mean score of 55% in this study. The factors significantly effecting the milk production were household size of the farmer, total number of dairy animals, ratio of cow to total dairy animals, level of technology at the farm, type of bran used in feed, and silage production at farm level.

Zia and Akram (2020) conducted a research to calculate the profitability and production efficiency of milk in Sargodha district, Punjab, Pakistan. Simple random sampling technique used for data collection across 75 dairy farmers at three different tehsil. Non-parametric technique (DEA) was used for the calculation of production efficiency. Tobit regression model was used to determine the inefficiency sources in the selected area. The average economic efficiency level was found 0.35. Technical efficiency level found 0.89 and allocative efficiency was found 0.40. Tobit model suggested that age of the farmers, education level of the farmers, and total land in operation and number of dairy animals at farm had significant and positive relation with the economic efficiency level of the dairy farmers, but the farmer family size had negative relationship with the economic efficiency level among the selected variables. Size of the herd, cost of the fodder, cost of dry fodder used, labor expense and number of dairy milking animals at farm had positive relationship with the income of the selected dairy farmers while expenses on the shed of animals and veterinary medicine

expense had negative impression on the income of respondents. The return to scale value found 1.46 depicted increasing return to scale condition.

Zietek et al. (2022) compared the technical efficiency of cooperative and non-cooperative dairy farmers based on production potential disparities in dairy animals, using the DEA across 108 farmers in Poland. Variables used in this study were revenue obtained by the net milk sale as an output variable and labor expense, expense on raw material, cost of depreciation, and farm operation expenses with the assumptions of CRS and VRS. The CRS assumption used in this study suggested that those farmers involved in cooperative dairy sector were technically inefficient than the farmers who were not involved. The average technical efficiency level in the study area found 0.895. Pure technical efficiency score in the research area found 0.953 but statistical difference found between the cooperative and non-cooperative dairy sector was not significant at the point. The non-cooperative sector had higher score in both cases (Technical efficiency and Pure Technical efficiency). Most of the farmers were operating at decreasing return to scale (DRS), suggested potential of improvement found for those farmers, who were operating at lower efficiency level by managing their deprecation and labor expenses in better way. Small dairy farmers need suitable processing facilities, market space and conditions to compete with the large dairy farms in the area.

Bravo-Ureta (1986) used production function approach for the calculation of technical efficiency of England dairy farmers. Tauer and Belbase (1987) used the Cobb-Douglas production function and ordinary least square method for the estimation of technical efficiency in New York, America. Battese and Coelli (1988) used stochastic frontier method for the calculation of technical efficiency across three years data in Australia. Kumbhaker et al. (1989) used exogenous and endogenous parameter in stochastic frontier approach for the calculation of technical efficiency of dairy farms in Ontario State. Brave-Ureta and Rieger (1990) used OLS, maximum likelihood and deterministic frontiers for the calculation of technical efficiency and its parameters. The highest efficiency level found using stochastic frontier method. Kumbhakar et al. (1991) used series of equation approach for the calculation of technical efficiency using stochastic frontier approach in USA. Cloutier and Rowley (1993) used non-parametric method (DEA) for the calculation of technical efficiency using multi-input variables and multi-output variables approach in Quebec dairy farms, Canada.

Heshmati and Kumbhakar (1994) used SFA and Trans log production function method for the calculation of technical efficiency of dairy farmers across four panels data in Sweden. Kumbhakar and Heshmati (1995) used multi-income sources from livestock sector as dependent variables and multiple inputs and farm characteristics as explanatory variables for the estimation of technical efficiency and suggested that the withdrawal of support price for livestock products, large portion of dairy farmers would run farmers out of the business. Ahmad and Bravo-Ureta (1995) used unbalanced panel data for the estimation of technical efficiency in Vermont. SFA method for the calculation suggested that size effect of dairy farm play vital role in milk production. Reinhard et al. (1999) used parametric and non-parametric approach for the estimation of environment efficiency of dairy farm in Dutch. SFA score (89%) found higher than DEA (78%) score. Jaforullah and Whiteman (1999) used the DEA for the estimation of technical efficiency of dairy farmers in NZ considering 3 outputs. Pure technical efficiency found 89% and scale efficiency was 94% in the research area. They suggested that small farmers should increase their farm size to achieve optimum level. Gerber and Franks (2001) calculated the scale efficiency of dairy farms in England and average level was 87% in research area. They suggested that the farmer having herd size ranges 70-160 operating at economies of scale level. The farmers having range above and below this level were operating at dis-economies of scale level. Moreira et al. (2003) measured technology change and efficiency level using SFA model across unbalanced data. Mean technical efficiency range and significant technological growth rate found 69-77% and 1.08%, respectively. Barnes and Oglethorpe (2004) calculated the technical efficiency along with the cost efficiency among Scottish farmers and suggested that farms size must at optimal level to operate efficiently.

2.9. Factor Effecting the Efficiency Level of Livestock

Ullah et al. (2021) reported a positive relationship between veterinary and extension services and dairy farmer efficiency through adoption of modern management practices, knowledge improvement, and disease control. Kompas and Tuong (2004) suggested that the number of peak milking animals, efficient labor force and suitable technology and proper water system at farm could increase the efficiency level of dairy farms in Australia. Sabir and Tahir (2011) recommended that appropriate extension, veterinary services, and market system could improve the efficiency level

of dairy farmers in Punjab, Pakistan. Ishaq et al. (2007) suggested that the more land acres, labor hours and grazing span for cattle in a year, better the milk yield. He added that small ruminants rearing is as vigorous activity in terms of income and profit of farm. Alabi (2005) reported vaccination of poultry birds; suitable feed, capital availability and adoption of innovation improve the technical efficiency of poultry farm. Omiti et al. (2009) suggested that age factor negatively affect the efficiency and technology adoption. He also reported that formal education of the dairy farmer improve management practices, reduce risk level and improve overall efficiency of farm. Oladeebo and Oluwaranti (2012) suggested young people participation and efficient use of resources to improve the efficiency and profitability of the poultry farms. Nwanchukwu et al. (2007) reported that farming experience improve the overall efficiency level of dairy farmers. Osbahr et al. (2008) suggested that credit facility, training programs at local level and technical support by the authorities and community will improve the efficiency of small dairy farmers. Transitioning to sustainable agriculture practices requires agricultural education and extension at gross root level (Özcatalbas et al., 2017). Boz (2018) suggested that better pasture management, quality breeds, appropriate extension services, subsidized loans, and advanced dairy knowledge improve the efficiency of dairy farmers in Turkey. Morgan-Davies et al. (2017) suggested that high labor cost limits the workforce at farm and limit the efficiency of dairy farms. Kavoi et al. (2010) suggested that the exotic dairy breeds, cooperative centers, all weather road infrastructure, extension visits and credit facility at suitable interest rate reduces the cost inefficiencies in Kenya. Gitau (2013) reported the high concentrate cost negatively affect the production efficiency of milk and farmer reluctant to use this innovation. Masuku et al. (2014) suggested that off farm income improve the resource availability and improve the production efficiency. Onumah et al. (2013) reported that efficient extension services improve the efficiency level of farming community. Pujiati et al. (2013) reported that adoption of modern technologies save time and labor cost, improve the efficiency of dairy farm whereas high veterinary cost negatively affect the efficiency of dairy farmers. Morantes et al. (2013) suggested that farm efficiency at medium-level can be improved through resource allocation, labor productivity, pasture size, and herd size; and farm efficiency at high-level can be improved through concentrate and feed guidelines. Silva and Marote (2013) reported that off farm income, community support fund and government assistance could improve the efficiency in Portugal and Spain. Mugambi et al. (2021) reported that

credit availability at high interest rates, halt the credit access and limit the efficiency. Nakanwagi and Hyuha (2015) reported negative relationship between the crossbred cattle and inefficiency. Parlakay et al. (2015) suggested that herd size at farm and concentrate to feed ratio significantly effecting the technical efficiency of dairy farms in Turkey. Ngozi (2016) reported that trained extension staff, adoption of modern technologies and community social interaction improve the efficiency of goat farming in Tanzania. Bozoglu et al. (2017) suggested that farming as main profession, herd size at farm, pure breeds, low labor cost, low feed cost, milk processing and government support for modern technologies adoption improve the efficiency of farmers in Turkey. Ngozi (2016) reported that the ratio of family labor to total labor, artificial insemination, herd size, milking machine, and age factor all have a significant impact on farmer efficiency. Bruijnis et al. (2013) suggest that the participation of young generation in dairy farming along with high yielding cattle improve the efficiency of dairy farms. Yilmaz et al. (2020) reported that corn silage, herd size, farm technology level and cow proportion to total herd address the inefficiency level of dairy farmers in Turkey. Durham and Mizik (2021) reported that healthy herd size, high cow percentage in herd, government subsidy and diversified farming effect the efficiency of dairy farmers in EU. According to Hawkins, (1993) and Van-Der-Voort et al. (2014) the parasite reduces dairy animals' feed intake, which reduces milk production indirectly and considered as vital reason of yield, productivity and health loses at dairy farms.

2.10. Literature Review on Innovation Adoptions

2.10.1. The Concept of Innovation and its Characteristics

Innovation is alternative framework of strategies or skill set to address the problem and need of individual, organization or society (Roger, 1995). Feder et al. (1985) defined 'adoption' a process in which a person develop understanding through interaction, bearing in mind the pros and cons of modern innovation. Roger et al. (2019) described innovation as whatever unique, an idea, thinking pattern or behavior, but miles extraordinary form the already existing in particular area. Özçatalbaş (2014) defined innovation as the Behavior, idea or technology in Conducting an agricultural practice will retain its progressive characteristics in an area where it newly being adopted. Roger (1995) defined innovation as "an idea, practice, object or technology that perceived as novel due to a distinctive character or different unit of adoption."

Innovation is a concept, a notion, and a product of mental divergence and creativity that has propagated virally throughout the system to which it belongs. It provides fuel for knowledge-based economies and opens up new horizons of knowledge and skill sets for system improvement. It is a departure from traditional thinking, in order to address the same challenges and problems with a different method and attitude with possible solutions acceptable to community (Gladwell, 2000 and Ducker, 2002). Innovation is the translation of ideas, methods, and approaches into products and services that can be used in daily life and contribute to the development of society. It is the curiosity to address the challenges and problems of professionals, businesses and people to revile the hidden secretes with new set of strategies and management. It is secrete or unknown strategies for organizations and business enterprises before adopted by the innovators (Berger, 2005). Innovation is the transformation of ideas, strategies and practices to bring improvement in ongoing operations at organizational level (Tigre, 2006).

Literature provides that there are differences between innovation and technology. Technology is a tangible object in terms of possibilities and available options to improve the production mechanism of enterprise or organization (Kelly, 2012). Innovation, on the other hand, is an intangible set of techniques, tactics, or approaches that people, organizations, and businesses can incorporate in their daily operations to achieve excellence. Although technologies aid in the adoption of the innovation process, but cannot produce innovation by itself (Dias, 2000). Rogers (1995) defined agriculture technology as a composition of hardware aspect composed of machines, insecticides, fertigator and foliar fertilizers and software aspect comprises of knowledge, skill set and information to implement hardware aspect. A package of technological elements composed of modern inputs machines, as well as the technical practices and talents required for their effective use constitutes new technology in agriculture (Samy, 1998). Technological innovations are the vital component of development at organization and country level. New technologies in the industry and business setup improve the production performance and continuous improvement provide the reason of innovation occurrence (Weick and Quinn, 1999; Motta, 2001; Tidd and Bessant, 2020).

2.10.2. Perceived Attributes of Innovation

In order to be accounted as an innovation, new ideas, concepts, practices or application should possess some specific characteristics. Rogger (1995) established the key characteristics for the diffusion to variety of innovative technologies and followed as:

- **Relative advantage:** It specify the assistance level and charges associated with the innovation adoption which includes profitability, cost of installation, reduction in discomfort level, time saving, energy efficiency and prestige among the community members. The technology with positive outlook have better adoption rate among the community members.
- **Compatibility:** It is the level of innovation, consistent with the adopter's existing outlook, historical behaviors, and needs. Physical compatibility is the degree to which it is consistent with current economic practices at field level with low level of ambiguity and are easier to adopt.
- **Complexity:** It is the degree of an innovation, perceive difficult to comprehend and implement. Technology, which is easy to understand and use have better diffusion rate in comparison to those having hard to cognize and practice among the society members.
- **Trailability:** it is a limited scale practice of innovation by the adopter for the decision of adoption at large scale level. For new set of practices or ideas, there is always insecurity in human mind and can be curtailed with taking on at small level. Success story of small adoption diminish the ambiguity level of risk and uncertainty and improve the adoption level among the society members.
- **Observability:** it is a degree to which the new idea, practice or mindset radiant to the members of community. Idea or practice that is more visible and communicative have better level of adoption in comparison to idea that is invisible and have reserved sort of characteristics.

Adoption of innovations typically begins with the recognition that a need exists and progresses to the search for solutions, the initial decision to pursue the adoption of a solution, and, eventually, the decision to continue with the implementation (Mendel et al., 2008). The adoption rate can be accelerated by these five attributed along with the decision making power of individual, better communication channels, proper and suitable social influences and effort incorporated for adoption of innovation.

The selected innovations for this research study was milking machine, milking refrigeration, vaccination, concentrate feed, mineral and salt, maize silage, record keeping, social media and internet, association membership. Manual milking is a time-consuming, difficult, and dangerous procedure for dairy farmers, and those who engage in these activities frequently suffer from multiple injuries. It's also expensive these days since labor wants a high salary rate for agricultural chores with less time for management and operational operations, and because it's a 24/7 job, there's always a labor shortage. The health of dairy animals harmed by manual milking because there is less milking frequency in a single day, poor hygienic conditions leave bacteria, and the cow feels stressed because of the low frequency, all of which add to the common mastitis problem in dairy animals. On contrary the milking machines is less time consuming and involve less human effort with no chance of injury and back pain and more time is available for management and operational issues of dairy farms. It improve the quality of milk as there is more frequent milking option normally three times a day which reduces the stress level on the udder of cow and improve the udder health and there is no hygiene issues in case of milking machine. Automatic milking machine reduces the chance of udder infection, which improve the milk contents, as well as productivity of dairy animal. This innovation and is widely adopted by the dairy farmers in developed as well as developing countries around the world (Jiang et al., 2017).

Normally, milk produced at the farm level should be processed at 10 °C within four hours to prevent the spread of bacteria that degrade milk quality and result in financial losses. Due to the lack of a cooling system, dairy producers are unable to store their product and must sell it to local vendors at a low price or risk it spoiling due to bacterial activity. Cooling systems are an innovative technology that should be placed at dairy farms to prevent post-harvest losses and allow milk to be delivered to its final destination without bacteria proliferating and is widely adopted in developed as well as in developing countries across the globe. In comparison to raw milk, milk that has been properly chilled has a biological quality that is 4-5 times better and has a lower likelihood of being rejected at the milk collecting point. As a result, chilling milk extends its shelf life and minimizes the risk of spoiling. A dairy farm with a properly installed refrigeration system has better farm activity organization and more free time for other operations. It is possible to milk at regular intervals, and as the

frequency of milking increases without causing storage issues, the yield and feed efficiency level improves (Torres-Toledo et al., 2018).

In developing countries, where the weather is typically hot and humid, and there is a lack of green fodder, farmers provide dry forages such as wheat straw and flour, which are difficult to digest and have low nutritional value, disrupting the health of dairy animals and resulting in low milk production during peak milking season. The conventional feed and forages normally offered by the dairy farmers are deficient of calcium, potassium, manganese, selenium, zinc and cobalt etc and affect the production and reproduction level of milk and is essential to offer them on regular basis to maintain good health status of animal. Traditional farmers must endure financial losses as a result of a dairy animal's poor health. The calving interval also increases, prolonging the animal's dry phase, making the dairy company difficult to handle in these conditions. Due to advancement of technology varieties of forage crop especially silage widely used all over the world that is healthy source of protein, dry matter and energy. Silage is well performing feed ration, fulfill the diet requirement of dairy animals, improve the health status of animal and is cheap feed. It reduces the labor effort of cutting green fodder on daily basis and provided more time for the other farm operations. Brewer grains treated with salt minimize supplementation costs, improve feed nutrition value, and ameliorate protein synthesis in dairy animals, which improves the health of bacteria in the rumen and is the main source of amino acids which is helpful in better milk production capacity. The balance ration (silage, mineral mixtures, concentrate and salt) improves the milk production by 0.9% and reduces the cost by 3.8%. The fat content of milk improved by 2-2.3% in buffalo's milk and methane emission reduces by around 2% in case of balance feed content and is widely used all around the country by the successful dairy farmers for smooth functioning of dairy business. The feed stuff is easily available in local markets with the online facility having minimal online charges. (Garg et al., 2014; Bhandari et al., 2016; Reiber et al., 2020).

In the traditional dairy farming system, record keeping is not regarded as a serious practice and is a technique that is less likely to be followed by the majority of farmers in developing nations, but it is one of the most prominent practices in developed and efficient dairy farms. This idea or information is useful for determining the availability of green fodder throughout the year because it is not available in hot

weather. Recording the quantity of concentrate offered at different times of lactation is beneficial for understanding the food requirements of animals during lactation and the dry period. It is helpful to manage the costs associated with dry and milking animals at farm. Quality semen and veterinary services records are useful for improving the pedigree of dairy animals and controlling disease outbreaks in a timely manner. Designing alternate strategies and pathways to lessen the risk and problems associated with operational and management activities is beneficial. It is useful to understand the opportunities associated under different farming systems and select the best one which maximizes profit and minimizes the cost as well (Rademaker et al., 2016). It is helpful in decision making and is widely used all over the world and is a timing and cost saving technique in modern days with day to day record keeping for business decisions.

Small dairy farmers in the traditional mode of production give their dairy animals little or no concentrate feed, posing a global food security hazard due to the dairy animals' low milk potential in most developing countries. Concentrate offers a comparative advantage over conventional feed because it has a higher protein content, and a reasonable quantity of energy content, all of which help to improve productivity, profitability, and animal welfare. Regular usage of these diets in daily feed reduces calving intervals and lengthens lactation by supplying the essential mineral source, which improves dairy animal reproduction health. This feed improves the immunity of dairy animals and lowers farm medical costs because 80% of the feed ingested by dairy animals is a byproduct or waste of an industrial product that is not suitable for human consumption. The use of a balanced diet with a suitable proportion of concentrate feed minimizes methane emissions and improves environmental sustainability. In comparison to dry forages with low protein and digesting percentages, this is widely practiced over the world and has a high acceptance rate (Balehegn et al., 2020).

In most of the developing countries the dairy has prime importance in income contribution but farmers have limited access to information, knowledge, and skill sets regarding the management, pricing and operational activities. On the other hand, the performance of government institutions is not up to par in addressing these deficiencies, as there is a significant gap between research institutions, government departments and farmers. Farmers association is the viable option to mitigate these

short coming in cost effective ways as they provide the regular interaction facilities through farmer meetings at local level where farmers can discuss issues such as quality animals, technological inputs, marketing issues, and other operational and management issues at dairy farms without incurring any consultation fees, giving them a competitive advantage over non-members who face higher consultation costs in terms of farm operation, transportation as well as more time and energy consumption (Chagwiza et al., 2016). A healthy percentage of the country's dairy farming industry is a member of these organizations, and they communicate with one another on a daily basis about dairy concerns that address the complexity, compatibility, and triability attributes of of dairy individuals.

Propogation of information through social media groups, tv channels and computers has potential benefit of record excess, informations and reports regarding weather and market conditions, disease outbreaks, precautionary measures, past trends of price and markets, experience sharing of successful dairy farmers, new set of practices installation at farm and research outcomes which influenced the support for timely decesion making have relative advantage over those mindset that are reluctant to adopt this innovation (Warren, 2002). It not only makes the process easier, but it also saves time, energy, and resources that can be used for other farm and everyday life tasks . The complexity, compatability, and triability features of this innovation are addressed by regular contact and frequent adoption of this innovation by the great majority, as well as sharing of regular success stories on these platforms.

Vaccination and parasite treatment adoption are both low-cost methods for preventing disease and increasing the feed efficiency of dairy cattle. Both of these inventions improve the health of dairy animals by boosting their immune systems, resulting in increased milk production on the farm. The availability, access, and demand of products available in markets influence the adoption of these innovations. Aвалиability is linked to the effectiveness and safety of these innovative items, as well as their widespread availability on the local market. The term "accessibility" referred to the product's cost, as well as whether or not farmers in the local community could afford it, and demand is linked to dairy farmers' degree of information and understanding. Both of these cost effective innovations are offered for almost no cost at the district hospital in the region. The intricacy and triability of this innovations are addressed by a significant number of dairy producers who use these treatments on their

farms on regular basis (Donadeu and Dungu, 2013; RK et al., 2016; Carter et al., 2017; Donadeu et al., 2019).

All of these strategies have a comparative advantage over traditional ways in that they are more profitable, cost-effective, and acceptable for the health of dairy animals, hence improving both human and animal welfare. All of these procedures are in use at various dairy farms with a successful record of accomplishment, and a complete set of advice is available over the phone or on the internet with a simple click, and is not overly complicated these days. These methods have been effectively implemented by large and medium-scale commercial dairy producers on their farms, and are visible to all stakeholders in the industry.

2.10.3. Adoption Diffusion Theories

All the members of social system do not all accept an innovation at the same time. Rather, they adopt in a chronological sequence, allowing individuals to class as early adopters based on when they first used a new idea or concept. Beal and Bohlen (1956) also defined the innovation diffusion process as follow:

- Awareness stage: The individual acquires information about the existence of the new concept or technology for the first time and gain some understanding, but at this stage is still short of information. Communication channels especially social media and mass media will address the shortcomings in this stage.
- Interest stage: Individuals at this stage recognize the benefits and drawbacks of technology and develop a thorough understanding of how to use it. At this stage, proper communication channels, level of knowledge, and perceived characteristics of the individual are critical.
- Evaluation stage: In this stage, individual have to decide whether to accept or reject the idea, technology or innovation keeping in light of his knowledge and understanding. Appropriate communication channel and personal persuasion is helpful for decision-making process.
- Trail stage: At this stage, the individual practically implements new ideas, thoughts, and technology on a small-scale level, influenced by communication channels.

- Adoption stage: At this stage farmer have gained practical experience through small trails and in the light of knowledge, understanding and practical results, individual decides to adopt the innovation at full scale or not.

Extensive knowledge of technology play a vital role for the improvement of production mode (Özçatalbaş, 2007). There are different theories of innovation adoption process. In this chapter, these theories examined since they explicitly utilized to identify the innovations used and objectives to achieve for this study. Rogers (2003) described adoption process composed of five key characteristics, which are;

- I. Knowledge stage: The individual initially exposed to a new idea, thought process or practices, but he or she has no knowledge of it. At this point, the individual is not motivated to learn more about the innovation.
- II. Persuasion: The person intrigued by the idea and is actively and seeking further and detail information to improve his or her capacity of knowledge in the new domain.
- III. Decision: The individual considers the concept of new ideas and practices and assesses the benefits and drawbacks of employing them before deciding whether to adopt or reject it. This level is the most difficult to obtain scientific evidence on because of its individualistic nature.
- IV. Implementation: Considering the situation, the individual uses new practices or ideas to varied degrees. During this stage, the individual assesses the innovation's utility and may seek additional information about innovation.
- V. Confirmation: In this stage the individual makes a final decision on whether or not to continue employing the innovation in his or her on going setup. This stage influenced by both intrapersonal and interpersonal set of opinions, confirming the group's decision was correct.

2.10.4. Individual Innovativeness

Measuring the innovativeness of society is helpful in strategy development and understanding the social behavior of members towards the innovation. Rogger (1995) defined a bell shaped curve pattern to express adoption rate in the society, which are as follow:

1. Innovators: These individuals are obsessed with new ideas, thoughts, practices, and technologies, have a peer group of intellectuals and scientists, and are

endowed with risk-taking skills as well as the financial stability to take the shock of failure with a percentage of 2.5 in the concerned area adopters.

2. Early adopter: These individuals are the missionaries of and propagate it in the society after realizing the pros and cons associated with innovative practices with traits of adoption leadership. They are the role model, trigger the diffusion of the innovation level with a vital role in communication networks, and reduce the uncertainty level among the masses of society and are 13.5% of the adopters.
3. Early majority: These are interconnectors in the social system with commonly interaction with the peer groups and rarely hold opinion leadership position in communication networks. They deliberately take a long time or practice to observe more success stories to minimize the risk level associated with adopted practice and innovation. They normally follow neither first nor last adoption strategy for decision-making and are the 34% of the adopters.
4. Late majority: These are individual who adopt some new idea or practice with the considerations of economic need and peer group pressure. These are cautious having limited resources and under the influence of cultural and tribal norms and strong support by these groups, incorporate new set of innovations in their routine practices and are the 34% of the adopters.
5. Laggards: These set of individual are more traditional, suspicious and no management attitude towards the new approach and rare peer group interaction with more strong believes on experiences. They are resistant to new ideas, thoughts, and take more time in decision-making strategies with limited set of resources, fear of failure, and are the 16% of adopters in concerned field.

In agriculture sector, success of innovation adoption among the key stakeholders aligned with heavy research funding, full government support with international partner's collaboration and extension administration to refine the knowledge and understanding through proper campaign among the farming community (Janicic and Jankovic, 2014).

2.10.5. Factors Effecting Innovations Adoption in Agriculture Sector

The nexus of farmers, extension services, and research organizations may solve the difficulties with an efficient set of approaches, resulting in sustainable agriculture (Budak and Yurdakul, 2004). Adoption of modern technologies in developing

countries influenced by economic, technical, social, and risk-taking behavior of individuals (Kebede et al., 1990). Socio-economic characteristics, cultural norms, interaction and communication skills and capacity of farmers are some key elements for the adoption of innovations in agriculture sector (Singh et al., 1993). Innovations in agriculture sector has impact on the living standards of the farming community (Mustaffa et al., 2019 and Bizikova et al., 2020). Agricultural innovations make the routine practices easy, efficient and technology oriented (Aubert et al., 2012). Innovations adoption reduces the cost of production (Finger et al., 2019). Innovation improve the production potentials of farms. Innovation improve the return on investment in agriculture enterprises (Halachmi et al., 2019; Gaffney et al., 2019; Bellon et al., 2020). Using various communication channels among targeted audience to minimize the period of contentment and adoption (Leeuwis and Aarts, 2011). Completion of technology adoption improve the economic and social well-being of rural community (Adnan et al., 2019). Learning from friend and social network circle is crucial for adoption of innovations (Le et al., 2020). Farmer field days and training workshops are healthy activities in innovations adoption and for sustainable practices in healthy environment and is apposite for economical, well-informed and healthy rural community (Bavorová et al., 2020). Adoption of innovations influenced by the norms of culture, personal land holdings and subsistence farming practices (Llewellyn and Brown, 2020). Public-private partnership (Government and NGOs) is healthy for innovations adoption (Yamoah et al., 2020). Carbon taxing on the conventional farmers and subsidized innovative technologies for low carbon production improve the adoption rate in rural areas and strengthening the agriculture extension system by providing modern equipment's (Tablets and projectors) improve the level of understanding and adoption rate (Dhehibi et al., 2020 and Liu et al., 2020). Progressive agriculture Entrepreneurs with government support, regulations and policies can improve the adoption rate in climate smart agriculture (Senyolo et al., 2021). Regular farmers meeting and mass media communication by the extension department of government is helpful in innovations adoption behavior in developing countries (Musabyimana et al., 2019). Credit facility, participatory irrigation approaches and regular interaction with trainers improve the adoption process in inputs selection Niyomugabo (2019) farming experience, membership in farming cooperatives and land holdings are helpful in adoption of modern technologies. Healthy communication for information, knowledge and ideas in social networks improve the understanding

and adoption rate in the community. Research on reality based field problems aligned with government policy improve the biodiversity conservation rate in agriculture sector (Mascia and Mills, 2018; Shaijumon, 2018; Baiyegunhi et al., 2019). Frequent social interactions with skillful persons in the community improve the adoption rate and skill set of individual member (Chen et al., 2018). Smart gadgets on cell phones and tablets, such as videos and training courses, aid in the adoption of insect and pest control technologies (Wyckhuys et al., 2018). Regular training through farmer field schools addresses social and cultural norms as a barrier to innovation adoption (Wilcox and Lawson, 2018). Lack of information, knowledge, and regulations is a significant barrier to technology adoption (Makundi et al., 2017). Access to real information about a subject through a proper channel improves the adoption of modern techniques (Simtowe et al., 2011). Government provide free extension services to farmer to improve the living standard of rural community (Budak and Budak, 2010). Age of milking animal, disease, and infections, lactation length, and mulching time are some of the significant factors to consider while determining milk yield at farms (Atasever et al., 2020).

Shibah et al. (2002) suggest that age of the farmer has no significant relationship with the adoption of technology; O'Brien et al. (1996) reported positive as well as significant relationship between age and adoption of innovations. Chang (2002) stated negative significant relationship between these two variables, Rogers (1995) stated that about 114 studies, which investigate these two variables, found no relationship between them. Mussei et al. (2001) reported no association between the family size and adoption, Shibah et al. (2002) reported positive and significant association between the household family size and adoption. While Getahun et al. (2000) reported negative significant association between the two variables. Chang (2002) stated positive and significant relationship between the education level of respondents and adoption, Zeller et al. (1998) reported significant and negative association between the level of education and adoption, Bulale (2000) stated no association between these two variables. Jabbar et al. (1998) stated positive relationship between the size of farm and adoption, Bulale (2000) reported positive and significant association between farm size and adoption, Kebede et al. (1990) reported differential effect in three different technologies. With single ox technology, the association reported as negative and positive in case of fertilizers and pesticide adoption. Batz (1999) reported significant

association among farm size, shelter spot and calf pan and significant negative association in case of herd fencing adoption technology. Shiyani et al. (2002) reported no significant association between these two variables in crop production. Pandey (1999) reported no relation and association between the social interactions with adoption, though it leads to better awareness and understanding of modern technologies and may improve adoption rate, Roger (1983) early adopters of technology have more social interactions, than those of late adopters. Goswami et al. (2000) reported significant positive association between cosmopolitan and adoption, Hossein (1998) reported no significant association between these two variables. Abd El-Razek (2002) reported significant positive association between the mass media and adoption of technology. While Ahmed (1994) found no significant association between these variables. Baidu-Forson (1999) reported significantly positive association between the extension agent's interaction and adoption. While Salama, (2001) found no significant association between these two variables. Hafz and Anwar (1999) found positive relationship between the veterinary contacts and adoption. Chang (2002) reported significant positive association between the size of the herd and adoption. While El- Gannam (2000) reported significant negative association between herd size and adoption, Al-Zahrani et al. (2018) reported no relationship between these two variables. Abd El-Razek (2002) reported significant positive association between farmers farm income and technology adoption, while Alsakran (2001) reported no association between these two variables. Shibah et al. (2002) reported positive association between the labors hired with the adoption of technology in agriculture, while Batz (1999) reported significant negative association with the hired labor and rate of adoption, Waithaka (1998) reported no relationship between these two variables in dairy sector. Bulale (2000) found no significant association between the credit facility and technology adoption, while Freeman (1996) observed influence of credit facility on the decision making of small milk producers. Fernandez-Cornejo et al. (2007) observed positive association between the off farm occupation and adoption of technologies at farm, while Mussei et al. (2001) observed no association between the off farm occupation and agriculture technologies adoption. Fliegel et al. (1968) reported significant impact of healthy returns on the technology adoption in case of small-scale farmers. Batz et al. (2003) reported negative association between the complexity and technology adoption. El- Ghamrini, (1998) reported positive association between the profitability of the farmer with the adoption of technology,

while Batz et al. (2003) observed negative association between investment and technology adoption. Cary and Wilkinson (1997) reported negative association of between the cost and technology adoption rate.

2.11. Issues Regarding Poor Technology Adoption

In developing countries, administration of agriculture sector has poor considerations about the changing environmental conditions, modern agriculture practices and updated technologies due to lack of knowledge, absence of regular training mechanism, poor access to modern technology and poor policy alignment with the desired development objectives. Extension part is still using short films training program, power point presentation and book literature for adoption of modern agriculture practices, without practical demonstration, well trained staff and appropriate training courses to address the problems in particular area (Venkatesan, 1985). There exist a difference between those individuals, who are unable to adopt modern technologies and those who are unwilling to adopt new set of ideas or innovations. Nowak (1992) explained these barriers type as following;

- Incapability to adopt innovation: it includes those individual, who lack information, poor resources for information, unable to understand the complex information system, poor managerial skills and poor decision-making mindset.
- Reluctance to adopt: it includes those individuals, who have conflict with information, relevance, ignorant about the modern production technologies, strong believe on the conventional practices and risk averse attitude.

The links between research in agriculture and innovations adoption in developing countries are widely perceived as a significant bottleneck in agrarian innovation frameworks and have received insufficient attention previously (Stands, 1988). Due to poor communication and coordination in their concerns, research in agriculture and the extension system have linkage issues. The research concerns with the knowledge creation and developing new technologies and on the other side extension key concerns is to deliver and promote the adoption rate, strongly relies the effective communication to improve the adoption behavior (Cassiman et al., 2010).

Despite the common objective of agricultural research and extension system, the links between them are often ineffective. In developing countries, an effective extension system can bridge the gap between available technology at research centers

and farm level through suitable communication networks, which would otherwise be a waste of resources if not adopted at the gross root level (Abubakar et al., 2009).

Financial constraints, a scarcity of well-prepared field staff and scientists, field research relevance, limited access to technical knowledge, limited budget allocation, no performance incentives, and low morale among field personnel in the research and extension sector are major barriers to technology adoption in developing countries (Anderson and Feder, 2007). The main barriers to the adoption of modern technologies in developing countries are a lack of research and development funding, a lack of intellectual property rights, and a limited research capacity. Production-oriented research, poor coordination of research institutes with farmers and the extension sector, a lack of verification research trials, a lack of staff training programs, a limited education mindset in farming, and slow delivery of information and deficiencies in skills, as well as a lack of investment in research and development, all hampered rural community technology adoption (Abbas, 1998). Limited transportation and equipment facilities, limited research mindset in research institutes and poor information dissemination to farmers all contribute to low adoption (Gales et al., 1992). Uniform access to resources is a critical component for poverty alleviation, as technology available at research institutions is incapable to address the common concerns of small-scale farmers having limited resources accessibility (Key and Runsten, 1999). Government policies, infrastructure availability, and an abundance of uniform resources, not synchronized with the technology adoption framework (Rose and Straub, 1998).

3. MATERIALS AND METHODS

This section would walk through the methods and techniques for conducting the current research in a systematic manner, and each aspect of efficiency and innovation adoption would be addressed and clarified. The institutional, environmental, and infrastructure factors that influence milk production decisions, including the cost of basic milk inputs and the socioeconomic characteristics of dairy farmers. Some of these factors are within dairy farmers' control, such as the availability of modern technologies, the balance of animal feed including crude protein dry matter and energy level in balance proportion, and the healthy environment for dairy animals, basic knowledge about disease and parasites, mineral and salt requirements of dairy animals. On the other hand marketing facilities, all-weather road development, environmental factors, and input pricing, which are important factors in the decision to get involved in dairy farming, are beyond their control. Making the decision to get the highest yield from dairy animals at the lowest possible cost is critical for running a successful dairy farm.

This section describes the techniques and procedures for analyzing collected data in order to gain a better understanding of the research problem and obtain reliable results (Labaree, 2013). The explanation of analysis procedures and techniques must be valid and clear for the research to be consistent and valid for the articulation of objective-oriented methodology. Furthermore, the method for investigating the factors influencing the efficiency of dairy farmers' and decisions to use their resources and land for dairy farming, as well as innovation adoption practices to become efficient farmers, described in detail.

3.1. Material

The problem associated with the specific enterprise and the research objective are critical in determining the research area. This study was concerned with the efficiency of dairy enterprises and the innovation practices used in milk production, and the area where all of these practices used in milk production will be of prime importance for research point of view.

3.1.1. Study Area

Faisalabad is the third largest city of Pakistan in terms of population situated in Punjab province, with an area of 1300 km² with population size of 3,203,846. The location coordinates are 31°25'0"N 73°5'28"E. Agriculture and industry are major income source of people with a GDP (nominal) contribution of \$ 20.5 billion. The average temperature ranges from 12.5°C- 33.9°C with rainfall ranges from 8mm to 119mm. The total livestock population in this area was 16251 male buffalo with 612107 female buffalos along with 129008 male cattle and 166000 female cattle in the area with 94% of dairy farmers having holdings up to 6 dairy animals.

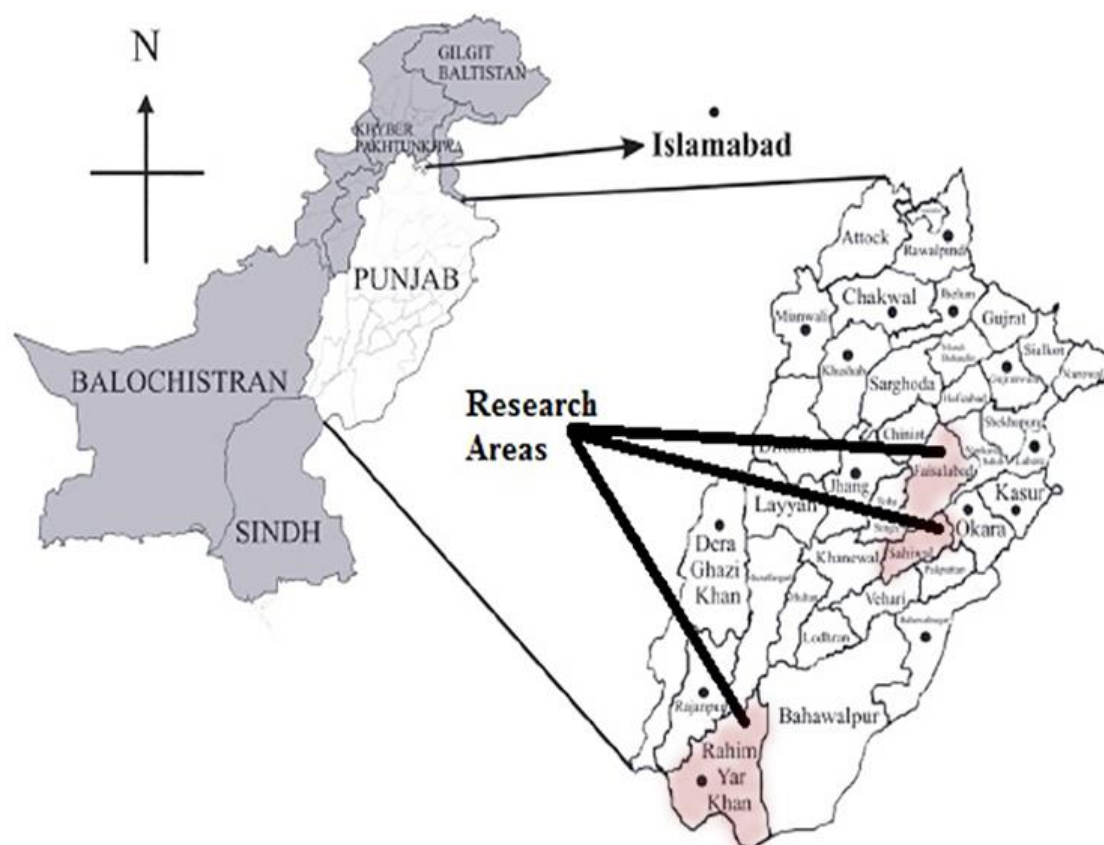


Figure 1: Map of Punjab province

Sahiwal is the 21 largest city of Pakistan situated in Punjab province, with an area of 3,201 km² square kilometer with population size of 2,513,011 with coordinates of 30°39'40"N 73°6'30"E having agriculture as major income source of people. The average temperature ranges from 19.5°C- 40.2°C with rainfall ranges from 13mm to 89mm. The total livestock population in this area was 7226 male buffalo with 375488

female buffalos along with 55431 male cattle and 95818 female cattle in the area with 93.6% of dairy farmers having holdings up to 6 dairy animals.

Rahimyar khan is the 17 largest city of Pakistan in terms of population and situated in Punjab province, with an area of 4,141-km² kilometer with population size of 477,100. The coordinates of city is 28°25'12"N 70°18'0"E having agriculture as major income source of people The average temperature ranges from 15°C- 42°C with rainfall ranges from 2mm to 53mm. The total livestock population in this area was 12224 male buffalo with 447971 female buffalos along with 48413 male cattle and 279302 female cattle in the area with 88.9% of dairy farmers having holdings up to 6 dairy animals (GOP, 2006).

Major crops in the country have a long payback period and make it difficult for farmers to meet their daily expenses; the majority of farmers in the selected area keep dairy animals as their primary or secondary source of income. In the study area, a random sampling technique used to select one tehsil from each district and then two union councils from each tehsil using the same criteria. In the second stage, one village from each union council chosen at random, and a pilot survey conducted with 15 respondents from each village, for 90 respondents from the selected research area. The pilot survey was used to put the data collection instrument in its final form. Since minor amendments were made in some questions to make them more understandable by farmers, the results of this pilot survey were not included in the main sample of this study.

3.2. Methods

3.2.1. Sampling and Data Collection Techniques

Simple random sampling technique deployed in this study for the data collection in the month of April 2021. This study conducted in three districts of Punjab including Sahiwal, Faisalabad and Raheemyarkhan, where dairy sector considered as main source of income. The literature review provide the source that Sahiwal, Faisalabad and Raheemyarkhan where dairy enterprise is considered as major income source for the farming community (Ashfaq et al., 2015; Khalid et al., 2017; Shahbaz et al., 2020).The personal interview of dairy farmer conducted to get information regarding the variables mentioned above to achieve the desired objective of the study. Total 300 dairy farmers involved in this research and 100 were selected form each district level

as innovation adoption concept is not very common in all three districts and has less number of available farmers

The details of dairy farmers obtained from livestock and dairy development department in each district and sample size for the research calculated by using the formula of Cochran, (1977) in equation 3.1

$$n_o = (Z\alpha/2)^2 P Q / e^2 \quad \text{Eq. 1}$$

n_o = Sample size for the study

P = estimated portion of population = .73

Q = 1 - P = .30

Z ($\alpha/2$) = 1.96; standard normal variation value at 95% confidence level

e = Error (5%)

n = 302.75 \approx 300

Out of the 300-sample size for the study, a sample size of 100 respondents from each district selected for data collection with the help of livestock assistant and veterinary officers in the area.

3.2.2. Description of Questionnaire for Research

Well-organized questionnaire developed under the supervision of supervisor, committee members and upgraded later on with the coordination of field staff, livestock assistant and milk producers for pretesting. The first section of the questionnaire composed of socio-economic characteristics of dairy farmers including age of the respondent, education level of dairy farmer, size of the family, experience in agriculture and dairy sector, total land holdings and area under the fodder crops. The second part is composed of dairy related activities took place at farm including the number of animals, total milking animals, milking yield of dairy animal, fodder cost and quantity, concentrate cost and quantity along with wheat straw and electricity usage is essential components for dairy production. The third stage composed of innovation adoption that includes silage, milking machine, refrigeration of milk, salt and minerals, vaccination schedules, parasite treatment, regular record keeping, membership of dairy associations and social media and internet facilities. Content validity of the instrument was assessed by a panel of experts including three college

professors, three animal scientists from the department of animal sciences, and three opinion leader farmers involved in dairy farm in the locality. Questions and the way they worded were deeply examined by the panel of experts considering relevant literature in the subject matter, and socioeconomic and cultural characteristics of research environment.

Reliability of the Likert items of the data collection instrument was assessed using the Chronbach's alpha internal consistency coefficient. This value was calculated as 0.83 from the 90 questionnaires completed for the pilot test of this study. Slight changes were made in wording of the other questions to increase the reliability of the instrument.

3.2.3. Data Analysis

The information of the selected variables were entered in excel sheet for descriptive and econometric analysis. Data envelopment analysis (DEAP) used in this study for the calculation of technical, allocative and economic efficiency of the dairy farmers. Later part of the analysis, STATA software package tool used to determine the factors affecting the technical, allocative and economic efficiency level and SPSS software package tool used for the calculation of descriptive analysis and partial correlation of sustainable innovation adoption index with the socio-economic variables (Demiryürek et al., 2017). New contribution to this research field was to determine the relationship of technical, allocative and economic efficiency with the sustainable innovation adoption index using SPSS software package and Microsoft word to compile the results to meet the thesis requirements.

3.2.4. Analytical Framework of the Study

In this study, DEA used to compute the technical, allocative, and economic efficiency of 300 dairy farmers. It is a non-parametric approach to achieving the best possible output level, with score ranges ranging from 0 to 1 and including single output with multiple sets of inputs. Score 1 indicates optimal level of production, while score less than 1 indicates inefficient level of production suggested by Farrell (1957). The results of the study obtained using Excel and the DEA software program.

The two models used in this study to address the objectives. At first stage of analysis, efficiency scores calculated, and in second part of analysis, the variables involved for efficiency change of dairy farmers were determined. The second part of

the analysis was completed by using the Tobit model where efficiency scores used as dependent variables. Since dairy farmers have control over the inputs used in milk production rather than output (milk production), an input-oriented efficiency model was used to determine the efficiency score of dairy farmers. TE and AE provided the economic efficiency (EE) as well. Table 3.1 demonstrates the signs and explanation of the variables used for the estimation of technical, allocative, and economic efficiency of the dairy farmers. Improving the quantity of feedstuff including green fodder along with concentrate improve the health positive association with the milk production of dairy animals (Richards et al., 2016).

Table 3.1. Determinants for the calculation of technical, allocative and economic efficiency

Variable	Description	Unit
Milk Production (Monthly)	Dependent variable	Liters
Fodder	Amount given to a dairy animal	Kg
Wheat Straw	Amount given to a dairy animal	Kg
Labor hours	Labor hours	Numbers
Labor cost	Price per treatment	Rs
Fodder cost	Price per kg	Rs
Wheat straw cost	Price per kg	Rs

Fodder is large portion of feed of dairy animal and per unit increase in price of these item will increase the cost of feed and reduce the profit margins of dairy animals. Wheat straw is an important feed item for dairy animals, especially in the absence of green fodder, which is a major feed item for dairy animals. That why all these necessary inputs items were incorporated in the model for the calculation of efficiency levels. The total milk output (Liter) used as output in the model (y_i). Labor (working hours) and fodder quantity (kg), and wheat straw quantity (kg) as inputs. The input (labor hours and fodder quantity, concentrate quantity, wheat straw quantity, mineral and salt quantity) matrix symbolized as $K \times N$ and the output matrix as $M \times N$. The model for the assessment of efficiency scores presented below.

Minimize θ, λ

Subject to $-y_i + Y\lambda \geq 0$

$$\theta x - X \lambda \geq 0 \quad i$$

$$\lambda \geq 0 \quad \text{Eq. 2}$$

θ = TE score

λ = N x 1 weight of vector

The Economic Efficiency model for the dairy farm calculated as follows:

$$\text{Minimize } \lambda x_{i^*} w'_i x_{i^*}$$

$$\text{Subject to } -y_i + Y \lambda \geq 0$$

$$X_{i^*} - X \lambda \geq 0$$

$$\lambda \geq 0 \quad \text{Eq. 3}$$

w'_i = transpose of vector of input prices

x_{i^*} = cost minimizing vector of input quantities for the i^{th} farmer

Above-mentioned functions subjected to a constant return to scale (CRS), representing that the input and output increased in same proportion. The economic efficiency of the i^{th} dairy farmer calculated as follows:

$$\text{Economic efficiency } i, \text{CRS} = w'_i x_{i^*} / w' x_i \quad \text{Eq. 4}$$

Economic efficiency is the minimum cost ratio at given level of technology of price (Coelli et al., 2005).

3.2.5. Factors Effecting the Technical, Allocative, and Economic Efficiency

A number of studies in the dairy farm sector have examined the various variables that influence dairy farmers' efficiency. Dhungana (2004) and Mburu et al. (2014) used a two-stage procedure for their studies. In the first stage, the efficiency level of dairy farmers calculated using the DEAP software package, and in the second stage, the results of this software transferred to an excel sheet, which then transferred to the STATA software package to analyze the factors affecting the efficiency level of dairy farmers using following equation:

$$\hat{u}_i = \alpha_0 + \alpha_1 Z_1 + \alpha_2 Z_2 + \alpha_3 Z_3 + \alpha_4 Z_4 + \alpha_5 Z_5 + \alpha_6 Z_6 + \alpha_7 Z_7 + \alpha_8 Z_8 + \alpha_9 Z_9 + \alpha_{10} Z_{10} + \alpha_{11} Z_{11} + \alpha_{12} Z_{12} + \alpha_{13} Z_{13} + \alpha_{14} Z_{14} + \alpha_{15} Z_{15} \quad \text{Eq. 5}$$

\hat{u}_i = score of efficiency

Z1 = Age of farmer (Years)

Z2 = Education level of dairy farmer (Years)

Z3 = Size of the family (Numbers)

Z4 = Experience in dairy farming (Years)

Z5 = Land ownership (Acres)

Z6 = Total number of milking animals at farm (Numbers)

Z7 = Dummy variable as dairy farming as main source of income (Yes = 1; No= 0)

Z8 = Dummy variable as milking machine used at farm (Yes = 1; No = 0)

Z9= Dummy variable as milking refrigeration at farm (Yes = 1; No = 0)

Z10 = Dummy variable as record keeping at farm (Yes = 1; No = 0)

Z11 = Dummy variable as vaccination at farm (Yes = 1; No= 0)

Z12 = Dummy variable as use of maize silage at farm (Yes = 1; No= 0)

Z13 = Dummy variable as use of mineral and salt at farm (Yes = 1; No= 0)

Z14 = Dummy variable as dairy association membership (Yes = 1; No= 0)

Z15 = Dummy variable as use of social media via internet (Yes = 1; No= 0)

This study used the two limit Tobit model for the analysis as range of efficiency score lies between 0-1 (Austin and Kopec, 2000; Mburu et al., 2014; Boz, 2019). The score of technical, allocative and economic efficiency were regressed against the explanatory variables mentioned above in equation 6 using level of significance at 1%, 5% and 10% respectively.

The age of the dairy farmer was considered who was in charge of all dairy action at farms regarding the purchase of inputs and the sale of dairy milk with hypotheses of a positive association between the age and the efficiency of the dairy farmer because he can make better management and decisions in relation to his life experience.

Education improves the level of knowledge, experience and understanding about the farm operations, management practices and efficient decision-making regarding the health of animals, farm activates and adoption of modern practices reported in his study with hypothesis of positive association with efficiency level of dairy farms.

In most developing countries, dairy enterprises are labor intensive and less mechanized, resulting in higher costs to meet family needs (feed, education, health care, clothing, and transportation), and less capital available for farming and dairy sector activities. On the other hand, more labor is available for farm and agricultural activities, and it is simple to perform timely operations at the farm with the hypothesis of a positive and negative relationship with the efficiency level.

Land ownership is an important factor in the smooth operation of a dairy business because shed and fodder requirements vary throughout the year due to price and weather conditions. Winter and summer shed requirements are very different, and necessary amendments are required for a healthy farm environment, which is a difficult task in the case of a rented farm. The land rent is also higher when compared to the price of milk, making it difficult to support a healthy environment for dairy animals on the farm with the hypothesis of a positive relationship with dairy farm efficiency.

The better percentage of milking animals in the herd will reduce dairy animal overhead costs, resulting in more milk at the farm and improved profitability. Large herd sizes with more milking animals hypothesized to be beneficial to dairy farmers' efficiency levels in the research area.

Dairy farmers whose primary source of income is the dairy industry can devote more time and energy to their farms without interruption and with greater focus than those who have diverted their attention to non-dairy activities and have gaps in their management and operational activities directly obstruct the smooth milk production and health of dairy animals. This variable hypothesized as positive association with the efficiency level.

Milking machines and milk refrigeration at the farm level are technological variables that reduce workload and labor costs at the farm level, which is a difficult and significant cost item in the dairy sector due to environmental, health, financial, and attention issues.

On the other hand, both of these technologies, which are electricity-oriented, raise the cost of electricity and disrupt the allocative efficiency of dairy farmers, reducing economic efficiency. This variable hypothesized to be positive for efficiency because it reduces major cost and saves time.

Table 3.2. Factors effecting the technical, allocative and economic efficiency

Variable	Description	Unit	sign
Age	Number of years	Years	±
Education	Number of schooling years	Years	+
Family size	Total household members	Numbers	±
Dairy farming experience	Total years involvement	Years	+
Land ownership	Land as an asset	Acres	±
Milking herd size	Animals in lactation	Numbers	+
Dairy as main income source	Dummy variable	Yes=1; No= 0	+
Milking machine	Dummy variable	Yes =1; No= 0	+
Milk refrigeration	Dummy variable	Yes=1; No= 0	+
Record keeping	Dummy variable	Yes=1; No= 0	+
Vaccination	Dummy variable	Yes=1; No= 0	+
Maize silage	Dummy variable	Yes=1; No= 0	+
Concentrate with minerals and salt	Dummy variable	Yes=1; No= 0	+
Association membership	Dummy variable	Yes=1; No= 0	+
Social media and internet	Dummy variable	Yes=1; No= 0	+

Through a better immune system and digestion process, timely vaccination against major diseases, as well as parasite treatment, improve the health status of dairy animals and increase milking capacity and lactation length. This improves technical and allocative efficiency by increasing milk yield and lowering farm treatment costs, which also improving the overall economic efficiency of dairy farms. Both variables hypothesized to have a positive relationship with dairy farmers' efficiency levels.

Maize silage has a higher percentage of crude protein and energy level than conventional fodder and requires less labor. It improves animal health, and because it is a balanced diet, it increases milk yield in dairy animals. The second advantage of silage is that it reduces farm workload and labor requirements, which improves allocative efficiency by lowering dairy animal overhead costs. This variable hypothesized to have a positive relationship with dairy farmer efficiency.

Farmer associations typically organize farmer meetings, farm trainings, and information and knowledge sharing of the best possible combination of balanced diet, quality breeds, and preemptive measures for the quality management of dairy farms, all of which improve dairy production. Farmers can discuss their management and financial issues and association suggested some self-help groups to those farmers to address their issues timely. These healthy activities on a regular basis reduces the

financial fatigue of dairy operators and improve the dairy animal milk production and reduce the cost of farm operational activities, and hypothesized to have a positive relationship with the efficiency level of dairy farmers in the research area.

Internet and social media provides large number of dairy experts, information and modern innovation in dairy sector on a single click. Enormous number of dairy groups are currently operating on social media and sharing the modern mode of production and address the dairy issues of dairy farmers. The main concerns on these platforms are understanding about the balance feed; concentrate composition and formulation at farm level, silage making and preservation, total mix ration, quality breeds and their potential and healthy environment for dairy animals without any cost on regular basis by just sharing the problems in the form of videos and photographs by paying minimal internet fee. This improves the nutritious content of feed, which in return improve the health and milk production of dairy animals. The second positive aspect of this innovation is, it reduces the veterinary and transportation cost in case of emergency to veterinary clinics for minor issues. Positive aspects of internet and social media improves the allocative and technical efficiency of dairy farms. Therefore, this variable hypothesized as positive relationship with efficiency scores of dairy farmers.

3.2.6. Diagnostic Tests for the Model

In second stage of the study, we have to run the Tobit model across different set of selected variable used in the model against the technical, allocative and economic efficiency scores. We have to checked the VIF value of all the selected independent variables in the model and it must lies below 4 as it the basic criteria for the to avoid the problem of multicollinearity. Literature review provides the different threshold criteria for multicollinearity with O'brien (2007) defined the maximum range would be 5, on the other hand Pan and Jackson (2008) recommended the range value of 4 in their study.

3.3. Calculation of Innovation Sustainability Index

In third stage, we calculated the innovation sustainability index of the dairy farmers and its relationship with the socio-economic characteristics, profitability and efficiency level of dairy farmers. Innovation adoption score of each dairy farmer calculated by using the method used by Demiryürek et al. (2017) in his study. This index takes into account the number of innovations adopted by dairy farmers as well

as the number of years that these practices practiced on dairy farms. A higher value of the sustainable innovation index indicates that farm-level innovations are becoming more sustainable. Farmers with high index values considered more innovative with low index values. The calculation procedure of this index is as follow:

$$\text{Innovation sustainability index} = \frac{\text{Number of adoption years x adopted innovation numbers}}{\text{Total number of innovations}}$$

The innovation adopted by the dairy farmers are milking machine, milk refrigeration, , record keeping, parasite treatments, vaccination, maize silage, concentrate feed with minerals and salt, association membership and social media and internet. The formula to calculate the total information score used by (Demiryürek et al., 2017) in his study is as follow:

$$\text{Total information score} = \text{FC} \times \text{IU}$$

Where

FC = The number of diary farmer's information source contacts

IU = Usefulness of information

Coefficient of Partial correlation was (Control variable: state of adoption) was determined and association between these selected variables and innovation sustainability index was calculated.

Mean score derived from 4-point Likert scale for each innovation, and total innovation score was derived and those farmers whose total adoption score was less than average mean considered as low-level adopters. Dairy farmers, whose score was greater than mean adoption score considered as high-level adopters.

3.3.1. Factors Effecting the Adoption Level of Dairy Farmers.

The explanatory variables are the characteristics and attitude of farmers towered the adoption of innovation. Age is the most frequent factor used in most of the studies effecting the adoption behavior of dairy farmers. The personal, farm, economic characteristics along with total information score and innovation sustainability index of partial and full adopters compared using an independent samples t test as used by Demiryürek et al. (2017) in their research study.

Table 3.3. Factor effecting the innovation adoption of dairy farmers

Variables	Explanation	Expected sign
Age	Number of years	±
Education	Number of years	±
Family size	Number of household members	±
Dairy experience	Number of years	±
Fodder area	Acres	±
Milking animals	Numbers of milching animals	±
Percentage of cow in herd	Percentage	±
Hired labor	Yes = 1 otherwise 0	±
Regular veterinary services	Yes = 1 otherwise 0	±
Credit services	Yes = 1 otherwise 0	±
Association membership	Yes = 1 otherwise 0	±
Social Media exposure	Yes = 1 otherwise 0	±
Training services	Yes = 1 otherwise 0	±
Regular extension services	Yes = 1 otherwise 0	±

Atanu et al. (1994) reported a significant and positive association between these two variables. Bali (1996) reported a positive and significant association between the education status and adoption level. Shibah et al. (2002) reported a positive significant association between the family size and adoption. Shahin (1995) reported a positive significant association between the social interaction and adoption level of the farmers. Goswami (2001) reported a significant positive association between the social media exposure and adoption level.

Participatory approach is useful approach to address the problem of society with the cooperation of extension experts in the concerned field (Ozcatalbas et al., 2011). Baidu-Forson (1999) reported significant and positive association between the extension contact and adoption level. Shibah et al. (2002) reported positive significant relationship between hired labor and adoption level of farmers. Jabbar (1998) reported positive association between credit services and adoption level. Salama (2001) reported positive and significant association between the veterinary services and adoption level. Quddus (2012) reported that milk production of exotic breed improved more than indigenous cattle with improvement in adoption level. Sawang and Unsworth (2018) reported a strong association between training level and innovation adoption level.

To determine the effect of explanatory variables on the adoption of innovation, Binary logistic model used in the study as binary choices available in this model (1 = full adopter and 0 = partial adopter). The estimates of explanatory variables the model determine the probability of adoption level (Nkonya et al., 1997). Level of adoption

which is dichotomous variable (1= high level adopters and 0 = partial adopters) considered as dependent variable in the model with 14 explanatory variables used as independent variables. The binary logistic model specified as;

$$P = p \left(y = \frac{1}{z} \right) = \frac{e^{\alpha_0 + \sum \alpha_i z_i}}{1 + e^{\alpha_0 + \sum \alpha_i z_i}} \quad \text{Eq. 7}$$

$$1 - P = p (y = 0/z) = 1 / 1 + e^{\alpha_0 + \sum \alpha_i z_i} \quad \text{Eq. 8}$$

$$P = \log (p / 1 - p) = \alpha_0 + \alpha_1 Z_1 + \alpha_2 Z_2 + \alpha_3 Z_3 + \dots \dots \dots \alpha_{14} Z_{14} \quad \text{Eq. 9}$$

P = Probability that y = 1 for given Z

e = natural logarithm

(p / 1 - p) = odd ratios

Odd ratios presented that how much probability of the dairy farmers to be a high-level adopter increased with one unit change in explanatory variables mentioned in the model.

4. RESULTS AND DISCUSSION

In last decade or so the cropping sector of the agriculture is under immense pressure due to poor management practices, lack of understanding, poor knowledge, poor skill set levels, shortage of water and quality inputs in the market, harsh climatic conditions and fluctuating market prices of commodities shifted the people from cropping sector to livestock enterprises. Even in worse time of economy, the livestock sector performing best among the entire sectors. The main income source in this sector is milk and meat production through cattle, buffalo, sheep, goat and camel. People rare their animals for religious occasion to reap a handsome profit. The local veterinary hospitals, semen production units, milking collection centers, proper markets for the sale and purchase of dairy animals with the dispensary and veterinary doctor for the treatment large and small ruminants and quality meat inspection are some of the basic level facilities at the each district level in Punjab, Pakistan. The most prominent features is the induction of modern technologies (Artificial insemination, milking machines, maize silage, concentrates with mineral and salts, parasite treatment, vaccination against the major diseases, social media groups and internet facilities) in this sector. These innovation practices enhanced the production of dairy animals and now is contributing a handsome share in the GDP of country. This chapter of the study defines the impact of these technological variables on the milk production, which is vital product of the dairy sector business and cost of dairy farmers.

The methodology section explained in previous chapter open the comparison of numerous characteristics of dairy farmers based on their socio-economic status and efficiency level. The first section of this chapter explains the socio-economic characteristic of the selected dairy farmers. The second section describes the farm management practices and operational activities of the dairy farms. The third section describes the technical allocative and efficiency level of the selected farmers. The fourth section describes the factor affecting the efficiency level of the dairy farms and in fifth section the study, there is detail discussion of the innovation adoption practices and how it effect the profitability of the dairy farms. Sahiwal and Nili-Ravi are the most common cow and buffalo in the research area, Poultry farms also find in the research area as income source.

4.1. Socio-economic Characteristics of Dairy Farmers

This section contains data on the age, education, family size and dairy farm experience of selected respondents, which is useful for analysis and organized into groups based on their characteristics.

Table 4.1. Frequency distribution of age of respondents

Age categories	Frequency	Percentage	Mean	Std. Deviation	Minimum	Maximum
15-30	37	12.33	25.67	3.17	21	30
31-45	129	43.00	37.86	1.73	32	45
46-60	121	40.33	52.38	1.49	46	60
61 and above	13	4.33	63.53	2.913	61	68
Total	300	100	43.40	9.66	21	68

4.1.1. Age

Age is a significant socioeconomic determinant in making decisions, carrying out family responsibilities, and completing tasks, with varied behavior patterns in different stages of life. Table 4.1 showed that that average age of the dairy farmers in the study area was 43.40 years with standard deviation of ± 9.66 years having minimum age value of 21 years and maximum age value of 68 years. Smith and Zopf (1970) suggested that thinking aptitude for compact decision-making associated with the age of person. It showed that 12.33% of the dairy population is between the ages of 15 and 30, with a number of 37 falling into this category. Approximately 43% of the farmers were between the ages of 31-45, with 129 dairy farmers falling into this category. Approximately 40% of the selected respondents were between the ages of 46-60, with 23 falling into this category. About 4% of the respondent lied in the age category of 61 and above, with 13 farmers lied in this age group.

4.1.2. Education Level of Dairy Farmers

Education status play a vital role in management practices under different circumstances for success of any business. The level of education is rural are of the country is not very high as people prefer farm activities to education. The education standards are not very high so therefore people take less interest in higher education. The education up to 10th standard is available at village level and 12th standard education facilities are not available at gross root level. Students have to travel a long distance for their education, which disturb their farm, and operational practices therefore most of the students left their education and engaged in family business. With

poor basic infrastructure and standards, it is difficult to compete with the other student that have proper facilities.

Table 4.2. Education level of dairy farmers

Education categories	Frequency	Percentage	Mean	Std. Deviation	Minimum	Maximum
0-5	42	14.00	3.24	2.37	0	5
6-12	213	71.00	9.90	1.48	7	12
13-18	45	15.00	13.94	1.89	13	18
Total	300	100	9.72	3.55	0	18

Table 4.2 showed that that average schooling years of the dairy farmers in the study area was about 10 years with standard deviation of ± 3.55 years having minimum education level of 0 years and maximum education level of 18 years. Yenice and Savaş (2016) mentioned high schooling status rather than university graduates in case of dairy respondents in their study and identical situation existed in our research area. The percentage of dairy farmers having only primary level of education is 14, with a number of 42 in the category of 0-5 year's education. The highest portion of the dairy farmers with a number of 213 having 71% with the education level from eighth standard to twelfth standard included in this category. The respondent with a number of 45 having 14% form the total selected dairy farmer's graduation level educational background and is very small in number. Small portion dairy farmers in the study area having the master level education qualification in the 3 district of the research area. Only 15% of the total population having the graduation level of education, which is not healthy sign for the understanding and adoption of innovative practices in dairy farming sector.

4.1.3. Family Size of Dairy Farmers

In rural areas of the country, families are typically large, with the belief that having more family members means having more earning hands. In the province's rural parts, the joint family structure is common, with all power concentrated in one hand. Table 4.3 showed that that average family member of the dairy farmers in the study area was about 6 in number with standard deviation of ± 2.36 in numbers having minimum family size of 17 members and maximum size was 2 household members. Osotimehin et al. (2006) in their study suggested that healthier the size of family more the number of labors available for the farming activities.

Table 4.3. Distribution of dairy farmers in family size categories

Family size	Frequency	Percentage	Mean	Standard Deviation	Minimum	Maximum
1-4	93	31.00	3.50	.65	2	4
5-8	173	57.66	5.85	.85	5	8
9-18	34	11.33	13.24	.47	9	18
Total	300	100	5.78	± 2.36	2	17

About 31% of respondents, with a number of 93 included in the category of 1-4 family members. Around 58% of the respond, with a number of 173 included in the category of 5-8 family member, the majority category in case of current study. About 11% of the respondent with a number of 32, included in the category of 9-16 family members and around 1% with a number of 2 included the dairy farmers having family size above 17 in numbers.

4.1.4. Dairy Farming Experience

Experience in any industry can assist an individual make timely decisions about the activities in which they are involved, as well as ensure that farm operations run smoothly. Those dairy operators that devote more time to dairy activities will be able to comprehend the system in a more efficient and methodical manner, and will implement a set of innovations as needed, which will be difficult for newcomers to the industry. Table 4.4 showed that that average farming experience of the dairy farmers in the study area was about 19 years with standard deviation of ± 8.478 years having minimum experience 5 years and maximum level of farming experience was 40 years. Gitau (2013) suggested that more experience in the dairy enterprises, better understanding level regarding the challenges and constraints with appropriate management strategy to cope the unfavorable circumstances in farm management and operational activities.

Table 4.4. Distribution of respondents in dairy farming experience categories

Farming experience	Frequency	Percentage	Mean	Standard Deviation	Minimum	Maximum
1-10	69	23.00	8.59	1.70	4	10
11-15	60	20.00	13.00	2.34	12	15
16-20	64	21.33	19.63	0.78	17	20
21-25	41	13.66	24.30	1.13	22	25
26-30	49	16.33	34.46	0.96	26	30
31 and above	28	9.33	39.29	1.25	37	40
Total	300	100	19.13	± 8.478	5	40

About 23% of respondents, with a number of 69 included in the category of 5-10 years of experience category. Around 20% of the respondents, with a number of 60 included in the category of 11-15 years of experience. Around 21% of the respondents, with a number of 64 included in the category of 16-20 years of experience, with majority farmers having dairy farming experience range 5-20 years. Around 14% of the respondents, with a number of 41 included in the category of 21-25 years of experience. Around 16% of the respondents, with a number of 49 included in the category of 26-30 years of experience. About 7% of the respondents, with a number of 22 included in the category of 31-35 years of experience and only 2% of the dairy farming, which is 6 in number having the dairy farming experience of above 35 years.

4.1.5. Land Ownership of Dairy Farmers

Normally there is small level of land holdings (< 1-5 acres) in Punjab, Pakistan due to the division of lands among the family members (Naseer et al., 2016). Only a small portion of hold a large portion of land in the country. The price of land is also very high and a middle class family cannot afford this price. Mostly those farmers who have small holding normally rare dairy animals to support their families. Table 4.5 showed that that average size of the land holdings of dairy farmers in the study area was about 13 acres in number with standard deviation of ± 15.55 having minimum size of holding among the respondent was 2 acres and maximum holding was 175 acres of agriculture land. About 12% of respondents, with a number of 35 included in the category of 1-5 acres of land. Around 42% of the respondents, with a number of 127 included in the category of 6-10 acres of land ownership, with majority portion of respondent included in this category.

Table 4.5. Distribution of respondents in dairy land ownership categories

Land Ownership (Acre)	Frequency	Percentage	Mean	Std. Deviation	Minimum	Maximum
1-5	35	11.66	4.34	.87	2.00	5.00
6-10	127	42.33	7.717	1.36	6.00	10.00
11-15	92	30.66	13.511	1.48	11.00	15.00
16-25	30	10.00	20.93	3.68	16.00	25.00
26 and above	16	5.33	62.69	39.98	28.00	175.00
Total	300	100	13.35	± 15.55	2.0	175.0

Note: 1 acre = 4.04 decare

Around 30% of the respondents, with a number of 92 included in the category of 11-15 acre land ownership. About 10% of the respondents, with a number of 30 included in the category of 16-25 acre of land ownership. More than 80% of the respondents are medium farmers in term of land holding criteria. Only 5% of the respondents with a number of 16 having land ownership above 25 acres, which considered as large farmers in the country Naseer et al. (2016).

4.1.6. Area Under Forage Crops of Dairy Farmers

People normally sow major crops at their lands and very small portion of land is available for the fodder and forage crops that is normally not sufficient to support the dairy animals throughout the season. During dry season, there is severe shortage of green fodder and healthy of dairy animals is at stake. In this scenario, adoption of maize silage as an innovation is healthy option as it can be stored for longer period and is short duration crop. Table 4.6 showed that average size of the land under forage crops of dairy farmers in the study area was about 4 acres with standard deviation of ± 2.15 acres. The minimum size of land under forage crops among the respondent was 1 acres, and maximum size was 15 acres of agriculture land and it observed in the research of Demiryürek et al. (2017) for dairy farm operators.

Table 4.6. Distribution of respondents among forage area categories

Forage crop (Acre)	Frequency	Percentage	Mean	Std. Deviation	Minimum	Maximum
1-5	247	82.33	3.474	1.01	1.0	5.5
6-10	47	15.66	6.60	.93	6	9
11-15	6	2.00	15.33	.51	15	16
Total	300	100	4.17	± 2.15	1.0	16

Note: 1 acre = 4.04 decaire

About 82% of respondents, with a number of 247 included in the category of 1-5 acres of land with majority portion of respondent included in this category. Around 16% of the respondents, with a number of 47 included in the category of 6-10 acres of total land is under forage crops. Only 2% of the respondents, with a number of 6 included in the category of 11-15 acres of land under forage crops.

4.1.7. Total Number of Dairy Animals

Dairy producers care more about the quantity of animals than the quality of animals since livestock ownership considered an economic practice in rural areas because they are the most immediately available form of cash in times of need. Without taking into account the management health issues, the more animals on the farm, the more farmyard manure is accessible for the land is the prime motive of dairy farmers. Table 4.7 showed that average herd size of dairy farmers in the study area was about 15 animals with standard deviation of ± 7.743 animals.

Table 4.7. Distribution of respondents among dairy animal's categories

Dairy animals	Frequency	Percentage	Mean	Std. Deviation	Minimum	Maximum
1-10	49	16.33	8.06	1.82	4	10
11-20	202	67.33	13.21	3.66	11	20
21 and above	49	16.33	28.20	11.113	21	61
Total	300	100	15.41	± 7.74	4	61

The minimum size of dairy animals among the respondent was 4 animals, and maximum size was 61 dairy animals observed in the research area. About 16% of respondents, with a number of 49 included in the category of 1-10 dairy animals at farm. About 67% of the dairy farmers, with a number of 202 included in the category of 11-20 dairy animals at farm with majority portion of respondent included in this category. Around 16% of the respondents, with a number of 49 included in the category of 21 and above dairy animals at farm level.

4.1.8. Total Number of Dairy Milking Animals at Farm

Those farmers that rely on dairy as a major source of revenue, the number of milking animals is generally insufficient at farm.

Table 4.8. Distribution of respondents among dairy milking animal's categories

Milking animals	Frequency	Percentage	Mean	Std. Deviation	Minimum	Maximum
1-10	215	71.7	4.58	1.62	2	10
11-20	77	25.5	12.45	2.98	11	20
21 and above	8	2.70	28.63	5.47	21	37
Total	300	100	9.37	± 5.10	2	37

The main cause of low milking animal numbers is an imbalanced diet, poor animal quality, and short lactation length, as poor quality feed is given to pregnant animals throughout their dry phase, disrupting the general health of dairy animals in

terms of productivity and reproduction.. Table 4.8 showed that average size milking animals of dairy farmers in the study area was about 9 animals with standard deviation of ± 5.10 animals. The minimum size of dairy milking animals among the respondent was 2 animals, and maximum size was 37 dairy milking animals observed in the research area. About 71.7% of respondents, with a number of 215 included in the category of 1-10 milking dairy animals at their farm with majority portion of respondent included in this category. About 26% of the dairy farmers, with a number of 77 included in the category of 11-20 dairy animals at farm. Around 3% of the respondents, with a number of 8 included in the category of 21 and above dairy milking animals at farm level.

4.1.9. Monthly Milk Production of Dairy Farmer

Most dairy farms' milk production is quite low, barely covering the farm's operating costs, and their young ones considered farm profit.

Table 4.9. Distribution of respondents among monthly milk production categories

Monthly milk production	Frequency	Percentage	Mean	Std. Deviation	Minimum	Maximum
100-1000	65	21.66	745.14	203.95	300	1000
1001-2000	102	34.00	1561.85	240.43	1200	1980
2001-3000	68	22.66	2612.65	300.97	2100	3000
3001-4000	37	12.33	3469.46	312.82	3060	4000
4001-5000	18	6.00	4434.71	265.00	4200	5000
5001 and above	10	3.33	6645.00	1126.34	5400	8880
Total	300	100	2155.20	± 1406.00	300	8880

Indigenous breeds have a low production potential due to their short lactation length and usually found on dairy farms. Table 4.9 showed that average monthly milk production of dairy farmers in the study area was about 2155 liters with standard deviation of ± 1406.006 liter. The minimum amount of monthly dairy milk production among the respondent was 300 liters, and maximum amount was 8800 liters of monthly dairy milking production observed in the research area. About 21% of respondents, with a number of 65 included in the category of 300 -1000 liter milk production at farm level. About 34% of the dairy farmers, with a number of 102 included in the category of 1001-2000 liters of monthly dairy milk at farm level. Around 22% of the respondents, with a number of 68 included in the category of 2001-3000 liters of monthly milk production, with majority portion of respondent included in this category. Around 12% of the respondents, with a number of 37 included in the category of 3001-4000 liters of monthly milk production. Exactly 6% of the

respondents, with a number of 18 included in the category of 4001-5000 liters of monthly milk production. Around 3% of the respondents, with a number of 10 included in the category of 5001 and above liters of monthly milk production at farm level.

4.1.10. Daily Milk Production per Animal at Dairy Farms

Indigenous and local crossbreed animals with poor health and body scores are common dairy animals on farms, which is why, despite the fact that the milking capacity of dairy animals in developed countries is 3 to 5 times higher, adoption rates are still low due to high prices and difficult management practices. Better yet, because of the milking capacity of dairy animals on the farm, it is simple for farmers to adopt innovative procedures.

Table 4.10. Distribution on daily per animal production categories

Milk production per animal	Frequency	Percentage	Mean	Std. Deviation	Minimum	Maximum
5-10	81	27.00	6.68	1.88	6	10
11-15	195	65.00	12.55	1.00	11	15
16 and above	23	7.99	17.00	1.41	16	35
Total	300	100	12.30	± 3.20	6.0	35.0

Table 4.10 showed that average milk production per animals at dairy farms in the study area was about 12 liters with standard deviation of ± 3.20 liter. The minimum amount of milk production per animals among the respondent was 6 liters, and maximum amount was 35 liters production observed in the research area. Exactly 27% of respondents, with a number of 81 included in the category of 5-10 liter milk production per animal on daily basis at farm level. Exactly 65% of the dairy farmers, with a number of 195 included in the category of 11-15 liters of dairy milk per animal at farm level, with major portion of the respondents in the study belong to this category. Around 6% of the respondents, with a number of 19 included in the category of 16-20 liters of daily milk production per lactating animals at farm. About 2% of the dairy farmers having animals with a potential of 20 liters and above daily milk production by a single animal at dairy farm which is healthy production level.

4.1.11. Percentage of Milking Animals at Dairy Farms

The percentage of milking animals at farm is satisfactory in study area but still not a healthy one as around 40% dry animals increase the overhead cost and it is hard for the dairy farmer to finance its family with the income of dairy farm. The next option

is compromised food for the dry animals, which disturb the healthy status of pregnant animal and the clave.

Table 4.11. Distribution of farms on milking animal's percentage categories

Milking animals percentage	Frequency	Percentage	Mean	Std. Deviation	Minimum	Maximum
25-45	43	14.33	38.32	5.44	25.00	44.44
46-60	113	37.66	54.24	4.25	46.15	60.00
61-75	115	38.33	67.80	4.37	60.86	75.00
76-90	27	9.00	81.50	4.16	76.19	90.90
91 and above	2	0.66	60.12	±12.73	25	94.11

Table 4.11 showed the percentage of milking animals at dairy farms in the study area was about 60% with standard deviation of ± 12.73 . The minimum milking animals percentage among the respondent was 25, which is not healthy one to run a farm successfully because overhead cost it to high and farmer hardly meet their expense, and maximum percentage was about 94% of the milking herd at dairy farm, which is very healthy one to finance the operation and management expense successfully. Around 14% of respondents, with a number of 43 included in the category of 25-45% of milking animals at their dairy farms, which is very low and problematic in long run to run the farm due to ever increasing operational and management expenses . Around 38% of respondents, with a number of 113 included in the category of 46-60% of milking animals at their dairy farms, which is very low and problematic as well to run a profitable farm. Around 38% of respondents, with a number of 115 included in the category of 61-75% of milking animals at their dairy farms, with major portion of the respondents in the study belong to this category, as is healthy percentage to achieve the breakeven point in business. Exactly 9% of the respondents, with a number of 27 included in the category of 76-90% lactating animals at farm, which is ideal percentage for the dairy farm. About 1% of the dairy farmers having milking percentage above 91%, which is step towards long run successful farm with highest number of milking animal's percentage among the respondents.

4.1.12. Per Liter Cost of Production

Per liter cost of milk, production is very high among the selected respondents. It is hard for the dairy farmer to operate the farm successfully at this production cost.

Table 4.12. Distribution of respondents among overhead cost categories

Per liter cost (Rs)	Frequency	Percentage	Mean	Std. Deviation	Minimum	Maximum
30- 40.00	32	10.66	32.66	9.17	30.52	38.51
41- 55.00	123	41.00	45.50	4.77	41.88	54.78
56- 70.00	82	27.33	63.12	5.13	56.23	70.00
71- 90.00	37	12.33	82.75	4.60	74.13	89.98
91- 105.00	13	4.33	98.17	4.58	92.48	104.89
106 and above	13	4.33	122.39	12.66	106.05	121.25
Total	300	100	59.63	22.24	29.52	79.90

Note: 1\$ = 175 Rs

The main reason of high cost is poor milk potential of indigenous animals, lack of exotic cow in the herd that have milk potential of 35-40 liter per day and high percentage of dry animals at farm. Table 4.12 showed that average per liter cost of dairy farmers in the study area was 59.63 Rupees (Rs) per liter of milk with standard deviation of ± 22.24 TL. The minimum amount of cost was 29.52 Rs among the respondents, and maximum amount was 79.90 Rs of dairy producers observed in the research area. About 11% of respondents, with a number of 32 included in the category of 30-40 Rs per liter of milk cost of production at farm level. Exactly 41% of the dairy farmers, with a number of 123 included in the category of 41-55 Rs at farm level with majority portion of respondent included in this category. Around 27% of the respondents, with a number of 82 included in the category of 56-70 Rs per liter cost of production. Around 12% of the respondents, with a number of 37 included in the category of 71-90 per liters of milk production at farm. Around 4% of the respondents, with a number of 13 included in the category 91-105 Rs per liter cost of milk production. Around 4% of the respondents, with a number of 13 included in the category 106 Rs and above per liter cost of milk production at farm level. The high cost of milk production by using conventional methods not only disturb the overall management of dairy farms but also threaten the stability level of farm (Winsten et al., 2010).

4.2. Profitability of Dairy Farmers

The research's second objective was to figure out how profitable dairy farmers are. Any business in the market operates with a profit motive, and those dairy operators who make a handsome profit will stay in the market, while those who lose money will be unable to maintain this business for an extended period. They must introduce innovations to their farm through breed and feed management in order to increase output potential and make the farm a lucrative enterprise. The Table 4.13 indicated

that average profitability of dairy farmers in the study area. Expense of the fodder was 92759.00 Rs with standard deviation of 48057.91 Rs. This section includes the cost of ordinary fodder and the silage cost and is major expense of the dairy farm. Average expense of the concentrate was about 42223.35 Rs with standard deviation of ± 29360 Rs. It is the best source of energy, protein and dry matter for the dairy animals and is the second major expense of dairy farm in the study area.

Table 4.13. Profitability of dairy farmers

Variables (TL)	Mean value	Standard deviation
Fodder cost	92759.00	± 48057.91
Concentrate cost	42223.35	± 29360
Vaccination cost	749.59	± 746.84
Treatment cost	1116.78	± 789.78
AI cost	1536.26	± 1454
Wheat straw cost	24258.70	± 11573.71
Electricity cost	2300.90	± 1357.71
Minerals and salt cost	4248.20	± 2669.58
Labor cost	16667.00	± 7516.16
Total variable cost	185875.04	± 91141.51
Dairy income	300095.90	± 153130.38
Gross Margins	114220.67	± 77442.32

Note: 1\$ = 175 Rs

Average expense of the vaccination was about 749.59 Rs with standard deviation of ± 746.84 Rs. It is necessary to avoid the major dairy diseases and improve the immune system of dairy animals to fight against the viral infections. Average expense of the treatment was about 1116.78 Rs with standard deviation of ± 789.78 Rs. It the expense for those animals who got sick or infected by some disease or parasite etc. Average expense of the artificial insemination was about 1536.26 Rs with standard deviation of ± 1454 Rs.. This technique is helpful for the breed improvement and quality semen available at district veterinary hospitals at affordable prices (350 Rs - 500 Rs). The third most expense item at dairy farm is wheat straw that commonly used to fulfil the feed requirement of dairy animals and is helpful especially in dry season for the dairy animals. Average expense of the wheat straw was about 24258.7 Rs with standard deviation of ± 11573.71 Rs. Average expense of the electricity at farm was about 2300.90 Rs with standard deviation of ± 1357.71 Rs. This is also compulsory expense for the dairy farm as the weather conditions are hard and lengthy summer season, dairy animals will become under stress and minimum water twice a day along

with bathing of dairy animals remove the heat stress to some extent. Average expense of the mineral mixture and salt at farm was about 4248.20 Rs with standard deviation of ± 2669.58 Rs. This is necessary component for the better digestion, important minerals for health and pregnancy and healthy immune system. The fourth major expense in dairy farm sector is labor and is important one for the smooth operation and management of dairy farms. Average expense of labor at farm was about 16667 Rs with standard deviation of ± 7516.16 Rs. Average variable cost at farm was about 185875.04 Rs with standard deviation of ± 91141.51 Rs. Income factor has vital importance for the smooth and healthy business. Healthy income from dairy farms not only finance the operational and farm management expense but also helpful to support the family as well. Mean dairy income level at farm was about 300095.9 Rs with standard deviation of ± 153130.38 Rs.. Gross margins is the key factor for the decision-making and define the success story of the business (Khalid et al., 2017). Healthy margins encourage extension of dairy farms along with innovations adoption and better management practices at farm level. Mean dairy profit margins at farm was about 114220.67 Rs with standard deviation of ± 77442.32 Rs.

4.3. Dairy Farms Efficiency Level

The research's third objective was to determine the efficiency level of dairy farmers. Table 4.14 showed the technical, allocative and economic efficiency levels of dairy farms in the study area. The minimum technical efficiency level was 51.4% and maximum level was 100% efficiency level with a mean value of 90.7%. The technical efficiency level of my study was identical to Mugambi et al. (2017) with the efficiency level of 83.7% in his study. Around 2% of the farmers have technical efficiency range of 51-60% with a number of 5 found among the respondents. The technical efficiency range of 61-70 containing 9% of the dairy farms with the number of 27 among the selected respondents. This mean that farmers have to reduce the inputs use without disturbing milk production of dairy animals. The technical efficiency range between 71-80% contained 100 respondents with the percentage of 33.33%, which depicted that farmers could reduce the input intake of dairy inputs by 20-30%, which did not disturb the efficiency level of the farm. Around 56% of the dairy farmers operating at technical efficiency level above 80% with the number of 168 dairy farmers among the total dairy farmers. The allocative efficiency of dairy farmers with mean value 66.4% having minimum value of 32.2% and maximum value of 100% found in this study.

Around 31% of the dairy farmers having allocative efficiency level of below, 60% indicated that 40-50% of the cost could reduce without disturbing the output level of the dairy farms. Around 63 of dairy farmers operation at allocative efficiency level of 60-80% with a number of 198 and they could reduce their expense up to 20-40% without disturbing output level. Only 3% with a number 9 having allocative efficiency level above 90% indicated a small portion of the farmers were operating at allocative efficient level. Identical level of allocative efficiency found in Nyagaka et al. (2009) with the value of 57.3%.

Table 4.14. Efficiency distribution on the dairy farms

Efficiency Distribution	T.E Number	%	A.E (Number)	%	E.E (Number)	%
1-50	0	0.00	28	9.33	61	20.33
51-60	5	1.66	65	21.66	106	35.33
61-70	27	9.00	95	31.66	70	23.33
71-80	100	33.33	72	24.00	42	14.00
81-90	100	33.33	31	10.33	12	4.00
91-100	68	22.66	9	3.00	9	3.00
Total	300	100.00	300	100	300	100.00
Min (%)	51.4		32.2		32.2	
Max (%)	100		100		100	
Mean	90.7		66.4		60.2	

T.E = Technical efficiency, A.E = Allocative efficiency and EE= Economic efficiency

The economic efficiency level of dairy farmers having minimum value 32.2% to maximum value of 100% with average value of 60.2 %in the study area. Identical results found in the study of Masuku et al. (2014) and Kibiego et al. (2015) in which the economic efficiency of dairy farmers were less than 70% level.

Table 4.15. Return to scale summary of dairy farmers

Return to scale	Frequency	Percentage
Increasing return to scale	147	49.00
Decreasing return to scale	72	24.00
Constant return to scale	81	27.00
Total	300	100.00

Around 78% of the dairy farmers with a number of 237, in the study area having the economic efficiency level below 70%. Only 22% of the farmers with a number of 63 having the economic efficiency level above 70% in the study area. The major reason of low economic efficiency is either the low milk production of dairy animal or the high cost of milk production. In this study, the reason of low economic efficiency was high cost of milk production rather than the milk production of dairy animals suggested

by Winsten et al. (2010) in their study. Table 4.3.2 presented the summary of return to scale of dairy farmers. The dairy farms having percentage of 49 with the number of 147 fall in the increasing return to scale category suggested that output is increasing more in proportion to the feed, treatment and operating in sub optimal region. The dairy farms having percentage of 24 with the number of 72 fall in the decreasing return to scale category suggested that output is increasing less in proportion to the feed, veterinary treatments and labor inputs describing suboptimal operating region of the dairy farms. The dairy farms having percentage of 27 with the number of 81 fall in the constant return to scale category suggested that output is increasing in same proportion to the feed, veterinary treatments and labor inputs.

4.3.1. Factors Effecting the Efficiencies Level

The fourth objective of research was to determine the factor affecting the efficiency level of dairy farmer. Table 4.16 Presented the results of Tobit model to determine the factor effecting the technical efficiency of dairy farmer, first used by Bravo-Ureta and Pinheiro (1997) in their study for which efficiency score bounded between zero and one range. In this model, twenty variables regressed against the score of technical efficiency of dairy farms. The age, owned area, total number of animals on the farm, and distance to the milk market all have a negative relationship with dairy farmers' technical efficiency, although the relationship is not significant at 1 and 5% level of significance.

Age have a negative relationship with technical efficiency and are statistically significant at 5% level of significance. Lachaal et al. (2002) reported similar effect in case of age and technical efficiency of dairy farmers. Family size, exhibit negative associations for technical, allocative and economic efficiency, but are not statistically significant at the 1 and 5% significance levels. Land ownership has negative association with the technical and economic efficiency but is positive in case of allocative efficiency but is statistically significant for technical efficiency at 10% level of significance. Opposite effect reported by Ahmad et al. (2002) in case of land ownership in their study.

Education factor has positive and significant association with the technical, allocative and economic efficiency of dairy farmers at 1 and 5% level of significance and identical result found by Ohe (2016) and Girma (2019) in their studies that improvement in education level of dairy farm enhance the technical efficiency of dairy

farms. Higher dairy farmer education levels, a better understanding of production management techniques, particularly total mixed ration and silage, capacity building and a suitable environment for milking animals with necessary farm equipment reduce work load and improve animal health, resulting in increased milk production at the farm level.

The coefficient of dairy farming as a main source of income has a positive and significant relationship with the technical efficiency of dairy farms at 1% level of significance. The positive relationship observed between dairy as main income source for allocative and economic efficiency but is not statically significant. More time, energy, concentration, and dedication to a single enterprise improve farm productivity and dairy as important income and livelihood source in most of the developing nation reported by (Thorpe et al. 2000; Mutoko et al., 2008; Duncan et al., 2013; Rao et al., 2016; Chandio et al., 2017) reported in their studies. When income generated from a variety of sources, the greater the desire for high-income sources, while other sectors receive less attention and concentration, lowering production efficiency. Dairy farmers' technical, allocative and economic efficiency linked to milking machines in a positive and significant way at 1% level of significance. The introduction of one milking equipment enhanced the milking of dairy animals by 6%. According to the findings. In their investigations (Hogeveen et al., 2004; Wade et al., 2004; Wirtz 2004) found that employing an automatic milking system increased milk production by 2% and 20%, respectively, by improving flexibility and increasing milking frequency from two to three times per day and reduce the labor cost.

The machines is available at any time for the milking, reduce the human milking effort, and save time as well. The management of large milking herd with automatic milking machines become more flexible and healthy for animals as well. Dairy farmers' efficiency inextricably connected to milk refrigeration. The relationship between milk refrigeration and technical efficiency found statistically significant at 1% level of significance and same trend found in case of allocative and economic efficiency of dairy farmers. Rather of selling milk to the local market, this facility allows farmers to sell milk directly to the milk market. In their studies, Gelan and Muriithi (2012) and Mhundwa et al. (2017) found that milk refrigeration improved the overall performance of the dairy farm. The overall advantage of dairy producers improved by reducing heat from milk and lowering the temperature of milk to make it

appropriate for transportation to the milk collection place to get suitable price of the product and lower the expense of energy especially in developing countries with extreme hot temperature.

Table 4.16. Factor influencing technical, allocative and economic efficiency levels

Variables	Technical efficiency		Allocative efficiency		Economic efficiency	
	Coefficient	T ratio	Coefficient	T ratio	Coefficient	T Ratio
Age (years)	-.001	- 2.31**	- .001	- 0.93	.001	0.21
Education (Years)	.003	1.72*	.009	5.98***	.007	5.97***
Family size	-.002	- 1.06	- .001	- 0.25	- .001	-0.51
Farming experience (Years)	.001	0.24	.001	0.67	.001	0.90
Land ownership (Acre)	-.007	-1.75*	.001	0.39	-.002	-0.49
Milking herd size	.003	2.21**	.001	0.44	.001	0.93
Dairy as main income source	.052	3.96***	.014	1.05	.02	1.86*
Milking machine	.087	5.39***	.07	4.41***	.117	8.90***
Milk refrigeration	.004	0.25	.063	4.36***	.062	5.26***
Record Keeping	.005	0.37	.001	0.04	.01	0.91
Vaccination	.147	4.00***	.045	1.18	.117	3.77***
Concentrate	.04	3.28***	.017	1.39	.005	0.49
Maize Silage	.04	3.06***	.023	1.73*	.045	4.17***
Minerals and salt	.049	4.16***	.038	3.23***	.01	1.03
Association membership	.027	1.97**	.024	1.80*	.006	0.56
Internet and social media	.036	2.60***	.052	3.76***	.028	2.43**
Log likelihood	207.72		324.75		381.31	
LR χ^2	177.10		277.26		412.26	

Significance at the following levels: *** p< .01, ** p< .05, * p< 0.1

Dairy producers' efficiency intrinsically linked to dairy animal vaccination, the positive and significant association found between the vaccination and technical efficiency of dairy farms and same trend observed in case of economic efficiency at 1% level of significance. In the case of allocative efficiency, a positive association detected, although it is not statistically significant at the 1 and 5% levels of significance. Timely vaccination course reduces dairy farm mortality and improves milk yield by taking preventative measures against seasonal disease outbreaks. Bradley et al. (2015) and Marsh et al. (2016) found the same thing in his study. Improvement in animals health through vaccination improve the yield of dairy animals and which indirectly effect the income of dairy farms and reduce the veterinary

expenditures for disease treatment and doctor expense and improve the profitability of dairy farms which is considered as main income source in many developing countries.

Milking herd size is important for smooth milk production throughout the season and a significant association found between the milking herd and technical efficiency at the 5% level of significance. Although there is a favorable positive relationship between parasite treatment and allocative and economic efficiency, it is not statistically significant at the 1% and 5% levels of significance. Yilmaz et al. (2020) reported positive effect of herd size on the technical efficiency of dairy farmers.

High-yielding animals require a higher-protein diet to maintain a healthy milk yield throughout their lactation period, and maize silage is one option for a higher-protein diet for dairy animals. The adoption of maize silage by the dairy farmers has positive and significant relationship with the technical, allocative and economic efficiency at 1 and 5% level of significance and same reported by Bajrami et al. (2017) and Yilmaz et al. (2020) in their studies. Silage has high percentage of dry matter, and energy level with healthy percentage of crude protein, which is helpful for smooth milk production and better immune system against the pest, and disease, which reduces the cost of treatment. If farmers produces their own silage at farm level, it reduces the fodder cost and is available throughout the season as a good feed source especially in harsh weather condition. It reduces the labor cost and save time for other farm operations.

Minerals and salt are important for dairy animal reproductive, animal health, and milk productivity, and have a positive significant association with dairy farm technical efficiency at the 1% level of significance. Although the positive association found with the allocative and economic efficiency level but not significant at 1 and 5% significance level. Dairy cows require less than 100 mg because it is essential for reproduction, immunity, and milk production. Kimenchi et al. (2014) and Bhalakiya et al. (2019) suggested that the deficiency causes reduced milk production and reproduction capacity in dairy animals. Longer the calving length of milking animal reduce the farm revenue with less milk production and increase the overhead cost of dairy farms which disturb overall efficiency of the dairy farms.

At 1 and 5% level of significance, a positive and substantial relationship discovered between social media and technical, allocative and economic efficiency of dairy farms. Susan et al. (2019) and Michie et al. (2020) found a positive and

significant relationship between milk production and social media and internet variable of dairy farms in their studies. The internet and social media are the best modes of communication and platforms for better understanding of milk production improving techniques by different feed and ration combination under unfavorable circumstances. It is helpful to understand the efficient management techniques at dairy farms with ideal animal reproduction technologies adoption for breed and milk improvement.

At a 1% level of significance, a positive and substantial relationship discovered between concentrate feed and the milk output of dairy farms for technical, allocative and economic efficiency level of dairy farms as reported by (Sehested et al., 2003; Hall, 2019; Meir et al., 2021) in their studies. Concentrate is an important component of the dairy diet, and snubbing it reduces feed energy intake, milk production, increases the calving interval, and degrades milk quality in dairy animals, not all of which are economically viable for the dairy industry. The milk average of low yielding cow can improve through balance ration, which include concentrate and forage is suitable proportion to fulfil the animal's requirement.

4.4. Innovation and Management Practices by the Dairy Farmers

Innovation is the technology, information or the mechanization of farm to address the need and demand of individual or an organization (Berger, 2005). In agriculture sector, the innovation is re-designing of farms, marketing strategies, and the adoption of new technologies to meet the farm need.

The fifth objective of the study was to determine innovation and management practices adopted by the dairy farmers. Table 4.17 presented the adoption level of innovation and management practices of partial and full adopters. Vaccination is the most often accepted practice in the partial and full innovation adopters the research area as is vital for the health status of dairy animals.

Mass media is second most adopted innovation among the dairy farm respondents as it is easy and cheap information source for the farm management practices and is available on single mobile phone click.

Milking machine and milk refrigeration are time and cost saving technological innovation but less adopted by the respondents due to higher markets price, handling issues and electricity load problem in the rural area.

Table 4.17. Innovation and management practices by the dairy farmers

Innovations	Full adopter	%	Partial adopters	%
Mass media	118	89.33	129	78.65
Silage	115	70.66	95	57.92
Record Keeping	74	54.00	78	29.26
Vaccinations	127	93.33	132	80.48
Concentrated feed	120	88.33	125	76.21
Milking Machine	76	56.66	82	50.00
Parasite Treatment	103	76.66	105	64.02
Milk refrigeration	85	62.33	63	38.41
Association Membership	64	47.33	78	47.56
Mineral Mixtures and Salt	85	62.00	94	69.11
Labor at farm	77	25.00	39	23.78
Regular veterinary services	101	74.26	69	42.07
Credit services	15	5.00	79	48.17
Exotic breeds	106	35.33	52	31.70
Training service	93	68.38	55	33.53
Regular extension services	126	93.33	87	53.04

A healthy percentage of full adopters, adopt the innovative practice of maize silage, along with concentrate, mineral and salt which is healthy source of food, fiber, protein and energy level. These is convenient innovative practice for the farm labor and improve the health status of dairy animal as well, but still a large portion of the respondents in partial adopter category did not exercise at farm.

The veterinary and extension services adoption percentage is very healthy in full adopter case but is not very healthy in case of partial adopter as these are free of cost services and available on single phone call with nominal treatment expenses and no expense for the field visits and suggestion in case of extension services.

Record keeping is important parameter to understand the reproduction and production potential of dairy farms and is helpful to make decision-making regarding farm operations and herd management but not healthy percentage of adoption in case of both partial and full adopters.

Trainings program regarding the dairy issues and disease outbreaks normally conducted at district hospitals free of cost. Partial adopter even have poor participation rate in these program because they have poor coordination and communication network with the peer group of doctors and veterinary staff.

Exotic breed are high milk yielding cattle with proper pedigree animal available at large dairy farms in the study areas but still not a common practice. Exotic breeds at farm have poor adoption rate among the respondents because both of these practices are highly cost associated.

Labor is required to handle animals in harsh weather conditions to maintain high milk production as water tanks not installed at farm. They offering water twice a day, with cleaning and milking of animals is common practice, which is hard job in case of large herd. Less than 50% are using hired labor at farm and family members are involved in these activities because its 24/7 job and labor is rarely available and is expensive.

4.4.1. Socio-economic Features of Partial and Full Adopters

The mean age level of full adopter was 42.69 years (SD= 8.44) with 74.81% of respondents fall in age category between 31-50, around 9% fall below this age category and 16.29% fall above this age category. In case of partial adopter, mean value was found 43.76 years (SD = 10.56) and with 56.36% of respondent fall in age category between 31-50, around 15% fall below this age category and 28.5% fall above this age category. Independent sample t test used to determine the significant difference between the ages of two groups and no significance difference found ($p > 0.1$). Mussei et al. (2001) reported that age has negative influenced the adoption level in case of wheat improvement technology on contrary Guta, (2018) reported that that in case of solar panel old people had better adoption rate as compare to young people.

The mean education level of full adopter was 10.43 years (SD= 3.78) with 46.6% of respondents fall in age category between 6-10, around 10% fall below this education level category and around 43% fall above this age category. In case of partial adopter, mean value was found 9.13 years (SD = 3.25) and with 55.75% of respondent fall in the category between 6-10 year, around 17% fall below this category and 28.5% fall above this category.

Table 4.18. Socio-economic features of high level and low-level adopters

Variables	High level adopters		Low level adopters		P value
	Mean	Std. Error.	Mean	Std. Error.	
Age (years)	42.96	0.72	43.76	0.82	0.475
Education (years)	10.43	0.32	9.13	0.25	.002**
Faimly size	5.05	0.19	6.05	0.19	.068*
Dairy Experience	20.89	0.72	17.69	0.64	.001**
Owned Area	12.03	1.00	14.43	1.40	.183
Fodder crop area	3.896	0.12	4.403	0.20	.042*
Total dairyAnimals	14.19	0.42	16.42	0.72	.013**
Milking Animal	8.77	0.31	9.85	0.46	.067*
Total Information score	461.71	13.76	421.18	15.41	.056*
Innovation sustainability Index	31.64	1.46	25.88	1.67	.012**
Milk yield per animal	8.07	0.25	7.018	0.19	.001**
Milk cost of production per liter	3.28	0.100	3.21	0.10	0.62
Revenue per animal	1188.01	37.62	1032.60	28.55	.001**

*, **, *** shows significant difference at 10%, 5%, and 1%

Independent sample t test used to determine the significant difference between two groups, and significance difference found ($p < 0.1$) in case of education level. Bulale (2000) reported that farmers with higher education level has better adoption rate in case of mixed farming system. Full adopters have healthy percentage of college and university education level in comparison to partial adopter. Primary and secondary education was not up to the standard and people in developing countries and at least higher education is required for the better understanding of technology. Those people who are receiving higher education can understand the technology, plan or idea in better way and those who have primary or secondary level education face hardship for innovation adoption at their farms.

The mean family size of full adopter was 5.05 (SD= 2.24) with 43.70% of respondents fall in family size category between 6-10 household, around 52% fall below this category and 4.4% fall above this category. In case of partial adopter , mean value was found 6.05 members (SD = 2.48) and with around 45% of respondent fall in the category between 6-10 family members, around 53% fall below this category and 1.8% fall above this category.

Independent sample t test used to determine the significant difference between two groups, and significance difference found ($p < 0.1$). Mussei et al. (2001) reported that family size has positive influence on the adoption level in case of wheat

improvement technology. More the family member it is easy to manage the farm operations timely and expense of labor at farm also minimized as well.

The mean dairy experience of full adopter was 20.89 (SD= 8.49) with 41.21% of respondents fall in category between 11-20 years, around 29% fall below this category and around 30% fall above this category. In case of partial adopter, mean value was found 19.69 years (SD = 8.21) and with around 42% of respondent fall in the category between 11-20 years of experience in this field, around 15% fall below this category and 43% fall above this category. Independent sample t test used to determine the significant difference between two groups, and significance difference found ($p < 0.1$) in case of dairy farming experience and same reported by Demiryürek et al. (2017) in their research findings. Experience in dairy sector enables the farmer to make better decision-making and management practices and will look for better mode of production to improve the human and animal welfare simultaneously through adoption of new ideas, management practices and innovation and same reported by Budak et al. (2012) in their research findings.

The mean owned area of full adopter was 12.03 acres (SD= 11.74) with 50.9% of respondents fall in category between 6-12 acres, around 10% fall below this category and around 39% fall above this category. In case of partial adopter, mean value was found 14.43 acres (SD = 18.05) and with around 54% of respondent fall in the category between 6-12 acres of agriculture land, around 14% fall below this category and 43% fall above this category. Independent sample t test used to determine the significant difference between two groups, and no significance difference found ($p < 0.1$) in case of land ownership. Rogers (2003) suggested land ownership and effective socio-economic tool for better adoption level. More land is available, more the space available for the dairy animals which is not possible in case of limited or no land option. Jabber et al. (1998) reported a positive association between land ownership and adoption level and differential effect observed by Bulale (2000) as pasture fencing has positive association with the farm size.

The mean forage area of full adopter was 3.89 acres (SD= 1.45) with around 10% of respondents fall in category between 6-12 acres, around 87% fall below this category and around 3% fall above this category. In case of partial adopter, mean value was found 4.40 acres (SD = 2.57) and with around 17% of respondents fall in the category between 6-12 acres of forage, around 79% fall below this category and

4% fall above this category. Independent sample t test used to determine the significant difference between two groups, and significance difference found ($p < 0.1$) in case of forage land and same reported by Demiryürek et al. (2017) in their research findings.. More land under the forage crop more the green and dry fodder is available, and this fulfil the fodder demand in hot and dry time period in which there is severe shortage of green fodder in Punjab, Pakistan. Unhealthy fodder is offered to milking animals in form of dry forages and flour and it disturb the health and production potential of milking animal which is not healthy for successful dairy business.

The mean number of dairy animals for full adopter was 14.19 (SD= 4.96) with around 73% of respondents fall in category between 11-20 dairy animals at farm, around 16% fall below this category and around 11% fall above this category. In case of partial adopter, mean value was found 16.42 animals (SD = 9.32) and with around 63% of respondents fall in the category between 11-20 dairy animals, around 16% fall below this category and 21% fall above this category. Independent sample t test used to determine the significant difference between two groups, and significance difference found ($p < 0.1$) in case of dairy animals at farm. Mussei et al. (2001) reported a positive association between herd size and innovation adoption level in mixed farming practices as it is helpful to maintain the organic matter in land and improve the overall health of soil. The dung also used for burning purpose, as it is the cheapest source of energy in rural area of the country.

The mean number of dairy milking animals for full adopter was 8.77 (SD= 3.71) with around 27% of respondents fall in category between 11-20 dairy milking animals at farm, around 62% fall below this category and around 1% fall above this category. In case of partial adopter, mean value was found 9.85 animals (SD = 5.98) and with around 25% of respondents fall in the category between 11-20 dairy milking animals, around 74% fall below this category and 1% fall above this category. Independent sample t test used to determine the significant difference between two groups, and significance difference found ($p < 0.1$) in case of milking animals at farm. More the milking animals at farm, it is easier for the dairy farmers to meet the operational and management expense of dairy farms. The dry animal, normally considered as burden to farm as is normally discarded at low rate to avoid the expenses. Çukur (2016) reported a positive assocaiton between the milking animals and adoption level.

The mean total information score for full adopter was 461 (SD= 160.57) with around 58% of respondents fall in category between 301-600 score level, around 7% fall below this category and around 35% fall above this category. In case of partial adopter, mean value was found 421.18 animals (SD = 197.39) and with around 55% of respondents fall in the category between 301-600, around 19% fall below this category and 26% fall above this category. Independent sample t test used to determine the significant difference between two groups, and significance difference found ($p < 0.1$) and same reported by Demiryürek et al. (2017) in their research findings in case of total information score of dairy farmers. Information seeking behavior is helpful in understanding and decision making of technology adoption in agriculture sector reported by Boz and Ozcatalbas (2010) in their research findings.

The mean innovation sustainability index for full adopter was 31.64 (SD= 17.06) with around 44% of respondents fall in category between 20-40 index range, around 11% fall below this category and around 45% fall above this category. In case of partial adopter, mean value was found 25.88 (SD = 21.47) and with around 31% of respondents fall in the category between 20-40 index range, around 39% fall below this category and 30% fall above this category. Independent sample t test used to determine the significant difference between two groups, and significance difference found ($p < 0.1$) and same reported by Demiryürek et al. (2017) in their research findings in case of total innovation sustainability index. Good, healthy and ecofriendly practices at farm open the gate toward sustainability (Agovino et al., 2019).

The mean milk yield per animal for full adopter was 8.07 (SD= 2.98) with around 50% of respondents fall in category between 8-15 liter of milk by single animal at farm, around 49% fall below this category and around 1% fall above this category. In case of partial adopter, mean value was found 7.08 liters (SD = 2.48) and with around 35% of respondents fall in the category between having milk yield per animal of 8-15 liter in a single day, around 64% fall below this category and 1% fall above this category. Independent sample t test used to determine the significant difference between two groups. Significance difference found ($p < 0.1$) in case of milk yield per animal and same reported by Demiryürek et al. (2017). High yielding milking animals are the real assets of the dairy farms as is source of income but also ensure food security through milk and by products. High yielding breed had positive and significant impact of adoption level reported by Adem et al. (2011) in their research findings.

The mean cost of production for single liter of milk for full adopter was 3.28 (SD= 1.17) with around 55% of respondents fall in category between 2.51-5.00 TL, around 36% fall below this category and around 9% fall above this category. In case of partial adopter, mean value was found 3.21 TL (SD = 2.48) and with around 59% of respondents fall in the category between cost of production for one liter of milk between 2.51-5.00 TL, around 31% fall below this category and 10% fall above this category. Independent sample t test used to determine the significant difference between two groups and no significance difference found ($p < 0.1$) in case of per liter cost of milk production. With high cost of production, it is difficult for the farmer to operate successful business. The main reason of high cost per liter of milk is large portion of dry animals at farm, poor milking potential, poor management practices, high treatment and labor cost

The mean monthly revenue generated by single milking animals in case of full adopter was 1188.01 (SD= 438.71) with around 44% of respondents fall in category between 1001-1500 TL around 35% fall below this category and around 21% fall above this category. In case of partial adopter, mean value was found 1032.6 TL (SD = 365.67) and with around 46% of respondents fall in the category of 1001-1500 TL monthly income per dairy animal, around 47% fall below this category and only 7% fall above this category. Independent sample t test used to determine the significant difference between two groups and significance difference found ($p < 0.1$) in case monthly income per dairy animal at farm. Mussei et al. (2001) reported a positive association between farm income and innovation adoption. Partial adopter has less monthly income per animal as compare to full adopter because with better level of technology and management practices at farm improve the overall wellbeing. Healthy animals with smooth milk production during lactation period and timely conceive pregnancy improve the overall income as well as value of animal.

4.4.2. Relationship between Innovation Sustainability Index, Efficiency Levels and Socio-economic Characteristics

The sixth objective of the study was to determine the relationship between the innovation adoption and efficiency levels of dairy farmers.

Table 4.19. Correlation between economic variables, efficiency levels and innovation index

Variables	Innovation sustainable index	Significance level	Coefficient description
Technical efficiency	0.14	**	Low (0.1- 0.29)
Allocative efficiency	0.35	***	Medium (0.3-0.49)
Economic efficiency	0.42	***	Medium (0.3-0.49)
Total information score	0.82	***	High (0.5-0.9)
Milk yield per animal	0.17	**	Low (0.1- 0.29)
Area under fodder crops	0.12	**	Low (0.1- 0.29)
Milking animals at farm	0.19	**	Low (0.1- 0.29)
Dairy cows at farm	0.20	***	Low (0.1- 0.29)

*, **, *** shows significant difference at 10%, 5%, and 1%

Table 4.19 presented the correlation between the socio-economic variables, efficiency levels of dairy farmers and innovation index where adoption of innovation taken as covariant. Innovation index showed significant positive correlation with technical efficiency, economic efficiency, total information score, area under fodder crops, number of milking animals and education years of dairy farms. The high-level correlation found between total information score and innovation sustainability index (0.82). Medium level correlation found between allocative efficiency and ISI, and economic efficiency and ISI. Milk yield per animal, area under fodder crops, number of milking animals at farm and number of dairy cows have lowest correlation with ISI. Mafimisebi et al. (2006) reported educational status and income from agricultural a significant factors influencing the adoption of breeding management technologies. Demiryürek et al. (2017) reported that information score, area under forage crops, education, and milk yield per animal all had a favorable and significant impact on dairy breeding members' adoption of innovations.

4.4.3. Factors Affecting the Adoption Level

The seventh objective of the study was to determine the factors effecting the adoption level of dairy farmers in the study area. The binary logistic model used to fulfil this objective. Data analysis described that 45.33% (136) farmers were full adopters and 54.66% (164) were the partial adopters. Fourteen explanatory variables used in the model, which are socio-economic and farm management characteristics. Most of these variables have positive sign except age, family size, labor at farm and credit services. Education, family size, area under fodder crops, labor at farm, credit services, association membership and extension services has no influence on adoption level.

Age was negative and significant ($\beta = -0.052$, $se = .021$ and $p = .013$) predictor of likelihood of farmer expressing the full adoption level. The odd ratio indicated that 1 unit increase of age, adoption level decrease by factor of 6%. People in their fifties are more reticent to adopt innovations because they trust in traditional ways and find it difficult to comprehend the inventive and management approaches used on dairy farms. As a result, they tend to resist changes in their operating methods because they see them as a threat to their production mode.

Dairy farming experience was positive and significant ($\beta = 0.064$, $se = .023$ and $p = .005$) predictor of likelihood of farmer expressing the full adoption level. The odd ratio indicated that 1 unit increase of farming experience, the adoption level increase by 6% and same is reported by Budak et al. (2012). Dairy farmers who have been doing this for a long time are more knowledgeable of operational and management issues and they are more likely to engage in family business during their school breaks. They have a higher adoption rate than those with less experience because they have a better awareness of dairy concerns and obstacles from a young age and have spent more time in their enterprises.

Total milking animals was positive and significant ($\beta = 0.139$, $se = .08$ and $p = .08$) predictor of likelihood of farmer expressing the full adoption level. The odd ratio indicated that 1 unit increase of milking animal, the adoption level increase by factor of 0.8%. Dairy farmers with a large number of milking animals on their farm have more resources available and can make timely decisions in relation to the cost and management expense of the dairy farm, as well as a higher adoption rate of technology and management practices to ensure smooth milk production throughout the season. The ever-increasing rate of input feed and labor items at farm, along with a decreased number of milking animals and a large percentage of dry animals, increases the per unit cost of milk production.

Table 4.20. Factor effecting the adoption of innovation

Variables	β	Standard error	P value	Exp (β)
Age	-0.05**	0.02	0.013	0.94
Education	0.08	0.05	0.12	1.09
Family size	-0.12**	0.08	0.124	0.88
Farming experience	0.06	0.02	0.005	1.06
Area under fodder crop	0.02	0.17	0.883	1.02
Total milking animals	0.13*	0.08	0.083	0.87
Percentage of cow in herd	0.04**	0.02	0.043	1.04
Labor at farm	-0.22	0.56	0.696	0.80
Veterinary services	2.11***	0.48	0.00	8.30
Credit services	-0.04	0.48	0.931	0.95
Training services	1.97***	0.54	0.00	7.17
Media exposure	1.34**	0.39	0.001	3.82
Association Membership	0.64	0.43	0.139	1.91
Extension services	0.73	0.45	0.106	2.07
Constant	-4.45**	1.58	0.005	0.01

*** p<0.01, ** p<0.05, * p<0.1

Veterinary services was positive and significant ($\beta = 2.11$, se = 0.48 and p = .00) predictor of likelihood of farmer expressing the full adoption level. The odd ratio indicated that 1 unit increase of veterinary services, the adoption level increased by 8.38 times and same is reported by Budak et al. (2012). Majority of people in rural areas of the country are uninformed of modern procedures and practices, veterinary services are the finest source of information and action to alleviate dairy difficulties. This service is beneficial in addressing virus and disease outbreaks through timely vaccination as a preventative measure, as well as developing balanced feed plans for milking animals that not only improve the milk potential of dairy animals, but also are also beneficial in terms of health and reproduction.

Training services was positive and significant ($\beta = 1.97$, se = .05 and p = .00) predictor of likelihood of farmer expressing the full adoption level. The odd ratio indicated that 1 unit increase of exotic breeds, the adoption level increased by 7.17 times. Farmers must understand the welfare concept for a successful business, as training programs not only improve dairy farmers' knowledge of modern practices through success stories of adopters, but also help them understand the need for farm technologies to improve farm, labor, and animal welfare, which is not possible through conventional practices, which are no longer profitable these days. As a result, farmers that participate in training programs have a higher likelihood of adoption. Personal training involves time-consuming, difficult, and money-oriented activities, but all of

this is now possible without leaving the farm using a mobile phone and the internet. Various training programs are available in management practices, feeding practices, and monitoring the day-to-day activity of animals on the internet, which not only improve the level of information but also influence the decision-making capacity of dairy farmers, because any innovation or idea is useless without a positive assessment. It is simple to access these practices and learn at which level these practices adopted at the farm level through regular connection with this group of people (Michels and Musshoff, 2019).

Media exposure was positive and significant ($\beta = 1.34$, $se = .039$ and $p = .001$) predictor of likelihood of farmer expressing the full adoption level. The odd ratio indicated that 1 unit increase of media exposure, adoption level increase by 3.82 times and same is reported by Goswami et al. (2001) in their research findings. All types of expertise, information, and new ideas are now available on the internet, and successful dairy farmers in Pakistan now have their own media channels that accessed with a single mobile click. Regular contact on these platforms improves overall comprehension of this company, as well as the concept of ease of doing business, because the dairy industry considered as a difficult one, and as a result, people are hesitant to invest in new and modern technologies for their farms. Adoption is more likely for dairy farmers that have more media exposure. The success or failure of a dairy operation largely determined by a dairy producer's expertise of various animal husbandry procedures such as breeding, feeding, and management of milking animals. In this environment, milk cooperatives have set themselves some lofty goals. They intend to improve not only the productivity of dairy animals, but also the economic condition of rural people in general, by increasing milk production. The only approach to boost the production potential of our milking animals scattered across our country is to introduce improved animal husbandry practices for broad adoption and to build the vital and necessary infrastructure facilities.

5. CONCLUSION AND RECOMMENDATIONS

5.1. Conclusion

Pakistan's diverse climatic conditions, which include all four seasons, are beneficial to the country's crop and livestock sectors. These weather conditions are ideal for sowing all-season forages for dairy farms. Pakistan is famous around the world for its dairy breeds and is the world's biggest raw milk producer among developed nations. Punjab province has the most dairy animals of any province in the country, and it consumes the second most milk per capita behind Sindh province. Milk is a vital part of the daily diet used for drinking purpose and utilized in tea, yogurt, desi ghee, butter, whey, and dairy confectionaries, among other things. All of these foods play a vital role in people's everyday diets across the country. Raw milk is in great demand compared to processed milk because those with lower income per capita cannot purchase processed milk. Raw milk costs roughly 70-85 Rs on average, while processed milk costs around 150 Rs. The need is growing by the day, thanks to an ever-increasing population. Despite being the world's fifth largest producer of raw milk, Pakistan nevertheless imports milk to meet local demand.

In current scenario, the dairy farmers are using commercial and conventional methods for raising the dairy animals for milk and meat and other dairy products. Dairy farming is common in rural, urban and peri-urban areas of the country. The rural economy in the country heavily dependent of crop-livestock integration. There are five main channels for milk production in the country. The major portion comes from rural small dairy farms (70 %) followed by market oriented small holders (20%) rural commercial (2.99%). In urban areas of the country contributes 2.005% only through subsistence and commercial production level. More than 50% of dairy population pertains in province Punjab, which is largest province in terms of population and milk production with active participation of woman in livestock sector. The province Punjab has the better veterinary hospitals, research, diagnostic labs and veterinary facilities among all other province, which is positive sign for the dairy business.

In this research study, we explored the technical allocative efficiency levels of the dairy farms in district Sahiwal, Faisalabad and Raheemiyar Khan in Province Punjab and relationship between the efficiency level of dairy farmers and farms with the innovation adoption practices in the area. The first section the study contained the important information regarding the dairy animals and their contribution in the

economy, type of management regarding the health and feed of dairy animals, feedstuff, milk market structure and veterinary facilities at provincial and national level of the country. This section is helpful to understand the potential of dairy sector in the country. The game changer stakeholders are the small dairy farmers, which has major stakeholder of this enterprise but has poor production level as compare to the commercial dairy farmers. They can improve their production at farm by adoption of modern technologies, reducing the overhead cost and through better management practices. To access these characteristics of the dairy farmers and farm, the technique used by the scientist were the technical and allocative efficiency of dairy farmers and farms. Technical efficiency is the characteristic of dairy farmer and is ability of dairy farmer to produce maximum amount of output, which is milk in case of our study with given set of inputs and available technology. Allocative efficiency is the characteristic of dairy farm, is price efficiency of dairy farmers, and is the selection of optimal input combinations without disturbing the output level of dairy farms. Economic efficiency of the dairy farms is the combine effect of both of the efficiencies mentioned above.

After determining the efficiency level of the dairy farmers, the next step is to explore the factor affecting the technical, allocative and economic efficiency level of the dairy farmers and farms. The main factors are the socio-economic characteristics of the dairy farmers, the farm characteristics, market characteristics and innovation adoption technologies of the dairy farms. These are the common set of metrics used in many different research studies on dairy farmer efficiency at the global and country level and selected after in depth literature review. A comprehensive methodology designed to access the efficiency level and explore the relationship of the selected indicator with the efficiency level. Three districts of province Punjab was selected which is famous for milk and meat production having well known breed of buffalos and cow all over the world and dairy sector has main or partial income source. A structured questionnaire was designed with the collaboration of supervisor, veterinary doctors, livestock assistant and progressive dairy farmers in the study area. From each district selected for the study, hundred dairy farmers were selected. The sample size of 300 dairy farmers, selected by using simple random sampling technique with the help of farmers. Livestock departments and private livestock assistants and interviewed for data collection purpose.

The socio-economic characteristic along with the farm characteristics analyzed to fulfil the first objective of the study. The socio-economic characteristics include age, education, family size and farming experience of the dairy farmers. The farm characteristics include the land ownership, land under forage crops, and total number of dairy animals, milking animals, animal milk production level and overhead cost. The average age of the dairy, farmers were around 43 year with a standard deviation of 9.66 years. The average education level is around 9 years with standard deviation of 3.5 years. Most of the farmers have education level of ninth standard, which is healthy percentage in Pakistan especially for the livestock sector. Average family size was around 6 indicating a large portion of population are directly or indirectly involved in dairy sector. Farming experience of around 19 years of the dairy farmers indicating that most of them have spent a reasonable time in this sector and knows the pros and cons of this business.

Average landholding were around 13 acres, which considered as subsistence level in the country and a certain portion of income comes from agriculture sector of the selected respondents. Area under forage crops is around 4 acres, which is very small in proportion to total available land. The farm's typical dairy animal population, milking animals, and monthly milk production were 15, 9, and 2150 liters; respectively that is subsistence level in Pakistan. Average milk production per animals was around 12 liters, which a healthy from farmers point of view but is 3 times less as compared to developed nations and less than 1% farmers in the study area have this potential. Average of 60% of the dairy animals on the farm were in the milking stage, which is a good sign from a business standpoint. The average overhead cost is 59.63Rs, which is extremely high, especially for dairy producers with a low percentage of milking animals and low milk production per animal, making it difficult for them to maintain a profitable business. Cost section included the variable costs associated with management and farm operations. The highest portion of the variable cost is the fodder cost followed by concentrate, wheat straw and labor cost which is around 88% of the total dairy farm cost. The average monthly cost of dairy farm was around 185875.04 Rs, which is very high from small farmer. The average monthly income level was around 300095.9 Rs, which is healthy income from farming prospective. The average monthly gross margin of the dairy farm were around 114220.67 Rs.

Data envelopment analysis used to determine the technical, allocative and economic efficiency of dairy farmers with major determinants were the fodder consumption, concentrate consumption, wheat straw consumption, salt and mineral consumption and medical treatments along with the unit price. The model results indicating that around 11% farmers were operating at technical efficiency level below 70% and around 66% of the farmers were operating at level between 70 to 90%. Around 23% farmers were operating at technical efficiency level above 90%. In case of allocative efficiency, around 62% of the farmers were operating below 70% level and 34% farmers were operating between 70 to 90% allocative efficiency level. Only 3% farmers were operating at allocative efficiency level above 90%. In case of economic efficiency, around 79% of dairy farms were operating at level below 70% and 18% were operating between 70 to 90% economic efficiency level and only 3% were operating at economic efficiency level above 90%. The mean technical efficiency level was 90.7% mean farmer can improve their output level up to 10% by using the same amount of inputs and technology. The mean allocative efficiency level of dairy farms was 66.4% mean farmers can reduce the cost up to 33% without disturbing the output level. The mean economic efficiency level was 60.2% and is mainly due to non-optimal inputs combination to produce the same level of output still there is chance of improvement in efficiency level of dairy farms as majority of the dairy farmers in the study area were operating in suboptimal region on production possibility curve. Exactly 49% of dairy farmers were operating at an increasing return to scale level, implying that they were operating at a point on the production possibility curve before the optimal level point. Exactly 24% were operating at a decreasing return to scale level, implying that they were operating at a super optimal level on the production possibility curve, and 27% were operating at a constant return to scale level.

The factors including age, landownership, total number of dairy animals and distance to milk market negatively affecting the technical efficiency of dairy farmers. The factors like education, dairy as main income source, milking machine, maize silage, vaccination, parasite treatment, concentrate feed and social media and internet adoption have positive and significant relationship with the technical efficiency of dairy farmers.

In case of allocative efficiency age, family size, land ownership, total number of dairy animals at farm and distance to milk market reducing the allocative efficiency

level of dairy farms. The factors education, milking machines internet and social media and concentrate feed showed positive and significant association at 1% level of significance and maize silage adoption presented same association at 5% level of significance.

The factor including family size, land ownership, total number of dairy animals and distance to milk market reducing the economic efficiency level of dairy farms. The factors like education, milking machine, milk refrigeration, vaccination, maize silage and concentrate feed has positive and significant association with the economic efficiency of dairy farms at 1% level of significance and social media and internet has found same relationship at 5% level of significance. By improving, the education level and with adoption of innovations farmers can improve their technical, allocative and economic efficiency level.

In last part of the study, we determine the innovation adoption level of the dairy farmers and factors affecting the adoption level of dairy farmers in the study area. The highest adoption rate found in case vaccination of dairy animals, followed by social media and internet and concentrate, feed. The poor adoption rate found in case of record keeping followed by mineral mixture and salt and milk refrigeration respectively. Sustainable innovation index were calculated for all the dairy farmers and determining the total years of innovation adoption and total number of innovation adopted by the farmers. Partial correlation technique used to determine the relationship among socio-economic variables, efficiency level and innovation sustainability index. Index has positive and significant association with technical efficiency, economic efficiency, information score, milk yield per animal, area under fodder crops, milking animals and dairy cows at farm level are significant. Binary logistic model used to determine the factor affecting the adoption level of dairy farmers with total fourteen explanatory variables used in the model. Age, family size, hired labor at farm and credit services has negative relationship with the adoption level. Farming experience, veterinary services, training programs, number of milking animals at farm, higher percentage of dairy cows and media exposure have positive and significant association with the adoption level of dairy farmers.

5.2. Recommendations

There are separate recommendations for the farmers and government sector for the promotion of dairy sector in the country. Recommendations for the dairy farmers is the first part

5.2.1. Recommendations For The Dairy Farmers

- Dairy farmers must gain the basic knowledge of herd management through social interactions and training programs as major portion of this sector is unaware of herd management techniques. There must be proper all weather sheds for the dairy animals with proper identification mark for each animal at farm. The identification mark is supportive for the milk production, disease and reproduction traceability of the animal.
- Proper record should maintain for all the dairy animals at farm to understand the potential of dairy animals. This includes milking record, lactation length, vaccination record, artificial insemination record, reproduction record and if possible, the pedigree of dairy animal as it is important step for the decision-making and breeding point of view.
- Dairy farmers used poor quality feedstuff for the milking animals in dry period, which not only disturb the milk production but also the health status of dairy animals. There must be proper arrangement of feedstuff at farm for the dairy animals as silage is commonly available in market and has percentage of dry matter, crude protein and crude fiber. This not only improve the milking potential of dairy animals but also improve the body score and reproduction status.
- There should be balance feed for the milking and pregnant animals, which is not common practice among dairy farms. There is separate feedstuff for the milking and pregnant animals Energy stress during the pregnancy level disturb the health and animal and calve as pregnant animals need energy enrich diet to complete their pregnancy cycle and give birth to healthy calf. Total mixed ration is common available in the market now a day. Farmer must consider the dry matter, crude protein and energy level of his feed with the assistance of dairy nutritionists for the smooth milk production and healthy lactation period.
- Due to harsh weather conditions in the country, the hygiene standards are highly compromised and dairy animals are prone to diseases and infection.

Farm hygiene not only improve the health of dairy animals but also reduce the medicine cost. There must be proper cleaning mechanism at farm level. Water tanks and farm stuff must be properly sanitized with the sanitizers and cleaning agents commonly available in markets

- Farmers must aware and follow the vaccination schedule of dairy animals against the infectious disease for healthy farm production. There must be proper arrangement for the infected animals to avoid the spread of disease among the healthy animal at farm. Proper care and treatment must be extended to the sick animals to improve the welfare of animal rather to sell the disease carrier animal in market which is very common reason of disease spread and is unethical practice.
- There is common practice to offer water two times a day and is not healthy, as animal cannot fulfil it water requirements properly. Water is important component of animal's body and source of mineral as well and is available 24/7 to the dairy animals with free excess as the weather condition is not supportive especially in summer season, which is peak milking period in the country. Animals with compromised healthy status cannot meet it full milking potential. So clean water must be, free available at farm level in water tanks.
- The weather is quite harsh, especially during the summer, and there is no adequate cooling system in place at the farm. The sprinkler and fog system, as well as a fan, must installed at farm level. These are low-cost method for lowering the temperature, and humid weather condition and creating an atmosphere that is conducive to dairy animals.
- Deworming dairy animals after three months is an essential guideline that is not widely followed on dairy farms. Dairy farmers should follow this practice on a regular basis by farmers to improve the digestive health of dairy animals, which will improve milk output indirectly. Farmers should repeat the procedure 15 days after the initial dose to destroy newly developed parasites in the body, which is impossible to perform with a single treatment after three months.
- Regular veterinary visit is also not a common practice especially on small dairy farms. Farmers must ensure these visits on regular basis to improve the

understanding of dairy management, production technologies and modern practices in the sector.

- The small and subsistence farmers using normal semen for their dairy animals to avoid transportation cost, farmer used indigenous semen for untrained and unregistered provider effect the quality and reproduction level of dairy animals. Quality and registered semen is available in district hospital level at low price for breed improvement motives. Farmers should avail these opportunities to improve the quality of dairy animals at farm which is not possible through indigenous sources.
- Mineral and feed block widely available at district veterinary hospital and research centers with minimum price but not commonly used by the dairy farmers. This improve the reproductive health status of dairy animals, reduce the calving interval, and improve the lactation length of animals. Farmers must avail this opportunity offered by the government to improve the health status of dairy animals.
- Dairy farmers involved in manual milking having common udder problem in the research area. By applying sanitizer of antibacterial agent for short span of time can address this problem effectively. Farmer should adopt these practices at farm to improve the udder healthy of animal.

5.2.2. Recommendations For Government

- In order to improve the milk production at country level, government should provide basic infrastructures like paved roads, milk markets, and standardized facilities in the rural areas of the country. Major portion of the milk comes from the rural area at national level but unfortunately, there is not proper milk market in these areas. This not only disturb the price of the milk product but also the qualities issues along with the transportation cost incorporated in the price of milk which make is less desirable business.
- The standard of education is the rural area of the countries are still very poor. Those who have education level up to 10th standard cannot understand the basics literature of dairy guide available in english format. Government should not only improve the literacy rate of the area but also the standard of education through proper training programs at school and college level on regular basis.

There must be proper evaluation criteria for the teachers at primary and secondary to ensure the quality standards.

- There was price hike in the price of concentrate and is difficult for the farmers to use this input in proportional amount to get good milk percentage from their dairy animals. There should be a regulation committee for the monitoring to ensure the quality, supply and price these feed products so that farmer can make timely decision accordingly.
- The vaccination schedule strongly followed by the veterinary staff in the study area but they have inadequate funds and facilities to maintain the quality of vaccination. Long hot weather conditions, the quality of vaccination is highly compromised and animals infected even after receiving the shot of vaccination. This is the reason that people do not trust the veterinary staff. There should be a proper timeline for vaccination and cold chain facility to ensure the quality.
- Mineral mixtures, feed blocks and medicine for parasite treatment medicines were commonly available at veterinary centers at low price during research time and is necessary for the good health and production but unfortunate the least adopted practice by the dairy farmers clearly indicating the poor communication level between the veterinary staff and the dairy farmers. Government is providing all these stuff at subsidized rate for the small dairy farmers but farmers were not availing this opportunity. So government officials must ensure the coordination and communication between veterinary staff and farmers by providing mobile phones to the staff and regular visits in the remote areas for the success of dairy sector. There must be fair distribution of subsidized resources among the small and large farmers.
- Milking machines, milk refrigeration are the most common dairy technologies in these days but still is not very common among the small dairy farmers usually installed at large dairy farms because there prices are very high in the market. Government should subsidized these imported item for the promotion of dairy commercial industry to channelized the milk supply chain and reap a handsome revenue in the form of tax collection from the dairy sector to balance the subsidized portion of sector.
- The veterinary staff were lagging in modern and up to date knowledge of the modern practices in dairy farming. People his misconceptions about the

modern practices and technologies and is overwhelmed with the poor knowledge level of the field staff as most of the staff members were diploma holders and had completed education in the veterinary field a very long time ago. Government should arrange proper training programs on modern technologies, total mix ration for the dairy animals, ideal management techniques for the dairy farms for the veterinary staff and doctors on regular basis to keep their knowledge level up to mark.

REFERENCES

- Abbas, S. G. (1998). Development of a computer based decision support system for introducing no-till technology: (Doctoral dissertation, Massey University). 125p.
- Abd El Razek, M. M. (2002). Thermal experimental investigation of,"traditional houses in south egypt,(Toshky Region). *ERJ. Engineering Research Journal*. 25(4). 145-158.
- Abd El-Razek, A. (2002). Peasants level knowledge related to environmental pollution resulting from chemical fertilizations and pesticides and its relationship to some variables in Babilonia Governorate. In *Second conference of recent technologies in agriculture, Cairo University* (Vol. 28, No. 30, pp. 737-743).
- Abdul-kareem, M. M., and Isgin, T. (2016). Technical efficiency of cassava production in the savannah zone of northern Ghana: stochastic frontier analysis. *J. Biol. Agric. Healthc*, 6(20), 62-72.
- Abedullah, Z. M., and Sabir, H. (2005). Competitive efficiency of milk production in the Central Punjab. *European Journal of Scientific Research*, 7(1).
- Abou Elez, A.S. (1985). A study of farmers' attitudes towards innovations in fifa area in
- Abou-Tahoon, A. A. (1993). Identify analysis for some social, cultural, economic and environmental factors and its relationship with endemic diseases distribution (Kafr Tanbeedy-Monoufeya Governorate). *Menofiya Journal of Agricultural Research (Egypt)*.
- Abubakar, B. Z., Ango, A. K., and Buhari, U. (2009). The roles of mass media in disseminating agricultural information to farmers in Birnin Kebbi local government area Of Kebbi state: a case study of state. Fadama ii development project. *Journal of Agricultural extension*, 13(2).
- Adam, B. D., Holcomb, R., Buser, M., Mayfield, B., Thomas, J., O'Bryan, C. A., and Ricke, S. C. (2016). Enhancing food safety, product quality, and value-added in food supply chains using whole-chain traceability. *International Food and Agribusiness Management Review*, 19(1030-2016-83149), 191-213.
- Adem, A., Murat, K. L. I., and Fahri, Y. (2011). Analysis of the factors affecting the adoption of innovations in dairy farms in Erzurum Province, Turkey. *African Journal of Agricultural Research*, 6(13), 2966-2970.
- Adnan, N., Nordin, S. M., Bahrudin, M. A., and Tareq, A. H. (2019). A state-of-the-art review on facilitating sustainable agriculture through green fertilizer technology adoption: Assessing farmer's behavior. *Trends in Food Science and Technology*, 86, 439-452.
- Afzal, M. (2009). Improving veterinary service in Pakistan. *Pak. Vet. J*, 29(4), 206-210.
- Agovino, M., Casaccia, M., Ciommi, M., Ferrara, M., and Marchesano, K. (2019). Agriculture, climate change and sustainability: The case of EU-28. *Ecological Indicators*, 105, 525-543.
- Ahmad, M., and Bravo-Ureta, B. E. (1995). An econometric decomposition of dairy output growth. *American Journal of Agricultural Economics*, 77(4), 914-921.
- Ahmed, E. A. (1994). Most important factors connected with decision making of innovations (sunflower).
- Ahmed, M.M., Gebremedhin, B., Benin, S. and Ehui, S., 2002. Measurement and sources of technical efficiency of land tenure contracts in Ethiopia. *Environment and Development Economics*, 7(3), pp.507-52
- Aigner, D., Lovell, C. K., and Schmidt, P. (1977). Formulation and estimation of stochastic frontier production function models. *Journal of econometrics*, 6(1), 21-37.

- Alabi, A., and Aruna, B. (2005). Technical efficiency of family poultry production in Niger-Delta, Nigeria. *Journal of Central European Agriculture*.
- Al-Sakran, M. (2001). Adoption of new technical practices of palm between farmers in the central region of Saudi Arabia. *Bulletin of Faculty of Agriculture, Cairo University*, 52(2), 185-206.
- Álvarez, A., Del Corral, J., Solís, D., and Pérez, J. A. (2008). Does intensification improve the economic efficiency of dairy farms?. *Journal of dairy science*, 91(9), 3693-3698.
- Al-Zahrani, K. H., Aldosari, F. O., Baig, M. B., Shalaby, M. Y., and Straquadine, G. S. (2018). Assessing the competencies and training needs of agricultural extension workers in Saudi Arabia.
- Anderson, J. R., and Feder, G. (2007). Agricultural extension. *Handbook of agricultural economics*, 3, 2343-2378.
- Angón, E., García, A., Perea, J., Acero, R., Toro-Mújica, P., Pacheco, H., and González, A. (2013). Technical efficiency and viability of grazing dairy cattle systems in La Pampa, Argentine. *Agrociencia*, 47(5), 443-456.
- Antanaitis, R., Žilaitis, V., Kučinskas, A., Juozaitienė, V., and Leonauskaitė, K. (2015). Changes in cow activity, milk yield, and milk conductivity before clinical diagnosis of ketosis, and acidosis. *Vet. Med. Zoot*, 70, 3-9.
- Arthur, W. B. (2011). *The nature of technology: What it is and how it evolves*. New York: Free Press.
- Ashfaq, M., Razaq, A., and Muhammad, G. (2015). Economic analysis of dairy animal diseases in Punjab: a case study of Faisalabad district. *JAPS: Journal of Animal and Plant Sciences*, 25(5).
- Ashraf, S., Iftikhar, M., Khan, G. A., Shahbaz, B., and Ashraf, I. (2013). Performance evaluation of the dairy farmers regarding adoption of precise dairy farming practices in the Punjab, Pakistan. *African Journal of Agricultural Research*, 8(29), 4074-4080.
- Atanu, S., Love, H. A., and Schwart, R. (1994). Adoption of emerging technologies under output uncertainty. *American Journal of Agricultural Economics*, 76(4), 836-846.
- Atasever, S., Garipoglu, A. V., and Erdem, H. (2020). Effects of Feeding Management on Milk Yield and Composition Traits in Crossbred Jersey Cows. *Pakistan Journal of Zoology*, 52(4).
- Aubert, B. A., Schroeder, A., and Grimaudo, J. (2012). IT as enabler of sustainable farming: An empirical analysis of farmers' adoption decision of precision agriculture technology. *Decision support systems*, 54(1), 510-520.
- Austin, P. C., Escobar, M., and Kopec, J. A. (2000). The use of the Tobit model for analyzing measures of health status. *Quality of Life Research*, 9(8), 901-910.
- Aydın, B., and Unakıtan, G. (2018). Efficiency analysis in agricultural enterprises in Turkey: case of Thrace Region. *Custos e gronegocio*, 14(2), 137-160.
- Baidu-Forson, J. (1999). Factors influencing adoption of land-enhancing technology in the Sahel: lessons from a case study in Niger. *Agricultural Economics*, 20(3), 231-239.
- Baiyegunhi, L. J. S., Majokweni, Z. P., and Ferrer, S. R. D. (2019). Impact of outsourced agricultural extension program on smallholder farmers' net farm income in Msinga, KwaZulu-Natal, South Africa. *Technology in Society*, 57, 1-7.
- Bajrami, E., J Wailes, E., L Dixon, B., Musliu, A., and Durand-Morat, A. (2017). Factors affecting the technical efficiency of dairy farms in Kosovo. *Journal of Central European Agriculture*, 18(4), 823-840.

- Balehegn, M., Duncan, A., Tolera, A., Ayantunde, A. A., Issa, S., Karimou, M., ... and Adesogan, A. T. (2020). Improving adoption of technologies and interventions for increasing supply of quality livestock feed in low-and middle-income countries. *Global food security*, 26, 100372.
- Bali, A. E. A. (1996). Adoption of animal production improvement technology among Kallin District farmers Kafr El-Sheikh Governorate (Doctoral dissertation, Dissertation, Tanta University, Egypt).
- Barnes, A., and Oglethorpe, D. (2004). Scale Efficiencies and the Mid-Term Review: An Analysis of Scottish Dairy Farming. In *Conference paper presented at the 78th Agricultural Economics Society*.
- Battese, G. E., and Coelli, T. J. (1988). Prediction of firm-level technical efficiencies with a generalized frontier production function and panel data. *Journal of econometrics*, 38(3), 387-399.
- Batz, F. J., Janssen, W., and Peters, K. J. (2003). Predicting technology adoption to improve research priority setting. *Agricultural economics*, 28(2), 151-164.
- Batz, F. J., Peters, K. J., and Janssen, W. (1999). The influence of technology characteristics on the rate and speed of adoption. *Agricultural Economics*, 21(2), 121-130.
- Bavorová, M., Unay-Gailhard, I., Ponkina, E. V., and Pilařová, T. (2020). How sources of agriculture information shape the adoption of reduced tillage practices?. *Journal of Rural Studies*, 79, 88-101.
- Bayiyana, I. A., Hepelwa, H., and Rao, E. J. (2019). Economic efficiency of dairy farmers participating in dairy market hubs in Tanga and Morogoro Regions, Tanzania. *Tanzania Journal of Agricultural Sciences*, 18(1).
- Beal, G. M., and Bohlen, J. M. (1956). The diffusion process (No. 761-2016-51585, pp. 111-121).
- Belbase, K., Grabowski, R., and Sanchez, O. (1985). The marginal productivity of inputs and agricultural production in Nepal. *The Pakistan Development Review*, 51-60.
- Bellon, M. R., Kotu, B. H., Azzarri, C., and Caracciolo, F. (2020). To diversify or not to diversify, that is the question. Pursuing agricultural development for smallholder farmers in marginal areas of Ghana. *World Development*, 125, 104682.
- Berger, J. I. (2005). Perceived consequences of adopting the internet into adult literacy and basic education classrooms. *Adult Basic Education*, 15(2), 103.
- Bezabih, M., Chambwera, M., and Stage, J. (2010). Climate change, total factor productivity, and the Tanzanian economy: a computable general equilibrium analysis. *Environment for Development Discussion Paper-Resources for the Future (RFF)*, 10-14.
- Bhalakiya, N., Haque, N., Patel, P., and Joshi, P. (2019). Role of trace minerals in animal production and reproduction. *International Journal of Livestock Research*, 9(9), 1-12.
- Bhanderi, B. M., Goswami, A., Garg, M. R., and Samanta, S. (2016). Study on minerals status of dairy cows and their supplementation through area specific mineral mixture in the state of Jharkhand. *Journal of animal science and technology*, 58(1), 1-8.
- Bizikova, L., Nkonya, E., Minah, M., Hanisch, M., Turaga, R. M. R., Speranza, C. I.,... and Timmers, B. (2020). A scoping review of the contributions of farmers' organizations to smallholder agriculture. *Nature Food*, 1(10), 620-630.
- Boz, I. (2018). Determinants of farmers' enrollment in voluntary environmental programs: evidence from the Eregli Reed Bed area of Turkey. *Environment, Development and Sustainability*, 20(6), 2643-2661.

- Boz, I. (2019). Estimating the efficiency level of different tea farming systems in Rize Province Turkey. *Ciência Rural*, 49.
- Boz, I., and Akbay, C. (2005). Factors influencing the adoption of maize in Kahramanmaraş province of Turkey. *Agricultural Economics*, 33, 431-440.
- Boz, I., and Ozcatalbas, O. (2010). Determining information sources used by crop producers: A case study of Gaziantep province in Turkey. *African Journal of Agricultural Research*, 5(10), 980-987.
- Bozoglu, M., Saglam, O., and Topuz, B. K. (2017). Economic sustainability of family dairy farming within the scope of technical efficiency: a case study of Bafra District, Turkey. *Custos e agronegocio*, 13(2), 295-316.
- Bradley, A. J., Breen, J. E., Payne, B., White, V., and Green, M. J. (2015). An investigation of the efficacy of a polyvalent mastitis vaccine using different vaccination regimens under field conditions in the United Kingdom. *Journal of dairy science*, 98(3), 1706-1720.
- Bravo-Ureta, B. E. (1986). Technical Efficiency Measures for Dairy Farms Based on a Probabilistic Frontier Function Model. *Canadian Journal of Agricultural Economics/Revue canadienne d'agroeconomie*, 34(3), 399-415.
- Bravo-Ureta, B. E., and Pinheiro, A. E. (1993). Efficiency analysis of developing country agriculture: a review of the frontier function literature. *Agricultural and resource economics Review*, 22(1), 88-101.
- Bravo-Ureta, B. E., and Rieger, L. (1990). Alternative production frontier methodologies and dairy farm efficiency. *Journal of agricultural economics*, 41(2), 215-226.
- Bruijnis, M., Hogeveen, H., Garforth, C., and Stassen, E. (2013). Dairy farmers' attitudes and intentions towards improving dairy cow foot health. *Livestock Science*, 155(1), 103-113.
- Brümmer, B., and Loy, J. P. (2000). The technical efficiency impact of farm credit programmes: A case study of Northern Germany. *Journal of Agricultural Economics*, 51(3), 405-418.
- Bucek, P., Zottl, K., Kyntäjä, J., Miglior, F., Leclerc, H., van der Westhuizen, J., and Oudah, M. (2015). World-wide trends in milk-recording in cattle. In *ICAR Technical Workshop, Krakow, Poland. ICAR, Rome, Italy*.
- Budak, D. B., and Budak, F. (2010). Livestock producers needs and willingness to pay for extension services in Adana province of Turkey. *African Journal of Agricultural Research*, 5(11), 1187-1190.
- Budak, D. B., and Yurdakul, O. (2004). Sustainable agricultural development through extension education. *Asian Journal of Plant Sciences*.
- Budak, D., Boz, I., Akbay, C., and Bas, S. (2012). Factors influencing the adoption of selected innovations by sheep farmers in the East Mediterranean region of Turkey. *Journal of Animal and Veterinary Advances*, 11(10).
- Bulale, A. I. (2000). Smallholder dairy production and dairy technology adoption in the mixed farming system in Arsi Highland, Ethiopia. Humboldt University.
- Byerlee, D. R. (1987). Maintaining the momentum in post-green revolution agriculture: A micro-level perspective from Asia.
- Candemir, M., and Koyubenbe, N. (2006). Efficiency analysis of dairy farms in the province of Izmir (Turkey): Data envelopment analysis (DEA). *Journal of Applied Animal Research*, 29(1), 61-64.
- Carter, N. A., Humphries, S., Grace, D., Ouma, E. A., and Dewey, C. E. (2017). Men and women farmers' perceptions of adopting improved diets for pigs in Uganda: decision-

- making, income allocation, and intra-household strategies that mitigate relative disadvantage. *Agriculture and Food Security*, 6(1), 1-24.
- Cary, J. W., and Wilkinson, R. L. (1997). Perceived profitability and farmers' conservation behaviour. *Journal of agricultural economics*, 48(3), 13-21.
- Cassiman, B., Golovko, E., and Martínez-Ros, E. (2010). Innovation, exports and productivity. *International Journal of Industrial Organization*, 28(4), 372-376.
- Chagwiza, C., Muradian, R., and Ruben, R. (2016). Cooperative membership and dairy performance among smallholders in Ethiopia. *Food policy*, 59, 165-173.
- Chandio, A. A., Rehman, A., Jiang, Y., and Noonari, S. (2017). Importance of the dairy industry and economic growth in Pakistan: an empirical study. *J. Appl. Environ. Biol. Sci*, 7(4), 13-20.
- Chang, H. J. (2002). Kicking away the ladder: development strategy in historical perspective. Anthem Press.
- Charnes, A., Cooper, W. W., and Rhodes, E. (1978). Measuring the efficiency of decision making units. *European journal of operational research*, 2(6), 429-444.
- Chen, X., Yi, N., Zhang, L., and Li, D. (2018). Does institutional pressure foster corporate green innovation? Evidence from China's top 100 companies. *Journal of cleaner production*, 188, 304-311.
- Chhachhar, A. R., Qureshi, B., Khushk, G. M., and Ahmed, S. (2014). Impact of information and communication technologies in agriculture development. *Journal of Basic and Applied scientific research*, 4(1), 281-288.
- Chukwuji, C. O., Inoni, O. E., and Oyaide, W. J. (2006). A quantitative determination of allocative efficiency in broiler production in Delta State, Nigeria. *Agriculturae Conspectus Scientificus*, 71(1), 21-26.
- Cloutier, L. M., and Rowley, R. (1993). Relative technical efficiency: data envelopment analysis and Quebec's dairy farms. *Canadian Journal of Agricultural Economics/Revue canadienne d'agroeconomie*, 41(2), 169-176.
- Cochran, W. G. (1977). Sampling techniques. *John Wiley and Sons*.
- Coelli, T. J., Rao, D. S. P., O'Donnell, C. J., and Battese, G. E. (2005). An introduction to efficiency and productivity analysis. *springer science and business media*.
- Çukur, T. (2016). Factors Affecting Dairy Farmers' Application of Agricultural Innovations: A Case Study from Muğla Province. *Turkish Journal of Agriculture-Food Science and Technology*, 4(7), 611-617.
- Dagistan, E., Koc, B., Gul, M. E. V. L. Ü. T., Parlakay, O., and AKPINAR, M. (2009). Identifying technical efficiency of dairy cattle management in rural areas through a non-parametric method: A case study for the east Mediterranean in turkey. *Journal of Animal and Veterinary Advances*, 8(5).
- Demiryürek, K., Abaci, N. İ., Abaci, S. H., Atasever, S., and Erdem, H. (2017). Effect of Dairy Cattle Breeders' Association (DCBA) Membership on Sustainability of Innovations in Samsun Province of Turkey. *Sustainable Agriculture and Environment Proceeding Book*, 375.
- Dhehibi, B., Rudiger, U., Moyo, H. P., and Dhraief, M. Z. (2020). Agricultural technology transfer preferences of smallholder farmers in Tunisia's arid regions. *Sustainability*, 12(1), 421.
- Dhungana, B. R., Nuthall, P. L., and Nartea, G. V. (2004). Measuring the economic inefficiency of Nepalese rice farms using data envelopment analysis. *Australian Journal of Agricultural and Resource Economics*, 48(2), 347-369.

- Dias, D. D. S. (2000). Motivação e resistência ao uso da tecnologia da informação: um estudo entre gerentes. *Revista de Administração Contemporânea*, 4(2), 51-66.
- Donadeu, M., and Dungu, B. (2013). Market Development and Adoption: Lessons learned and observations during Phase 1 of Protecting Livestock, Saving Human Life (PLSHL-1) programme. GALVmed (Global Alliance for Livestock Veterinary Medicines).
- Donadeu, M., Nwankpa, N., Abela-Ridder, B., and Dungu, B. (2019). Strategies to increase adoption of animal vaccines by smallholder farmers with focus on neglected diseases and marginalized populations. *PLoS neglected tropical diseases*, 13(2), 69-89.
- Donkor, E., and Owusu, V. (2014). Effects of land tenure systems on resource-use productivity and efficiency in Ghana's rice industry. *African Journal of Agricultural and Resource Economics*, 9(311-2016-5617), 286-299.
- Drucker, P. F. (2002). The discipline of innovation. *Harvard business review*, 80(8), 95-102.
- Duncan, A., Valbuena, D., Smith, J., Descheemaeker, K., Thorne, P., Homann-KeeTui, S., and Tarawali, S. (2013). Sustainable intensification of agriculture in Africa: The case for mixed crop-livestock farming. *International Livestock Research Institute (ILRI)*.
- Durham, T. C., and Mizik, T. (2021). Comparative economics of conventional, organic, and alternative agricultural production systems. *Economies*, 9(2), 64.
- El-Gannam, A.R. (2000). The effect of some farmer's socio economic characteristics on using recent techniques and agricultural productivity for principle crops (Cotton, Wheat, Rice, and Corn) in Governorates of Alexandria, Beheira and Garbia. *Bull. No. 239*.
- El-Ghamrini, S. A. H. M. (1998). Economic evaluation of farmer's adoption for raising fish in cages in Egypt.
- Emana, B., Gebremedhin, H., and Regassa, N. (2010). Impacts of improved seeds and agrochemicals on food security and environment in the rift valley of Ethiopia: implications for the application of an African green revolution.
- FAO. (2020). Dairy market review. Milk production trends in 2019.
- Farooq, U. (2016). Milk Supplies in Pakistan: Issues and Challenges Facing the Dairy Economy.
- Farrell, M. J. (1957). The measurement of productive efficiency. *Journal of the Royal Statistical Society*, 120(3), 253-281.
- Feder, G., Just, R. E., and Zilberman, D. (1985). Adoption of agricultural innovations in developing countries: A survey. *Economic development and cultural change*, 33(2), 255-298.
- Fernandez-Cornejo, J., Mishra, A. K., Nehring, R. F., Hendricks, C., Southern, M., and Gregory, A. (2007). *Off-farm income, technology adoption, and farm economic performance*.
- Finger, R., Swinton, S. M., El Benni, N., and Walter, A. (2019). Precision farming at the nexus of agricultural production and the environment.
- Fliegel, F. C., Kivlin, J. E., and Sekhon, G. S. (1968). Cross-national comparison of farmers perceptions of innovations as related to adoption behavior. *Rural Sociology*, 33(4), 437-449.
- Flinn, J. C., and Mubarik, A. L. I. (1986). Technical Efficiency in Basmati Rice Production. *Pakistan journal of applied economics*, 5(1), 63-79.
- Freeman, C. (1996). The greening of technology and models of innovation. *Technological forecasting and social change*, 53(1), 27-39.

- Gaffney, J., Challender, M., Califf, K., and Harden, K. (2019). Building bridges between agribusiness innovation and smallholder farmers: A review. *Global food security*, 20, 60-65.
- Gales, L., Porter, P., and Mansour-Cole, D. (1992). Innovation project technology, information processing and performance: a test of the Daft and Lengel conceptualization. *Journal of Engineering and Technology Management*, 9(3-4), 303-338.
- Garg, M. R., Sherasia, P. L., Phondba, B. T., and Hossain, S. A. (2014). Effect of feeding a balanced ration on milk production, microbial nitrogen supply and methane emissions in field animals. *Animal production science*, 54(10), 1657-1661.
- Garipoglu, A. V., Can, M., Kaymak, G., Ozturk, E., Acar, Z., and Ayan, I. (2020). Determining Nutritive Value of Mixed Silage of Forage Rape, Forage Pea and Oat Supplemented With Molasses and Tea Wastes. *Fresenius Environmental Bulletin*, 29(1), 178-183.
- Gelan, A., and Muriithi, B. W. (2012). Measuring and explaining technical efficiency of dairy farms: a case study of smallholder farms in East Africa. *Agrekon*, 51(2), 53-74.
- Gerber, J., and Franks, J. R. (2001). Technical efficiency and benchmarking dairy enterprises. *Farm Management: Journal of the Institute of Farm Management*.
- Gethun, D., Mawangi, W., Verkuijl, H., and Abdishekur, W. A. (2000). An assessment of the adoption seed and fertilizer packages and the role of credit in smallholder Maize in Sidama and North Oma Zones, Ethiopia. *Mexico, DF: International Maize and Wheat Improvement Center (CIMMYT) and Ethiopian Agricultural Research Organization (EARO)*.
- Girma, H. (2019). Estimation of technical efficiency of dairy farms in central zone of Tigray National Regional State. *Heliyon*, 5(3), e01322.
- Gitau, K. J. (2013). Factors influencing milk production among small scale dairy farmers in Mirangine in Nyandarua county and Mauche in Nakuru county, Kenya (Doctoral dissertation, University of Nairobi).
- Gladwell, M., and Point, T. (2000). How little things can make a big difference.
- GOP, (2007). Economic Survey, 2006-07. Economic Affairs Division, Government of Pakistan, Islamabad.
- GOP, 2006. Livestock Census. Agricultural Census Organization, Statistics Division, Government of Pakistan, Lahore
- GOP. (2019), Economic Survey of Pakistan, finance division, economic advisors, wing, Islamabad
- GOP. (2020), Economic Survey of Pakistan, finance division, economic advisors, wing, Islamabad.
- Goswami, A. (2001). Factors related with adoption behavior of livestock owners about vaccination against contagious diseases. *Environment and Ecology*, 19(1), 226-228.
- Goswami, A., Roy, N., Mazumdar, A. K., and Duttagupta, R. (2000). Behavioural study of the livestock owners to enhance the productivity in saline belt of Sundarban, West Bengal. *Indian Journal of Animal Health*, 39(2), 42-46.
- Grabowski, R. (1985). Technical efficiency in Nepalese agriculture. *The Journal of developing areas*, 19(4), 515-526.
- Greenhalgh, T., Robert, G., Macfarlane, F., Bate, P., and Kyriakidou, O. (2004). Diffusion of innovations in service organizations: systematic review and recommendations. *The milbank quarterly*, 82(4), 581-629.

- Gül, M., Demircan, V., Yilmaz, H., and Yilmaz, H. (2016). Technical efficiency of goat farming in Turkey: a case study of Isparta province. *Revista Brasileira de Zootecnia*, 45, 328-335.
- Gül, M., Yilmaz, H., Parlakay, O., Akkoyun, S., Bilgili, M. E., Vurarak, Y., and Kilicalp, N. (2018). Technical efficiency of dairy cattle farms in East Mediterranean region of Turkey. *Sci. Pap. Ser. Manag. Econ. Eng. Agric. Rural Dev*, 18, 213-226.
- Guta, D. D. (2018). Determinants of household adoption of solar energy technology in rural Ethiopia. *Journal of cleaner production*, 204, 193-204
- Habib, G., Hameed, A., and Akmal, M. (2007). Current feeding management of peri-urban dairy buffaloes and scope for improvement. *Pakistan Veterinary Journal*, 27(1), 35.
- Hafz, M. K., and Anwar, A. M. (1999). A study of the factors affecting animal productive behaviour among livestock raisers in some villages, Itay El-Baroud District, Beheira Governorate. *Menoufia Journal of Agricultural Research, Egypt*, 24(1), 373-393.
- Hailu, G., Goddard, E. W., and Jeffrey, S. R. (2005). *Measuring efficiency in fruit and vegetable marketing co-operatives with heterogeneous technologies in Canada* (No. 378-2016-21367).
- Halachmi, I., Guarino, M., Bewley, J., and Pastell, M. (2019). Smart animal agriculture: application of real-time sensors to improve animal well-being and production. *Annual review of animal biosciences*, 7, 403-425.
- Hall, H. (2019). Evaluating the Impact of Feed Supplementation on Productive and Reproductive Efficiency in Smallholder Dairy Cattle in Arusha, Tanzania.
- Hasnain, H. U., and Usmani, R. H. (2006). *Livestock of Pakistan*, Livestock Foundation Islamabad.
- Hawkins, J. A. (1993). Economic benefits of parasite control in cattle. *Veterinary Parasitology*, 46(1-4), 159-173.
- Heshmati, A., and Kumbhakar, S. C. (1994). Farm heterogeneity and technical efficiency: some results from Swedish dairy farms. *Journal of Productivity Analysis*, 5(1), 45-61.
- Hogeveen, H., Heemskerk, K., and Mathijs, E. (2004). Motivations of Dutch farmers to invest in an automatic milking system or a conventional milking parlour. *Automatic milking: A better understanding*, 56-61.
- Hossain, S. M. A. (1998). Agricultural technology and development communication networking patterns in differentially developed villages of Bangladesh. *Journal of Sustainable Agriculture*, 12(1), 57-80.
- Ibrahim, I. E., Al-feel, M. A., and Ahmed, A. E. (2014). Identification of Factors That Influence Technical Efficiency of Cash Crops Production (Sesame and Groundnut) In North Kordofan State, Sudan. *International Journal of Scientific and Technology Research*. 2277, 8616.
- Iqbal, M. A., Iqbal, A., Akbar, N., Khan, H. Z., and Abbas, R. N. (2015). A study on feed stuffs role in enhancing the productivity of milch animals in Pakistan-Existing scenario and future prospect. *Global Vet*, 14(1), 23-33.
- Ishaq, M. N., Xia, L. C., Rasheed, R., Nguyen, N. B., Abdullah, M., and Abbas, N. (2016). Economic analysis of milk marketing channels in south region of Punjab, Pakistan: an empirical estimation of marketing and profit efficiency. *Russian Journal of Agricultural and Socio-Economic Sciences*, 51(3), 30-43.
- Ishaq, M., Farooq, A., and Farooq, U. (2007). Economies of scale in small ruminants farming in Southern North West Frontier Province-Pakistan. *Young*, 27(68), 4.

- Jabbar, M. A. (1998). Adoption pathways for new agricultural technologies: An approach and an application to Vertisol management technology in Ethiopia, 23.
- Jaforullah, M., and Devlin, N. J. (1996). Technical efficiency in the New Zealand dairy industry: a frontier production function approach. *New Zealand Economic Papers*, 30(1), 1-17.
- Jaforullah, M., and Premachandra, E. (2003). Sensitivity of technical efficiency estimates to estimation approaches: An investigation using New Zealand dairy industry data.
- Jaforullah, M., and Whiteman, J. (1999). Scale efficiency in the New Zealand dairy industry: a non-parametric approach. *Australian journal of agricultural and resource economics*, 43(4), 523-541.
- Jalil, H., Rehman, H. U., Sial, M. H., and Hussain, S. S. (2009). Analysis of milk production system in peri-urban areas of Lahore (Pakistan): A case study. *Pakistan Economic and Social Review*, 229-242.
- Janicic, R., and Jankovic, M. (2014). Strategic marketing planning of Montenegro tourism and hospitality. *Economic and Social Development: Book of Proceedings*, 262.
- Jeffrey, S. R., and Richards, T. J. (1996). Factors influencing costs of milk production in Alberta. *Advances in Dairy Technology*, 8, 333-47.
- Jensen, R. G. (2002). The composition of bovine milk lipids: January 1995 to December 2000. *Journal of dairy science*, 85(2), 295-350.
- Jiang, H., Wang, W., Li, C., and Wang, W. (2017). Innovation, practical benefits and prospects for the future development of automatic milking systems. *Frontiers of Agricultural Science and Engineering*, 4(1), 37-47.
- Jiang, N., and Sharp, B. (2015). Technical efficiency and technological gap of New Zealand dairy farms: a stochastic meta-frontier model. *Journal of Productivity Analysis*, 44(1), 39-49.
- Jin, S., Rozelle, S., Alston, J., and Huang, J. (2005). Economies of scale and scope and the economic efficiency of China's agricultural research system. *International Economic Review*, 46(3), 1033-1057.
- Kamal, G. M., Rehmani, M. N., Iqbal, S. Z., Uddin, J., Nazir, S., Rehman, J. U., and Khaneghah, A. M. (2022). The determination of potentially toxic elements (PTEs) in milk from the Southern Cities of Punjab, Pakistan: A health risk assessment study. *Journal of Food Composition and Analysis*.
- Kavoi, M. M., Hoag, D. L., and Pritchett, J. (2010). Measurement of economic efficiency for smallholder dairy cattle in the marginal zones of Kenya. *Journal of Development and Agricultural Economics*, 2(4), 122-137.
- Kebede, Y., Gunjal, K., and Coffin, G. (1990). Adoption of new technologies in Ethiopian agriculture: the case of Tegulet-Bulga District, Shoa Province. *Agricultural economics*, 4(1), 27-43.
- Kelly, K. (2012). Para onde nos leva a tecnologia. *Tradução: Francisco Araújo da Costa. Porto Alegre: Bookman*.
- Key, N., and Runsten, D. (1999). Contract farming, smallholders, and rural development in Latin America: the organization of agroprocessing firms and the scale of outgrower production. *World development*, 27(2), 381-401.
- Khalid, U. B., Shahbaz, P., Haq, S. U., and Javeed, S. (2017). Economic Analysis of Integrated Farming Systems on Farm Income. A case Study of Sahiwal District, Punjab, Pakistan.
- Khan, M. J., Abbas, A., Naeem, M., Ayaz, M. M., and Akhter, S. (2013). Current issues and future prospects of dairy sector in Pakistan. *Sci. Tech. Dev*, 32(2), 126-139.

- Kibiego, M. B., Lagat, J. K., and Bebe, B. O. (2015). Assessing the economic efficiency of dairy production systems in Uasin Gishu County, Kenya. *Journal of Economics and Sustainable Development*, 6(2), 146-153.
- Kimenchu, M. D., Mwangi, M., Kairu, W. S., and Macharia, G. A. (2014). Evaluation of technical efficiency of dairy farms in eastern central highlands, Kenya. *International Journal of Innovation Research and Development*, 3(4), 342-347.
- Kirigia, J. M., Asbu, E. Z., Greene, W., and Emrouznejad, A. (2007). Technical efficiency, efficiency change, technical progress and productivity growth in the national health systems of continental African countries. *Eastern Africa Social Science Research Review*, 23(2), 19-40.
- Knight, C. H. (2020). Dairy Care ‘blueprint for action’: husbandry for wellbeing. *Journal of Dairy Research*, 87(1), 1-8.
- Kompas, T., and Tuong, N. C. (2004). Production and technical efficiency on Australian dairy farms.
- Kumbhakar, S. C. (1987). The specification of technical and allocative inefficiency in stochastic production and profit frontiers. *Journal of econometrics*, 34(3), 335-348.
- Kumbhakar, S. C., and Heshmati, A. (1995). Efficiency measurement in Swedish dairy farms: an application of rotating panel data, 1976–88. *American Journal of Agricultural Economics*, 77(3), 660-674.
- Kumbhakar, S. C., and Lovell, C. K. (2003). *Stochastic frontier analysis*. Cambridge university press.
- Kumbhakar, S. C., Biswas, B., and Bailey, D. (1989). A study of economic efficiency of Utah dairy farmers: a system approach. *The review of Economics and Statistics*, 595-604.
- Kumbhakar, S. C., Ghosh, S., and McGuckin, J. T. (1991). A generalized production frontier approach for estimating determinants of inefficiency in US dairy farms. *Journal of Business and Economic Statistics*, 9(3), 279-286.
- Lachaal, L., Chahtour, N. and Thabet, B., 2002. Technical efficiency of dairy production in Tunisia: a data envelopment analysis. *New Medit*, 3, pp.22-26.
- Labaree, R. (2013). Lib Guides. Organizing Your Social Sciences Research Paper. Writing a Field Report.
- Le, T. Q. A., Shimamura, Y., and Yamada, H. (2020). Information acquisition and the adoption of a new rice variety towards the development of sustainable agriculture in rural villages in Central Vietnam. *World Development Perspectives*.
- Leeuwis, C., and Aarts, N. (2011). Rethinking communication in innovation processes: creating space for change in complex systems. *Journal of agricultural education and extension*, 17(1), 21-36.
- Liu, L., Zhu, Y., and Guo, S. (2020). The evolutionary game analysis of multiple stakeholders in the low-carbon agricultural innovation diffusion. *Complexity*.
- Llewellyn, R. S., and Brown, B. (2020). Predicting adoption of innovations by farmers: What is different in smallholder agriculture?. *Applied Economic Perspectives and Policy*, 42(1), 100-112.
- Mafimisebi, T. E., Onyeka, U. P., Ayinde, I. A., and Ashaolu, O. F. (2006). Analysis of farmer-specific socio-economic determinants of adoption of modern livestock management technologies by farmers in Southwest Nigeria. *Journal of Food Agriculture and Environment*, 4(1), 183.
- Makundi, H., Huyse, H., Develtere, P., Mongula, B., and Rutashobya, L. (2017). Training abroad and technological capacity building: Analysing the role of Chinese training and

- scholarship programmes for Tanzanians. *International Journal of Educational Development*, 57, 11-20.
- Manjunatha, A. V., Speelman, S., Van Huylenbroeck, G., and Chandrakanth, M. G. (2009). Impact of groundwater markets in peninsular India on water use efficiency: A Data Envelopment Analysis approach.
- Marsh, T. L., Yoder, J., Deboch, T., McElwain, T. F., and Palmer, G. H. (2016). Livestock vaccinations translate into increased human capital and school attendance by girls. *Science advances*, 2(12), e1601410.
- Marshall, K. (2014). Optimizing the use of breed types in developing country livestock production systems: a neglected research area. *Journal of Animal Breeding and Genetics*, 131(5), 329-340.
- Mascia, M. B., and Mills, M. (2018). When conservation goes viral: The diffusion of innovative biodiversity conservation policies and practices. *Conservation Letters*, 11(3), e12442.
- Masuku, B. B., Masuku, M. B., and Belete, A. (2014). Economic efficiency of smallholder dairy farmers in Swaziland: An application of the profit function. *Journal of Agricultural Studies*, 2(2), 132-146.
- Mbaga, M. D., Romain, R., Larue, B., and Lebel, L. (2003). Assessing technical efficiency of Quebec dairy farms. *Canadian Journal of Agricultural Economics/Revue canadienne d'agroéconomie*, 51(1), 121-137.
- Mburu, S., Ackello-Ogutu, C., and Mulwa, R. (2014). Analysis of economic efficiency and farm size: A case study of wheat farmers in Nakuru District, Kenya. *Economics Research International*, 2014.
- Meeusen, W., and van Den Broeck, J. (1977). Efficiency estimation from Cobb-Douglas production functions with composed error. *International economic review*, 435-444.
- Meir, Y. B., Nikbachat, M., Portnik, Y., Jacoby, S., Adin, G., Moallem, U., and Mabjeesh, S. J. (2021). Effect of forage-to-concentrate ratio on production efficiency of low-efficient high-yielding lactating cows. *Animal*, 15(1), 100012.
- Meireles, T. E. F., Rocha, M. F. G., Brilhante, R. S. N., Cordeiro, R. D. A., and Sidrim, J. J. C. (2008). Successive mycological nail tests for onychomycosis: a strategy to improve diagnosis efficiency. *Brazilian Journal of Infectious Diseases*, 12(4), 333-337.
- Mendel, P., Meredith, L. S., Schoenbaum, M., Sherbourne, C. D., and Wells, K. B. (2008). Interventions in organizational and community context: a framework for building evidence on dissemination and implementation in health services research. *Administration and Policy in Mental Health and Mental Health Services Research*, 35(1), 21-37.
- Mhundwa, R., Simon, M., and Tangwe, S. (2017). Energy management opportunities in raw milk cooling in a dairy farm: the potential of using a raw milk pre-cooler. In *Proceedings of The annual South African Universities Power Engineering Conference (SAUPEC), Stellenbosch University 30 January* (pp. 164-169).
- Michels, M., Bonke, V., and Musshoff, O. (2019). Understanding the adoption of smartphone apps in dairy herd management. *Journal of dairy science*, 102(10), 9422-9434.
- Michie, C., Andonovic, I., Davison, C., Hamilton, A., Tachtatzis, C., Jonsson, N., ... and Gilroy, M. (2020). The internet of things enhancing animal welfare and farm operational efficiency. *Journal of Dairy Research*, 87(S1), 20-27.
- Mlay, P. S., Pereka, A., Chikula Phiri, E., Balthazary, S., Igusti, J., Hvelplund, T., ... and Madsen, J. (2006). Feed value of selected tropical grasses, legumes and concentrates. *Veterinarski arhiv*, 76(1), 53-63.

- Morantes, M., Dios-Palomares, R., Peña, M. E., Rivas, J., Perea, J., and García-Martínez, A. (2017). Management and productivity of dairy sheep production systems in Castilla-La Mancha, Spain. *Small Ruminant Research*, 149, 62-72.
- Moreira, V. H., Bravo-Ureta, B. E., and Vasquez, J. A. (2003, September). The analysis of technical efficiency for small dairy farms in southern Chile: a stochastic frontier analysis with unbalanced panel data. In *VIII European Workshop on Efficiency and Productivity, Oviedo, Spain*.
- Morgan-Davies, C., Wilson, R., and Waterhouse, T. (2017). Impacts of farmers' management styles on income and labour under alternative extensive land use scenarios. *Agricultural Systems*, 155, 168-178.
- Motta, P. R. (2001). *Transformação organizacional: A teoria e a prática de inovar*. Rio de Janeiro: Quality mark.
- Mugambi, D. K., Wambugu, S. K., Gitunu, A. M. M., and Mwangi, M. (2017). Estimation of milk production efficiency of dairy cow farms in Embu and Meru counties of Kenya.
- Mugambi, P., Blanco, M., Ogachi, D., Ferasso, M., and Bares, L. (2021). Analysis of the regional efficiency of European funds in Spain from the perspective of renewable energy production: The regional dimension. *International Journal of Environmental Research and Public Health*, 18(9), 4553.
- Musabyimana, A., Lundeen, T., Butrick, E., Sayinzoga, F., Rwabufigiri, B. N., Walker, D., and Musange, S. F. (2019). Before and after implementation of group antenatal care in Rwanda: a qualitative study of women's experiences. *Reproductive Health*, 16(1), 1-9.
- Mussei, A., Mwangi, J., Mwangi, W. M., Verkuijl, H., Mongi, R., and Elanga, A. (2001). Adoption of improved wheat technologies by small-scale farmers in Mbeya District, Southern Highlands, Tanzania.
- Mustaffa, F., Singaravelloo, K., and Azmah, O. (2019). Multiplicity in entrepreneurship economic development of Malaysian smallholder farmers. *Academy of Entrepreneurship Journal*, 25(1), 1-6.
- Mutoko, M. C., Benhin, J., Ritho, C. N., and Mbatia, O. L. E. (2008). Analysis of economic efficiency in smallholder maize production in north western Kenya. *East African Agricultural and Forestry Journal*, 74(1-2), 139-147.
- Náglóvá, Z., and Rudinskaya, T. (2021). Factors Influencing Technical Efficiency in the EU Dairy Farms. *Agriculture*, 11(11), 11-14.
- Nakanwagi, T. T., and Hyuha, T. S. (2015). Technical efficiency of milk producers in cattle corridor of Uganda : Kiboga district case. *Modern Economy*, 6, 846-856.
- Naseer, A., Ashfaq, M., Abid, M., Razzaq, A., and Hassan, S. (2016). Current status and key trends in agricultural land holding and distribution in Punjab, Pakistan: Implications for food security. *J. Agric. Stud*, 4(4), 14-27.
- Ngozi, S. (2016). *Efficiency and effectiveness of participatory research approaches among smallholder farmers in Babati District; Tanzania* (Doctoral dissertation, Egerton University).
- Nguyen, N. V., Nguyen, V. T., and Dang, T. (2021). Color blind: Can you sight?. In *The 12th International Conference on Advances in Information Technology* (pp. 1-5).
- Niyomugabo, J. D. D. (2019). *Effects of Farm Household Heterogeneity on Agricultural inputs Adoption in Rwanda* (Doctoral dissertation, UR-CAVM).
- Nkonya, E., Schroeder, T., and Norman, D. (1997). Factors affecting adoption of improved maize seed and fertiliser in northern Tanzania. *Journal of Agricultural Economics*, 48(1-3), 1-12.

- Nowak, P. (1992). Why farmers adopt production technology: Overcoming impediments to adoption of crop residue management techniques will be crucial to implementation of conservation compliance plans. *Journal of soil and water conservation*, 47(1), 14-16.
- Nyagaka, D., Obare, G. A., and Nguyo, W. (2009). Economic efficiency of smallholder Irish potato producers in Kenya: A case of Nyandarua North District (No. 1005-2016-79081).
- O'brien, R. M. (2007). A caution regarding rules of thumb for variance inflation factors. *Quality and quantity*, 41(5), 673-690.
- O'Brien, D. J., Patsiorkovski, V. V., Dershem, L., and Lylova, O. (1996). Household Production and Symptoms of Stress in Post-Soviet Russian Villages 1. *Rural Sociology*, 61(4), 674-698.
- Ogunniyi, L. T., and Ajao, A. O. (2011). Measuring the technical efficiency of maize production using parametric and non-parametric methods in Oyo state, Nigeria. *Journal of Environmental Issues and Agriculture in Developing Countries*, 3(3), 113.
- Ohe, Y. (2016). Technical efficiency in dairy farms conducting educational tourism: an approach by stochastic frontier production function. *International Journal of Sustainable Development and Planning*, 11(3), 458-468.
- Oladeebo, J. O., and Ambe-Lamidi, A. I. (2007). Profitability, input elasticities and economic efficiency of poultry production among youth farmers in Osun State, Nigeria. *International Journal of Poultry Science*, 6(12), 994-998.
- Oladeebo, J. O., and Oluwaranti, A. S. (2012). Profit efficiency among cassava producers: Empirical evidence from Southwestern Nigeria. *Journal of Agricultural Economics and Development*, 1(2), 46-52.
- Oladunni, O. A., Aduba, J. J., and Onojah, D. (2013). Technical efficiency of smallholder maize farmers in Nigeria: The stochastic frontier approach. *Global Journal of Current Research*, 1(4), 132-140.
- Omar, A. M. (1992). Contemporary agricultural extension. *Egypt for Scientific Services, Cairo*.
- Omiti, J. M., Otieno, D. J., Nyanamba, T. O., and McCullough, E. B. (2009). Factors influencing the intensity of market participation by smallholder farmers: A case study of rural and peri-urban areas of Kenya. *African Journal of Agricultural and Resource Economics*, 3, 57-82.
- Onumah, J. A., Al-Hassan, R. M., and Onumah, E. E. (2013). Productivity and technical efficiency of cocoa production in Eastern Ghana.
- Osbahr, H., Twyman, C., Adger, W. N., and Thomas, D. S. (2008). Effective livelihood adaptation to climate change disturbance: scale dimensions of practice in Mozambique. *Geoforum*, 39(6), 1951-1964.
- Osoimehin, K. O., Tijani, A. A., and Olukomogbon, E. O. (2006). An economic analysis of small scale dairy milk processing in Kogi State, Nigeria. *Livestock Research for Rural Development*, 18(11), 157.
- Özçatalbaş, O. (2007). The Evaluation of Horticultural Extension in Hanover Region of Germany. *Akdeniz Üniversitesi Ziraat Fakültesi Dergisi*, 20(1), 137-142.
- Özçatalbaş, O. (2014). Extension and Innovations, Diffusion of Innovations. *Gaziosmanpaşa publications*, Tokat, 1.
- Ozcatalbas, O., Boz, I., Demiryurek, K., Budak, D. B., and Karaturhan, B. (2011). Developing participatory extension applications in Turkey. *African Journal of Agricultural Research*, 6(2), 407-415.

- Özcatalbas, O., Imran, M., Gurkan, G., Durmuş, H., and Unlu, T. (2017). The role of agricultural extension and agricultural education for sustainability. In *ESEE 2017 conference—transformative learning: new directions in agricultural extension and education* (pp. 4-7).
- Pan, Y., and Jackson, R. T. (2008). Ethnic difference in the relationship between acute inflammation and serum ferritin in US adult males. *Epidemiology and Infection*, 136(3), 421-431.
- Pandey, K. K. (1999). A study of chemical structure of soft and hardwood and wood polymers by FTIR spectroscopy. *Journal of Applied Polymer Science*, 71(12), 1969-1975.
- Parlakay, O., Semerci, A., and Çelik, A. D. (2015). Estimating technical efficiency of dairy farms in Turkey: a case study of Hatay Province. *Custos e Agronegócio Online*, 11(1), 106-115.
- Pujiati, R., Ohtani, Y., Ichura, H., and Wishimura, Y. (2013). Insecticidal activity of melaleuca leucadendron oil against green haouse whitely trisleurode vaporarium. In *Book of Abstract The Fifth International Symposium of Indonesia Wood Resarch Society. November* (pp. 7-9).
- Quddus, M. A. (2012). Adoption of dairy farming technologies by small farm holders: practices and constraints. *Bangladesh Journal of Animal Science*, 41(2), 124-135.
- Rahman, S. A., and Umar, H. S. (2009). Measurement of technical efficiency and its determinants in crop production in Lafia local government area of Nasarawa State, Nigeria. *Agro-Science*, 8(2).
- Rao, E. J., Omondi, I., Karimov, A. A., and Baltenweck, I. (2016). Dairy farm households, processor linkages and household income: the case of dairy hub linkages in East Africa. *International Food and Agribusiness Management Review*, 19(4), 95-108.
- Rehman, A., Jingdong, L., Chandio, A. A., and Hussain, I. (2017). Livestock production and population census in Pakistan: Determining their relationship with agricultural GDP using econometric analysis. *Information Processing in Agriculture*, 4(2), 168-177.
- Reiber, C., Schultze-Kraft, R., Peters, M., and Hoffmann, V. (2020). Lessons from silage adoption studies in Honduras.
- Reinhard, S., Lovell, C. K., and Thijssen, G. (1999). Econometric estimation of technical and environmental efficiency: an application to Dutch dairy farms. *American Journal of Agricultural Economics*, 81(1), 44-60.
- Reinhard, S., Lovell, C. K., and Thijssen, G. J. (2000). Environmental efficiency with multiple environmentally detrimental variables; estimated with SFA and DEA. *European Journal of Operational Research*, 121(2), 287-303.
- Richards, S., VanLeeuwen, J. A., Shepelo, G., Gitau, G. K., Wichtel, J., Kamunde, C., and Uehlinger, F. (2016). Randomized controlled trial on impacts of dairy meal feeding interventions on early lactation milk production in smallholder dairy farms of Central Kenya. *Preventive veterinary medicine*, 125, 46-53.
- RK, R., Periyaveeturaman, C., Selvaraju, D., Kinhekar, A. S., Dutta, L., and Kumar, V. (2016). Community oriented ectoparasite intervention system: Concepts for on-farm application of indigenous veterinary medication. *Adv. Anim. Vet. Sci*, 4(1s), 9-19.
- Rogers, E. M. (1983). Communication as an Academic Discipline: A Dialogue. *Journal of Communication*, 33(3), 18-30.
- Rogers, E. M. (1995). Diffusion of Innovation. Free press, New York.
- Rogers, E. M. (2003). Diffusion of Innovations fifth Ed Free Press. New York.
- Rogers, E. M. (2010). Diffusion of innovations. *Simon and Schuster*.

- Rogers, E. M., Singhal, A., Quinlan, M. M., Stacks, D. W., Salwen, M. B., and Eichhorn, K. C. (2019). An integrated approach to communication theory and research.
- Rose, G., and Straub, D. (1998). Predicting general IT use: Applying TAM to the Arabic world. *Journal of Global Information Management (JGIM)*, 6(3), 39-46.
- Rukhsana, R., Xia, L. C., Nadeem, I. M., and Majid, L. (2017). Improving agricultural farm specific efficiency and wheat productivity in perspective of microcredit: implications for food security in Pakistan. *Russian Journal of Agricultural and Socio-Economic Sciences*, 62(2), 211-220.
- Sabir, H. M., and Tahir, S. H. (2011). Role of Advance Agri-Technologies in Reducing the Rural Poverty in Central Punjab, Pakistan. *Forman Journal of Economic Studies*, 7.
- Saifullah, J., and Zulfiqar A, M. (2006). Experience of cefotaxime as first line antibiotic in acute bacterial meningitis.
- Salam, M.S., (1992). Objectives, limitation and technical of agricultural development in nineteen decades from the social view conference of Egyptian agricultural strategies in nineteen decades, Ministry of Agricultural, Economic Affairs.
- Salama, F. A. (2001). A path analysis of innovativeness of animal production innovations. *Minufiya Journal of Agricultural Research (Egypt)*.
- Samy, M. M. (1998). Constraints to effective transfer of corn technology as identified by farmers in Menoufia Governorate, Egypt. *Zagazig Journal of agricultural Sciences*, 12(2): 340-358.
- Sawang, S., and Unsworth, K. L. (2018). A model of organizational innovation implementation effectiveness in small to medium firms. In *Promoting Innovation in New Ventures and Small-and Medium-Sized Enterprises* (pp. 179-201).
- Schmidt, P., and Lovell, C. K. (1979). Estimating technical and allocative inefficiency relative to stochastic production and cost frontiers. *Journal of econometrics*, 9(3), 343-366.
- Sehested, J., Kristensen, T., and Søgaard, K. (2003). Effect of concentrate supplementation level on production, health and efficiency in an organic dairy herd. *Livestock Production Science*, 80(1-2), 153-165.
- Senyolo, M. P., Long, T. B., and Omta, O. (2021). Enhancing the adoption of climate-smart technologies using publicprivate partnerships: lessons from the WEMA case in South Africa. *International Food and Agribusiness Management Review*, 24(5), 755-776.
- Shah, H. N. (1995). Nonparametric efficiency analysis of Punjab, Pakistan agriculture (Doctoral dissertation, Kansas State University).
- Shahbaz, P., and Boz, I. (2020). Adaptation options for small livestock farmers having large ruminants (cattle and buffalo) against climate change in Central Punjab Pakistan. *Environmental Science and Pollution Research*, 27(15), 17935-17948.
- Shahin, A. S. A. H. (1995). Adoption and diffusion of technological innovations in the field of animal production in Ashmoun district in Menoufiya Governorate Egypt.
- Shahzad, M. A. (2022). The need for national livestock surveillance in Pakistan. *Journal of Dairy Research*, 89(1), 13-18.
- Shaijumon, C. S. (2018). Social learning in information diffusion and capability of farmers. *International Journal of Social Economics*.
- Shalabi, R.H. (1988). A study the relationship between knowledge level, adoption level and characteristics of new technology in some village in Kafr El- Sheik District, Kafr El-Sheik Governorate. *Tanta Journal of Agric. Tanta University*. 14 (2):113-132.

- Shapiro, K. H., and Müller, J. (1977). Sources of technical efficiency: the roles of modernization and information. *Economic Development and Cultural Change*, 25(2), 293-310.
- Shibah, M. M., Salama, F. A., El-Hag, E. A., and Al-Khuraiji, K. A. (2002). Some aspects associated with adoption of some modern irrigation methods by Al-KharJ Governorate farmers, Saudi Arabia. *Journal of King Saud University*, 14, 149-171.
- Shiyani, R. L., Joshi, P. K., Asokan, M., and Bantilan, M. C. S. (2002). Adoption of improved chickpea varieties: Kribhco experience in tribal region of Gujarat, India. *Agricultural economics*, 27(1), 33-39.
- Silva, E., Almeida, B., and Marta-Costa, A. A. (2018). Efficiency of the dairy farms: A study from Azores (Portugal). *European Countryside*, 10(4), 725-734.
- Silva, E., and Marote, E. (2013). The importance of subsidies in Azorean dairy farms' efficiency. In *Efficiency, measures in the agricultural sector* (pp. 157-166). Springer, Dordrecht.
- Simtowe, F., Kassie, M., Diagne, A., Asfaw, S., Shiferaw, B., Silim, S., and Muange, E. (2011). Determinants of agricultural technology adoption: The case of improved pigeonpea varieties in Tanzania. *Quarterly Journal of International Agriculture*, 50(892-2016-65202), 325-345.
- Singh, V. A. K., Singh, S., and Venkatasubramanian, V. (1993). Relationship between farmers socio-personal traits and adoption of dairy innovations. *Cheiron (India)*.
- Smith, T. L., and Zopf Jr, P. E. (1970). Principles of inductive rural sociology. *Principles of inductive rural sociology*.
- Sofranko, A. J., and Fliegel, F. C. (1984). Dissatisfaction with satisfaction. *Rural Sociology*, 49(3), 353.
- Susan, K., Chimoita, E. L., Mburu, J., and Wanjala, T. (2019). The Effectiveness of Communication Channels for the Uptake of Modern Reproductive Technologies in Dairy Cattle: The Case of Kangema, Murang'a County, Republic of Kenya. *International Journal*, 5(2), 242-249.
- Swanson, B. and Sofranko, A.J. (1984). Introducing technological change: the social setting. Food and Agricultural organization of the United Nations.
- Tahir, M. N., Riaz, R., Bilal, M., and Nouman, H. M. (2019). Current standing and future challenges of dairying in Pakistan: a status update. Milk production, processing and marketing.
- Tauer, L. W., and Belbase, K. P. (1987). Technical efficiency of New York dairy farms. *Northeastern Journal of Agricultural and Resource Economics*, 16(1), 10-16.
- Thorpe, W. R., Muriuki, H. G., Omore, A. O., Owango, M. O., and Staal, S. J. (2000). Dairy development in Kenya: the past, the present and the future.
- Tidd, J., and Bessant, J. R. (2020). Managing innovation: integrating technological, market and organizational change. *John Wiley and Sons*.
- Tigre, P. B. (2006). *Gestão da Inovação: A economia da tecnologia no Brasil*. Rio de Janeiro: Elsevier.
- Torres-Toledo, V., Hack, A., Mrabet, F., Salvatierra-Rojas, A., and Müller, J. (2018). On-farm milk cooling solution based on insulated cans with integrated ice compartment. *International Journal of refrigeration*, 90, 22-31.
- Ullah, S., Brummer, B., and Ahmed, U. I. (2021). Role of Extension Services in Enhancing Efficiency of Market Oriented Dairy Farmers: An Evidence from Punjab, Pakistan. *Sarhad Journal of Agriculture*, 37(4), 1314-1322.

- Van der Voort, M., Van Meensel, J., Lauwers, L., Vercruyse, J., Van Huylenbroeck, G., and Charlier, J. (2014). A stochastic frontier approach to study the relationship between gastrointestinal nematode infections and technical efficiency of dairy farms. *Journal of dairy science*, 97(6), 3498-3508.
- Venkatesan, V. (1985). Policy and institutional issues in improving research-extension linkages in India. *Research-extension-farmer: A two-way continuum for agricultural development*, 13-22.
- Wade, K. M., Van Asseldonk, M. A. P. M., Berentsen, P. B. M., Ouweltjes, W., and Hogeveen, H. (2004). Economic efficiency of automatic milking systems with specific emphasis on increases in milk production. *Automatic milking: a better understanding. Wageningen Academic Publ., Wageningen, the Netherlands*, 62-67.
- Waithaka, M. (1998). Intergration of a user perspective in research priority setting: the case of dairy technology adoption in Meru. Kenya. *Dissertation. Humboldt Universitat zu Berlin. Weikersheim, mararafverlag*.
- Warren, M. F. (2002). Adoption of ICT in agricultural management in the United Kingdom: the intra-rural digital divide. *Zemedelska ekonomika-praha-*, 48(1), 1-8.
- Weick, K. E., and Quinn, R. E. (1999). Organizational change and development. *Annual Review of Psychology*, 50, 361-386.
- Wilcox, K. C., and Lawson, H. A. (2018). Teachers' agency, efficacy, engagement, and emotional resilience during policy innovation implementation. *Journal of Educational Change*, 19(2), 181-204.
- Winsten, J. R., Kerchner, C. D., Richardson, A., Lichau, A., and Hyman, J. M. (2010). Trends in the Northeast dairy industry: Large-scale modern confinement feeding and management-intensive grazing. *Journal of Dairy Science*, 93(4), 1759-1769.
- Wirtz, N. (2004). Vergleich zwischen automatischem und konventionellem melken im Hinblick auf Milchleistung und Futteraufwand (Vol. 124). *Cuvillier Verlag*.
- Wyckhuys, K. A., Bentley, J. W., Lie, R., Nghiem, L. T. P., and Fredrix, M. (2018). Maximizing farm-level uptake and diffusion of biological control innovations in today's digital era. *BioControl*, 63(1), 133-148.
- Yamoah, F. A., Kaba, J. S., Amankwah-Amoah, J., and Acquaye, A. (2020). Stakeholder collaboration in climate-smart agricultural production innovations: insights from the Cocoa industry in Ghana. *Environmental Management*, 66(4), 600-613.
- Yenice, G., and Savaş, S. (2016). Rize ilinde yapılan süt sığırcılığının mevcut durumunun araştırılması. *Atatürk Üniversitesi Veteriner Bilimleri Dergisi*, 11(1).
- Yilmaz, H., Gelaw, F., and Speelman, S. (2020). Analysis of technical efficiency in milk production: a cross-sectional study on Turkish dairy farming. *Revista Brasileira de Zootecnia*, 49.
- Younas, M., and Yaqoob, M. (2005). Feed resources of livestock in the Punjab, Pakistan. *Livestock research for rural development*, 17(2), 63-71.
- Zeller, M., Diagne, A., and Mataya, C. (1998). Market access by smallholder farmers in Malawi: Implications for technology adoption, agricultural productivity and crop income. *Agricultural Economics*, 19(1-2), 219-229.
- Zia, K., and Akram, W. (2020). Economic efficiency and profitability analysis of milk production in district sargodha. *Applied Economic Review*, 1(2), 90-125.
- Zia, U. (2009). Pakistan: A dairy sector at a crossroads. *Small Holder Dairy Development: Lessons Learnt from in Asia*, 76-92.

- Zia, U. E. (2007). Analysis of milk marketing chain–Pakistan. *Italian Journal of Animal Science*, 6(2), 1384-1386.
- Ziad, K. T., Hayat, U., and Bacha, M. S. (2019). An Economic Assessment of Problems Associated with Small-Scale Farmers in the Dairy Sector of Pakistan (A Case Study of Punjab Province). *Sarhad Journal of Agriculture*, 35(1).
- Ziętek-Kwaśniewska, K., Zuba-Ciszewska, M., and Nucińska, J. (2022). Technical Efficiency of Cooperative and Non-Cooperative Dairies in Poland: Toward the First Link of the Supply Chain. *Agriculture*, 12(1), 52.

ETHICAL COMMITTEE DECISION



ONDOKUZ MAYIS ÜNİVERSİTESİ SOSYAL VE BEŞERİ BİLİMLER ARAŞTIRMALARI ETİK KURUL KARARLARI

KARAR TARİHİ	TOPLANTI SAYISI	KARAR SAYISI
30.04.2021	04	2021/351

KARAR NO: 2021-351
Üniversitemiz Lisansüstü Eğitim Enstitüsü öğrencisi Umer Bin KHALİD'in Prof. Dr. İsmet BOZ danışmanlığında "Pakistan'ın Punjab İlinde Faaliyet Gösteren Süt İşletmelerinde Etkinlik Analizi ve Yeniliklerin Benimsenmesi (Efficiency Analysis and Innovation Adoption among the Dairy Farms of Punjab, Pakistan)" isimli doktora tezine ilişkin anket ve mülakat çalışmalarını içeren 11474 sayılı dilekçesi okunarak görüşüldü.

Üniversitemiz Lisansüstü Eğitim Enstitüsü öğrencisi Umer Bin KHALİD'in Prof. Dr. İsmet BOZ danışmanlığında "Pakistan'ın Punjab İlinde Faaliyet Gösteren Süt İşletmelerinde Etkinlik Analizi ve Yeniliklerin Benimsenmesi (Efficiency Analysis and Innovation Adoption among the Dairy Farms of Punjab, Pakistan)" isimli doktora tezine ilişkin anket ve mülakat çalışmalarının kabulüne oy birliği ile karar verildi.

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2. **Khalid, U. B.**, Shahbaz, P., Haq, S. U., and Javeed, S. (2017). Economic Analysis of Integrated Farming Systems on Farm Income. A case Study of Sahiwal District, Punjab, Pakistan. *International Journal of Management and Economics Invention*
3. Ali, A., Shahzad Mushtaq, M. A., Maqbool, M. Q., and **Khalid, U. B.** the effect of authentic leadership on employee performance: a moderating role of islamic work ethics.
4. Shahbaz, P., Ul Haq, S., **Khalid, U. B.**, and Boz, I. (2021). Gender-based implications of the COVID-19 pandemic on household diet diversity and nutritional security in Pakistan. *British Food Journal*.
5. **Khalid, U. B.**, I. Boz, M. Riaz. (2022). Innovation Adoption and Its Effect on the Profitability of Dairy Farms in Sahiwal District, Punjab, Pakistan. *ISPEC Journal of Agr. Sciences 6(2): 236-246, 2022*.

Award and Scholarship:

- Success Scholarship Program by Turkiye Burslari