Information Communication Technology (ICT) and Livelihood Improvement in Rural Pakistan: A Comparative Study of Small- and Large- Holder Citrus Farming Households in the Sargodha District

Nadeem Akmal

A thesis submitted in fulfilment of the degree of

Doctor of Philosophy in Agricultural Community Development

University of Canberra, Australia

2021

Abstract

Pakistan's agricultural sector is facing many problems such as smallholdings, rising production costs, water shortages, lack of innovative agricultural knowledge, weak marketing systems, and the absence of extensive information communication mechanisms. The performance of public institutes in Pakistan, like many other developing countries, is poor. The existing public agricultural extension and marketing infrastructure has failed to communicate the latest information and knowledge to the whole farming community, discriminating in favour of farmers with large holdings. With recent developments and fast adoption of information communication technology (ICT) such as mobile phones, computers, and the internet, in addition to radio and television, it is believed that ICT have the potential to alleviate production and marketing inefficiencies.

This research project has been designed to examine the role and impact of ICT in bridging quality information and knowledge communication gaps and improving livelihoods without discriminating against farmers with small- or large- holdings. The research takes a pragmatic approach. Data were collected from 200 small and large citrus farmers using purposive random sampling in the Sargodha district of Punjab, Pakistan. Information was gathered on almost all aspects of citrus production and marketing. Information was also collected on livestock management as it is the second key contributor to the agricultural enterprise of citrus farmers. A comparison was made of small- and large holder farmers, with respect to the current modern ICT era including pre-existing communication technologies such as television, radio and fixed-line telephone. Focus group discussions were conducted with other stakeholders of the citrus value chain, such as input dealers, preharvest citrus contractors, commission agents, and exporters. Young people were included in the focus group discussions because it was expected they would be more familiar with ICT.

Research findings reveal that awareness, adoption, and use of ICT among the farming community is considerable. The level of landholder education is a key determinant, as is citrus acreage, in the level of awareness, adoption, and usage of ICT in agriculture. The adoption of modern ICT has contributed significantly to improving the social capital of the farming community, allowing for farmers to connect more with each other as well as with the stakeholders of input-output markets. Farmers who make greater use of ICT have increased access to formal sources of information. ICT use has a positive impact on the productivity of farmers. Overall, ICT contribute considerably to improving the social, human, and financial livelihood capitals of the citrus farmers. Smallholder farmers are not far behind in reaping the benefits of recent ICT developments although there remains concern regarding their lack of awareness, knowledge of the technology, and the expense of ICT usage, as they are less advantaged in the adoption of other agricultural innovations.

The research findings suggest government and other relevant stakeholders should devise specific strategies to make the best use of modern as well as conventional ICT. The farmers' lack of financial capacity and limited education should be key considerations when devising any program for ICT usage which improves information delivery, especially the smallholders.

Conferences and Publications

Akmal, N., Heaney-Mustafa, S., & Fitzgerald, R., (2019). Information Communication Technologies (ICTs) Pave the Way to Make Farmers Information Poor to Information Rich. Presentation at the Australasia-Pacific Extension Network Conference held September 2019 at the Mindil Beach Casino Resort, Darwin, Australia.

Akmal, N., Heaney-Mustafa, S., & Fitzgerald, R., (2019). Information Communication Technologies (ICT) Role in Improving Social and Financial Capitals: A Case Study of Citrus Farmers in Pakistan. Virtual Presentation at the Asia International Multidisciplinary Conference- Connecting Asia, April 2020 at the Johor Bharu, Malaysia.

Achieved Crawford Student Award and visited Nepal in September 2019, to learn practical experiences in relevance to my PhD research.

Based on this thesis I am working to develop research publications which are potentially included in this thesis. There are five potential research aspects as enlisted below which are under process. I am intending to finalise these articles in near future and will be submitting to some credible domain-specific journals for the research community feedback. The potential aspects are:

- An Investigation of The Digital Divide and Limiting Factors in ICT's Adoption and Usage: A Comparison of Smallholder and Large Holder Citrus Farmers
- Information Communication Technologies (ICTs) Pave the Way to Make Farmers Information Poor to Information Rich: A Comparison of Small and Large Citrus Farmers
- Determinants of Information Communication Technology (ICT) Awareness, Adoption and Usage for Agriculture
- The ICT's Contribution in Increasing the Citrus Farmers' Efficiency
- To explore small- and large- holder citrus farmers' perceptions of the value and impact of ICT on their farming practices

Acknowledgments

First, I owe countless thanks to Allah Almighty for his mercy and support throughout my Ph.D. journey. I want to express my most profound gratitude to various people who have helped and supported me throughout this long academic journey. I want to thank ACIAR for honouring me with the John Alright Fellowship (JAF) award to support my study at the University of Canberra, Australia.

I am incredibly grateful to many people who have supported me— their help, guidance, support and assistance have made it possible to write this dissertation. I am immensely thankful to my former primary supervisor, Professor Robert Fitzgerald for providing learned guidance and inspiration. I would also like to thank my primary supervisor and elder sister Dr. Sandra Heaney-Mustafa for her continued technical and moral support, valuable suggestions, and insightful contributions at all stages of this research and living in Canberra, Australia. My acknowledgments are incomplete if I do not mention Professor Caroline Lemerle, who has contributed valuable feedback throughout my PhD. I am grateful to Professor John Spriggs for supporting me to get this prestigious opportunity, and for his guidance throughout the project. I am thankful to brother Dilair for his moral support. I am also grateful to the late Dr. Iftikhar Ahmad (Late), ex-chairman of the Pakistan Agricultural Research Council and Dr. Muhammad Azeem Khan, Chairman of the Pakistan Agricultural Research Council and Dr. Munawar Raza Kazmi for their support and trust in me and for providing me with the opportunity for higher education in Australia.

I am indebted to Dr. Umar Farooq, Dr. Muhammad Sharif, Dr. Tariq Hassan, Mr. Asif Masood Ghumman, Dr. Abdul Jabbar, Dr.M. Azam Niazi, Dr. Ghulam Sadiq Afridi, Dr. Zubair Anwar, Dr. Ihsan ul Haq, Dr. Akhtar Ali, Dr. Muhammad Qasim, Dr. Abid Hussain, Mr. Murad Ali and all my other friends and colleagues at NARC and PARC for providing support and care during my off times. I am greatly indebted to my sister and colleague, Dr. Sajida Taj, friends and colleagues Dr. Hassnain Shah, Mr. Waqar Akhtar and especially Dr. Muhammad Ishaq for continuous technical and moral support during this journey. My special thanks and appreciation go to my friends and colleagues Mr. Qaisar Khan, Mr. Zahid Ullah Khan, Mr. Waqas Farooq, and Mr. Gohar Din for their support in conducting survey and at SSRI office.

I owe an enormous debt of gratitude to my parents and family members, especially my mother (Late), Dr. Sumaira Sharif, brothers Kamran Salamat and Muhammad Ikram for their immense contribution to me achieving this level of education.

My thanks list would not be complete if I did not mention the continuing support, in Australia, from my friends Dr. Yasir Iqbal Paracha, Mr. Masood Khan, Mr. Javed Khan, Mr. Muhammad Farhan, Mr. M. Salman Malik, Dr. Mohammad Abu Alsheikh, Dr. Shahid Hussain, Dr. Duaa Ahmad, Dr. Destina, Dr. Gauri Sharma, Dr. Tariq Alzyadat, Dr. Sigit Jati , Dr. Majid Alsubaie and Mr. Ziqi Gua. Last but not least, it is really impossible to include the names of all the people who have been a support through this long journey, but I would like to thank all the technical and administrative staff of the Faculty of Education, IT and library, as, without their help and support, it would have been difficult to manage all my work.

Nadeem Akmal

Table of Contents

List of Tables

List of Figures

List of Abbreviations and Acronyms

BRC	British Retail Consortium
CNIC	Computerized National Identity Card
CSF	Competitive Support Fund
CTA	The Technical Centre for Agricultural and Rural Cooperation
DOI	Diffusion of Innovation
FAO	Food and Agriculture Organization
FDI	Foreign Direct Investment
FFS	Farmer Field School
FGD	Focus Group Discussion
GAP	Good Agricultural Practices
GOP	Government of Pakistan
HACCP	Hazard Analysis, and Critical Control Point
ICTs	Information Communication Technologies
IFS	International Featured Standards
ISO	International Standard Organization
IT	Information Technology
ITU	International Telecommunication Union
MoITT	Ministry of Information Technology and Telecommunication
PARC	Pakistan Agricultural Research Council
PEMRA	Pakistan Electronic Media Regulatory Authority
PHDEC	Pakistan Horticulture Development & Export Company
PKR	Pakistani Rupee
PTA	Pakistan Telecommunication Authority
R&D	Research and Development
TAM	Technology Acceptance Model
TRA	Theory of Reasoned Action
TRI	Technology Readiness Index
UTAUT	Unified Theory of Acceptance and Use of Technology

Chapter One: Introduction

1.0. Introduction

Generally, Pakistan experiences a lack of information communication mechanisms and this is one of a number of issues in agriculture. This chapter introduces a research study that explores the role and impact of information communication technology (ICT) on livelihood improvement of small- and large- holder citrus farming households in rural Pakistan.

Recent improvements in ICT research and development (R&D) enabled me to focus my research on to explore ICT role in agricultural enterprises. ‘ICT is used as an umbrella term encompassing all information and communication technologies including devices, networks, mobiles, services, and applications; these range from innovative internet-era technologies and sensors to other pre-existing aids such as fixed telephones, televisions, radios and satellites’(Food and Agriculture Organization[FAO] & International Telecommunication Union[ITU], 2016).

Figure 1.1: ICT in Agriculture

This chapter outlines the importance of, and background to, this research. It explains the study settings and gives an overview. I briefly cover current information and communication systems, the overall agricultural economy of Pakistan, and the importance of citrus in the agricultural economy. The chapter also provides a brief overview of the uptake of ICT by the individuals. This background is essential for the reader to fully understand the research context and its significance. It also establishes the research aim and objectives.

1.1. Overview of the Research

Globalization has affected agriculture as well as other sectors of the economy. It has offered many opportunities and options for improving household incomes through challenges, such as competitiveness and motivation for well-timed adoption and diffusion of technologies. Globalization is bridging the technological gap with the assistance of international organizations and the developed world. However, many rural people have not increased their productivity due to inadequate information access (Malhan & Rao, 2007). Farmers require information ranging from cultivation practices, farm inputs, pest and disease management, prices, and weather forecast (de Silva & Ratnadiwakara 2008; Mittal et al., 2010). Information and communication can make a significant contribution to agriculture. The lack of information is the largest hurdle in farmers adopting new technology and improving their productivity (Siraj, 2011). Key information regarding crop production and price empower farmers' decision-making abilities for better livelihoods (Armstrong & Gandhi, 2012).

In developing countries, agriculture is characterized by small landholdings with inadequate access to production and market information of agricultural enterprises. Farmers are unable to get potential production and marketing options due to information constraints and higher transaction costs (Nakasone & Torero et al., 2014). The growing population and the commercialization aspect of agriculture have increased agriculture value chain stakeholders' demand for information. The unavailability of timely information is hindering agricultural value chains from realising potential outcomes.

The agriculture sector in Pakistan faces many structural problems, such as small land holdings, increasing production costs, and water shortages. The farmers lack of innovative ideas; they have marketing problems; and there is a lack of information communication mechanisms.

Agricultural productivity in Pakistan is far below that in comparable countries. In addition, productivity varies between small- and large- holder farmers (Raza et al., 2017). To date, the country has been unable to tap its real production potential, despite agriculture being a significant contributor to Pakistan's economy (Noor et al., 2018). The low adoption and use of innovative information technologies by the farming community is one of the reasons the potential gains from agriculture have not been realised. The absence of information relating to innovative technologies is the reason for poor adoption among the farmers (Ahmad et al., 2016). Agricultural extension covers an array of communication and learning activities organized for rural people by professionals from diverse specialties, including agriculture and business studies (Khan et al., 2006). Extension is a catalytic agent in agricultural development (Luqman et al., 2005). The agricultural extension department has prime responsibility for disseminating updated knowledge to farmers; however, they tend to concentrate on progressive farmers (Raza et al., 2017). Farmers lack the latest information within the existing agricultural system. The situation is worse for smallholder farming communities due to the bias towards the influential and large holder farmers. The majority of farmers, 90% of whom are smallholders (less than 4 hectares), remain unable to get the latest technical knowledge.

Extension and marketing activities have been in progress in Pakistan since the 1950s. However, the current approach still uses traditional extension methodology. This approach is ineffective because of the low numbers agricultural extension officers. According to the agricultural census of 2010, there is one agricultural extension officer for every 3500 private farmers. This gap widens when all persons involved in agricultural enterprises are included, and when changing land distributions result in an increase in the number of smallholding farms and farmers. Lack of commitment and biases do exist, but beyond these, the agricultural extension department struggles to satisfy the given mandate. The agricultural extension system is unable to address the innovative information needs of the farmers due to financial constraints, lack of coordination among relevant departments, poor professional capacity, and infrequent use of ICT (Yaseen et al., 2015). Poor coordination among line departments, poor logistic support for mobility, shortage of extension staff training regarding the latest knowledge, and an inadequate career structure for staff, further contribute to the system's low performance (Ashraf et al., 2009). Despite this, agricultural extension contributes in numerous ways to food security and poverty alleviation (Farooq et al., 2010). A well-organized agricultural information and extension system is essential to increase the agricultural productivity of a country (Burton et al., 2012). Also, agricultural extension can play a role in the sustainable use of natural resources (Ikram-ul-Haq et al., 2009).

The traditional extension system helped to achieve the green revolution, which significantly enhanced agricultural productivity. Still, there is clearly a demand for a new revolution in 'smart agriculture' that reduces prices for the end-user and encourages farmers to intensify their production through more efficient value/supply chain management. For a long time, public and private sectors have looked, with little success, for appropriate solutions to tackle both short and long-term challenges in agriculture, including how to address the information needs of farmers.

ICT is one of these solutions that has the capacity to expand agriculture, particularly in developing economies (George et al., 2011). ICT bridges the supply-demand information gap to some extent, and has the potential to improve market access with quality production, market information, transactional cost reductions, market research, market identification, and networking (Kiveu & Ofafa 2013). The adoption of ICT is increasing rapidly for farm and household purposes. The rapid growth of ICT, especially in developing economies, has caused scholars to become interested in assessing how ICT might affect the livelihood of agricultural households and how one might improve its effectiveness (Nakasone et al., 2014).

ICT positively impacts income growth in developed and developing economies (Röller & Waverman, 2001; Waverman et al., 2005). In rural areas, ICT can increase incomes by expanding agricultural output and initiating income networks, other than conventional farm jobs (Lio & Liu 2006). Abbas et al. (2008) claim that the shortage of information adapted to local requirements, and paucity of technical knowledge at the farm level, are the principal factors responsible for this low yield. Information is believed to be one of the essential resources in agricultural and rural development that helps farmers to make decisions and to take suitable actions with regard to farm expansion (Harris et al., 2001; Morrow et al., 2002; Stefano et al., 2005).

New approaches and methodologies like Farmer Field Schools (FFS) and recent developments in ICT have helped to expand the reach of the agricultural extension. Still, there remains a need to explore cost-effective means to supplement modern agricultural extension methods. ICT are considered to be the most innovative, as well as the most cost- and time- effective modern agricultural extension technique that can expand the reach of agricultural extension to low-income rural households (Wijekoon & Rizwan,2011).

The current scenario emphasizes the importance of ICT in resolving the scarcity of timely information available for the whole farming community. The recent development of ICT in Pakistan, particularly mobile phones and low-cost internet services, has pushed the traditional agricultural information systems towards using these advancements. According to the Pakistan

Telecommunication Authority (PTA), the teledensity in Pakistan is 77 percent, with 35 percent 3G/4G and 36 percent of citizens subscribing to broadband. The teledensity is also very encouraging in rural Pakistan. At present, all the government departments ranging from federal ministries to provincial agriculture departments, agricultural research, and education organizations and institutions are attempting to make all their information accessible through the use of ICT. However, to get the full benefit from different departments/institutions, ICT-related efforts are still needed to focus the existing resource base, including the finances and education level, etc., of the farmers, especially the smallholders.

Farming communities in developing countries like Pakistan face several structural and behavioural problems. To improve their well-being, farmers need to develop a commercial orientation rather than an attitude of subsistence farming. Traditional extension and market information systems cannot meet their requirements. Now is the time for the extension system to take a market-oriented direction and for it to consider the opinions of all stakeholders (Davis et al., 2010; Swanson & Rajalaht, 2010).

A comprehensive study analyzing the current situation is required. The current study intends to assess the recent adoption and impact of ICT-based agricultural information across the citrus value chain. This research study takes place in the Sargodha district, the largest citrus-producing area of Punjab, Pakistan. The majority of people have small landholdings and mainly earn their livelihood from citrus, livestock, and wheat production. Farmers in the study area face the same general structural problems common to the country's agricultural sector.

The following sections explain the background and significance of smallholder farmers and the citrus value chain. The importance of the research study is explained, as are the research aim, specific objectives, and research methods. The chapter ends with an overview of the thesis structure.

1.2. Statement of the Problem

ICT can bridge the gaps in quality knowledge and communication. It can enable livelihood improvement, potentially without discriminating between small- and large- holder citrus farmers, and is the key focus of this research.

Smallholder farmers require easy access to quality information to improve their livelihoods. Until now, they mainly depended on previous experience and word of mouth. Lack of timely and quality information affects farm productivity, management practices, and decision-making. The traditional extension has favoured large holder farmers who also have better education and access to computers and capital. Thus, perhaps they are better able to make use of ICT. Conversely, smallholder farmers have poor literacy, limited access to computers, and less capital.

Developing countries with existing ICT infrastructure and utilisation have reaped the rewards (Ajani, 2014; Jain et al., 2015). ICT adoption is prized in rural areas. In Pakistan, small-scale farmers now have access to mobile phones and internet, but are starting from a much lower base, and so small improvements in information and knowledge can make a big difference. This study aims to explore the differences in ICT awareness, adoption, and use by small- and large- holder farmers. The study looks at what, if anything, can be done to assist the implementation of ICT in enhancing the livelihoods of small-scale farm households.

1.3. Significance of the Study

Agriculture is one of the key contributors to Pakistan's economy and to the livelihoods for a major proportion of the rural population, much of which comprises smallholder farming communities.

Analysis and exploration of ICT development and its adoption among the rural masses will reveal the possible approaches that could be used to alleviate the inefficiencies in information acquisition and dissemination. This study gives insights into ICT awareness, its level of adoption, its use in agriculture, the perceived benefits, and constraints hindering its effectiveness.

Previous research on the topic has generally focussed on the use of radio, television, mobile phone, mobile phone-based advisory services, and the difficulties encountered with their use. This research study will provide insights into the effectiveness of all ICT available in Pakistan's farming community, including mobile phones, smartphones, internet, and as well as, radio, television and fixed-line phone.

The study improves our theoretical understanding of the problem and provides empirical findings relating to the role and impact of ICT generally in agriculture and, more specifically, in citrus farming. It is hoped that the knowledge gained through this research will enable emerging ICT to be used for transferring research findings, farm advisory services, and input-output price information for agricultural development with smallholder farmers specifically.

The research study findings collected from the district of Sargodha; Punjab Pakistan are likely to be generalizable to the whole country's farming community. Smallholder farmers tend to have the similar socioeconomic conditions all over the country, and generally face the similar challenges in acquiring updated information. Virtually all the relevant departments, including the Pakistan Agricultural Research Council (PARC), provincial research and extension departments are striving hard to develop communication strategies that will inform the farming community on agricultural advances. Cellular phone companies have initiated services to disseminate agricultural production and marketing-related information to their subscribers. The research results will help the departments and cellular companies devise specific communication plans to effectively fill the information gap. Furthermore, the research results will provide useful information to policymakers, responsible for agricultural development, in alliance with the Ministry of Information Technology and Telecommunication (MoITT) to develop strategies to improve the farming community's effective information communication system.

This investigation of the current use and effectiveness of ICT, based on empirical evidence, provides the opportunity for future national agricultural growth. Primarily, it offers the basis for relevant public departments and private companies to devise innovative information acquisition and dissemination strategies for resource-poor smallholder farmers.

1.4. Research Aim and Objectives

Bearing in mind that smallholder farm households have different opportunities and incentives, compared to large holder farmers, in their use of ICT, the overall goal is to undertake a comparative study of small- and large- holder farmers, focusing on their awareness, adoption, and patterns of ICT use. The research will specifically focus on a sample of citrus farmers in the Sargodha district of Punjab, Pakistan.

Research Aim

The specific research aims to assess the potential of ICT to enhance the livelihood of smallholder farming families in Pakistan.

Research Objectives

The study is planned with the following specific objectives:

1. To investigate factors optimising and limiting the awareness, adoption, and patterns of ICT use in farm businesses, by small- and large- holder citrus farmers in the Punjab, Pakistan;
2. To examine the contribution of ICT use in agriculture for small- and large- holder citrus farmers in Punjab, Pakistan; and
3. To explore small- and large- holder citrus farmers' perceptions of the value and impact of ICT on their farming practices.

1.5. Theoretical Context

The theoretical and conceptual frameworks lay the foundation for eloquent and credible research. This study theorizes that livelihood assets (human capital, social capital, financial capital, physical capital, and natural capital) have a role in adopting and using ICT in agriculture. The adoption and usage of ICT for agricultural enterprises can enhance the livelihood of citrus farming households. In the prior research on the adoption of novel agricultural information/technologies among the farming community, large holder farmers are favoured with higher adoption rates and utilisation for agricultural purposes in comparison to smallholder farmers. This study proposes that, in under the present agricultural extension and marketing systems in Pakistan, smallholder farmers compared to large farmers can equally adopt ICT and use in getting innovative knowledge for improving better production and marketing of their farm produce.

The Diffusion of Innovation (DOI) theory and Technology Adoption Model (TAM) among various theories in relevance to adoption, diffusion, and usefulness of technologies are used to analyse the above-mentioned conceptual arguments compared to smallholders and large holder farming households under theoretical perspective. DOI describes the attitude and belief of innovation effects to perceive innovation characteristics. The perception of innovation characteristics is described by comparing the smallholder and large holder farming communities. The perceived innovation characteristics or vital elements of the DOI theory, including the relative advantage, compatibility, trialability, and knowing the technology's complexity, act together with the farmers' personal characteristics, demographics, product experience, intent to use technology, resulting in the adoption and usage of ICT for agricultural purposes are well described. The social influence and social relation as one key aspect of DOI theory, with locality demographics and personal characteristics, is also explained in ICT adoption and usage context. TAM's key attributes are perceived usefulness and perceived ease of use of technologies. TAM mainly depends on the quantitative method, Likert Scale type items to build the model. Researchers use TAM in qualitative methods within a specific context, but it is mainly based on quantitative approaches used in the description of research results. The DOI and TAM encompass all relevant components, and their use in agricultural innovations and information technology are explained in this research study.

The conjunction of Diffusion of Innovation (DOI) and the Technology Adoption Model (TAM) provide the theoretical context of this dissertation.

1.6. Research Strategy

Mixed methods research design was used to conduct this study, with quantitative and qualitative data being collected from farmers and other citrus value chain stakeholders in the Sargodha. In mixed-method research, both the quantitative and qualitative aspects are linked for a better in-depth understanding and substantiation of research (Johnson et al., 2007). The main objective of the mixed methods research is to improve the research study's inferences linking the quantitative and qualitative elements (Schoonenboom & Johnson, 2017). Two hundred farmers consisting of 142 smallholders and 58 large holder farmers were surveyed from 32 villages in the district of Sargodha. All the villages have similar socioeconomic characteristics, with most of the villagers relying on agriculture for their livelihood, specifically citrus (mandarin) production. Focus group discussions (FGDs) were conducted to collect data from input dealers, preharvest citrus contractors, commission agents from the fruit market, citrus exporters, and youth from the farming community. Suitable analytical techniques were applied to address each research question appropriately. A detailed methodology with a comprehensive description of the different steps is presented in the research methodology chapter.

1.7. Thesis Outline

This research study is arranged in six chapters. References are listed at the end. A summary of every chapter is described here:

Chapter 1 provides an overview of the research with a brief description of agriculture in Pakistan, and the importance of innovative information, agricultural extension system performance, and recent developments in ICT, followed by the problem statement. This chapter also sets out the aim and objectives of the research and its significance in agricultural development by briefly considering the methodology and the thesis outline.

A detailed description of the importance of agriculture to the Pakistan economy, the contribution that citrus (mandarin) makes to the agriculture sector, and the status of ICT in Pakistan, are outlined in Chapter 2. It also reviews the literature on the role of ICT in agriculture, mainly in the context of developing countries.

The theoretical and conceptual framework is also outlined in Chapter three.

Chapter 4 elaborates on the methodology and methods used in this study. This chapter provides information about the research design, research site, sample size, and sampling technique. It considers the survey instruments, data collection processes, analytical techniques and provides a detailed description of the hypothesis and ethical considerations.

The research findings, both from quantitative and qualitative data, are presented in Chapter 5. The results drawn from the quantitative data present the small- and large- holder farmers' viewpoint on the role and impact of ICT. It describes the awareness, adoption, and use of ICT among the small- and large- holder farmers, as well as its perceived benefits and constraints. The qualitative data not only gives the farmers’ perspective, but also expresses the views of other citrus value chain stakeholders regarding the contribution that ICT makes to their businesses.

Chapter 6 provides a thorough examination of the key findings. It describes the outcomes and consistency with previous research. It also provides key findings regarding the adoption and impact of ICT on the livelihood of the farming community, focusing on smallholders. This chapter provides robust information to conclude the research outcome.

Conclusions of the research study and ways to improve the effectiveness of ICT are described in Chapter 7. Inferences are drawn as to how the livelihoods of those in the farming community, particularly the smallholder farmers of Pakistan, could be improved.

1.8. Chapter Summary

This chapter commences with the concept of information communication technology (ICT) and how it is used in agriculture. I present an overview of the study that explains the importance of innovative information needs and the existing extension and marketing systems; systems that are currently unable to address smallholder farmers' needs. It highlights the importance of agriculture generally, and citrus specifically, to the economy of Pakistan. The productivity and contribution that agriculture makes to the country's GDP is far below its potential. The recent rapid adoption and diffusion of modern ICT gadgets throughout Pakistan provides a promising opportunity to fill the information gaps. It emphasizes that transformation may bring significant improvements to the livelihood of rural people, especially the smallholder citrus farmers. In brief, it highlights the importance of this research from the smallholder farmers' perspective and describes the importance of the citrus enterprise. One section of this chapter explains the significance of this research study. The research aim, objectives, and brief explanation of research methods are also set out in this chapter. Lastly, the chapter completes the outline of the thesis structure.

Chapter 2: Research Background and Review of Literature

This chapter consists of two major sections. The first section describes the context and importance of agriculture in Pakistan. It includes a brief overview of the farmers' categorization based on their landholdings and the constraints of the agriculture sector. It goes on to elaborate on the importance of citrus in Pakistan's agriculture. The vital position of citrus, foreign reserve contribution in the national economy, and low productivity of citrus are described. The third section gives an overview of the status of ICT in Pakistan, providing a brief description of the development of ICT over time in Pakistan. The second section of this chapter reviews the literature on the evolution of ICT, its adoption by the farmers, contribution in agricultural enterprises, and constraints facing by the farmers in adoption and usage of ICT for farm businesses.

The research background is vital for insight into the primary focus of this research and is described under four headings: the significance of agriculture in the country's economy, the position of citrus in agriculture, importance of livestock in the study area and the prominence of information communication technology (ICT) in Pakistan.

2.1.1. Agriculture of Pakistan

Agriculture is a leading player in the economy of Pakistan, contributing 19.3 % to GDP and providing a livelihood for 38.5 percent of the rural population. The sector promotes trade and has sufficient growth to safeguard food security for the mounting populace (Government of Pakistan, 2019-20). However, the performance of the agriculture sector does not match the available resource base. There is a gap between existing production and potential productivity which is due to factors like the slow pace of technological innovation, the partial adoption of improved techniques, untimely availability of quality inputs, marketing problems, trade constraints, disease, and pest problems and lack of financing specific to agriculture (Government of Pakistan, 2016). Inefficient use of resources, loss of biodiversity, climate change, global warming, water availability, malnutrition, and poverty are the critical problems of today's agriculture. Sustainable and equitable development requires revisiting the role of knowledge, science, and technology in the agricultural context (Farooq, 2016).

Farmers with larger holdings and consumers have benefitted more from productivity gains than have smallholder farmers. Pakistan's agriculture in general and in Punjab province, in particular, is dominated by smallholders. According to the Census of Agriculture 2010, there are 8.26 million private agricultural farms with an average size of 2.6 hectares (ha). These are distributed as follows (Census of Agriculture, 2010; Rashid & Sheikh, 2015):

- Marginal farms (under 2 ha) make up 64 % of 8.26 million, and over 19% of total farmland.
- Small-sized farms (2-5 ha) make up 25 % of 8.26 million, and up to 29% of total farmland.
- Medium-sized farms (5-10 ha) make up 7 % of 8.26 million, and up to 18% of total farmland.
- Large-sized farms (greater than 10 ha) make up 4 % of 8.26 million, and up to 34% of total farmland.

The Census of Agriculture (2010) also states that smallholding farms effectively use up to 93 percent of their land to produce crops, that medium-sized farms use up to 91 percent, whereas large farms use only 60 percent. This implies that smallholding farms are more efficient in their land use. Therefore, technological dissemination to the smallholder farmers may have more impact on increasing crop production efficiency as they lack in comparison to large holder farmers.

Historically, there have been issues related to land distribution and usage in rural areas. The R&D personnel perceived that more land needed to be distributed to those who didn't have any. The Government of Pakistan made land reforms in 1959, 1972, and 1979 to resolve the land development and usage issues (Rashid & Sheikh, 2015). However, these state interventions were not as effective as anticipated due to landlords' resistance. By the end of the 1970s, less than 10 percent of the total land had been distributed. Landlords resisted the implementation of land reforms through political influence and under the protection of religious laws of inheritance with male consideration. Although Islamic law provides the right of inheritance to women, local customs prevent them from inheriting property (Brohi, 2010). Land productivity and the livelihood of low-income families could be improved by giving more land ownerships through land reforms, by truly observing Islamic laws of inheritance, and by improving landowners' access to the latest innovative technologies. Without these changes, according to PANOS (2011), attempts to distribute land will remain unsuccessful as land fragmentation hurts agricultural productivity.

Smallholder farming households earn their livelihoods by cultivating smallholdings and supplementing their incomes with fish farming, poultry, and dairy (Government of Pakistan, 2012). On the one hand, smallholders have some specific problems, including low access to information, technology, and finance; high transaction costs due to small surpluses; low risk-bearing capacity; and low capacity to implement food safety measures (Joshi et al., 2007). In comparison to the last four agricultural censuses, the average farm size has decreased from 5.28 ha to 2.59 ha while farm households have doubled in size. It is anticipated that as the population increases, the average farm size will further decrease to 1.90 ha by 2050 (Farooq, 2015a). On the other hand, the smallholder has the advantage of abundant family labour, a necessity since most of the high-value commodities are labour-intensive. One of the crucial questions pertaining to the agriculture economy of Pakistan is how to support smallholder farmers so that they can participate consistently in the modern markets (Sharif, 2011).

Presently climate change, globalization, higher costs of production, traditional marketing systems, unavailability of timely quality information regarding best production practices, are the reasons behind farmers' low returns. In order to meet the challenges of low returns, determined efforts are needed to expand farm-level practices to achieve higher yields and market linkages of farmers. The lack of private sector interest in utilizing the capability of rural areas and failure to finance the development of the rural sector is one of the main reasons of rural areas under development (Sattar, 2007). While Pakistan has an underdeveloped agricultural setting, it is still the 27th largest economy in the world; therefore, it is worthwhile pursuing agriculture (Faridi, 2012).

To ensure the sustainable growth of agro-industry, the government's prime focus is on horticulture, livestock, and fisheries. Horticulture has enormous potential for increasing on-farm employment, with on-farm jobs in harvesting, processing, packaging, and marketing (World Bank, 2008). At present, the main emphasis of the government is on promoting high-value agriculture, i.e., the production of horticultural crops and animal-based products, through agricultural diversification. High-value agriculture has remarkable potential in Pakistan as it offers more livelihood prospects in its value chains than conventional major crops. This is not only due to its high value but also due to its market integration, product development and diversification, employment generation, rural industrialization, and implications for alleviating poverty. Concerted efforts have been poured into developing practices at the farm-level and to improving the linkages of farmers with market; into developing an industry-based upon the latest ideas; into providing technological tools; and developing upcoming pathways for the growth of sustainable agro-industry (Government of Pakistan, 2015).

To conclude, the prime responsibility of Pakistan agriculture is to deliver healthy and abundant food to the growing population, fodder for livestock, and to generate modest export surpluses. Increased urbanization, changing consumption patterns, rising per capita income, and globalization have further increased the scope of agriculture. The growing demand for agricultural products, particularly high-quality farm products, also provides opportunities for producers to sustain and improve the livelihoods of rural communities. On the other hand, farming has become more scientific and requires the knowledge-based application of agricultural inputs, better handling of harvested output, improved marketing channels, and value chain options. The farmers' dependence on purchased inputs, farm machinery services for crop and livestock production, has also considerably increased. Therefore, the intensive use of knowledge, science, technology, and ICT are realities for the future farming in Pakistan.

2.1.2. Citrus (Mandarin) in Pakistan

Horticulture is an area of great challenge and opportunity in the agricultural economy of Pakistan. Citrus fruit has secured an important place in Pakistan. Citrus is among the top fruits that contribute significantly to the country's exchequer. Citrus, as an esteemed fruit of the land, claims the highest rank among all the fruits in terms of area and production (Bashir et al., 2006; Ghafoor et al., 2008). Pakistan is the 12th leading citrus producer and the leading producer of mandarins globally, but the average yield is far behind that of other citrus-producing countries (FAO, 2019).

Citrus (mandarin) variety was developed at Citrus Research Institute, California, in 1915 with crossbreeding of leaf and king citrus varieties (Ali, 2004). With gradual improvement, the citrus growing area is 193 thousand hectares, with a total production of 2396 thousand tons (Government of Pakistan, 2014-15). Punjab is the leading producer of the kinnow, one of the best varieties of fresh mandarins, with an area of 183 thousand hectares (95% of the total area of the country and with a total production of 2328 thousand tons (97% of the country production) during 2014-15. In the Punjab province, Sargodha is the largest citrus growing district, followed by Mandi Bahauddin and Toba Tek Singh. Sargodha produces 1012 thousand tons (49% of Punjab production during 2013-14).

There is growing demand both in national and international markets. In the past, most of the citrus production was used domestically in an unprocessed form without any significant value adding (Iqbal et al., 2009). However, over time, Pakistan has established the citrus processing industry which makes a substantial contribution to generating employment (Government of Pakistan, 2013). There are more than three hundred citrus processing factories working seasonally, with a production capacity of more than five tons per hour based on regular farm supply. Pakistan Horticulture Development & Export Company (PHDEC) has more than one hundred and eighty registered processing factories. PHDEC also contributes capacity building and transfer of advance improved technology, focusing on productivity and quality aspects of the citrus supply chain. This industry only enhances the physical appearance of the mandarins by cleaning, washing, and waxing. Two factories transform the low-quality mandarins to juice. Pakistan's citrus processing industry aims to achieve protocols and guidelines for food safety regulations, as well as meeting Sanitary Phytosanitary schedules. At present, about forty-two units of citrus processing are qualified and listed in Hazard Analysis and Critical Control Point (HACCP), International Standard Organization (ISO) 2000;2005, British Retail Consortium (BRC), International Featured Standards (IFS) and a production area of about 8093.7 hectares is certified in Global Good Agricultural Practices (GAP).

Pakistan exports mandarins to many countries. In 2008-09, it was the fifth-largest citrus exporter, and more than 90 percent of citrus exports were mandarins. During 2012-13, mandarin exports from Pakistan were 342,391 tons worth Rs.15 billion (US$150 million). Major international markets for Pakistani mandarin during 2012-13 were Afghanistan, EU (Germany, UK, Belgium, Italy and the Netherlands), Indonesia, Iraq, Russian Federation, Saudi Arabia, UAE, and Ukraine. There exists a massive gap between the current and potential mandarin yield that may be due to the number of problems confronted by the country's citrus farmers. Ghafoor et al. (2008) conclude that the most crucial input related issues are the high inputs price, the absence of finance, and lack of water for irrigation. Citrus production and marketing problems are currently not getting attention in the electronic media. Niazi (1993) reported difficulties such as a lack of technical knowledge, the unavailability and uncooperative behaviour of agricultural extension field staff towards farmers. Khan et al. (2012) argue that training of the extension workers could be of economic benefit to mandarin growers in the Sargodha, whereas, improvement in orchard production and post-harvest management practices would enhance the country’s economic growth.

Citrus producers get a low price for their produce due to inadequate marketing systems. The fruit is sold mainly through a pre-harvest contract system to a middleman. Sharif et al. (2005) revealed that 95 percent of citrus growers sell their orchards when at the stage of flowering to the pre-harvest contractors, due to risk aversion behaviour and fear of exploitation by market intermediaries. The pre-harvest contract system results in low returns of farmers. This study's results indicate that farmers, the primary stakeholders of the citrus value chain, only get 35 Pakistani Rupee (PKR) out of 100 PKR paid by the consumer. The remaining amount is distributed among market intermediaries. This result shows that market intermediaries are exploiting citrus producers. The marketing intermediaries are well informed of market behaviour. The farmers who bear high production costs and risks, would be in a better position to gain control over their marketing activities if they had stronger business relations, more timely availability of information, and shared more with peers (Sharif et al., 2005).

Figure 2.1 represents the number of marketing channels, that is the way the commodity gets from producer to consumers who exist in citrus marketing. The various marketing channels carry citrus produce from producer to domestic and international consumers. The two main marketing channels entail the transfer of citrus product from producer or through preharvest contractors to commission agent (domestic wholesale markets) and the transfer through pre-harvest citrus contractors to processing factories. The link between producers and citrus processing factories/exporters is gradually improving. The range and complexity of the number of marketing channels results in farmers' exploitation to get less price of their product. The information attainment at the producer level is of utmost importance from all other stakeholders being the main actor of citrus value chain. They comprise individuals, as well as firms, involved in processing the fruit or value-adding to fruit products. Apart from production, there are some critical aspects that need the careful consideration of farmers, such as risk in transport, price fluctuation, labour-management, etc. As mentioned previously, most farmers contract out their orchards before harvesting, and receive a lower price for their produce. Farmers generally do not get involved in self-marketing due to outdated market information, multiple marketing channels, and reasons of risk aversion. Timely information with ICT use can bring about significant improvements in production practices and can change farmers' exiting pre-harvest contract marketing practice. Farmers could expect to attain higher returns if they got involved in self-marketing (Sharif, 2004).

To sum up, citrus holds a vital position among the horticultural crops grown in Pakistan. Its contribution to foreign reserve building is recognized. However, the existing marketing arrangements result in low productivity and fewer gains for farmers. ICT can contribute to increasing farmers' gains by helping to provide the latest production and marketing information.

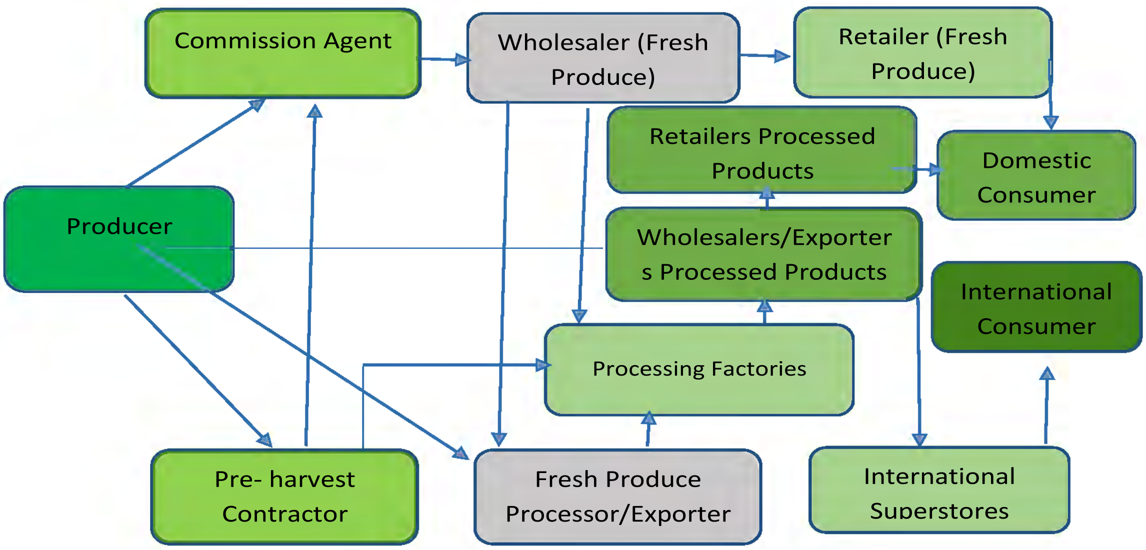


Figure 2.1: Marketing Channels
Source: Adapted from Sharif (2004)

2.1.3. Importance of Livestock in Study Area

Livestock is a dominant subsector of Pakistan's agriculture. Livestock contributes a 60.56 percent share in the overall agriculture sector and 11.69 percent in the country's GDP (GOP, 2020). About 8 million rural families derived their livelihood from this sector. Within the livestock sector, milk is the largest single commodity, and over time growth of the livestock sector was mainly attributed to milk production. Pakistan is the 4th largest milk-producing country in the world (Government of Pakistan, 2020). Among the country's provinces, Punjab province dominates Pakistan's livestock sector. Punjab province has 49% of Pakistan's cattle, 65% buffaloes, 24% sheep, and 37% goats. In the value of the product, it is producing 62% of milk, 43% of beef, 32% of mutton, and 75 % of the poultry of Pakistan (Livestock Census, 2006). The current livestock data based on the projections developed from the report (livestock Census, 2006) recognizes the livestock contribution in the rural economy across the provinces.

The Livestock-production system is mostly mixed crop-livestock farming. Cattle and buffaloes production systems include subsistence small-holdings, market-oriented small-holdings, rural commercial farms, and peri-urban dairy farms (Afzal & Naqvi, 2004). In the mixed cropping system of Punjab, the majority of farm households had both livestock and crop farming systems. Livestock remained the second major source of income, especially where there is a mixed cropping system (Asghar, 2014). A mixed cropping system is followed in district Sargodha, whereas this region is also famous for its variety of crops and livestock (Hayat et al., 2017).

Within the citrus growing areas of Sargodha, livestock is the second key agricultural enterprise of citrus farming households, especially the smallholders. The smallholder farmers intercrop fodder in the citrus orchard to feed the livestock, compromising the citrus productivity because the milk production provides a regular cash income besides fulfilling household milk consumption requirements. They consider citrus livestock interaction as the optimal strategy to enhance whole farm income. In the Sargodha district, most farmers adopt crop and livestock farming as a livelihood strategy, and more than half of farmers adopt livestock farming on a semi-commercial basis. The realization of livestock importance and modern line management could improve the livelihood and enhance farmers' food security situation (Hayat et al., 2017).

Given the livestock importance and its role in the livelihood earning of citrus farming households, especially the smallholders, the usage and contribution of ICT for livestock enterprise is also explored in this research study.

2.1.4. Status of Information Communication Technology in Pakistan

Telecommunication is the exchange of information over substantial distances. In today's world, mobile phones, computers, and emails are valuable means of communication. The telecommunication sector makes a significant contribution to the economic growth of a country. Therefore, its development is considered to be a sign of a country's economic, social, and cultural development (Khan, n.d.).

The information communication journey, through electronic media, began in Pakistan on the day of its inception with radio announcements and newspaper articles. In 1964, television became part of the country's information communication system. The developed world had already been enjoying the benefits of modern ICT inventions for many years. Up until 1985 in

Pakistan, radio, television, fixed-line phones, and newspapers were the primary sources of information and communication. Then the modern ICT era surfaced in the country as a result of formal government policy promoting information technology (IT) imports for business-related purposes (Gupta, 2006). This policy gave people easy access to IT hardware and resulted in enormous foreign direct investment (FDI) in the country by reducing import duties (Arif, 2018).

The Pakistani government established the Pakistan Software Export Board (PSEB), recognizing that the future of the country’s development was linked to progression in the IT sector. Among the many functions of PSEB, its main emphasis is to research the ICT sector's status and to devise strategies for IT sector growth in software development and service provision (Pakistan Software Export Board[PSEB], 2020). In 1996, the Pakistan Telecommunication Authority (PTA) was formed to reorganize the pre-existing telecom industry regulatory framework. The PTA's primary function is to ‘regulate the establishment, operation and maintenance of telecommunication systems, and the provision of telecom services.’

Before deregulation of the telecom sector in 2003, government expenditure on the IT sector did not match the IT sector’s potential, nor was it comparable to other similar countries, such as India and Bangladesh. From 2003 onward, enormous investment in the IT sector resulted in increasing economic gains (Gupta, 2006). Deregulation of the telecom sector laid the foundation for the fast growth of teledensity, especially of the mobile phone (Hanif, 2018). The Ministry of Education for the Government of Pakistan has developed a National Information and Communication Technology Strategy. Under this strategy, the National ICT R&D Fund was created in 2007. There have been efforts made under previous government regimes to boost the IT/ICT industry, but in Pakistan, the telecommunication sector was not given due importance, despite having a long history. Pakistan is ranked 146 out of 175 countries based on the global ICT development index (ITU, 2016). According to the World Bank, in Pakistan, during 2010, the subscription of mobile cellular numbers was 57.13 per 100 people. The number of internet users per 100 people during the same year was 16.78 (Burton et al., 2012).

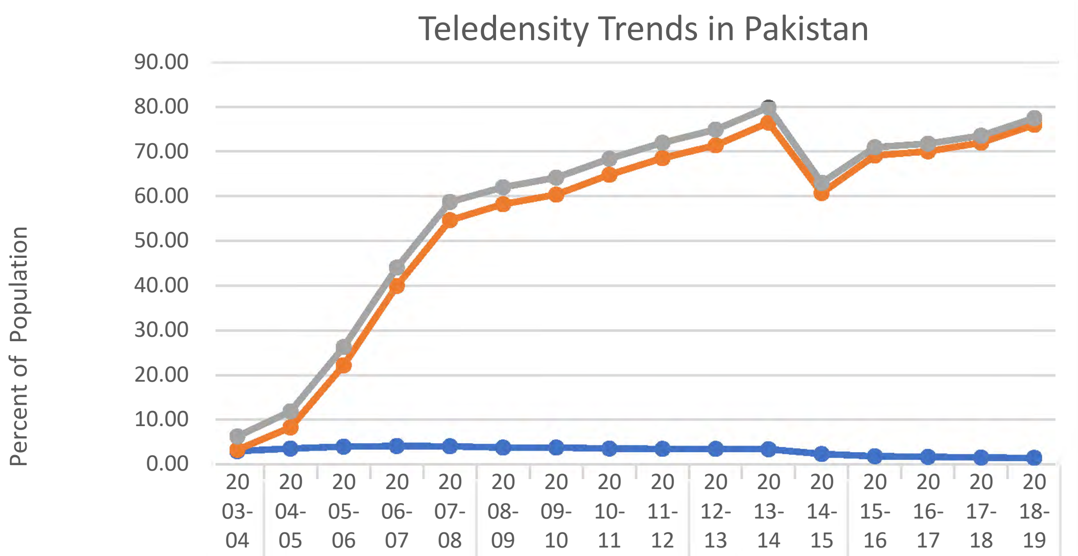
Table 2.1 and Figure 2.2 present the data and give a graphic illustration of the adoption of ICT in roughly the last twenty years. In the past ten years, this sector remained unchained from policy and regulatory constraints, making telecom one of the country's fastest-growing sectors (Farooq, 2016). The adoption of ICT is most promising compared to some years back, with mobile phone subscribers now above 133 million. It has become the 7th largest network among developing nations. The mobile phone industry is a pivotal contributor to this rapid growth. Over time, teledensity has dramatically improved. In 1999-2000 there were 0.3 million subscribers, and then by 2013-14, 140 million subscribers, but with subscriber's identity module (SIM) verification through the computerized national identity card (CNIC), this figure dropped to 116 million in 2014-15. The teledensity regained rise and reached more than 77 percent in 2018-19.

Mobile phones are the mainstay of Pakistan's telecom sector due to its subscribers, coverage, economic importance, and services. In 2004, deregulation and the introduction of new players gave a substantial boost to this sector. Table 2.1 presents the recent advancements, availability of high-speed internet access through 3rd Generation (3G) and the 4th Generation (4G) which has significantly boosted the number of broadband users from 16.8 million in the year 2014-15 to 32 million in 2015-16. These developments have introduced new kinds of telecommunication services. For example, the use of Short Message Service (SMS) has dropped compared to the average outgoing minutes per month per subscriber, as a result of the use of social media applications through the internet on smartphones, iPads, and laptops (Farooq, 2016).

Table 2. 1: Phone Subscribing in Pakistan **(Million Subscribers)**

Years	PCOs	FLL	Cellular	WLL	3G/4G	Broad-Band
1995-96	---	---	0.07	---		0
1996-97	---	---	0.14	---		0
1997-98	---	---	0.20	---		0
1998-99	---	---	0.27	---		0
1999-00	---	---	0.31	---		0
2000-01	---	---	0.74	---		0
2001-02	---	---	1.70	---		0
2002-03	---	---	2.40	---		0
2003-04	0.19	4.50	5.02	---		0
2004-05	0.28	5.28	12.77	0.27		0.00
2005-06	0.36	5.24	34.51	1.01		0.03
2006-07	0.39	4.81	63.16	1.80		0.05
2007-08	0.45	4.42	88.02	2.21		0.17
2008-09	0.41	3.53	94.34	2.58		0.41
2009-10	0.34	3.42	99.19	2.59		0.90
2010-11	0.31	3.02	108.90	2.73		1.49
2011-12	0.29	2.99	120.15	2.95		2.10
2012-13	0.29	3.02	127.74	3.11		2.72
2013-14	0.15	3.17	139.98	2.06	1.38	3.80
2014-15	---	3.14	114.66	0.79	13.50	16.89
2015-16	---	2.95	133.24	0.56	29.53	32.30
2016-17	---	2.66	139.76	0.33	42.08	44.59
2017-18	---	2.65	150.24	0.30	56.09	58.33
2018-19	---		161.02		68.93	71.03

FLL = Fixed Local Loop subscribers WLL = Wireless Local Loop
Subscribers Source: Website & Annual Reports of Pakistan Telecommunication Authority, Islamabad.



	2003-04	2004-05	2005-06	2006-07	2007-08	2008-09	2009-10	2010-11	2011-12	2012-13	2013-14	2014-15	2015-16	2016-17	2017-18	2018-19
Fixed LL&WLL (%)	3.00	3.60	4.03	4.12	4.10	3.80	3.76	3.60	3.50	3.50	3.42	2.33	1.82	1.73	1.54	1.45
Mobile %	3.29	8.30	22.2	39.9	54.6	58.2	60.4	64.8	68.5	71.4	76.4	60.7	69.1	70.0	72.0	76.0
Total %	6.29	11.9	26.2	44.0	58.7	62.0	64.1	68.4	72.0	74.9	79.8	63.0	70.9	71.7	73.5	77.4

Figure 2.2: Trends in Teledensity in Pakistan
Source: Website & Annual Reports of Pakistan Telecommunication Authority, Islamabad.

Pakistan's teledensity is currently more than 77 percent, with nearly 35 percent 3G/4G and 36 percent for broadband subscribers (Pakistan Telecommunication Authority[PTA], 2020). The conventional ICT, radio stations, and TV channels have also shown a significant increase in numbers. Pakistan Electronic Media Regulatory Authority (PEMRA) had released 88 licenses to satellite TV channels by 2018 (Pakistan Electronic Media Regulatory Authority[PEMRA],2018). The number of radio stations has passed the 150 figure with more than 90 percent of regional FM stations. This conventional ICT, including TV and radio broadcasting coverage, has reached almost every corner of the country.

The recent ICT developments in Pakistan justify the need for my research into ICT and agriculture. In summary, section 2.1 I have explained the need by farmers for innovative knowledge and how the current extension and marketing programs do not meet farmers' needs. In Pakistan, the agriculture sector makes a considerable contribution to the economy, and citrus is an important source of foreign exchange earnings. As the number of smallholder farmers increases, it becomes a challenge for the government to provide them with the latest knowledge. The recent rapid adoption and dissemination of new ICT provides an exciting opportunity to fill the knowledge gaps. The prevalence of ICT among the farming community could pave the way for the transition from traditional agricultural methods to innovative commercial agriculture. This change could improve the livelihoods of rural communities, especially smallholder citrus farmers. The explanation, provided above, supports the reasoning behind this research and justifies the need for it.

2.2. Review of Literature

In this section, I provide a brief description of ICT evolution, followed by a review of the ICT literature. This section is divided into seven sub-sections: firstly, ICT research and development; secondly, ICT's contribution to the development sector; thirdly, the information need and importance in agriculture; fourthly, ICT's importance and contribution to improving smallholder farmers' livelihoods; fifthly, the awareness and constraints faced by farmers in promoting the adoption of ICT with respect to demographic and contextual perspectives; sixthly, the empirical work in this research context; and finally the research gaps and justification.

An Overview of the Evolution of Information Communication Technologies[1]

Information and communication technologies have continued to make a difference to farming. Ever since the start of farming, livestock rearing, and fishing to feed the growing population, farmers have needed information. In the beginning, farmers sought information from one another. However, over time, changes in weather patterns and soil conditions, and infestation of diseases and pests have meant that farmers need the latest information not only to cope with the changes but even to be benefited from these changes. In this fast-growing world, the value of crops mainly subject to access to market and market price and the most efficient delivery of goods and services. The provision of such information was a challenging job because of the highly restricted nature of agriculture. It necessitates that the information is customized precisely for different environments.

Prior to ICT, communication was made through messengers and postal services. The telegraph was invented in 1831 and telephone in 1849. The farmers adopted telegraphs and telephones as a means of communication only gradually. The development of technology made communication technologies cheaper. Farmers bought their telegraph machines and telephones and replaced the traditional modes of communication. Within 50 years, telephones became the primary source of communication. Digital data storage devices followed these means of communication. Although telephones and telegraphs transformed the transfer of information between farmers, they still considered the old-style analogue methods (pen and paper) appropriate for keeping track of information. However, as the dimensions of information mounted over time, the old means of communication became inadequate. In the 1940s, mainframe computers were introduced and proved to have the immense processing power essential for searching sizeable documentation. As the flow of information increased, the technology behind it continued to progress and it was adopted for agricultural use.

Information Communication Technology (ICT) currently tends to refer to innovations such as phones, computers, and the internet. Some people still believe that technologies such as radio and television have significant value. Newspapers, magazines, radio, telephone, and television

---

[1] This section is mainly based on "Information and Communication Technology (ICT) in Agriculture a Report to the G20 Agricultural Deputies" prepared by the Food and Agriculture Organization of the United Nations (FAO) with inputs from International Food Policy Research Institute (IFPRI) and Organization of Economic Cooperation and Development (OECD). Available at http://www.fao.org/3/a-i7961e.pdf, accessed on May 16, 2020.
The Role of Technology in the Evolution of Communication. Available at https://www.forbes.com/sites/solrogers/2019/10/15/

have paved the way for the emergence of modern ICT, including mobile devices and computers, thereby triggering a technological revolution (Grover, 2007).

E-Agriculture as an embryonic field that focuses on the development of agricultural and rural development via better-quality information and communication processes (Franklyn & Tukur, 2012). However, recent developments in the field of ICT have transformed the globe more than any other advancements since the industrial revolution. ICT includes any communication appliance including radio, television, computer, networking hardware and software, mobile phones, satellite communication systems, and other types of applications associated with these devices. These advances in computing, electronics, software, wireless communication, speech processing, telecommunications, and video have introduced new experiences for humankind.

In this age of information technology, ICT substantially impacts all sectors of the economy, and the agriculture sector is no exception. Farmers across the globe are utilizing a variety of ICT inventions for different agricultural purposes, including, but not limited to, for cultivation, for identifying, preventing and curing various crop diseases, for the purchase and application of different farm inputs, for crop management and harvesting, and for marketing. ICT has the ability to effectively address farmers' constraints, including scarcity of timely agricultural information and the absence of market services where farmers can sell their produce. It is widely believed that ICT can efficiently improve the quality of farming. ICT has changed the style and process of agricultural extension services so that they deliver information, advice, and market linkage facilities specific to the farmers' crop management activities.

In short, the invention of communication technology has provided easy and effective communication for people from every walk of life, including the farming community. The advent of ICT has reduced the need for different stakeholders, previously involved in the information exchange, and reduced the communication gap precisely. Farmers are now benefitting from using ICT when carrying out various agricultural operations.

2.2.1. ICT Research and Development

ICT has revolutionized the global economy in recent decades, leading to increased productivity and higher living standards. The economies that accrue the most significant benefits will be those that continue to aggressively support ICT research and development (R&D) to keep their firms and industries at the cutting edge of innovation and application.

ICT affects the economy directly through the ICT sector, and indirectly, through other sectors driven by ICT improvements. ICT enhances the productivity of both workers and organizations significantly, especially in service and trade industries. Ezell and Andes (2010) noted that ICT R&D is key to supporting ICT as the driver of global economic growth. They identified the intersection of ICT with scientific disciplines, one of the eight priorities areas for ICT R&D. They state that efforts need to be focused on ICT's impact on critical areas, such as education, energy, healthcare, and transportation to meet the 'grand challenges' of the 21st century. Ezell and Andes (2010) believe that ICT is of great importance in many research fields for conceptualizing and testing new products.

ICTs have become core elements of development (Nonso, 2012). ICT research for development needs to involve the practitioners, legislators, and consumers to draw the best results (Walsham, 2017). The researchers have been contributing to assessing the research in ICT development and its role in economic growth. Designing and developing applications for ICT (Duncombe & Boateng, 2009); require knowing the context, including best practices, field interactions, evaluation, advantages, challenges, and accomplishment aspects for ICT-related initiatives (Zewge & Dittrich, 2017). Zewge and Dittrich (2017) further argued that not enough research exists to design and create ICT applications, particularly for uneducated folks, and to facilitate community participation in developmental activities. There is minimal investigation into the evaluating financial requirements for mobile phone finance research (Duncombe & Boateng, 2009). There has been some work on the adoption of ICT, but the development of ICT applications and its role in the development process has largely been ignored (Lwoga & Sangeda, 2019).

The current research in ICT development has paid more attention to getting a clear understanding of what and how ICT contribute to development, while the clarification of why is lacking (Sein et al., 2016). ICT development (ICTD) projects must define the form of technology to be employed, the implementation objective, and the purpose of combining why and how together (Islam & Grönlund, 2011). It is of utmost importance that any technological advancement needs to be compatible with the local environment, that is it should consider the possible effectiveness and community capability to absorb that intervention. Performance of any ICT-related intervention requires its design and execution to be allied with local communities to ensure governance and socio-political and economic development outcomes are maintained (Heeks, 2010). The optimal use of ICT for information dissemination requires comprehensive ICT development and ICT-related infrastructure in order to benefit the farming community (Gummagolmath & Sharma, 2011).

To conclude, it is pertinent to focus on research into ICT development that could make ICT-related technological advancements more effective, ensuring that they are aligned with end-users' needs.

2.2.2 Information and ICT's Role in the Development Sector

Information is of crucial importance in almost all human activities. In human societal development, information has consistently been a vital factor (Meyer, 2005). Information contribution to development has been a debatable topic. Many authors like Bell (1986), Boon (1992), and Sturges and Neil (1998) are of the view that information unavailability harms the development. Researchers and academics recognize the value of information in the development process, but this potential resource is not emphasised. Many authors have pointed out that governments and development planners do not acknowledge the important role ICT has as an elementary resource or are ignorant of its prospective value (Sturges & Neill, 1998). Information alone is valueless; its practical use and application give it power (Boon, 1992; Martin, 1984; Paez-Urdaneta, 1989). ICT makes innovative information available, enhancing knowledge and usable for specific developmental activities. But, ICT contribution is not recognizable considering just its potential. The main factor that defines the needs and critical success factors for the development and implementation of ICT are the "End Users" (Franklyn & Tukur, 2012). The countries with telecommunication advancement have rapid economic growth (Hardy, 1980; Norton,1992). Saunders et al. (1994) consider that telecommunication investment yields a 20 percent internal rate of return (IRR). Conversely, scarce ICT infrastructure hinders economic growth. ICT can enhance efficiency by reducing information search costs and increasing information flow. Therefore, in developing and developed countries, the effectiveness of ICT at stimulating economic growth is a proven fact (Röller & Waverman 2001; Waverman et al., 2005). Madden and Savage (1998) concluded after understanding the mechanics of ICT's positive effects on development that information is vital to markets' functioning, and communication technologies are powerful enablers of information transfer. Bedi (1999) advocated the need for the minimum possible ICT density threshold to have an impact on development.

The potential of ICT in social and economic development has been acknowledged over time with its propagation as evidence of economic development (Baqir, 2009). The livelihood of the rural poor in Tanzania has improved via improved businesses, increased access to education, easy communications and increased access to key information (Economic and Social Research Foundation [ESRF], 2008). Ndahiriwe (2015) concluded that the majority of respondents, irrespective of their ICT use, or not, recognize the considerable contribution that ICT make to socio-economic development. ICT has functioned as a means of globalization (Needle, 2010). Langmia (2006), Bello and Aderbigbe (2014), and Oosterlaken (2014) view ICT as catalysts for global development. There is a prevailing viewpoint that ICT make a substantial contribution to GDP growth, employment, capacity development, and poverty reduction (Irawan, 2014; Kozma, 2005) in developing countries. Puri (2007) considered ICT's contribution in the socio-economic development of developing nations to make the world better. ICT's development has changed the competitive nature of businesses by making a valuable contribution to establishing innovative ideas (Palvia et al., 2018). ICT has made an impact on the rural economy. Its diffusion into rural settings of developing countries is inspirational (Wiggins, 2014) and has had a significant effect on social connectivity (Lastra-Gil, 2018).

There is an intriguing idea, not based on evidence, that if ICT access and usage can be rolled out all over the country, it will lessen the income inequalities that exist between urban and rural people (Forestier et al., 2002). To get gains from ICT, organizations must increase their funding to corresponding services and novel organizational practices (Askenazy, 2000; Bresnahan et al., 2002; Brynjolfsson & Hitt, 1995; Greenan et al., 2001; Pilat, 2003). This idea encourages policymakers to take steps to ensure that ICT is accessible all over the country. Although with positive considerations, ICTs are not well integrated with the rural economy due to the varying local capacity of the end-users, which demands ICT interventions' development, keeping in view the capacity of individuals (El Bilali and Allayyari, 2018). The technological contribution varies with context. In the agricultural context, the ICT potential to replace existing knowledge sources is faded due to lacking the local capacity of the farmers (Khan et al., 2019).

To sum up, many researchers have established the role of ICT in economic growth through its contribution to GDP, employment, capacity development, and poverty reduction, but, the aligned factors and local capacity effects the effectiveness of ICT.

2.2.3 Information and ICT's Importance in the Agriculture Sector

Information is essential for improving agricultural productivity and devising marketing strategies (Oladele, 2006). It opens new avenues to capitalize on best practices, it gives access to financial institutions, empowers farmers to execute informed decisions related to agricultural activities, and enables them to handle daily life difficulties (Idiegbeyan-oseJ & Akpoghome, 2009). Information, rather than technology, is considered to be a key input into agriculture's sustainability (Allahyari, 2008).

In developing countries, including Pakistan, rural areas have a weaker infrastructure with less farm-to-market connectivity (Dorosh et al., 2010), and they are usually hindered by scarce information. The agricultural sector and the farming community face problems in trying to increase crop productivity (Kumar & Ratnakar, 2016). Farmers need information on weather conditions, new seeds, preparation of soil, planting methods, storage methods, crop care, disease and pest control, agricultural credit and loans, availability and application of pesticides, harvesting activities, animal husbandry, and marketing (Benard et al., 2014; Naveed & Anwar, 2013). Most advancements in agricultural research do not reach the farming community and the farmers continue to obtain yields below their potential (Kumar & Ratnakar, 2011). Limited access to, and usage of, the required information are the major contributing factors behind farmers' low socioeconomic conditions (Naveed & Anwar, 2013).

The majority of the farmers trust information from interpersonal sources due to its regular availability and accessibility; therefore, parents or family, personal experience, neighbours, and agriculture extension officers are the farmers' primary information sources (Benard et al., 2014). Other information sources for the farmers are print media, followed by fellow farmers and television (Rehman et al., 2013). Farmers face considerable difficulties in obtaining new market price details, weather updates, and information related to other issues (Man & Sadiya, 2012).

ICT plays a significant role in developing countries by helping educators, doctors, and agriculturists (Chhachhar et al., 2013). ICT could promote effective and speedy information exchange among farmers (Baruah & Mohan, 2018). It is already being used as a source of market information by farmers who produce abundant quantities of crops or have high demand crops. Farmers themselves, relatives, and traders are the market's primary information sources (Mwakaje, 2010). The availability of agricultural information is dependent on the effective and efficient services provided by the agricultural extension agents. The proper utilization of ICT by agricultural extension agents has the potential to transform the agricultural sector, rural development, and foster food security (Owotogbe et al., 2018). Accessibility to advanced ICT is increasing worldwide, leading to many exciting innovations that aim to improve the productivity of small-scale farmers (Steinfield & Wyche, 2013). The use of ICT for information dissemination is cost-effective and has extensive coverage, compared to traditional extension methods, such as farmer field school (FFS) and field days (Cox & Sseguya,2015).

Gurmu (2014), and Adegbidi et al. (2012) identified agricultural extension workers followed by radio and mobile phones as the primary sources of agricultural information. The most commonly used ICT tools by the farmers are radio, television (Adegbidi et al., 2012; Armstrong & Gandhi, 2012; Chhachhar et al., 2014; Grover et al., 2007; Gurmu, 2014; Kezi e al., 2012; Tegegne, 2014) and mobile phone (Adegbidi et al., 2012; Armstrong & Gandhi, 2012; Chhachhar et al., 2014; Gurmu, 2014; Kezi et al., 2012). This will eventually have a positive influence on agricultural production at a regional level (Armstrong & Gandhi, 2012).

Although farmers use radio and television to obtain information on agricultural and household issues, the reading of newspapers and magazines in local language continues to increase (Grover et al., 2007; Tegegne, 2014). Newspapers are the best medium for providing farmers with farm-related information (John & Barclay, 2017). However, smallholder farmers gain their agriculture-related information from fellow farmers and extension officers; few smallholder respondents having access to radio, TV, and mobile phones for agricultural information (Matto, 2018).

Both traditional and new media have substantial impacts on farmers and how much farm-related information reaches them. Moreover, the use of media has a positive correlation with the amount of agricultural information used by the farmer (John & Barclay, 2017). More modern ICT media like video players, digital cameras, computers, and internet have not yet developed much popularity among the rural farming communities (Baruah & Mohan, 2018; Tegegne, 2014). The younger farmers are more educated and access the internet and other web-based services like e-mail, YouTube, Facebook, and e-books (Syiem & Raj, 2015). Mobile phone usage is increasing rapidly among farmers; whereas, computers are generally only owned and used by the wealthy and elite farmers (Adegbidi et al., 2012; Gurmu, 2014). Smartphones are in the diffusion phase in developing regions and it is expected that voice and

SMS/text applications will gain popularity in the near future for agricultural services (Steinfield & Wyche, 2013).

Mobile phones are a crucial ICT tool that could spread agricultural information quickly and efficiently (John & Barclay, 2017). They are considered the most popular ICT usage tool among the farmers (Syiem & Raj, 2015). Mobile technology enables farmers to successfully access information on agricultural technologies and extension services (Karim et al., 2020) and therefore, plays a significant role in the improvement of the farmer's business. Furthermore, mobile phones have enabled farmers to communicate directly and to share their experiences (Chhachhar et al., 2013). They have made farmers aware of the latest innovations, weather forecasts, and provided them with the latest market prices (Asif et al., 2017).

ICT is commonly used to provide agricultural information services on input accessibility, input quality, input prices, and on contacting intermediaries for commodity marketing, pest, and disease control, among other matters (Syiem & Raj, 2015). ICT has provided a broad scope and support to assist accurate and rapid access to expert information (Balagi et al., 2007; Karim et al., 2020). The successful utilization of ICT is the transmission of information to farmers, mainly small landholders. However, infrastructure improvement, capacity building of small farmers requires utilisation of the full potential of mobile phones (Mittal, 2012). ICT, particularly mobile phones, are considered to improve small farmers' access to information, knowledge and capacity-building possibilities in developing nations. However, in developing countries, including Pakistan, human and physical capitals aligned challenges lead to poor access and ineffective use of ICT to enhance their knowledge and skills (FAO, 2017). ICT cannot bring change to meet farmers' knowledge needs without continuous government support in services provision, information needs assessments, promoting knowledge culture and capacity building (Lwoga, 2010).

ICT offers a forum to connect farmers in the shortest possible time, enables them to share knowledge and improve their interactions with other farmers, extension agents, and research stations. A variety of information can be shared through ICT, including but not limited to the availability of inputs, market information, and suggested practices to boost agricultural activities and farm harvests (Nnenna et al., 2015).

Khan et al. (2019) studied mobile phone usage among farmers accessing agricultural information. He found that the majority of farmers have a mobile phone for getting agriculture-related information, mainly access to market information. The adoption of ICT would influence their economic, social, and cultural values, and bring about a productivity increase in Pakistan (Stryjak & James, 2016).

Pakistan's farmers are struggling with their limited resources to get information about weather, techniques, prices, and other essential resources; however, in the near past, numerous mobile services launched programs for accessing information (Stryjak & James, 2016). Mobile phone usage has encouraged poor farmers to participate more in the market and to move towards high-value crop diversification, resulting in increased farm earnings. Therefore, mobile phone usage has helped to reduce the knowledge gap among small- and large- holder farmers (Mittal & Mehar, 2012).

Mobile phones, through SMS or voice message, can be connected with new knowledge and information sources that were not formerly existed with the possibility of real-time, highly tailored information delivery (Mittal & Mehar, 2012). Mobile phones are used by farmers to get marketing and weather information to save time and reduce effort. However, a gap exists among businesses, customers, and farmers (Chhachhar et al., 2013). Effective ICT based extension services would have real growth potential in the agricultural sector of a nation (Jimma, 2017). Multiple strategies like TV, radio, and mobiles in the agriculture sector are needed for the provision of value-added information and services to small scale participants (Steinfield & Wyche, 2013). The behavioural attention of farmers of mobile phones usage for agricultural-related information and how the abilities of farmers are impacted by mobile phones to get the updated weather and market information are identified by (Chhachhar & Memon, 2019) in Sindh, Pakistan. Most of the farmers own personal mobile phones; and more than three-fifths of their calls are directly to the market seeking crop information. The farmers are unaware of the proper use of the mobile phone (Chhachhar & Memon 2019).

Mobile and digital industries have evolved rapidly in Pakistan; new services and applications have emerged that transform the way people live, work, play, and communicate (Stryjak & James, 2016). Moreover, radio and television are apparently used daily, while computers, CD-ROM, DVDs, and cable television are used only occasionally by farmers (Fawole & Olajide, 2012).

Livestock farmers need information on the availability of credit, good breed availability, feeding and nutrition, disease control and treatment, markets prices of livestock products, by-laws and biogas information for keeping their animals in an environmentally sustainable manner (Consolata, 2017).

ICT aids the growing demand for farmers to take new approaches, it empowers rural people through the provision of better access to financial services, banking, exposes them to effective production strategies and improved agricultural technologies, natural resources, and markets (Lokeswari, 2016). Adoption and promotion of ICTs seem difficult without development of ICT centers, training of the staff, and provision of the support staff and farmers education (Franklyn & Tukur, 2012). ICTs are not effective in knowledge transfer due to a lack of technological mix with the local context, capacity, economic, social, and environmental sustainability (Kolshus et al., 2015).

The information needs of farmers, their access to, and utilization of this information should be taken seriously. Considerable effort and attention should be geared towards enhancing agricultural production in order to meet the ever-increasing challenges of food security and poverty alleviation (Zarmai et al., 2014). Innovation in agriculture needs to be documented in multimedia form and shared with farmers. Mobiles shall serve as the most promising ICT for extension work, and farmers are eager to gain more knowledge in using ICT. It allows farmers to provide regular feedback to extension and saves time and effort through rapid dissemination of knowledge (Baruah & Mohan, 2018).

To conclude, access to reliable and timely information on weather conditions, crop management practices, agricultural credits and loans, animal husbandry, and marketing remains the main hurdle to improving crop productivity. In the past, farmers relied on interpersonal sources, print media, fellow farmers, and television for their information. Recent developments in ICT have revolutionised farming by providing fast and convenient innovative information communication for getting quick solutions of agricultural problems. ICT plays a vital role in meeting the demand for new approaches, for empowering rural dwellers through better access to financial services, banking, effective production strategies, improved agricultural technologies, natural resources, and markets. However, lack of proper integration of ICT with the rural economy considering the local context and capacity are the challenges to enhance ICT effectiveness.

2.2.4. Contribution of ICT to Improving Information Access and the Livelihood of Farmers

Appropriate and effective information communication could eliminate agricultural development problems. Therefore, ICT opens up new opportunities in agricultural knowledge management to enable, strengthen, or replace the present information systems and networks. ICT has a significant role in meeting the current prevailing challenges associated with innovation, sharing, exchanging, and disseminating agricultural information, knowledge, and technologies to the intended smallholder farmers (Jimma, 2017).

The absence of timely information places farmers in a weaker position of the agriculture value chains. Other actors benefit more from having access to timely information. Information communication technologies, especially mobile phones, have vital importance in streamlining information mechanisms in agriculture-like sectors (Mittal et al., 2009). Radio access in remote areas and the visual aspect of television ensure they remain valuable communication sources. These sources have been acknowledged as valuable scientific knowledge diffusion media; TV is considered to be a vital communication medium for rural masses of developing nations (FAO, 2001). Agricultural programs are not generally broadcast at times that suit farmers. The result is that farmers depend on their fellow farmers to seek information related to agricultural activities, which may not be useful (Nazari & Hassan, 2011). Mobile phones are an inexpensive way of transmitting information about the production and marketing of agricultural products (Jehan et al., 2014). The mobile phone is being used for fishing communities to caution them against weather conditions (Salia et al., 2011). It is crucial to evaluate the contribution of mobile phones to farmers' market participation decisions (Munack & Speckmann, 2001; Mutto & Yamano, 2009). The vital role of ICT is to reduce asymmetric information linked issues, which increase transaction costs and weaken farmers' access to markets (Fafchamps & Hill, 2005; Shiferaw et al., 2009). Farmers now depend on their mobile phones to obtain weather information at different stages of the agricultural value chains. Farmers are exploited by the middlemen to sell their produce at cheaper rates due to unapprised decisions and conveyance management problems (FAO, 2001).

The positive impact of valuable information communication through modern technologies has become a fact. ICT is recognized as a means of information exchange and dissemination in the modern era. It has tremendous potential for livelihood improvement of the vulnerable rural population through cost-effective essential service delivery (Wijekoon & Rizwan,2011).

Zaremohzzabich et al. (2014) identified the role of ICT in the sustainable wellbeing of communities in the perspective of all livelihood capitals. This argument is further supported by Thapa and Sæbø (2014) who claim that ICT has the ability to enhance human and social capital in isolated communities. Mehta (2010) advocated that ICT could be viewed as a promising opportunity to boost the region's livelihood and growth. Due to the multiple uses of mobile phones, their affordability and portability, they have emerged as a valuable tool for accessing information related to agriculture production and marketing activities (Murthy, 2009). Mobile phones with lower search costs may also increase access to information for a farmer who is a social networking user (Aker & Mbiti 2010; Baye et al., 2007). In Peru, there was a thirteen percent increase in income with the use of mobile phones (Chong et al., 2005). Rural producers have improved their productivity, market access, and options using mobile phones (Jansen et al., 2006). Moreover, effective improvements in agricultural production are only possible through adoption and utilization of new technologies that require higher level of education and skills (Chavula, 2014).

In Bangladesh, the mobile phone has increased the chances of enhancing productivity and reducing in socioeconomic imbalances. (Islam & Gronlund, 2011). Furthermore, farmers have increased their bargaining power with information access through the high diffusion of mobile phones (Myhr & Nordstrom, 2008). Researchers found a strong relationship between mobile usage and productivity (Ogbeide & Ele, 2015).

Mobile phones can contribute effectively to socio-economic growth for smallholders, and farmers with medium sized farm holdings (Martin, 2010). The adoption of innovative farming practices and measures by poor resource farmers, through mobile communication, provides openings to greater profitability gains, despite many constraints (Mittal et al., 2010).

Lokeswari (2016) reveals that ICT can revolutionize the farming sector, including smallholder farmers, by addressing the traditional agricultural challenges facing agriculture and rural development. The traditional farming approach challenges include production, marketing, and profit. The author is of the view that ICT has the potential to improve rural livelihoods of small landholder farmers through effective utilization of ICT for innovative information acquisition.

ICT offers innovative access and methods for rural development. Various communities get the advantage, but the farmers are unable to tap ICT' potential properly to acquire innovative information about new seed, weather, pesticide, and the markets (Chhachhar et al., 2013). In addition to price information, ICT contributes great benefits by sharing information on supply and demand among farmers and other market intermediaries (Madon 2009a; Molony, 2008; 2009). ICT, in the form of internet and mobile/web applications, contributes significantly to enhancing the marketing efficiency of farmers who have better negotiation power after acquiring real-time market information, resulting in agricultural growth (Driouchi, 2006). In developing countries, agriculture is generally the profession of the majority of the poor, resource-based farming community. For poor resource farmers, ICT provides an exciting opportunity to move from traditional farming to innovative farming methods (Bhattacharjee & Saravanan, 2013). Improving information quality seems difficult without teaming up with relevant agricultural organizations from whom to access and integrate relevant information (Opolot et al., 2016).

Stienen et al. (2007) consider ICT in agriculture to be a source of production enhancement, increasing market access, improving capability, and empowering farmers. Mugwisi et al. (2015) concluded that the unavailability of modern-day ICT has detrimental implications for agricultural growth. ICT 's position is essential to economic growth, because it improves market performance, efficiency, and competitiveness (Noor Sharifah, 2003). ICT helps to establish a link between farmers, other stakeholders of agricultural value chains, and reduce transaction costs (Lastra-Gil, 2018). The author further argued that medium-sized producers are more advantaged than the smallholders with ICT access, having better market access, finance and training access, better negotiation possibilities, and other collaborative opportunities. The smallholders are also benefiting from the use of it. Meena et al. (2012) found that ICT contributes significantly to enhancing the efficiency, profitability, and sustainability of smallholders’ farms. ICT supports effectively in tackling challenges and raising rural poor's livelihoods (Chikaire et al., 2016; Meena et al., 2012). Richardson (2006) concluded that ICT initiatives that improve rural poor livelihoods could also contribute to substantial investment by rural families in agricultural production. However, Chavula (2014) by using 2000 to 2011 panel data for 34 African countries, has concluded that telephone main lines have significant impact while mobile phones have insignificant impact on agricultural growth even with wide spread of mobile technologies. Likewise, improvement in the livelihood of the rural poor through ICTs is not possible without active support of government, NGOs, development partners and the private sector in the development of ICT sector (ESRF, 2008). Makoza and Chigona (2012) found that ICT cannot improve the livelihood only with the physical access but need business expertise and skills to integrate technology with the enterprise requirement to enhance technologies' contribution. McNamara (2008) found the relevant gaps that halt the effectiveness of ICT in enhancing the livelihood of rural poor. David et al. (2005) found no reliable evidence linking ICT access to rural livelihoods; it is difficult for development planners and the ICT sector to make educated judgments about ICT and livelihoods projects and programs. As a result, limited development resources may be squandered, or the possibility of effective pro-poor efforts may be missed.

In order to increase agricultural productivity for smallholders, improvement of ICT-related resources must be made available to farmers, and proper deployment of ICT-related resources is crucial to this growth (Chikaire, 2016).

To sum up, modern ICT has a significant impact and provides invaluable information communication. Researchers have concluded that ICT is revolutionising the agricultural sector by helping to resolve conventional farming problems, by improving access to information, and by reducing transaction costs. Farmers have increased their bargaining power with access to information through ICT, especially mobile phones. ICT contributes significantly to improving the productivity, profitability, and sustainability of the farming community, including the smallholders. Overall, ICT, specifically recent ICT innovations, has been demonstrated as being instrumental in improving farmers' livelihoods but proper deployments of ICT-related resources and improving the local capacity are challenges to tap ICT potential.

2.2.5 Awareness, Constraints and Enhancement of ICT Adoption

2.2.5.1 Socio-Economic Factors

Rehman et al. (2013) ascertain the sources of agricultural-related information and establish an association between the socioeconomic characteristics of the respondents and their access to agricultural information. The factors that affect the ICTs usage on input information in agriculture in developing countries are farmers' perceptions on compatibility, relative advantage, observability, simplicity and social influence (Macire et al., 2016). Silva et al. (2011) ascertain that social influences play a key role in mobile adoption and people tends to get connected in groups.

Educational qualifications and landholding size have a positive and highly significant effect on access to agricultural information; whereas, farming experience and age of the farmer have a non-significant relationship. Farm families utilise ICT for both household and farm use (Grover, 2007). Many socioeconomic factors contribute to the awareness, adoption, and usage of ICT depending on the cultural contexts of the farming communities.

All parameters indicating the inconsistency between data sets do not suggest any difference in the knowledge and use of ICT between smallholders and large holder farmers (Fawole & Olajide,2012). The authors found that farm size, marital status, gender, and educational status have no significant relationship to respondents' awareness of ICT because of technological revolution in Nigeria, and income has no association with farmers' ICT usage (Fawole & Olajide, 2012). In contrast, Anoop et al. (2015) studied the market information services based on ICT and analysed the determinants for the adoption of ICT. Their study indicated that family size, education, and contact with extension agents were positive influencing factors in the adoption of ICT based market information services by the farmers. At the same time, income from other sources is considered a negative influencing factor for market information services based on ICT by the farmers. While Waqar et al. (2018) acknowledge that the use of mobile phones is widespread amongst farmers and among marketing intermediaries, internet usage is low as most of the marketing intermediaries are poorly educated. In contrast, the exporters make much higher use of mobile phones and internet. In the citrus value chain, processors and exporters are the highest users of ICT, followed by growers and intermediaries.

Waqar et al. (2018) identified age, education, and landholdings as the main factors that influence ICT use in the farming community. They found that age is negatively correlated with ICT use among the farming community. Other work shows, age, gender, family size, income level, farming experience, membership of cooperative societies, and distance from the source of ICT are statistically significant factors for farmers accessing and using ICT facilities (Nenna et al., 2015). Older farmers and female farmers are negatively correlated with ICT access and usage. That means the younger the farmer, the more ICT-compliant he/she appears to be.

Meena (2012) reports a positive and significant correlation between ICT exposure and education, family size, livestock herd, annual income, extension participation, knowledge about animal husbandry practices, adoption of animal husbandry practices, social engagement information source, and risk orientation. She further identified a non-significant association of ICT exposure with age and family size.

The level of ICT adoption increases with farm size and is therefore low amongst smallholder farmers. Age, education, farm size, caste, and occupation type significantly impact technology adoption (Grover, 2007). The educational level of farmers, mobile phone use skills, the number of mobile phones in a family, and the length of time they have possessed a mobile phone are all positive and significant factors. In contrast, the age of farmers and contact with extension agents are negatively correlated with mobile phone adoption (Khan et al., 2019).

Grover et al. (2007) points out that the level of adoption of ICT is low by landless, smallholder, and marginal farmers. They further argue that the age of the farmer, level of education, size of land holdings, and occupation have a significant effect on the adoption of ICT. Similarly, Naveed & Anwar (2013) investigate that low levels of education, language, and lack of timely access are the main hurdles faced by the farmers to get the required information. Haller & Siedschlag (2011) reveal that age, firm size, skill intensity, exposure to foreign markets, and proximity to early adopters of ICT in the same industry and region are the characteristics that influence the speed of ICT diffusion. They further argue that the influencing factors are broadly the same for inter-and intra-firm adoption of ICT except for foreign ownership and firm size. Access to financial, human, and physical resources impacts the adoption of innovations (Gottret, 2007). There is a positive correlation between farm size and innovation adoption (David, 1969; Diederen et al., 2002;2003; Perrin & Winkelmann, 1976).

ICT contributions in agricultural growth as identified by (Saidu et al., 2017) are insufficient ICT facilities and infrastructure, lack of personnel, harmonization of knowledge and language, power supply and farmers' perception. Adegbidi et al. (2012) identify four positive drivers for effective use of mobile phones for agricultural purposes. These are literacy level, amount of land cultivated during the short rain season, ownership of the mobile phone, and participation in ICT projects. While household size, distance to the nearest mobile phone services, and land in fallow during the short season are the three negative drivers. Similarly, they also confirm that the intensity of mobile phones in agriculture usage is determined by mobile phone ownership, farming experience, and distance to the nearest centre with electricity.

Farmers' attitudes to the dissemination of agricultural information using ICT is assessed by (Armstrong & Gandhi, 2012). They studied the education level, demographic data, household income, agricultural activities, usage of ICT tools in the agricultural sector, i.e., kind and preference of ICT tools, information source, trust of information sources, preferences for different types of information, timing and frequency of information delivery, that frame the attitude of the farmers. Additionally, the farmers' attitudes towards the use of ICT is governed by their overall expectations of the ICT tools, the applicability and credibility of the information received, and the kind of available support. Haller and Siedschlag (2011) reveal in their study that the diffusion path of ICT is not the same across space, industries, and firms. Younger, larger firms, which are skill-intensive and fast-growing, located in the capital city region, are comparatively more effective in adopting ICT, as are export-intensive firms. Okello et al. (2014) revealed that literacy level, transportation cost, asset endowments, and farmer location generally accompany an awareness of ICT-based market information services.

Ashraf et al. (2015) in their work, describe a relationship between socio-economic characteristics and the awareness and adoption of citrus recommended production practices. Their study results reveal that age, education, and the citrus cultivation area have a significant effect on the awareness and adoption of ICT in agriculture. Ali and Kumar (2011) hold the view that social category, education levels, landholding size, and income level also have a significant role in impacting decision-making attitude related to ICT. Ali (2012) reveals that sociodemographic factors such as age, education, income, social category; and farm-related variables such as farmers considering farming as a business venture, practising diversified cropping systems, and smallholding farms influence the adoption of ICT. Maqsood (2015) concluded that educational status is significantly related to mobile technology usage for accessing telecommunication-based agricultural extension information services.

Aldosari et al. (2019) examined the farm community's perceptions of electronic media (TV and radio) in Khyber Pakhtunkhwa, Pakistan and the relationship between different demographic characteristics. A significant correlation was found between the respondent's age and information received through radio and TV. A profoundly meaningful relationship is also found between the respondent's education and the information application in agricultural enterprise received through radio only. They found no relationship between farming experience and the information application received through TV and radio.

Chhachhar and Memon (2019) found the level of education had a negative contribution to the use of mobile phones by farmers in obtaining agricultural related information. Moreover, age shows a negative but significant contribution. At the same time, social influence, monthly income, facilitating conditions and performance expectations make a positive contribution towards mobile phone usage by farmers for marketing information. Farmers believe that their income could be increased with capacity building of new technology and provision of other facilities related to farm business.

Tirkaso and Hess (2015) found that the income of farm households significantly determines the farmers’ level of spending on various ICT goods and services. Annual income, education, age, cosmopolitan attitude towards ICT, and social participation are positively associated with the farmers' ICT usage (Syiem & Raj, 2015). Other work confirms that age, education, and gender are related to ICT usage; younger people use media technologies like radio, internet, and mobile phones more than their elder counterparts; whereas, the older farmers watch television more than the younger ones. Further, well educated people use media technologies like radio, television, newspapers, and mobile phones, more than less well educated people (John & Barclay, 2017).

The owners of small ruminants tend not to use mobile phones, internet, and computers as a source of information which is due to their low level of education, their income level, and their ages (Kezi et al., 2012). Similarly, as Mwakaje (2010) points out, the cost of acquisition, lack of knowledge, unreliability, and poor accessibility are limiting factors for ICT usage. Mwakaje (2010) suggested that the government and private sectors should focus their efforts on using renewable energy sources to get electricity to the rural areas.

Lwasa et al. (2011) concluded that universal primary and secondary education, the introduction of ICT education programs, as well as public - private partnerships are measures that could address the constraints faced by the smallholder farmers in the study area.

Illiteracy, service failure, electricity, cost, lack of maintenance, fake and substandard ICT accessories, and inadequate infrastructure are the hurdles identified by the respondents that constrain their usage of ICT (Fawole & Olajide, 2012). The high cost of ICT services deters the ICT usage of agricultural input information in developing countries (Kante et al., 2016).

2.2.5.2 Contextual Factors Perspective

Aleke et al. (2011) propose a balance between the efforts used in the design of ICT and social factors like traditional life and language for successful diffusion and fruitful results. Dey et al. (2008) believe that mobile telephony technology is limited in its ability to provide some crucial agricultural information needed by the farmers. It is their view that for effective usage, technology needs to be personified within the social process and could only be useful when it is consistent with the social processes and farmers' lifestyles. Further, the content of the information and the applications need to be developed using a bottom-up approach in order to meet the information needs of farmers.

The factors which significantly impact agricultural extension personnel are many, including but not limited to, years of service, education, possession of smart gadgets, and methods of learning and training (Raksha & Meera 2015). These authors also found influences such as scientific orientation, innovativeness, and orientation towards the extension service profession positively affect extension workers' attitudes to ICT while age is negatively correlated. Similarly, simplicity, compatibility, relative advantage, ICT social influence, and information quality are positively associated with ICT usage in developing countries (Kante et al., 2016).

Khan et al. (2019) in their research on the use of farmers' mobile phone-based farm advisory services (FAS) in rural areas, found that the private sector has more users than do the public sector's helplines. Farmers prefer local language, voice-based content more than information based on SMS. Cassim and Obono (2011) show that the level of adoption of ICT is moderated for factors like ICT awareness, perceptions on usefulness of ICT, attitude towards ICT, and the ease-of-use of ICT. These factors also have a significant influence on ICT adoption. Respondents, who understand the general importance of ICT, have better levels of ICT adoption in urban areas as compared to rural areas.

Baliamoune-Lutz (2003) studied the relationship between ICT diffusion and per capita income, trade and financial indicators, education, and freedom indicators. In his study, he concludes that ICT could provide an additional source of economic growth; however, the crucial determinants of ICT diffusion are the variables of trade policies and social development, as well as economic development.

Regardless of the availability of ICT to farmers, there are challenges in its usage by farmers for agricultural input information, that impact ICT potential contribution (Kante et al., 2016). The major constraints faced by farmers are lack of confidence in operating ICT, their difficulty in charging mobile phones, the lack of connectivity in rural areas, and a general lack of awareness of the socio-economic benefits and stimulus that ICT could bring to their lives. Except for personal communication, lack of repairing centers and repairing facilities of ICT for mobile phones and television, and lack of training and practical exposure to use mobile phone applications as well as internet also limit the use of ICT (Syiem & Raj, 2015).

Mahant et al. (2012) attempted to better understand the issues involved in ICT adoption and the barriers to active ICT uptake for agricultural development and rural viability. Their study reveals that in agriculture, ICT is increasingly important, while E-Agriculture is an evolving field focusing on the enhancement of agriculture and rural development. E-agriculture is an innovative way of using ICT that mostly involves design, development, conceptualization, and application in the rural domain. Despite the increasing spread of mobile broadband coverage, limited people subscribed to mobile broadband services in Pakistan because of its expense, their illiteracy, and security issues in the country (Stryjak & James, 2016).

The farmers' reluctance to take up innovative technologies, such as the internet, is primarily due to their lack of awareness of the advantages of technology, their lack of expertise and the limited time they have to spend on learning how to use ICT (Bernard et al., 2014).

Low-cost ICT services and facilities are the prerequisites for successful usage by the poor. Farmers are unable to concentrate on e-commerce agricultural practices due to hurdles involving cost and confidence (Jamaluddin, 2013). Dagne and Oguamanam (2018) identified several limitations constraining the small-scale producers' accessibility to markets and agricultural-related information in most developing countries. The traditional means of communication are often used by producers to sell their produce at the farm gate in developing countries. The marketing intermediaries and other stakeholders in the product chain are taking a significant share of the products' value. ICT could both link the producers with markets in ways that could affect their decisions at both production and marketing levels, and foster collective action and collaboration among local stakeholders. Smallholder farmers are hindered from achieving higher productivity as a result of their limited access to accurate and relevant information (Matto, 2018).

Baruah and Mohan (2018) found respondents were constrained in taking up ICT by a lack of training on using ICT tools and inadequate power supply. They further identified that respondents found using ICT to be complicated, and that poor internet/phone connectivity, scarce availability of ICT services to rural farmers, insufficient financial resources, and low levels of faith/trust in ICT tools were also critical constraints in ICT adoption. They noticed that the high cost of ICT tools, lack of support from extension agents, lack of formal education among farmers, and social barriers to using the internet limit ICT adoption.

In their findings, Anoop et al. (2015) identify the barriers to farmers adopting ICT based market information services as technical restrictions, language issue, lack of reliability, lack of awareness, and the cost.

The low level of accessibility to ICT infrastructure has slowed the sharing and exchange of knowledge and information generated from research centres at national and regional levels (Jimma, 2017). Waqar et al. (2018) identify low use of internet in production and intermediary trade, lack of information sharing in intermediary trade, and lack of certifications at the export stage as the limitations to the adoption of ICT. The ICT's effectiveness, sustainability, and its benefit to farmers need to be monitored. The results of the assessment show that farmers have limited awareness of services, role of mobile phones for obtaining market information, low mobile phone use competency, literacy and language problems, lack of pre-paid credit, phone charging problems, gender differences, role of community groups, and NGOs (Steinfield & Wyche, 2013).

For ICT to be adopted and to be effective among the farming community, numerous measures are required. Armstrong and Gandhi (2012) show that there is an enormous opportunity to improve the dissemination of agricultural information received by farmers from fellow farmers, relatives, and government officers. They encourage the use of ICT tools in rural areas, the development of ICT infrastructure, and training on ICT tool usage for smallholder farmers to get market information (Adegbidi et al., 2012). For effective adoption of ICT, Ashraf et al. (2015) suggest the promotion of formal and non-formal education of farmers through the organization of training programs. Extension field staff, electronic media, and social media could also play a role in the provision of educating farmers. The younger generation should be prioritized in the provision of education and training facilities.

Owotogbe et al. (2018) found that affordable ICT facilities to the extension agents and farmers are important to provide timely access to accurate information. Need to encourage and support farmers financially for access and use of ICT for agricultural purposes. However, Armstrong and Gandhi (2012) find that gender and land ownership do not significantly affect the use of ICT. The study proposes strengthening and motivating farmers' groups for using technologies like the internet. The government should promote private and community provision of dissemination services through increasing access to the internet and establishing training centres. Moreover, the education of farmers in IT and the establishment of IT-based information centres in rural areas could boost access to market information.

Nyamba and Mlozi (2012) found that factors that affect the use of cell phones in the communication of agricultural information are ownership of the mobile phone, agricultural information type, agricultural system, network access, and socio-economic attributes of the respondents. Kante et al. (2012) identify factors that affect farmers' use of ICT in accessing and using the information on agricultural inputs as: relative advantage, ease of use, seeing is believing, social relations, and information quality. The cost of the ICT service hinders its ability to be used as a means for providing information on agricultural inputs (Kante et al., 2012). Adegbidi et al. (2012) study the factors associated with the adoption and use of ICT. They show that mobile call-up, mobile SMS, radio programs, and the television are the four main common types of media used by farmers for various farm operations.

The primary constraints include the limited aptitude of farmers for using mobile phones and their lack of awareness of information sources. The government institutions and concerned authorities have shown a lack of interest in promoting ICT-based information services in agriculture (Khan et al., 2019). Lwasa et al. (2011) conclude that low levels of development of the supportive infrastructure constrain the smallholder farmers from taking-up mobile phones. Silva and Ratnadiwakara (2010) suggest adopting measures and taking necessary steps to access ICT at a rural farm level. Usman and Said (2012) reveal that culture, policy, and cost might be the factors that influence the acceptance of ICT. Hence, legal regulations and policies, culture, and beliefs could successfully promote the acceptance of ICT.

Ali (2012) showed in his research work that a single delivery mechanism might not be appropriate as farmers are not be a homogenous group. Therefore, Ali recommends considering the information needs and farmers' constraints along with the continuous studying of information delivery technologies.

Farmers in developing countries are facing many problems such as lack of infrastructure, education level, and electricity shortage (Chhachhar et al., 2014). The full potential benefits of mobile phones are not reached due to limitations in the physical infrastructure that affects access to markets, storage, and irrigation (Mittal & Mehar, 2012). There are still essential challenges for active learning and utilization of ICT development, including expensiveness, lack of trained personnel, and language of disseminated information (Otete, 2018).

Grover et al. (2007) confirmed that higher charges by private internet players, poor internet connectivity, and lack of organization are the obstacles faced by farmers. The authors suggest that the technology acceptance model may be more valuable if integrated with specific issues like perception, infrastructure, consumer trust, and security aspects of technology Armstrong and Gandhi (2012) identify factors constraining the increased uptake of ICT, that comprise the gap among the currently used technology and the technology preference.

The hurdles faced by farmers in accessing agricultural information are allied with inadequate funds, lack of awareness of information sources and information not easily accessible, an insufficient number of extension agents, and lack of information services (Benard et al., 2014). Cox and Sseguya (2015) identified a lack of coordination, weak linkages, lack of skills to fully exploit the use of ICT as the constraints faced by farmers. The reason for the low take-up of ICT might be a low level of ICT infrastructure resulting in weak linkages among research-extension-farmer for knowledge sharing (Tegegne, 2014). Mahant et al. (2012) concluded that the practical issues in the adoption of ICT for agriculture development and rural viability are ICT training, content development, investment in ICT infrastructure, capacity development, compatibility with stakeholders' needs, the involvement of end-users in ICT development, a collaboration between relevant entities in sharing the ICT adoption experience and engagement in providing ICT services for farmers. Baliamoune-Lutz (2003) reveals that income, government trade policies, political rights, civil liberties and economic development are associated with ICT diffusion.

Armstrong et al. (2011) propose the development of strategies for integrating ICT into agriculture supply and value chains by presenting examples of effective integration of ICT. Mobile communications, sensor networks, and GPS technologies are claimed to transform the efficiency of these supply chains and hence improve food security. However, Love et al. (2006) view that a rigorous evaluation process is needed while implementing IT; otherwise, there will be inefficiencies in performance. Training and educating farmers in mobile phone usage are required so that they can access the available information sources. Extension practitioners are advised to consider the digital literacy of farmers before starting ICT-based initiatives. The study emphasizes the policy implications for utilizing the true potential of these ICT-enabled solutions in agriculture (Khan et al., 2019).

Information in farmers' language is one of the most significant factors that helps to encourage the use and usefulness of ICT (Ninsiima, 2015). Extension professionals with no exposure to modern ICT should be trained with emerging technologies via in-service training and capacity building programs. Moreover, extension personnel are required to motivate and create awareness about the usage of electronic media among the farming community. They can act as a source of advanced information about agriculture production techniques (Aldosari et al., 2019).

Howland et al. (2015) suggest implementing ICT training, and developing infrastructure in rural areas to enhance sharing and using the information in a better way. Also, attractive and straightforward tools for record-keeping should be made. The younger generations and the women on farms need to be facilitated to access ICT tools. Irungu et al. (2015) suggest the need for a simple pack of technologies to be displayed on websites for easy access. Moreover, ICT tools should be affordable and straightforward and have targeted content; they should be localized, valuable, dependable, and treasured. Tirkaso and Hess (2015) reveal that the use of the mobile phone is vital for cash crop production. The government needs to facilitate mobile phone adoption services in rural areas to engage rural farmers in successful cash crop production.

Raksha and Meera (2015) assume that positive attitude of the extension personnel towards the use of ICT in agricultural extension system should be promoted through proper facilities like budget, infrastructure, training, incentives, and awareness for developing the agricultural extension personnel's attitude towards the use of ICT in the agricultural extension system. Extension agencies should be funded to enable them to make more radio and television programs. Collaboration between agricultural extension agencies and education extension services should be established to promote adult education and computer education (Kezi et al., 2012).

New technology centres and media houses, technical and educational programs for farmers, and the creation of alternative sources are needed for the dissemination of agriculture information among farmers in rural areas (Chhachhar et al., 2014). The government should encourage the development of the ICT sector, change the extension system and form a suitable environment for linking farmers with information technology via improved ICT extension services (Jimma, 2017).

For effective adoption of ICT in agriculture, Mahant et al. (2012) recommend: (1) focus and consolidate all national and public ICT policies, budgets, and investments for agriculture and rural sector; (2) involve all ICT stakeholders in the setting of ICT R&D priorities and the measures needed to attain the successful transfer of these technologies; (3) strengthen the 'agriculture ICT' curriculums in formal and informal education and training programs; (4) focus ICT training for teachers/researchers/extension workers and farmers on practical aspects; (5) link village knowledge centres and agri-clinics to farmers' needs.

Angello (2017) recommends: (1) improving usage of radio and television in accessing livestock information; (2) enhancing the use of mobile phones and internet to access livestock information; (3) promoting and improving the use of extension services; (4) forming organizations for livestock keepers; and (5) introducing livestock information centres.

Khan et al. (2019) conclude that education and digital literacy are crucial for mobile-based alternatives usage for information acquisition by the farmers. Their study suggests that policymakers and practitioners should consider farmers' socioeconomic characteristics in the field of ICT-enabled agricultural extension services. Farmers need the transformation of information by agricultural extension agencies, adult literacy education programs, the ability to access the needed inputs and loans, in order to use modern production practices (Zarmai et al., 2014). There is a need for more research to be conducted for drawing relevant ideas and suggestions for enhancing successful implementation of ICT to develop agriculture (Saidu et al., 2017).

To sum up, a review of the literature on the awareness and adoption of ICT and enhancing its effectiveness, suggests it is the socioeconomic factors, mainly, the farmers' education and financial capacity that are the key contributors to the effectiveness of ICT. It also suggests that the main constraints to the use of ICT by farmers are: (a) the lack of awareness of the possible contribution of ICT by older farmers; (b) the low level of ICT infrastructure; (c) the lack of coordination, sharing of knowledge and; weak linkages among researchers, farmers, and extension personnel; and (d) a lack of skills to fully exploit the usage of ICT. The literature review also suggests that the governing factors of the farmers, researchers, and extension personnel and their attitude towards the use of ICT should be promoted through proper facilities like budget, infrastructure, digital literacy/training, incentives, and awareness campaigns.

2.2.6. Empirical Research in ICT Perspective

Research work on ICT is still in its infancy and needs further attention from researchers. However, some researchers have carried out studies on the issues in different parts of the world. Ganju et al. (2016) used secondary econometric analysis of data from the Gallup World Poll in 160 countries (2006–2014) and from the World Bank database. They identified that use of ICT may not only enhance productivity but also promote wellbeing of the people. They concluded that ICT use is associated with measures of national wellbeing; in less developed countries, use of mobile phones is associated with wellbeing; in more developed countries, wellbeing is associated with use of the internet and fixed line as well as mobile telephones. Therefore, less developed countries should invest in mobile data technology. Leonardi et al. (2016) tested the adaptive structuration theory using archival data analysis to identify secure delivery of government benefit payments to 'unbanked' people in remote areas of Brazil. Leong et al. (2016) used a comparative case study, interviews and focus groups, and archival research to report on rural development in Chinese villages that participated in the Alibaba- sponsored Taobao Villages program. Oreglia and Srinivasan (2016) tested the empowerment theory in multiple locations in China and India using comparative case analysis with open-ended and semi-structured interviews and observation. Srivastava et al. (2016) tested institutional theory for open government and transparency in business transactions to enable and sustain fair and efficient markets and the flow of foreign investments using econometric panel data analysis for 63 countries over a period of 4 years.

Various researchers have used different techniques and analyzed different models to meet their research objectives. For example, to determine the drivers of awareness of ICT project sites (BROSD and WOUGNET), and decision of mobile phone usage in Mayuge and Apac districts of Uganda, Lwasa et al. (2011) have estimated bi-variate logistic and zero-inflated negative binomial regression models. Adegbidi et al. (2012) investigate the factors that determine the use of ICT by rice farmers in the central region of Benin using Logit, Probit, and Poisson regressions models. In his study, Ali (2012) uses sociodemographic factors, the business orientation of farmers, and farm characteristics to examine the factors influencing the adoption of ICT-based information systems by analyzing the Poisson Count Regression model. Anoop et al. (2015) studied the ICT based market information services (MIS) analyzing the determinants and barriers to adoption, using a logistic regression model. Tirkaso and Hess (2015) conducted a study to investigate the simultaneous causality between income-generating activities and expenditure on ICT for smallholder farmers, by estimating two stage least square (2SLS) regression analysis. Similarly, Tirkaso and Hess (2018) investigate the prevalence of the potential link between commercialization and predicted technical efficiency scores of smallholder farmers using 2SLS regression analysis.

To sum up, ICT has revolutionized the global economy; economies that support R&D in ICT may succeed by adopting innovations in their firms and industries. Despite the established role of ICT in economic growth, R&D in developing economies is at an earlier stage. There is a strong need for less developed countries to invest in ICT so as to reap the benefits.

2.2.7. Research Gaps and Justification of the Research Study

ICT has played a significant role in facilitating information dissemination for agricultural enterprises in developing countries. Mwakaje (2010) encourages the effective and efficient utilization of information use in the agricultural sector. It is evident, from the literature review, that ICT supplements the role of agricultural extension in many ways. For example, ICT helps in the timely dissemination of appropriate knowledge to the farming community (Kumar & Ratnakar, 2011), it provides employment to the youth (Irungu et al., 2015), information on prices (Grover et al., 2007; Mwakaje, 2010), profit to the farmers (Gurmu, 2014), and an additional source of economic growth (Baliamoune-Lutz, 2003). ICT also helps to reduce the high transaction costs and help poor farmers to move toward commercialization. It has the potential to improve the management of world agriculture resources (Agrahari & Tripathi, 2012). Grover et al. (2007) concludes that time, comfort, their energy-saving nature, ease of operation, and ready availability are the accelerators for the uptake of ICT. In the future, ICT will become prevalent and cost-effective; it will revolutionize the way agriculture-related information is used, maintained, and stored. Farmers using ICT have better decision-making than those who do not, in many agricultural practices across the agricultural supply chain (Ali & Kumar, 2011).

To sum up, in the context of developing countries, accessibility to advanced ICT is increasing all over the developing world. This will result in many exciting innovations that aim to improve the productivity of small-scale farmers. ICT will help in the growing demand for new approaches, empowering rural people through the provision of financial services, banks, effective production strategies, improved agricultural technologies, better access to natural resources markets, etc. ICT is considered an easy, fast, and convenient way for getting quick solutions.

Farmers in Pakistan are striving hard with their limited resources to access information on weather, modern agricultural techniques, and market prices of different inputs and outputs. Mobile and digital industries have evolved rapidly in Pakistan; new services and applications have emerged that are transforming the way people live, work, play, and communicate. Different mobile service providers have launched various programs for accessing the information on agriculture. Farmers are using these advisory services to get agricultural information, with the majority enquiring about access to market information. It is anticipated that the adoption of ICT would influence the economic, social, and cultural values, in addition to increasing productivity in Pakistan.

The majority of the farmers in Pakistan have mobile phones and basic operating skills. Mobile phone usage has also reduced the knowledge gap between the large holder and smallholder farmers. They have encouraged poor farmers to greater market participation and encouraged their diversification to high-value crops, resulting in increased farm earnings and reduced wastage. Although farmers are unaware of the proper use of mobile phones, they do use them to keep in contact with the market and buyers, while a limited number of the respondents get weather information.

Considering the above, despite its proven role in promoting agriculture and an overall improvement in people’s livelihood, ICT has received researchers' due attention globally. However, E-Agriculture as an embryonic (Franklyn and Tukur, 2012) and research work on ICT is still at its beginning in Pakistan and demands the researchers' due attention. Studies by Ashraf et al. (2015), Chhachhar and Memon (2019), Chhachhar et al. (2013,2014), Khan et al. (2019), Lokeswari (2016), Mittal and Mehar (2012), Naveed and Anwar (2013), Stryjak and James (2016), and Waqar et al. (2018) have been conducted in Pakistan covering different aspects of ICT. This work has limitations that will be addressed in this research. For example, the most recent study by Khan et al. (2019) identify the use of farmers’ mobile phone-based Farm Advisory Services (FAS) and associated factors with their adoption in the rural areas of the district Faisalabad, Punjab, Pakistan. They analysed the data (240 farmers) using logistic regression by taking farmers’ age, farmers’ educational level, mobile phone use skills, mobile possession time, the number of mobile phones in a family, and contact with extension agents, as determinants of use of farmers’ mobile phone-based FAS. Similarly, Waqar et al. (2018)

while working on the mapping of ICT usage along the citrus value chain, identify information on the channels being used, factors influencing ICT usage, challenges, and weaknesses faced by value chain stakeholders. Ashraf et al. (2015), in their research work, studied the relationship between socio-economic characteristics and the awareness and adoption of citrus recommended production practices with descriptive analysis.

Previous research conducted on ICT' role and contribution to agriculture has ignored some of the challenging aspects of ICT in agriculture. This research includes a comparative analysis of the uptake of ICT and its application to agriculture by small- and large- holder farmers as determined by their varying financial capacity and opportunities. There is no study analysing the shifting of farmers from traditional information sources to innovative ones using ICT. In addition, this research examines the role and impact of ICT usage in agricultural enterprises based on the empirical evidence. The published literature is mainly based on the perceptions of ICT's possible contribution to agriculture. Previous studies have also ignored citrus crops, except Waqar et al. (2018), but this study lacks a comprehensive analysis of the socio-economic impact of ICT. Citrus is among the significant horticultural crops of Pakistan, contributing to foreign exchange earnings. Also, earlier studies have only used descriptive statistics, with the exception of Khan et al. (2019) who applied logistic regression. This current research uses different analytical techniques to investigate the role and contribution of ICT in improving livelihoods such as ordinary least square (OLS), logistic regression, Poisson regression, and factor analysis, to produce robust research conclusions which devise strategies to enhance the effectiveness of ICT. Secondly, this study also carries out efficiency analysis of the impact ICT usage has on citrus and livestock productivity in the area. This study quantifies the impact of ICT on productivity and revenue and makes suggestions for future research (Mittal et al., 2010; Ogbeide & Ele, 2015; Ogutu et al., 2014).

In an attempt to fill these gaps, there are three objectives for this study: (1) to investigate factors optimising and limiting the awareness, adoption, and patterns of ICT use in farm business by small- and large- holder citrus farmers in the Punjab, Pakistan; (2) to examine the contribution of ICT use makes to small- and large- holder citrus farmers in agriculture; and (3) to explore small- and large- holder citrus farmers' perceptions of the value and impact of ICT on their farming practices. This study also intends to gauge the potential and importance of ICT for citrus producers with a specific focus on the smallholders. It provides an in-depth understanding of ICT capabilities and issues enabling policymakers to develop effective strategies for the dissemination and access of information and integrated production and marketing planning.

To summarise, ICT has transformed the agriculture sector. Farmers use advisory services through different platforms to receive timely and reliable information on weather, modern agricultural techniques, and market prices. It is expected that ICT may persuade the economic, social, and cultural values along-with productivity increases in Pakistan. Regardless of its role in improving the livelihoods of rural people, researchers still need to work on the role of ICT in agriculture and draw inferences based on empirical evidence. This study attempts to fill the existing gap in the literature on the impact of ICT on farmers' livelihoods.

2.3 Chapter Summary

The background section describes the importance of agriculture generally, and citrus in particular, to the economy of Pakistan. The productivity and contribution that agriculture makes to the country's GDP does not fulfil its potential (Chikaire, 2016; Kumar & Ratnakar, 2016; Matto, 2018; Ogbeide & Ele, 2015; Ogutu et al., 2014; Steinfield & Wyche, 2013; Stryjak & James, 2016). Every agricultural commodity, such as citrus and livestock management as second major enterprise of citrus farming households, requires the work of many stakeholders. The innovative knowledge base is the solution to enhance productivity at the level of the farmers and to improve the efficiency of other value chain stakeholders (Baruah & Mohan, 2018; Fawole & Olajide, 2012; Kumar & Ratnakar, 2011; Mittal, 2012; Mittal & Mehar, 2012). It emphasizes the significance of fast information exchange among the stakeholders, farmers being the leading contributor (Baruah & Mohan, 2018). The recent rapid adoption and diffusion of modern ICT gadgets provides a promising opportunity to fill the information gaps (Adegbidi et al., 2012; Lwoga & Sangeda, 2019; Mittal, 2012; Silva et al., 2011; Stryjak & James, 2016). Adoption and diffusion of ICT also paves the way for the transition from the traditional agricultural approaches to innovative commercial agriculture (Anoop et al., 2015; Ashraf et al., 2015; Chavula 2014; Khan et al., 2019; Mahant et al., 2012; Maqsood, 2015; Raksha & Meera, 2015; Waqar et al., 2018). This transformation may bring improvement in the livelihood of the rural masses, especially the smallholder farmers (Jimma, 2017; Kante et al., 2012; Lastra-Gil, 2018; Thapa & Sæbø, 2014; Tirkaso & Hess, 2015; Wiggins, 2014; Wijekoon & Rizwan, 2011). The potential for, but also the constraints to, this transformation provides the justification and necessity of this research.

Aderbigbe (2014), Bello and Oosterlaken (2014), Irawan (2014), Kozma (2005), Needle (2010) Palvia et al. (2018), Waqar et al. (2018), and Zaremohzzabich et al. (2014) recognize the essential aspects related to the role of ICT and its contribution to development generally, specifically the agricultural development for smallholders. Information and knowledge are the key elements needed to shape and progress the development process (Armstrong et al., 2011; Gummagolmath & Sharma, 2011; Heeks, 2010; Lwasa et al., 2011; Lwoga & Sangeda, 2019). Different communication methods have evolved in accordance with the available resources and the need to channel information acquisition and dissemination (Chhachhar et al., 2013; Driouchi, 2006; Mittal et al., 2009; Mwakaje, 2010). The researchers Baliamoune-Lutz (2003), Jimma (2017), Mahant et al. (2012), and Walsham (2017) identify the significant contribution that ICT makes to enhance the pace of agricultural development. The benefits of attainment vary among different segments of the farming community. The variety of socioeconomic characteristics determines the awareness, adoption, and usage of ICT, especially the modern ones (mobile, computer, internet) among the farming community (Macire et al., 2016; Silva et al., 2011). The reviewed literature recognizes the progressive role of ICT in the current environment and its perceived future roles in livelihood improvement of the farming community (Adegbidi et al.,2012; Wijekoon & Rizwan, 2011). Many authors, including El Bilali and Allahyari (2018), FAO (2017), Khan et al. (2019), Kolshus et al. (2015), and Macire et al. (2016) also identify ICT insignificant contribution in enhancing knowledge, development and livelihood of farmers due to lack of capacity in aligned contributing factors. The obstacles faced by farmers are mainly linked to poor resource bases which limit the effectiveness of ICT (Mittal et al., 2010; Stryjak & James, 2016). The researchers Fawole and Olajide (2012), Mittal et al. (2010), Ogbeide and Ele (2015), Ogutu et al. (2014), and Waqar et al. (2018) found that empirical work lacks the means to gauge the social and economic impact of ICT usage in agriculture. This chapter attempted to cover all possible ICT-related aspects such as awareness, adoption, usage in agriculture, the social and economic impacts, and to make implementable suggestions for policymakers and other relevant research & development organizations which could ultimately benefit farmers, especially the smallholders. Having explored the literature to establish the need for this research the following chapter, will explain the theoretical and conceptual framework of this research study.

Chapter Three: Research Framework

This chapter describes the theoretical and conceptual framework of this research. Theoretical and conceptual frameworks drive research paths and provide the basis for making research meaningful, acceptable, and for establishing its credibility (Adom et al., 2016). Both frameworks are the lifeline of research (Imenda, 2014). The theoretical and conceptual frameworks assist the reader in understanding the rationale and reasoning of the research theme, developed by a researcher (Evans, 2007).

The first section outlines the theoretical aspect and is based on the comparison of technology adoption and diffusion theories, including a detailed description of the theoretical background best suited to this study. The second part of this section illustrates the conceptual framework.

3.1 Theoretical Background:

The theoretical framework makes research outcomes profound and generalizable (Akintoye, 2015). It directs the researcher in their search for suitable literature and provides structure to intellectual discussions of research outcomes (Imenda,2014). The theoretical framework extends the crux of the research study (Maxwell, 2012; Simon & Goes, 2011) and helps researchers to contextualize their research (Ravitch & Carl, 2019).

There are various theories of relevance to technology adoption and diffusion. Some researchers interchangeably use adoption and diffusion terms (LaRose et al., 2007). Hall and Khan (2003) introduced a new approach to hypothesize innovation attributes other than innovation characteristics to emphasize the adopter's role. In the existing dynamic environment, technological emergence and change in relevance of effectiveness prevail for shorter periods and vary, depending on previous diffusion research. The approach to the adoption of technology for the first time or rejection decision of technology also varies in this new, continually transforming technological era.

Some theories emphasize the adoption of technology by end-users, whereas, others emphasize the diffusion aspect (Grzeslo, 2018). However, those technologies with a decent impact diffuse faster through the society.

3.1.1 Discussion of Different Theories in this Research Perspective

This section clarifies a suitable theoretical path for this dissertation. The technology acceptance model (TAM) was proposed by Davis in 1989 and is considered a version of Ajzen's (1985) theory of reasoned action (TRA). This theory asserts that any thought of doing something is based on the plan or intention to do. TAM suggests that 'perceived ease and use '(PEU) and 'perceived usefulness' (PU) both develop behavioural intention (Sousa et al., 2016). These two constructs of perceived usefulness and perceived ease and use make end-user confidence and attitude for accepting of the technology. TAM specifies that PEU and PU of technology have an impact on adoption (Davis, 1989).

Davis (1989) conducted many experiments for TAM validity. He came up with the conclusion that PU was associated with self-predicted future usage and self-reported current usage. Perceived ease of use (PEOU) also had a strong relationship with current and future use.

Ma and Liu (2004) analyzed the associations between PEOU-PU and PU-technology acceptance (TA) and found them to be high. The association between PEOU and TA does not pass the fail-safe test due to the weak relationship. TAM has been applied in ICT related studies, for example, to the adoption of broadband (Irani et al., 2009; Nayak et al., 2010). Schepers and Wetzels (2007) described the extensive use of TAM in young adult studies, specifically of developed countries. TAM mainly depends on the quantitative method, Likert scale type items to build the model. Researches use TAM in qualitative methods within a specific context, but it is mainly based on quantitative approaches (Kwee-Meier et al., 2016).

Venkatesh et al. (2003) extended TAM and developed the unified theory of acceptance and use of technology (UTAUT). UTAUT classifies four main factors, namely, effort expectancy, performance expectancy, facilitating conditions, and social influence, and the variables like gender, experience, and age impact the outcome variable (Venkatesh et al., 2016). Venkatesh et al. (2012) suggested and tested UTAUT2, incorporating new constructs like price value, motivation, and habit that emphasize theoretical aspects. The propagation and diffusion of new information technologies like the mobile phone, internet for consumers set the constant increase of UTAUT-based research (Thong et al., 2011; Venkatesh et al., 2012).

Zhou et al. (2010) used UTAUT in China to study mobile banking and resolved that UTAUT, TAM, and other relevant adoption theories are inadequate as an individual entity. Multiple theories might be applied depending on the technology type and specific task.

Parasuraman (2000) established the technology readiness index (TRI) measuring scale to assess the readiness level for technology use. The author acknowledges Davis et al. (1989) as the inspiration for TRI. TRI emphasizes the disposition aspect of technology uses rather than the competence in technology use (Parasuraman & Colby, 2001). Berger (2009) advocates that TRI is the extended version of TAM. Nevertheless, TRI explains four technology user groups based on their character traits: innovativeness, optimism, insecurity, and discomfort (Esen & Erdoğmuş, 2014). Parasuraman and Colby (2015) recently updated the TRI with five new individual characteristics: *Sceptics* have a divided opinion of technology. *Explorers* see the great inspiration for technology use. *Avoiders* have less motivation and more hesitation. *Pioneers* make both positive and negative opinions keeping in view the technology type and lack in innovativeness. *Hesitators* have low level of creativity.

Rogers gave deep philosophical thought to innovation diffusion (Somers & Stapleton, 2012). In 1962, Rogers developed the theory of diffusion of innovation (DOI) after combining the work of some renowned innovation diffusion scientists, such as Tarde (1903), Ryan and Gross (1943), and Katz (1956). Diffusion of innovation (DOI) theory perceives why and how the adoption of technological innovations occur (Freeman & Mubich, 2017). DOI is a social process in which communication of information about new ideas occurs. New idea, object or practice has time, mode and specific channels for adoption by institutions or persons (Rogers, 1983). Rogers and Scott (1999) defined diffusion as a procedure in which innovation is communicated via specific networks, among people of a social system, over time. Four aspects arise from this description: innovation, time, communication, channel, and social system. These aspects are explained below to give the reader a better understanding of DOI theory.

Rogers (2003) describes *innovation* as an idea, product, or practice considered as new by people of the social system. There are certain characteristics comprised of relative advantage, complexity, compatibility, trialability, and observability to regulate the adoption of any innovation (Rogers & Scott, 1997). Relative advantage is the superiority or advantageous over present product or practice. This advantageous aspect accelerates the adoption rate (Rogers & Scott, 1997). Compatibility of innovation emphasizes existing values, previous experiences, and addresses the needs of adopters, there being more compatibility of innovation with the system, more possibility of faster adoption (Rogers & Scott, 1997). Complexity addresses the difficult comprehension of innovation. More uncomplicated innovations attain more adoption rather than the complex ones that need more knowledge and required skills for understanding (Rogers & Scott, 1997). Trialability is the experimentation of innovation with limitation consideration. Adjusting well with the limitations increases the possibility of innovation adoption at a faster rate (Rogers and Scott, 1997). The observability aspect describes the visibility of innovation. More visible innovation has more prospects for adoption (Rogers and Scott, 1997).

The second key component of DOI is the communication channel. According to Rogers (2003), in the communication process, information is shared with other members of the social system using specific means to get knowledge of innovation. Innovative information is disseminated for its introduction, developing an attitude to support and effect innovation evolution (Rogers and Scott, 1997). Interpersonal communication and mass media are communication sources. Interpersonal communication is the way of sharing information among the masses of the system, and mass media involves both electronic and print media (Rogers, 2003).

The third vital element of DOI recognised by Rogers and Scott (1999) is time. This element is overlooked in behavioural research, and the addition of time enhances the strength of diffusion research (Rogers, 2003). It places emphasis on three dimensions, the individual's innovativeness, decision making, and adoption rate (Rogers, 1995). Considering the individual's innovativeness, Rogers and Scott (1997) suggested five groups of people: the innovators, early adopters, early majority, late majority, and laggards.

The fourth essential element of DOI is the *Social System* described as 'a set of interrelated units such as individuals, groups, organizations, subsystems, that are engaged in joint problem-solving to accomplish a common goal' (Rogers & Scott, 1997). Every social system has norms, leaders, and individuals as change agents, which affect the diffusion process (Majanja and Kiplang'at, 2005). The norms, social values, and social coherence among the members of the social system get important consideration in innovation acceptance within the society.

3.1.2 Application of Diffusion of Innovation Theory to ICT Research

Diffusion research examines the interaction of key diffusion elements and other factors to enable or obstruct the adoption of innovation among a particular group of people (Surry &

Farquhar, 1997). Professionals have used DOI theory across many disciplines, including agriculture and marketing, to intensify the adoption of practice or product (Majanja & Kiplang'at, 2005). DOI theory may be relevant for use as a theoretical basis for the ideas and techniques related to information technology (Clarke, 1999). Larsen (2001) says that the DOI theory is best for the diffusion of information science and technology. There is the widespread use of DOI theory in the documentation of the agricultural innovations' diffusion process (Sunding & Ziberman, 2001; Rogers & Scott,1999) This theory provides the option for documenting factors that affect the adoption performance of adopters and non-adopters (Lewis, 1997; Ojiambo, 1989). In this research, this theory provides guidance for examining the factors involved in the adoption and usage of ICT among the farming community. A critical aspect of DOI theory is addressing the innovation characteristics in diffusion explanation, including the costs and benefits of innovation, testing ability, individual's awareness, competency and compatibility with the existing socio-economic and environmental systems (Elia et al., 2014).

The introduction of the majority of innovations rests on the reasons behind addressing some problems. Identification of the problem arises first, and then particular innovations come into place as a means to handling the issue (Majanja & Kiplang'at, 2005). The role and impact of the ICT under investigation in this research were not developed as innovation to cope with innovative or latest information acquisition for the farming community, especially smallholder farmers, one of the essential existing structural problems of the developing countries agriculture. These ICT were developed with general communication in mind, but subsequently proved to be innovative ways of addressing this crucial problem for farming communities in the developing world. As in Pakistan, the poor performance of the agricultural extension and marketing departments made way for innovative uses of ICT to deal with the timely and accurate dissemination of information for the farming community. Without innovative information acquisition, there is low productivity in the agricultural sector.

This research intends to document the diffusion process of ICT (innovation) with respect to four main aspects of DOI theory:

a) ICT as Innovation:

In the past, the small number of farmers obtained their agricultural information from one-way communication via radio and TV, with occasional personal visits from agricultural experts. In the more recent past, innovative ways of communication have been adopted such as ICT, including mobile phones, computers, and the internet which have given access to email, websites, Facebook, and other social media applications. Rogers' theory describes innovation of specific attributes that affect the adoption rate (Cullen, 2001).

i) Relative advantage and compatibility among the farming community

This research compares the acquisition of information in the past and the present. This research clarifies whether the introduction and use of ICT are more advantageous than the conventional methods of communication. This study determines if the compatibility aspect, either existing resources or skills of the farming community are enough for adoption and usage of ICT for agricultural purposes. As Rogers and Scott (1998) describe, the adoption rate of innovation is higher if it has a more significant relative advantage.

ii) Complexity of ICT

The farming community in developing countries has a variable level of education, from none to higher education and skills. Education of the individual plays a vital role in the adoption of technology-related innovations (Riddell & Song, 2017). This research explores farming community views about the complexity of some ICT. It seeks to determine if the farming communities are comfortable with its adoption and usage and if they have enough skills and knowledge. This study helps to identify farmers' needs and determine whether they face difficulties in adoption and usage. Easy to understand technologies are more readily adopted than more complex ones, for example standard mobiles are adopted faster among societies than the smartphone, putting aside the financial aspect.

iii) Trialability and observability

Considering the farmers' lack of education, knowledge, and skills, it is not easy for many of them to become familiar with and use ICT such as the smartphone, computer, internet, and some social media applications. Generally, the farming communities in developing countries have the attitude of 'seeing is believing' in the adoption of agricultural innovations. Fellow farmers or friends have been the primary sources in the adoption of innovations related to agriculture. Such is the case in ICT, as previous research explains. This research considers this aspect.

iv) Risk and uncertainty

The financial capacity of the farming community is a determining factor in the adoption of innovation, such as ICT. Development of human capacity and the effectiveness of sustainable technology demand reasonable capital investment in ICT innovations (O'Farrell & Norrish, 1999). In the past, inadequate finance has been the hurdle in the expansion of ICT and modernizing the agricultural sector (Kiplang' at & Ocholla, 2004). The majority of the farmers are smallholders. ICT affordability for farming community is an important aspect for consideration in this ICT related research.

b) Communication Channels:

Two aspects require important consideration when discussing communication channels. One aspect is to think of ICT adoption as a product. The personal interaction with other people and ICT like TV and radio contribute to the adoption rate of ICT as a product. The second aspect is the role ICT plays as the communication source for transfer of innovative technologies. As a product, the use of ICT is acknowledged for social,, as well as business purposes. Thus, patterns of use are worthy of consideration in this research. The role of communication channels is somewhat different based on use from a social or business perspective.

The adoption of ICT as a product used for social interactions requires different communication channels for their adoption compared to ICT used for agricultural business. When the product is to be used for social purposes, even those with a low skill level contribute to enhancing the adoption rate of ICT; whereas, when the product is to be used for agricultural purposes, it requires more knowledge to acquire the latest information. For the poorly educated and less knowledgeable farming community, the adoption and diffusion of ICT requires farm friendly communication methods including language, visual content, among others and specific training in the use of the smartphone, internet, and the like. This study considers the communication channels required for the adoption and usage of ICT.

c) Time:

Time is relatively more important to ICT innovation in agriculture than other agricultural innovations. To make the best use of ICT in agriculture requires more skills at the individual level. ICT innovation needs reasonable time and timing to increase the adoption rate. Farmers with a poor resource base in education, knowledge of technologies, and finance take more time to adopt information technology-related innovations. Higher literacy levels among farmers increases the adoption rate of these types of innovation. It also takes time to attain the requisite skills and trust to adopt ICT. To gauge the impact of innovative ICT adoption and the best possible usage, removing the uncertainty and reversibility aspect requires proper time and careful planning. This study investigates the aspects that make up the categories of innovators concerning time and ICT adoption.

d) Social System:

The social system requires important consideration with respect to innovation adoption, especially from the farming community perspective. Farming community living at place exhibits a true definition of the social system ‘A social system is an interdependent set of cultural and structural elements that can be thought of as a unit’(Crossman, 2018). Farming communities with the same culture are interdependent because of their meagre resources in all livelihood capitals' perspective. Farmers have strong relationships among themselves. They are well connected socially, as well as, from the agricultural business point of view. Previous research reveals that fellow farmers have been the main source of any innovative information because of many same characteristics. Calvo and Rahring (1997) consider that population characteristics and innovation characteristics should be carefully examined before making innovations in the social system. The failure of technology consistent with social systems cannot be diffused in society (Freeman & Mubich, 2017). This research examines the social system factors affecting the adoption and usage of ICT.

To summarise, the above discussion comparing the relevant theories informs the reader that concepts of TAM, TRI, and Rogers’ (2003) DOI theory are similar. Although TAM developed by Davis and DOI developed by Rogers, have been used in different fields, both theories have similarities (Lokeswari, 2016). The main reason for the DOI framework is the provision of detailed insight into ICT innovation complexities and ways of exploring the relationship and communication between players in ICT adoption. TAM emphasises several attitudes that can affect ICT usage (Aleke et al., 2011).

Based on the discussion and broad scope of this research, including adoption, usage, and perceived benefits of ICT, and using a mixed-method approach, DOI and TAM both provide a sound theoretical base for this dissertation. The DOI and TAM deliver comprehensive coverage of all due aspects and their application in agricultural innovations and information technology.

Figure 3.1 reflects the essential attributes of both DOI and TAM required for adopting innovative technologies as ICT.

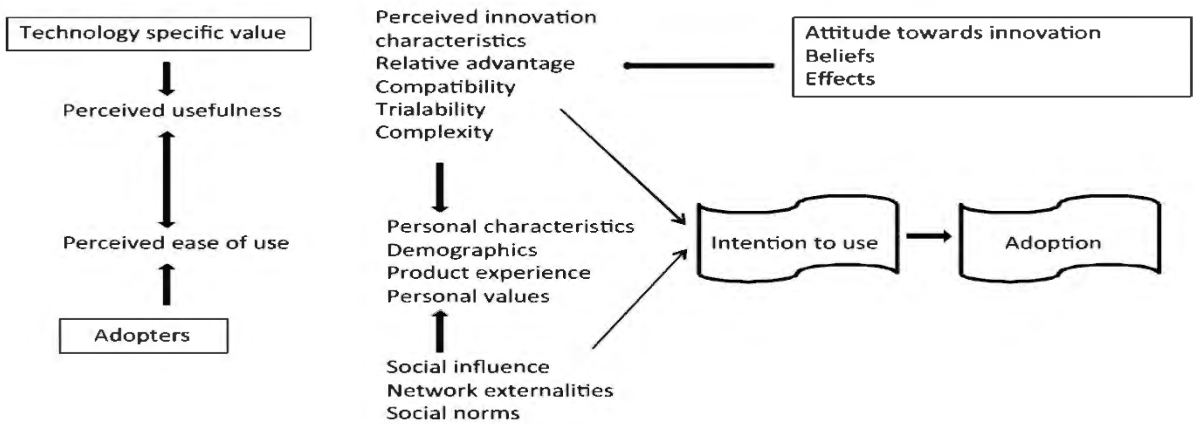


Figure 3. 1: DOI and TAM Integrated Model
Source: Adapted from Aleke et al. (2011)

DOI describes the attitude and belief of innovation effects to perceive innovation characteristics. The perceived innovation characteristics, including the relative advantage, compatibility, trialability, and knowing the technology's complexity, act together with the farmers' personal characteristics, demographics, and product experience, intent to use technology, resulting in the adoption. The social influence and social norms, with locality demographics and personal characteristics, also contribute to the developing innovation's adoption and use. The conjunction of DOI & TAM's attributes of perceived usefulness and perceived ease of use make consideration in adopting innovative technologies.

3.2 Conceptual Framework

The conceptual framework provides a brief explanation of the research idea's rationale, plan, and process for conducting a study. Maxwell (2013, p. 39) opined that 'it is primarily a conception or model of what is out there that you plan to study, and of what is going on with these findings and why.' This framework facilitates researchers to specify and explain the research idea within the study problem (Luse et al., 2012). It supports the researcher in building a viewpoint on the research idea to be probed, and it is organized in a logical way to link-up ideas as a visual display or pictorial exhibition (Osanloo & Grant, 2014).

The framework describes the citrus industry, including all value chain stakeholders from the information acquisition/knowledge viewpoint. This research focuses on the farmer, especially the smallholder farmer, as a leading player in the agricultural value chain. The conceptual framework is introduced into the adoption of ICT and uses the perspective of farming activities, mainly citrus production.

3.2.1 Information Flow and Knowledge Exchange across the Citrus Value Chain

Success in farming requires obtaining the right information (about new markets, policy, and production techniques) and evaluating, processing, and using this information in a better way. The means of information acquisition and exchange have been changing over time with the advancements in information communication technologies. Famers have been dependent for a long time on interpersonal communication either from fellow farmers or the relevant agricultural experts.

An explanation of the adoption process and role of adopted ICT in the acquisition of the latest information, across the citrus value chain, in the farming community is required. Figure 3.2 illustrates that every stakeholder connects to others across the citrus value chain, and information is exchanged among all the stakeholders to different degrees. The value addition of citrus produce occurs with varying contributions at different value chain stages, either with the movement of citrus produce or the value adding processes, from the production stage to the value chain process's consumption stage. The amount paid by the domestic consumer in PKR, or dollars by the international consumers of citrus produce, flows back from consumers to all stakeholders and is distributed according to their contribution to the whole value chain process. Farmers, like any producer, have a pivotal position.

Figure 3.3 explains the research focus on farmers' information acquisition processes with all stakeholders of the citrus value chain. This research is not focused on evaluating the whole citrus value chain but assesses the perception of some other key stakeholders about the farmers' information acquisition process and gains with modern ICT inflow. Access to reliable information has a significant role in the way people perform their daily activities, and agriculture is not the exception.

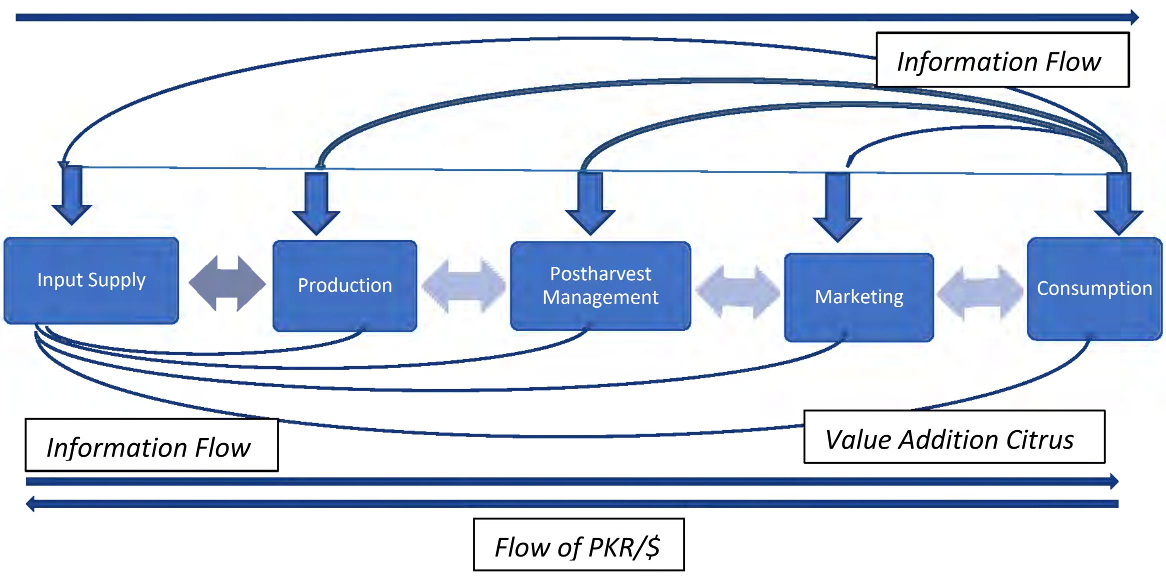


Figure 3. 2: General Information Flow and Knowledge Exchange Across Citrus Value Chain
Input Supply: Extension (latest knowledge), Research (knowledge, quality plants), Inputs/Service providers, Training Institutes, Private companies, Banks/financing agencies etc.
Producers : Small and Large holder Farmers
Postharvest : Farmers, Pre-harvest Contractors, Processors, Transporters, Packaging, Storage etc.
Marketing : Exporters, Commission Agent, Wholesalers, Retailers, Others
Consumption: Consumers
Source: Adapted from CARDI (2014)

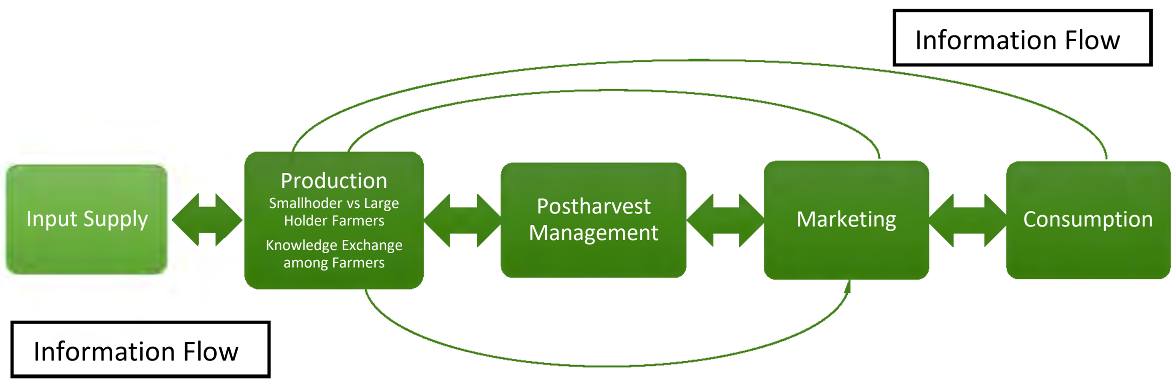


Figure 3. 3: Research Focus- Information Flow and Knowledge Exchange
Input Supply: Extension (latest knowledge), Research (knowledge, quality plants), Inputs/Service providers, Training Institutes, Private companies, Banks/financing agencies etc.
Producers : Small and Large holder Farmers
Postharvest : Farmers, Pre-harvest Contractors, Processors, Transporters
Marketing : Exporters, Commission Agent,
Source: Adapted from CARDI (2014)

In the current arena, farmers are working in the influx of information. Several studies have shown that ICT can better harness the benefits. Recent developments in ICT availability in developing countries, including Pakistan, provides the opportunity to document ICT adoption and contribution at the farming community level. Farming communities in Pakistan have scarce livelihood capital. They always struggle to earn a livelihood because the majority are smallholder farmers. Livelihood capital plays an important role in innovation adoption. According to the nature of innovation or a combination of other livelihood capital, it could be social capital, financial capital, human capital, physical capital, or natural capital alone.

Previous studies reveal that large holder farmers have been the early adopters of the agricultural innovations because they have more livelihood capitals and are able to get innovative information from relevant institutions due to biases in the system. Smallholder farmers are late adopters of the agricultural innovations due to their weak livelihood capital base.

The conceptual model in Fig.3.4 for this research is framed with the above argument from a livelihood perspective. A set of ICT including radio, TV, fixed-line phone, normal mobile, smartphone, computer, and the internet are included. Modern ICT is grouped as including normal mobile, smartphone, computer, and using the internet for different purposes. The adoption and usage of ICT varies among the farmers from none, to some, to all the ICT. Farmers adopt ICT for agriculture purposes, or they use it more for social or entertainment purposes.

This research hypothesizes that livelihood assets (consisting of human capital, social capital, financial capital, physical capital, and natural capital) contribute to the adoption and usage of ICT for agricultural purposes. This is shown in Figure 3.4 (box 1) and represented by the dark green to light green. The dark green colour indicates that large holder farmers usually have a rich livelihood capital base, and light green colour represents smallholder farmers with a poor livelihood capital base. The probability of adoption and usage of ICT depends on the ICT itself and the characteristics of livelihood capital. The features of different capitals or resource base vary among the farming community. Numerous factors contribute to enhancing agricultural enterprise productivity. The latest innovative information is one of the key contributing factors.

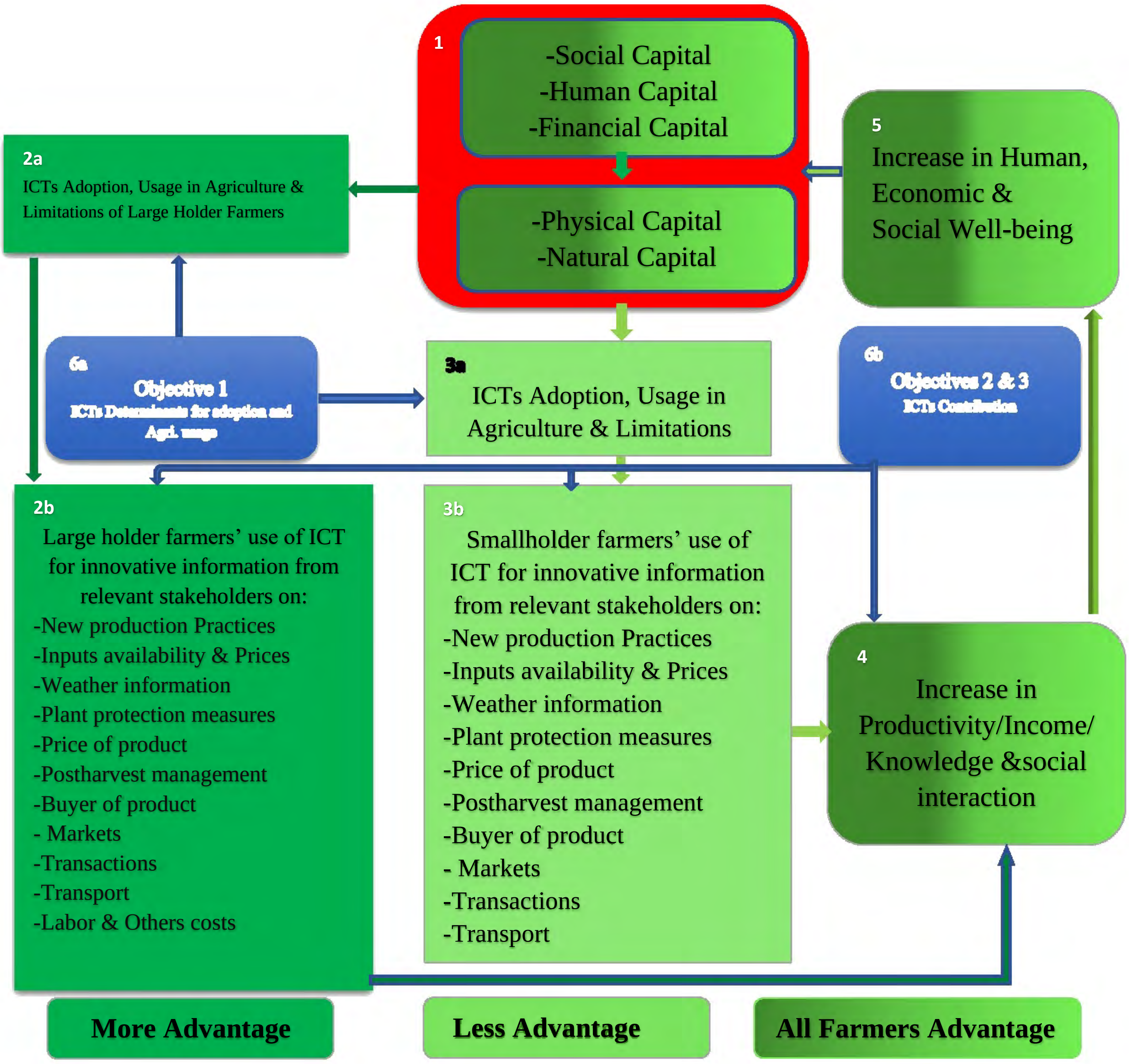


Figure 3. 4: Conceptual Model of Research
Source: Developed by Author

Farmers need information on several production and marketing aspects from different stakeholders to run their business efficiently. The existing farm extension and marketing system lacks innovative information needed across all farmer categories.

Large holder farmers' rich livelihood capital base and literature support provides the justification of more adoption and usage of ICT for agricultural purposes (box 2a). The other way around is for smallholder farmers with less possibility of adopting ICT and using it for agricultural purposes to get innovative information (box 3a). The limiting factors in adoption of innovations are more pertinent to smallholders than large holder farmers, possibly, in the case of ICT adoption and usage in agriculture.

Greater adoption and usage of ICT for agricultural purposes, especially the modern ones for acquiring innovative and latest information, can improve farmers' livelihood. Generally, it emerges that large holder farmers are advantaged with higher adoption rates and usage for agricultural purposes (box 2b) in comparison to smallholder farmers (box 3b) in consequence to previous research on the adoption of agricultural innovative information/technologies among the farming community. This research assumes that ICT affordability and services that are accessible to smallholder farmers to some extent could help to minimise the disadvantage of ICT adoption and use in obtaining innovative information compared to the current agricultural extension and marketing system.

The adoption and usage of ICT for agriculture could enhance the productivity/income, knowledge, and social gains (box 4) of the farming community with less discrimination between the small- and large- holder farmers. It increases the human, economic and social wellbeing (box 5), results in the accumulation of social, human, and financial capital, followed by the enhancement of physical and natural capital (box 1).

The objective of this research is to explore determinants of ICT adoption, its use in agriculture, and its limitations (box 6a). The conceptual goal of this research and that explored by objectives 2 and 3 is the real and perceived contribution to improving the livelihood of farmers, comparing the smallholder and large holders with due focus on smallholder farmers (box 6b).

This chapter has established the conceptual and theoretical frameworks underpinning the research. The following chapter will explicate the research methodology and methods.

Chapter Four: Research Methodology

This chapter describes the research process in detail, including the research questions, research design, and a description of the procedure to address research objectives appropriately; another part provides a critical reflection of the methods used for data collection in the study. Details of participants, sampling processes, recruitment procedures, surveys/interview setting, and the content of focus group discussions (FGDs) are outlined. The empirical models used in the study are explained following the data collection methods. Together, the sections describe how the research was initially constructed, how adjustments were made, and why they were necessary during the implementation phase. Further, the hypothesis and ethical considerations are discussed.

4.0 Research Methodology and Methods

Research is the process of investigating the available information and discovering knowledge that could benefit any aspect of society. This process is also known as scientific research, which has evolved over the centuries (Blaxter, 2010). In scientific research, to get an appropriate output and quality results, we use a systematic, explicit, feasible, and disciplined method, which is known as research methodology (Goddard & Melville, 2004; Kothari, 2004). The research methodology is a specific approach to classify, collect, and evaluate information about a research topic. It considers the types of processes used in attaining the objective (Howell, 2013). There are different aspects of research methodology for different domains of research, i.e., research methodology for social sciences and information technology (Punch, 2013). Similarly, if we look into qualitative research, the scholars extract all the insights and fetch only those results which are feasible and concern the scenario and situation categorized as ethical (Farrimond, 2012), quantitative (Balnaves & Caputi,2001), and qualitative research methodology (Black,1999; Flick,2018). The methodology is the overall plan that outlines the means to conduct a research project and finds suitable methods to be part of the research process. Methods defined in the methodology explain how to collect data and results computation (Igwenagu, 2016). The explanation of how results are estimated denotes the method, not the description of the methodology (Katsicas, 2009).

4.1 Research Questions

To achieve its objectives, the study proposed the following research questions. This section intends to make an explicit link between objectives and research questions.

The research questions addressing objective 1 will include:

1.1 What are the basic socio-economic characteristics of respondents?

1.2 What are the key underlying factors affecting competence in use, importance in agriculture, and level of use of various types of ICT?

1.3 What are the significant determinants of ICT awareness, adoption, and usage by small- and large- holder citrus farmers?

1.4 What are the limiting factors on the use by small- and large- holder farmers of ICT for agriculture?

The research questions addressing objective 2 will include:

2.1 How does the use of ICT by small- and large- holder farmers affect the acquisition of information, cost and time involved in getting information?

2.2 What has been the effect of ICT on the small- and large- holder citrus farmers in innovative information acquisition and the adoption of new technologies on farming practices?

The research questions addressing objective 3 will include:

3.1 What are the perceived benefits to small- and large- holder farmers using ICT?

The research questions addressing objectives 1, 2 and 3 will include:

- What does the existing literature have to say about the role and prospects on the use of ICT by small- and large- holder farmers in developing countries?
- Based on this analysis, what are the implications of the current research described here, and directions for further research?

4.2 Research Design

Research design is of pivotal importance in any research activity. Identification of methods and techniques are necessary to draw meaningful results and they describe how to address the research questions. Silverman (2010) explains that the choice of research design is based on what a researcher is aiming to investigate. The research design also clarifies the nature and background of research that is taking place. According to Cohen et al. (2007), the research design is based on a theory with some assumptions. While Crotty (1998) explains research design in terms of i) proposed methods, ii) choice and use of methods, ii) theoretical perspective behind the methodology, and iv) the knowledge of theory that apprises theoretical perspective. However, no single technique or assessment is regarded as the best method (Holloway & Wheeler, 1996). Creswell (2003), Gay et al. (2013), and Turner et al. (2015) among other researchers, conclude in their findings that all research techniques have some limitations. They further argue that intrinsic prejudices of a single procedure may create concerns over validity, reliability, generalization, and hence on the quality of research. Therefore, a realistic model composed of mixed methods is an alternative and practical approach to addressing the research questions in social sciences (Patton, 2002; Tashakorri & Teddlie, 2010). This pragmatic approach is recognized as the leading methodological approach in social sciences. It enhances the research validity (Gay et al., 2013).

The mixed-methods approach describes the use of quantitative and qualitative techniques in a single study (Ågerfalk, 2013). A mixed-method approach examines various viewpoints and perspectives from different angles and outlines the incorporation of both quantitative and qualitative perspectives in a one study (Johnson & Christensen, 2004; Kangai, 2012; Turner et al., 2015). The interaction of quantitative and qualitative data has an added benefit, apart from allowing the researcher to respond to complicated research queries, but allows them to develop more profound intuition and interpretation of the research questions with confidence, otherwise not possible (Creswell, 2003; Gay et al., 2013; Leeuw & Vaessen, 2009; Onweuegbuzie & Leech, 2004; Yin 2009).

The mixed-methods approach gives the provision to explore the research idea in detail, but it has some critics. According to Teddlie and Tashakkori (2009), the quantitative and qualitative procedures follow distinctive epistemological paradigms, making it unsuitable to combine them, and giving more prominence to quantitative methods than qualitative methods. Managing and giving an insight of two approaches is challenging for the researchers to combine in analyse

(Johnson & Onwuegbuzie, 2004) and questioned the scale of mixed methods approach for researchers to analyse, interpret results in complementing quantitative and qualitative data, furthermore, the ability of researchers to study about multiple methods to make their use appropriately for the effective outcome (Bryman,2007). In brief, both the quantitative and qualitative methods shift the balance on a research scale, with more weight on quantitative and less on qualitative or with more weight on qualitative and less weight on quantitative (Johnson & Christensen, 2019).

In this study, qualitative data obtained during formal and informal discussions with farmers are used to substantiate the discussion part of the research for further clarity and confirmation of findings without disrupting results from quantitative methods. The qualitative method of data collection was used to collect information from relevant citrus value chain stakeholders from the farmers' perspective, as well as to get insight into the research problem and meet the objectives.

4.3 Research Site

Punjab is the biggest province in Pakistan. This province has been the main contributor to agricultural GDP in the agricultural economy of Pakistan. This province consists of distinctive agroclimatic zones with varying surface and below surface resources that suit various crops and the production of livestock. Nearly 90 percent of farmers are smallholders with less than 5 hectares of land. They mainly rely on mixed cropping systems and manage appropriate livestock to earn and sustain their livelihoods. Some regions of this province are explicit in the cultivation of cereal or horticultural crops. Productivity from the cereal, horticultural, and livestock is below potential. Many structural problems exist, including but limited to, smallholdings, low financial positions of the farmers, lack of innovative information due to inefficient extension systems.

The growing importance of the horticulture sector due to the higher returns realized and employment opportunities provides inducement to research the horticulture sector in this research project. The district Sargodha was chosen from 36 districts of Punjab province to conduct this research. Farmers of this district mainly rely on citrus enterprises, followed by livestock production for their livelihoods. The district is the highest administrative level of local government, consisting of 3-8 tehsils and is located in the northeast of Pakistan. Sargodha city itself is located 206 kilometers from Lahore and 244 kilometers from Islamabad, the capital of Pakistan. The area of district Sargodha is 5864 square kilometres, with around 3.91 million people, more than 70 percent of whom are rural residents. This district consists of seven tehsils, namely, Sargodha itself, Bhera, Kot Momin, Bhalwal, Sahiwal, Shahpur, and Silanwali. Sargodha district is favourable and famous for agricultural production. In addition to the cultivation of wheat and sugarcane crops, it is considered as the largest and best citrus-producing district of Pakistan. Citrus (kinnow) is the best and most abundantly produced citrus type in the district. The purpose of selecting district Sargodha rested on two considerations. Firstly, an innovative and relatively crucial horticulture sector compared with conventional cereal crops, and secondly, citrus is one of the major exporting commodities for Pakistan.

4.4 Sample Selection and Size

A sample is a small representative part of the statistical population for studying properties to attain information about the population as a whole (Webster, 1985). Sampling is the procedure for selecting an appropriate sample to represent characteristics or attributes of the whole population (Igwenagu,2016; Mugo,2002). Sampling is considered an important component of research activity. It has a great impact on the research outcome. This study used a mixed-methods approach; hence, the probability and non-probability techniques were used for sample selection. For quantitative data probability and qualitative data, nonprobability procedures are used (Neuman,2003). In the research process, sampling is important to draw quality inferences constituted from the underlying outcome by the researcher (Onwuegbuzie, 2007). The sampling strategy is the key to drawing a representative sample successfully. Study objectives, population, degree of heterogeneity, and resources are important for develop a sampling strategy. Nevertheless, from the target population, the statistically illustrative and analytically controllable sample size has key importance (Sharif et al., 2005). A purposive stratified random sampling technique was adopted. Stratified random sampling increases the accuracy of the equal estimates in different regional segments if population concentration changes considerably within the region (Igwenagu, 2016). This study aims to evaluate the effectiveness of information communication technologies (ICTs) across the citrus value chain. Farmers are considered key players of any agriculture value chain. Therefore, farmers were the main sampling group. Additionally, to supplement and consolidate research findings, contractors, exporters, commission agents, transporters, and youth from the farming community have also been selected randomly for focus group discussions.

Different suitable techniques are available in the literature to determine representative sample size like Poate & Daplyn(1993) have developed the following formula to determine sample size:

$$n = \frac{(ZC)^2}{X}$$

where *Z* represents confidence level (90% in this case), *C* stands for the coefficient of variance (standard deviation/mean), and *X* symbolises accuracy (± 10%).

In the case of an unknown population, i.e., in the absence of information about population, then Cochran (1963), has determined the sample size using the following formula:

$$n_0 = \frac{Z^2 pq}{e^2}$$

Where: n_0 is the needed sample size, *Z* is a level of confidence, *p* is the estimated proportion of the attribute that is present in a population, q is 1-p, e is the margin of error. The margin of error and level of precision are inversely related. Lower the margin of error, higher will be the precision.

In developing countries like Pakistan, there always has been the problem of knowing the exact population due to lack of commitment of relevant administered individuals. In this research, the Cochran (1963) formula has been used due to the uncertainty around the exact population size. For each category of producers, the probability distribution of the sample is presented below using the above-described expression. Farmers from the four tehsils of district Sargodha including Sargodha tehsil, Bhalwal, Kot Momin, and Silanwali, were surveyed. The other stakeholders of the citrus value chain were selected randomly from these four tehsils to conduct focus group discussions.

4.5 Data Collection

Data implies the raw information in its original form without the researcher's interpretation (Räsänen & Nyce 2013). Data collection is the procedure to collect information on relevant variables in a systematic way to address research questions and test hypotheses (Kabir, 2016). This process demands the utmost attention to lessen possible bias when collecting information to answer research questions without compromising credibility and logic (Sapsford & Jupp, 2006). Data collection is considered to be a key research activity in social sciences (Shokane et al., 2018). As for every research field, data collection is at the heart of the research process, and precision in data collection enhances research efficacy (Parveen & Showkat, 2017).

A cross-sectional survey design was adopted for this research. This design is important within time limits and financial constraints. Before data collection, informal discussions were conducted with farmers and other stakeholders of the citrus value chain to get a clear and complete picture of the information communication technologies adopted and in use. The quantitative and qualitative data were collected due to the application of the mixed methods approach in this research. Data were collected with survey/interview and focus group discussion (FGDs) methods.

a) Survey

This study employs mainly data collection using a survey method with well-structured questionnaires for the citrus producers. The survey is the best data collection technique because it permits the gathering of data from sample respondents (Mooi & Sarstedt, 2011). A questionnaire was used as an instrument in a survey method of data collection. It comprises questions, scales, ranks, and statements relevant to the research phenomenon (Stake, 2010). It can be managed in many ways, like face to face, mail, online, or by telephone with respondents (Neuman, 2003). Questionnaires are effective modes of measuring opinions, intentions, and preferences of a large sample quickly and cheaply (McLeod, 2014).

The questionnaire was designed for citrus producers based on a rigorous review of the literature. Besides information on identification and site classification, the questionnaire contained information on respondent information, family composition and education level, farm and household assets, employment status of family members, and permanent hired farm labour, in order to obtain information about the general characteristics of the respondents. Information on farm characteristics, including farm size and tenancy status, cropping pattern, and livestock led to getting an idea about the farming status and existing practices of the farmers in the area. Questions on adoption, knowledge, and use of ICT provide information related to ICT-use in farming and livestock, especially in citrus. Information is also sought on time and cost in attaining information for agriculture, the importance of ICT in decision making, managing risks regarding citrus and other crop production, and its impact on livelihood capital. Questions were also incorporated to gain an insight into the limiting factors of the use of ICT and the level of priority for sources of information for different agricultural practices, and usefulness and perceived benefits of ICT.

Digital data collection method was used for citrus producers' survey. CommCare application was used in the digital data collection process. This platform was developed by Dimagi Incorporated, for-profit, a social enterprise company. This application is an open-source mobile platform for data collection. It has been used for more than 2000 projects in nearly 80 countries. This application is contributing to improving the efficiency of field workers in different disciplines like agriculture and health, among others. In this technological advancement era, CommCare is a broadly adopted ICT platform used by front-line field workers (Chatfield et al. 2015). The CommCare proficient health workers delivered quality services compared to less proficient workers (Kaphle et al., 2015). The use of the CommCare App on extension workers' mobile phones has raised the quality of their services (Tata et al., 2018). The University of Canberra provided the opportunity to learn and apply digital data collection. The questionnaire was developed in the CommCare app. It made the job easy for the enumerator to get rid of the relatively cumbersome method. The use of CommCare helped the researchers/enumerators to shift from papers to paperless data collection with ease and accuracy. This application was very useful for data storage and management. Digital data collection saved on cost and improved the accuracy of data controlling outliers. Digital data collection reassured the farmers that their words and concerns would reach the relevant experts and authorities. Two scientists from the candidate's parent department in Pakistan were trained in conducting the survey using CommCare application in the android system. Before the conduction of the final survey, the questionnaire was pretested and modified accordingly, incorporating missing information and removing information irrelevant to this research context.

Checklists were used to substantiate the required information for focus group discussions with other value chain stakeholders in the context of farmers' ICT use. Observations recorded during informal visits to the area were also incorporated to substantiate the collected data. Consent was obtained from producers and participants of FGDs before conducting the survey or focus group discussion.

Figure 4.1 shows the location of the study site (Sargodha district) on the country's map and Figure 4.2 indicates the location of survey sites (villages) within the Sargodha district.

Figure 4.1: Location of Research Site
Source: Google maps, www.google.com

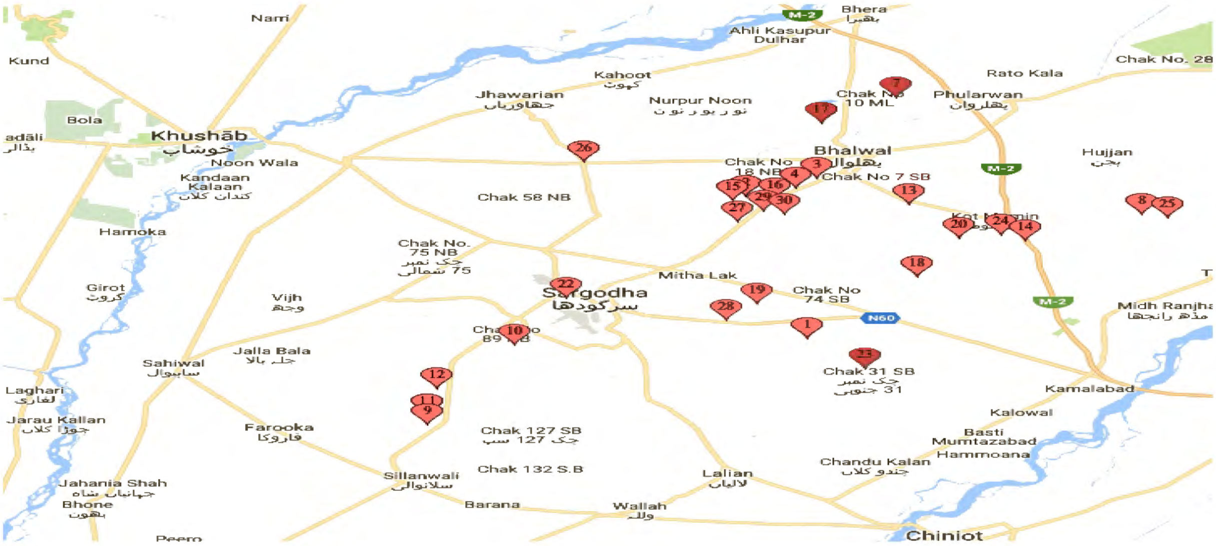


Figure 4.2 : Producers' Data Collection Sites (31 Villages)
Source: Google maps, www.google.com

b) Focus Group Discussions

Focus group discussions (FGDs) are used to collect information for obtaining qualitative data from a group (Badar,2015). The main objective of FGDs is to gather information about a specific topic (Saunders et al., 2009). The FGDs provide an opportunity for the participants to discuss and share the issues in detail as a group (Bryman, 2001). FGD is a useful tool to seek detailed information on the changing aspects of any complex phenomenon (Chambers et al. 2007; Krueger & Casey 2014). Therefore, this method validates the findings researchers get from structured questionnaires. Additionally, as FGDs are structured and directed, but also expressive, they can yield much information in a relatively short time. Therefore, FGDs are an excellent way to gather in-depth information about a community's thoughts and opinions on a topic. It generates qualitative data and information. In this research, farmers were not part of FGDs, but discussions and observation methods were followed to substantiate quantitative research outcomes from the farmers' perspective. FGDs with other influential, relevant stakeholders like input suppliers, contractors, commission agents, and exporters were conducted from the perspective of ICT use by farmers in the area. The youth of the farming community was also included in FGDs considering the relevance of ICT use. The youth of the farming communities are a useful source of information due to their familiarization with ICT and are able to give assistance to their elders.

Table 4.1explains the details of survey and FGDs conducted with the citrus farmers and other citrus value chain stakeholders. The sample size for the smallholder farmers (142) and large holder farmers (58) was calculated using the Cochran formula. Two focus group discussions were conducted with the input dealers, one with the agricultural research involving citrus and agricultural extension, and one with agricultural marketing professionals. The FGDs were also conducted with the other value chain stakeholders, two for pre-harvest contractors, two for commission agents, one for each of the transporters involved in citrus enterprise and citrus exporters. Two FGDs were conducted with the youth.

Table 4. 1: Sample Size

Survey	
Respondent type	**Number**
Survey/Interview	
Smallholder Farmers	142
Large Holder Farmers	58
Total Citrus Farmers	200
Focus Group Discussions	
Input Dealers	**2** (Four participants in each discussion)
Agriculture Research(Citrus) & Extension	**1** (Seven participants)
Agriculture Marketing	**1** (Four participants)
Pre-harvest Contractors	**2** (Five participants in each discussion)
Commission Agents	**2** (Five participants in each discussion)
Transporters	**1** (Six participants)
Citrus Exporters	**1** (Five participants)
Youth	**2** (Seven participants in each discussion)

In this case, respondents were selected purposively randomly to represent a given population. These respondents were interviewed in a group of 4-7 members for other stakeholders of the citrus value chain. The group composition and the group discussion were carefully planned to create a conducive environment so that participants felt free to talk openly and give honest opinions. Participants were actively encouraged to not only express their views but also respond to other members and questions posed by the moderator. In this way, focus groups offered variety to the discussion that would not be available through surveys.

c) Secondary Information

To complement the research process, information on various aspects of ICT and its use in agriculture was collected from public and private organizations, different journals, websites, books, and other published and unpublished work.

4.6 Field Implementation of Instruments for Primary Data Collection/Field Experience

Before proceeding for data collection, a meeting was conducted with the head of the Social Sciences Research Institute, NARC, so that scientists could be released as enumerators to assist the researcher in data collection and logistic support. After obtaining permission and support from the candidate's parent institute, a comprehensive field plan was developed for the judicious use of resources and availability of the scientists/enumerator to accompany the researcher for data collection. The enumerators were trained to conduct the survey using the CommCare app on the tablets, and questionnaire contents were discussed. The enumerators were well experienced, and their suggestions regarding the questionnaire were incorporated.

The data were collected in four rounds. In the first round, in addition to the secondary information for selection of citrus growing areas/tehsils of district Sargodha, the district and tehsil agricultural extension offices were visited to validate the process. They were asked to support their field staff to gain easy access to sites, and respondents were asked to implement the previously developed field plan. Ten farmers were interviewed as part of the informal survey to improve the questionnaire. This informal survey aided questionnaire improvement in relevance, logic, and flow. It took one week to incorporate changes into the questionnaire content and CommCare App accordingly. The informal survey respondents remained part of the research because the main reason for changes in the questionnaire was some extra information and information flow.

The survey data was completed in the second and third rounds of field visits. It was not easy for the three enumerators to collect data from the 200 hundred farmers in one go. It could compromise data quality. In the first round, 90 and the second round, 110 farmers were surveyed. Fourth-round informal discussions were conducted with the farmers and focus group discussions held with the other citrus value chain stakeholders to gain insight into their own business experiences and from the farmers' perspective. In some cases, government officials and representatives of market intermediaries' associations were contacted for facilitation to conduct FGDs smoothly and effectively.

4.7 Interview Setting

In the educated communities, the questionnaires are emailed or sent through the surface mail to the respondents. The majority of farmers in the developing world are unable to respond via email or surface mail due to low education and lack of trust of the researcher. In countries like Pakistan, sometimes, farmers are reluctant to share information because they think that researchers might be government agents trying to impose taxes after obtaining their agricultural enterprise information. Thus, to overcome these concerns, the survey was conducted by face-to-face interview which helped build farmers' trust, confidence and willingness to share accurate information. It is imperative to value the time of the respondents. Researchers should be courteous and appreciative with due consideration of respondent's trust, time, and privacy related to their personal information (Bhattacherjee, 2012). Trust and empathy with respondents are important for conducting successful interviews (Esterberg, 2002). Previous experience of the researchers helped them to approach the farming community showing their respect for the farmers' social norms and values. The researchers introduced themselves, and built rapport and trust with the respondents by explaining the research purpose. The respondents were interviewed at their homes or farms so they would feel comfortable. Before conducting interviews, consent was obtained from every respondent. The consent form was translated to 'Urdu,' the national language of Pakistan. The majority of the farmers could read the survey consent form, but they preferred, like other uneducated farmers, to be briefed verbally by the enumerators. It was clearly explained to them that they have the right to deny sharing any sensitive information. The respondents had the right to withdraw from the survey interview at any point in time, but it never happened due to believing that information would be used to benefit the farming community. During the survey interview, sometimes respondents complained against the government policies. The researchers listened to them patiently and tried to get the research discussion back on track. Misunderstood questions were rephrased by the researcher to obtain correct information from the respondents. The responses were revalidated in cases of unusual responses from the respondents. CommCare App also helped to cross-check and detect unusual information due to the fixation of possible lower and upper limits for that particular quantitative information. After each questionnaire, the overview of shared information was discussed with the respondent to validate and cross-check respondent's ultimate viewpoint about the acquired information.

4.8 Data Analysis

The study used a mixed method approach. Both the quantitative and qualitative data were collected and analysed. The quantitative and qualitative methods have unique strengths and are being used to attain the same objective (Maxwell, 2004). The quantitative data were analysed, employing descriptive statistics and inferential statistics. For the qualitative data, thematic analysis was conducted to draw a logical conclusion from the data.

4.8.1 Quantitative Data Analysis

Data analysis is the reduction of large data set collected by the researcher to make logic or sense of it, and quantitative research emphasizes numbers in data collection and analysis (Bryman, 2016). More importantly, quantitative research seems scientific, and with this approach, the scientific methods used for data collection and analysis create possibilities for making generalizations (Eyisi,2016). Quantitative research is of great importance in social science founding the leading methodological paradigm, and mainly methodical theories and hypotheses are developed to be addressed with the quantitative approaches (Johnson,2010). The quantitative approach provides full prerogative for explanations, interpretations, and conclusions without compromising researcher objectivity (Bryman, 2012; Litchman, 2012).

Before analysis, data were transformed to excel software from CommCare application then edited and coded. Mainly the statistical package for social scientists (SPSS) was used for quantitative analysis. Data analysis requires a reasonably good understanding of the type of issue, descriptive statistics, and inferential statistics. The data were categorized by landholding and education level of the key respondent. After categorization, descriptive statistical and inferential statistical methods/models were used to address the research objectives logically.

a) Categorization of the sample based on landholding and schooling

i) Categorization based on landholding

According to the Census of Agriculture 2010, there exist 8.26 million private agricultural farms with an average size of 2.6 hectares (ha). Smallholder farmers with farm size less than or equal to 5 hectares make up 89 percent of total farmers in Pakistan; medium holding farmers with farm size 5 to 10 hectares make up 7 percent; large holder farmers make up 4 percent of total farmers (Census of Agriculture, 2010; Rashid & Sheikh, 2015).

Before analyzing the collected data, all the respondents (200) were categorized into two groups based on operational landholdings. In the survey, the prime focus was to interview farmers who fall into the smallholder or large holder category of farming groups. In the survey, 30 medium landholding farmers were also interviewed because, as a researcher, one cannot refuse to interview the farmer if he is willing to share his farming experience. After adjusting medium-sized farmers with due consideration of their characteristics to align with smallholders or large holders, two farmers categories were developed: smallholders (142) if their operational land holdings were less than eight hectares (< 8 hectares) and large holders (58) if their operational landholdings are equal to or greater than eight hectares (≥ 8 hectares).

ii) Categorization based on the education level

The information technology (IT) or ICT related innovation requires a certain level of education to adopt and use in comparison to other agricultural innovations. Taking into consideration the importance of education in ICT-related aspects, respondents were categorized into two groups: less than ten years of education, and ten years or more schooling years. These two groups were developed with the logic that in the country, ten years of education is the minimum education level to qualify for jobs where education matters. Other jobs require a level of education below ten years or no education. Based on the categories of schooling years, i.e., 81 respondents fell into the category of educated up to ten years (< 10 years education) and were described as less educated. The 119 respondents who fell into the category of equal to and above ten years of education (≥10 years education) were described as more educated. These categorizations (based on operational landholdings and schooling) are important for comparing household and farm characteristics of the respondents with their awareness and the availability of ICT; competence; importance and level of ICT use; limiting factors on the use of ICT for agriculture;

the cost of information acquisition using ICT and personal visit; awareness/adoption of innovative farming practices and income with ICT use in agriculture.

iii) Categorization of ICT

In the survey, farmers were asked about awareness, adoption, and usage of all existing ICT used in agriculture. Such ICT includes radio, TV, fixed-line phone, normal mobile, smartphone, computer, internet, data recording devices, satellite and sensor networks. The adoption of ICT varies among the farmers from none of the ICT to some or all ICT. They are grouped as all ICT and as modern ICT. Modern ICT include normal mobile, smartphone, computer, and using the internet for different purposes. The term used 'all ICT' farmers have two choices, i.e., either they have adopted at least one or can explain the availability of ICT. The term used 'modern ICT' explains the presence of at least one ICT of the current era, as explained earlier.

b) Analytical techniques to find the determinants and contribution of ICT

As mentioned in the introduction section, ICT adoption by farmers in Pakistan is a relatively unexplored area of research. However, research interest has been growing in the use of ICT illustrative factors. Empirical studies suggest a positive relationship between technology adoption and the size of the farm. Following Schumpeter's (1912) work, several researchers have noted a positive relationship between technology adoption with the farm size. All the researchers argue that large firms have a sizeable resource base to invest in new technology and, therefore, can absorb the new technologies. The specific farm activity-related information and the extent to which ICT may affect information dissemination to farmers, influences the adoption of ICT with other socio-economic characteristics.

Researchers, Adegbidi et al. (2012), Ali (2012), Anoop et al. (2015), Buabeng-Andoh (2012), Olaniyi et al. (2013), and Lawasa et al. (2011) have used the following techniques in ICT-related or relevant studies including descriptive statistics for data summary and behaviour; independent t-test for finding the significant difference between two groups; binary models for the determinants of technology (ICT) awareness, adoption, and usage; estimated ordinary least square (OLS) for the determinants of yield (crops and milk) and Poisson regression to gauge the intensity of technology. Therefore, this study also follows previous work and uses OLS, Logit, Poisson models, and stochastic production frontier models in the light of pre-set objectives, to test the hypotheses.

Table 4.2 provides a brief description of the analytical techniques used to address different research questions.

Table 4. 2: Overview of Research Questions and Quantitative Data Analysis

Research Questions	Data Analysis Techniques Used
1.1 What are the basic socio-economic characteristics of respondents?	Descriptive Statistics- means, and independent *t*-test and Welch *t*-test statistics was used to find the mean and significant difference between the small vs large holder farmers, less educated vs more educated farmers. Welch *t*-test statistics was used on violation of homogeneity of variance assumption due to variation of sample size between comparing groups.
1.2 What are the key underlying factors affecting competence in use, importance in agriculture, and level of use of various types of ICT?	Descriptive Statistics- Means, and Independent *t*-test and Welch *t*-test statistics were used to find the mean and significant difference between the smallholder vs large holder farmers, less educated vs secondary and above farmers.
1.3 What are the significant determinants of ICT awareness, adoption, and usage by small- and large- holder citrus farmers?	Logistic regression was used to find the determinants of small- and large- holder farmers
1.4 What are the limiting factors on the use of small- and large- holder farmers of ICT for agriculture?	Descriptive statistics- means, and independent *t*-test and Welch *t*-test statistics were used to find the mean and significant difference between the small vs large holder farmers, less educated vs more educated farmers. Welch *t* Test statistics was used on violation of homogeneity of variance assumption due to variation of sample size.
2.1 How does the use of ICT by small- and large- holder farmers affect the	Descriptive Statistics- Means,

Research Questions	Data Analysis Techniques Used
information acquisition, cost and time involved in getting information?	Independent *t*-test and Welch *t*-test statistics and Z Score were used to find the mean and significant difference between the small vs large holder farmers, less educated vs more educated farmers
2.2 What has been the effect of ICT on the small- and large- holder citrus farmers in innovative information acquisition and adopting new technologies on farming practices?	Ordinary Least Square (OLS) regression, Poisson regression, and stochastic production frontier model were used to gauge the contribution of ICT.
3.1 What are the perceived benefits to small- and large- holder farmers using ICT?	Descriptive Statistics- means, and independent t-test were used to find the mean and significant difference between the small vs large holder farmers, less educated vs more educated farmers. To draw the factors for perceived benefits, factor analysis using principal component analysis (PCA) with oblimin and varimax rotations was conducted.

Detailed description and importance of the analytical techniques are described as follow:

i) Descriptive Analysis

Descriptive statistics illustrate data in a meaningful way (Sharma,2019). Descriptive Analysis describes what exists and tries to pave the ground for finding new facts. It includes the gathering of data related to productions, people, individuals, events, and situations and then organizes, tabulates, depicts, and describes the outcome. It deals with describing a phenomenon of how we think something. It attempts to examine the situations to describe the norms (Waliman, 2011).

Descriptive statistics reveal the basic characteristics in a summary form of data and provide a base for quantitative analysis (Trochim & Donnelly, 2001). It is argued if properly interpreted, the data analysed can provide useful insights that may lead to the formation of hypotheses. Its main objective is the description; it does not make predictions and does not determine cause and effect (Jamie Hale, 2018).

The tools which are mostly used for descriptive research to analyze and summarize a large amount of data into magnitudes are; frequencies, mean, median, mode standard deviation, scatter plot, graphs, tables, charts, histograms, among others (Jong et al., 2002).

One of the main advantages of descriptive analysis is its high degree of objectivity and neutrality (Lans & Van Der Voordt, 2002). Descriptive analysis is considered more expansive than other quantitative methods, and it gives a broader picture of an event or phenomenon. It is mostly done before an experimental or inferential study and is considered the first step for further complicated models and analysis (Marsh & Stocker, 2002). Knowledge of descriptive analysis helps one to understand a topic and can assist researchers in interpreting the output from more complex statistical models. It is considered useful for identifying variables and new hypotheses, which can be further analyzed through inferential studies. This type of study gives the researcher the flexibility to use both quantitative and qualitative data in order to discover the characteristics of the population.

ii) Independent T-Test and Welch T-Test

The t-test is a type of statistical test that is used to compare the means of two groups. The t-test implies an inferential statistical technique to define the probability of rejecting the null hypothesis on the basis that two means are identical (McMillan & Schumacher, 2010). It is one of the most widely used statistical hypothesis tests in research studies (Yim, 2010). T-tests can be divided into three types. The first one is one sample t-test that evaluates the mean with predefined sample value. The second is the independent t-test, which can be used when the two groups under comparison are independent of each other, and the third is a one paired t-test, which can be used when the two groups under comparison are dependent on each other (Kim,2015).

This study follows the independent t-test to compare the difference between the means of two groups within the farmers' category, based on landholdings and education level. The independent or the student t-test is commonly used to analyze independent groups with normally distributed data assessed on continuous or interval scales (Stoltzfus, 2015). An independent sample t-test is applied to compare two groups with independent means (University of Arizona Military Reach, 2009). An independent sample t-test reveals whether the difference in mean values between two groups of test variables is statistically significant or not (Gerald, 2018) and that helps the researcher when drawing certain conclusions and exploring the rationale with the difference in the result or not.

In this study, the independent t-test assessed the mean value, whether the difference is significant of the studied variable within the small- and large- holder farmer groups. The independent t-test was also used to test the studied variable between two groups based on the education level. To avoid the violation of the assumption of homogeneity of variances due to variation of sample size between the groups based on farm size and education level, the Levene's test for homoskedasticity (equal variance) is used to overcome the results' biases in reporting significance level. If the homogeneity of variance qualifies the equivalence of variance test (Levene's test), the student's t-test with independent samples is more robust (Erceg-Hurn et al., 2008; Wilcox et al., 2013). The Welch's *t*-test is used when the homogeneity of variance assumption is violated. The Welch's *t*-test results are robust if the equal variance assumption violates due to variation in sample sizes and is more suitable for social sciences research (Delacre et al., 2017). The Welch test is the most advantageous method in violation of the assumption of homogeneity of variances due to variable sample sizes (Tomarken & Serlin, 1986). Welch's *t*-test controls the Type I error (Zimmerman, 2004). The Type I error is false positive akin to no significance of the result, but the test misleads with significance.

iii) Logistic Regression Models

Logistic regression is used specifically to explore the association between binary (dichotomous) or ordinal response probability ($0 \leq y \leq 1$) and explanatory variables. The logistic regression is linearization of the logit probability model, and the parameters are solved via OLS techniques. Logistic regression allows ease of calculations and it is much easier and more direct to interpret the statistics of a linear model than it is for a probability or nonlinear model. The analysis and prediction of dichotomous outcomes are traditionally addressed through ordinary least squares (OLS) regression or linear discriminant function analysis. These techniques have strict statistical assumptions, including continuity, linearity, and normality for OLS regression and multivariate normality with equal variances and covariances for discriminant analysis. Therefore, researchers (Cabrera, 1994; Cleary & Angel, 1984; Cox & Snell, 1989; Efron, 1975; Lei & Koehly, 2000; Press & Wilson, 1978; Tabachnick & Fidell, 2001) have found these techniques not to be optimal for dichotomous outcomes. To deal with the dichotomous outcomes, logistic regression is considered to be an alternative.

The central concept of logistic regression is the logit - the natural logarithm of an odds ratio. According to Cabrera (1994), the logistic regression proposed in the late 1960s and early 1970s has gained popularity among social scientists since then. The leading principle in the logistic regression is the same as the linear regression to compare the response variable observed values with the predicted values obtained from the model (Hosmer et al., 2013). Apart from the health-related fields, logistic regression usage is widely used in social and economic research and physical sciences (Hilbe, 2009). Logistic regression is among the most common approaches developed after finding problems with linear led models in the analysis of the dependent variable as dichotomous (Allison, 2013). In recent years, logistic regression has become popular due to its flexibility in making normality assumptions as in the linear regression (Korkmaz et al., 2012).

Logistic regression is a most appropriate technique for describing the association between the categorical response variable and a set of categorical or continuous explanatory variables (Peng et al.,2002), and it provides odd ratios in estimates in correspondence to relevant confidence intervals rather than only p values (Pandis,2017). The basic notion of logistic regression is the natural logarithm of an odds ratio. Mostly, logistic regression is the best for analyzing and explaining propositions vis-à-vis associations among a categorical outcome variable and one or more categorical or continuous predictor variables.

In this situation, OLS regression fails to explain the dichotomy of outcomes because data do not follow a linear trend and non-normality of the errors across the data (Peng, Manz, & Keck, 2001). Logistic regression takes care of these issues as this technique transforms the dependent variable in its logit form (natural logarithm (ln) of odds).

As the logit is the natural logarithm ln of odds of Z, and odds are ratios of probabilities (n) of Z occurrence to probabilities $(1 - \pi)$ of Z not occurring. The logistic regression can also take care of polytomous categorical (ordinal- and nominal-scaled) variables. The logistic model, in its simplest form, is presented below:

$$logit(Z) = natural \log(odds) = ln\left[\frac{\pi}{1-\pi}\right] = \beta_0 + \beta_1 X_1$$

This association between $logit(Z)$ and X is linear, and the probability of occurrence of Z is estimated by taking the antilog of the above equation.

$$\pi = probability(Z = outcome\ of\ interest | X = x) = \frac{e^{\beta_0 + \beta_1 x_1}}{1 + e^{\beta_0 + \beta_1 x_1}}$$

Where Z is a categorical variable, π is the probability of the outcome of interest, β_0 a is the intercept term, β_1 is the coefficient of regression, X can be either a categorical or continuous variable, and e is the base of natural logarithms (2.71828). When $H_0{:}\,\beta_1 = 0$ is rejected, it implies that a linear association exists between X and $logit(Z)$. The direction of the association between X and $logit(Z)$ is determined by the coefficient β_1. When $\beta_1 > 0$, then direct association occurs between X and $logit(Z)$ i.e., smaller (larger) values of X are linked with smaller (larger) $logit(Z)$. On the other hand, when $\beta_1 < 0$, then inverse association occurs between X and $logit(Z)$ i.e., smaller (larger) values of X are linked with larger (smaller) $logit(Z)$.

Extending simple logistic regression (X_1) to multiple logistic regression $(X_1, X_2, \dots \dots . . X_n)$:

$$logit(Z) = ln\left[\frac{\pi}{1-\pi}\right] = \beta_0 + \beta_1 X_1 + \beta_2 X_2, \dots \dots . . + \beta_n X_n$$

$$\pi = probability(Z = outcome\ of\ interest | X_1 = x_1, X_2 = x_2, \dots \dots . . X_n = x_n)$$

$$= \frac{e^{\beta_0 + \beta_1 x_1 + \beta_2 x_2, \dots \dots + \beta_n x_n}}{1 + e^{\beta_0 + \beta_1 x_1 + \beta_2 x_2, \dots \dots + \beta_n x_n}}$$

where X_i are predictors. Maximum likelihood (ML) technique is used to estimate β_i and has a preference over weighted least squares (WLS). The rejection of the null hypothesis (H_0: $\beta_i = 0$) infers that at least one $\beta \neq 0$ in the population. This further explains that logistic regression estimates the probability of the event better than the mean of the dependent variable Z. The analysis of results is decided by applying the odds ratios for both categorical and continuous variables.

Logit regression is estimated to check the determinants of ICT awareness, adoption, and use by citrus farmers.

$$logit(Z) = \beta_0 + \beta_1 Edu + \beta_2 Age + \beta_3 FE + \beta_4 Int + \beta_5 HA + \beta_6 CA + \beta_7 FS + \varepsilon$$

Z	Outcome of interest
Edu	Education (Years)
Age	Age (Years)
FE	Farming Experience (Years)
Int	Interaction with input and output markets
HA	House Area
CA	Citrus Area (Acres)
FS	Family Size (No)
β_i	Coefficients

iv) Factor Analysis

The factor analysis aims to reduce data from many observable variables to a few unobservable variables called factors to understand better and interpret data patterns and relationships. Factor analysis is used in many disciplines such as social and behavioural sciences, economics, medicine, and geography (Yong & Pearce, 2013). Factor analysis works on the dimension reduction concept. The assessable and observable variables are reduced to some common variance sharing latent variables (Bartholomew et al., 2011). Factor analysis informs common factors and supports the narrative around these factors (Fabrigar & Wegener, 2011). Factor analysis follows mathematical processes to discover and develop set patterns in variables (Child, 2006). Factor analysis is established on correlation or covariance matrix with the assumption that the observed indicators are continuous, normally or at least symmetrically distributed, and linear.

The two main factor analysis methods are exploratory factor analysis (EFA) and confirmatory factor analysis (CFA). The EFA has made a significant contribution to social science research for more than 100 years, and it has come to be one of the most frequently used methods (Fabrigar & Wegener, 2011). EFA attempts to unfold complicated data patterns by analysing data sets (Child, 2006).

Exploratory factor analysis (EFA) is a data reduction procedure with an 'ordered-categorical' measure. Current methods of carrying out factor analysis (based on a Pearson's correlations matrix) assume that the continuous variables follow the normal distribution. When the model contains dichotomous (scored 0-1) or ordinal variables, then the polychoric correlation matrix is used to perform factor analysis. Researchers propose employing tetrachoric correlations when the dichotomous variables are continuous latent variables. Tetrachoric estimators assume that the dichotomous measured variables are imperfect measures of underlying latent continuous variables. This assumption is rationally using a Likert scale while it does not make sense in the case of using the nominal variable (gender or race and the like).

Different extraction methods are used in factor analysis, but principal component analysis (PCA) and principal axis factoring (PAF) are extensively used among researchers (Henson & Roberts, 2006; Tabachnick & Fidell, 2007; Thompson, 2004). The prevalence of large data sets is common in many research disciplines to obtain important information and reduce dimensionality with a clear understanding and interpretation. PCA is one of the oldest and most frequently used (Jolliffe and Candima,2016) multivariate techniques (Addi & Wiliam, 2010). It is used to obtain linear relationships from a set of variables (Simeonov et al., 2003) and offers information on important parameters with the least possible loss of actual information (Singh et al., 2004). Thompson (2004) revealed that with high-reliability variables, differences in these two are insignificant, and PCA is the default procedure in many statistical programs hence the reason it is used so frequently. Pett et al. (2003) advised that PCA is used to develop initial solutions in EFA. PCA is believed to be the pillar of modern-day data analysis with its wide use, but sometimes it is inadequately understood (Shlens, 2014).

In this research, PCA is used with both oblimin and varimax rotations through Kaiser normalization. Bartlett's test of sphericity is estimated to test the overall significance of all the correlations within the correlation matrix. Bartlett's test indicates the fitting to use the factor analytic model on data. The Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy indicates the strength of the relationships among variables.

v) Correlation Analysis

Correlation analysis is a widely used statistical technique to gauge the association strength between variables (Franzese & Iuliano, 2019; Zhang et al., 2018) and its use is widespread in social science studies to analyse the linear correlation between the variables (Senthilnathan, 2019). Correlation analysis provides the description of association intensity and direction between variables with suitable statistics but is not suited to infer causation and analysis of agreement (Schober et al., 2018). The evidence of correlation does not necessarily mean causality or impact of one variable on another, even if there is a robust and significant correlation between variables (Harrison, 2013).

A simple linear correlation is used to gauge the extent to which two variables vary jointly or a degree of concentration of the association between two variables. The parameter being measured is r (rho) and is estimated by the statistic r, the correlation coefficient. r can range from -1 to 1 and is independent of units of measurement. The force of the association increases as r reaches the absolute value of 1.0. A value of 0 indicates there is no association between the two variables tested. An improved estimate of r can be obtained by estimating r on treatment means averaged across replicates. Association does not have to be implemented only between independent and dependent variables. Correlation can be done on two dependent variables. The X and Y in the equation to determine r do not necessarily correspond between an independent and dependent variable, respectively. Methods measuring correlation- widely used techniques for the study of correlation are scattered diagrams, Karl Pearson's coefficient of correlation and Spearman's rank correlation. A scatter diagram visually presents the nature of the association without giving any specific numerical value. Karl Pearson's coefficient of correlation gives a numerical measure of the linear relationship between two variables. A relationship is said to be linear if it can be represented by a straight line. Another measure is Spearman's coefficient of correlation, which measures the linear association between ranks assigned to individual items according to their attributes. Attributes are those variables that cannot be numerically measured, include but are not limited to the intelligence of people, physical appearance, honesty.

vi) Poisson Regression

Ordinary least squares (OLS) is the most straightforward technique to estimate the regression equation. However, the log-linearization of the data changes the property of the error term.

Variance and predicted error term remain constant if the data is homoskedastic, while the predicted error term is a function of independent variables if the data is heteroskedastic. In the case of heteroskedastic, the OLS estimation technique is erratic because the variance of the predicted parameters is biased, and the t-values are deceptive (Liu, 2009).

Researchers are using Nonlinear least squares (NLS), Poisson pseudo maximum likelihood (PPML), among other techniques to deal with the presence of zeros in data. Silva and Tenreyro (2006) pronounced the NLS technique inefficient because it is not robust to heteroskedasticity as it gives more weight to observations with more substantial variance. On the other hand, the PPML technique assigns the same weight to all observations (Martin & Pham, 2008). Jayasinghe et al. (2010) working on different estimators in a Monte-Carlo experiment found that the PPML estimator deals with the problem of heteroskedasticity when zeros are limited.

Keeping in mind the above discussion, this study is considering the Poisson and its variants for estimation because of its superiority over the other techniques in count data. In count data the Poisson regression method is considered as a yardstick due to its robustness. The normal linear model is the standard model for continuous data (Winkelmann, 2008). In parametric models for analysing count data, the Poisson distribution is considered as a benchmark (Cameron & Trivedi, 2013). For count data, it is desirable to use Poisson regression, which relates well to the outcome data distribution (Gagnon et al., 2008). Poisson regression offers an easy and better method for count data analysis (Coxe et al., 2009).

The PPML equation is estimated in its original multiplicative form because of Jensen's inequality due to the presence of zeros and heteroskedasticity. It is assumed that X_i is the independent variable and has a Poisson distribution with conditional mean μ.

$Pr(X_i|H_i) = \frac{\exp(-\mu)\mu^{X_i}}{X_i!}$ (10) here $\mu = \exp(\beta' H_i)$. The consistency of PPML depends on the assumption that $var(X_{ijkt}|H_{ijkt}) \infty E(X_{ijkt}|H_{ijkt})$. PPML has the conditional equi-dispersion property, i.e., conditional mean and conditional variance must be equal (Cameron & Trivedi, 2010). However, this property is violated because of the over-dispersion of the dependent variable. This results in the inefficient estimation of PPML.

Burger et al. (2009) found that the variants of Poisson accommodate the overdispersion of the data well. These variants include the negative binomial (NB), the zero inflated Poisson (ZIP), and the zero inflated negative binomial (ZINB). Burger considered NB as the generalization of PPML. The conditional mean of NB is also based on PPML, but it has an additional parameter to capture over dispersion $var(X_i|H_i) \infty E^2(X_i|H_i)$. The confidence intervals of NB regression are likely to be narrower as compared to PPML if the outcome variable is over-dispersed. PPML and NB models fail when the observed zeros exceed predicted zeros. In this case, zero inflated models (ZIMs); ZIP and ZINB are used.

$$Pr(X_i = x|H_i) = \begin{cases} P(\beta_i H_i) + \left(1 - P(\beta_i H_i)\right) f(0|H_i) & if\ x = 0 \\ \left(1 - P(\beta_i H_i)\right) f(x|H_i) & if\ x > 0 \end{cases} \quad (12)$$

here $P(\beta_i H_I)$ is the probability of zero and $f(.)$ is the density function of the data generating process that produces the levels. The ZIP and ZINB have the same conditional mean of PPML. While in ZIP model the $var(X_i|H_i) \infty E(X_i|H_I)$ like that of PPML and in ZINB the $var(X_i|H_i) \infty E^2(X_i|H_I)$ like that of NB model.

$$Pr(X_i) = \beta_0 + \beta_1 Edu + \beta_2 FE + \beta_3 Int + \beta_4 HA + \beta_5 FS + \beta_6 MICT + \beta_7 ICT + \varepsilon$$

Edu	Education (Years)
FE	Farming Experience (Years)
Int	Interaction with input and output markets
HA	House Area
FS	Family Size (No.)
$MICT$	Modern ICT use in Agriculture[2]
ICT	ICT use in Citrus[3]
β_i	Coefficients

vii) Ordinary Least Squares (OLS) regression

Ordinary least squares is used as a very robust technique for continuous data modeling, with data transformation and dummy variable aggregation (Hutcheson, 2011). OLS is considered one of the most important methods for data analyses, and it provides the basis for several other

[2] Modern ICT use variable is based on the perception of farmers. Farmers use modern ICT (Normal mobile, smartphone, computer and internet) mostly for agriculture=1 and mostly personal=0

[3] ICT use for citrus variable is based on if farmers use ICT to get information relating to citrus yes=1and No=0

techniques, e.g., generalized linear models and ANOVA (Rutherford, 2001). Ordinary least squares is a compelling analytical method with wide adaptation to solve problems (Hanushek & Jackson, 2013). OLS regression is one of the most popular statistical techniques used in the social sciences. It can analyze multiple variables simultaneously to answer complex research questions and identify the strength of the relationships between the dependent and independent variables. The Gauss-Markov theorem states that OLS estimates are better than estimates from all other linear model estimation methods when the assumptions hold.

The following linear model is developed and estimated in the light of the discussion on the determinants of ICT.

$$Y = f(X_i)$$

Where Y is a dependent variable (citrus yield or milk production in this case) and X_i is a vector of independent variables.

The above model is estimated in log-linear form for citrus yield

$$lnC = \alpha_0 + \alpha_1 lnX_1 + \alpha_2 lnX_2 + \alpha_3 lnX_3 + \alpha_4 lnX_4 + \alpha_5 lnX_5 + \alpha_6 lnX_6 + \alpha_7 lnX_7 + \alpha_8 X_8 + \alpha_9 X_9 + \epsilon_i$$

C	Citrus Yield
X_1	Quantity of Cultivation Practices
X_2	Total Fertilizers (Bags)
X_3	No. of Irrigations
X_4	Total Labour (hrs)
X_5	Citrus Area (acre)
X_6	Education (years)
X_7	Farming Experience (years)
X_8	Modern ICT use in agriculture
X_9	ICT use in citrus
ln	Natural Log
α_i	Coefficient

Model estimated for milk yield is:

$$lnM = \alpha_0 + \alpha_1 lnRF + \alpha_2 lnKF + \alpha_3 lnAU + \alpha_4 lnMS + \alpha_5 lnTE + \alpha_6 lnMSp + \alpha_7 lnFW$$

$$+\alpha_8 LICT + \alpha_9 LMICT + \alpha_{10} Edu + \alpha_{11} FE + \mu_i$$

M	Milk Productivity
RF	Area under Rabi Fodder (acre)
KF	Area under Kharif Fodder (acre)
AU	Total Animal Units
MS	Average Milk Sale (litres per day)
TE	Treatment Expenditures (PKR per animal)
MSp	Milk Supplements (kg per month)
FW	Fulltime farm workers (No.)
$LICT$	ICT for Livestock
$LMICT$	Modern ICT use in agriculture
Edu	Education (years)
FE	Farming Experience (years)
ln	Natural Log
α_i	Coefficient

viii) Technical Efficiency

Empirical efficiency measures determine the attainment of production improvement gains with available technological resources (Binam et al., 2004). Stochastic frontier production function enables one to estimate farm-level efficiencies that make it more advantageous over other procedures (Dessale, 2017). The stochastic frontier production function procedure provides a better estimation of parameters from a production and efficiency perspective (Bwala et al., 2015). The prominent aspect of the stochastic frontier production function is the consideration disturbance term and exogenous factors not in production unit control, adding the inefficiency element (Mohammed, 2012).

The common practice technique to find the efficiency determinants is to regress the efficiency index as a dependent variable to the number of independent variables that are assumed to affect efficiency (Alena, 2007; Jema & Andersson, 2006). The second procedure is the simultaneous estimation of efficiency scores and to examine the effects of the explanatory variables on efficiency. This procedure used by (Battese & Coelli, 1995; Beshir,2016; Wondimu et al., 2014)

For this study, technical efficiencies were appraised using Battese and Coelli (1995) specification. A Stochastic Cobb-Douglas Production Frontier was applied. The Cobb-Douglas production function is the most commonly used function by economists (Dennis et al. 2010), for estimating technological progress (Sircar & Choi, 2009), and productivity (Banker & Natarajan, 2008; Pendharkar et al., 2008) because of its mathematical convenience and realistic properties. The Cobb-Douglas Production Frontier to data like as,

$$lnY = ln\beta_0 + \beta_1 lnCULP + \beta_2 lnFERT + \beta_3 lnIRRG + \beta_4 lnLABH + \beta_5 lnCITA + (V_i - U_i) \quad (1)$$

where

Y	Yield in maunds per acre
$CULP$	Total cultivation practices (No.)
$FERT$	Total fertilizer bags (No.)
$IRRG$	Total irrigation hours (No.)
$LABH$	Labour in hours for hoeing/pruning/inputs application
$CITA$	Total citrus area (acres)
V_i	A random variable (which is assumed to be independently and normally distributed with mean 0 and constant variance σ^2)
U_i	A non-negative technical inefficiency effect which is assumed to have a half normal distribution
ln	Natural Log
β_i	Coefficients

In the production frontier, Ui is deducted instead of added as in cost frontier to observe the inefficiency effect. The reason is that cost function signifies minimum cost, but the production frontier signifies maximum output (Sadiq et al., 2009). Standard econometric methods can be applied for parameter estimation as listed in equation (1). Stochastic production and cost frontier are measurable in a similar way using corrected ordinary least squares (COLS) or maximum likelihood (ML) (Schmidt and Lovell, 1979).

The efficiency effect model of the following type was fitted.

$$Ui = \alpha 0 + \alpha 1 \text{ EDU} + \alpha 2 \text{ FEXP} + \alpha 3 \text{ MICTU} + \alpha 4 \text{ ICTU} + \mu i \quad (2)$$

where EDU represents education of the farmer in years, FEXP is the farmer's experience in years, MICT is the use of modern ICT in agriculture (1=mostly agriculture and 0= mostly personal), and ICTU represents (any ICT use from a set of ICT=1 and no use of ICT at all=0)

The β and α in equation (1) and (2) are the unknown parameters to be estimated together with the variance parameters which are expressed in terms of

$$\sigma 2 = \sigma^2 v + \sigma^2 u \quad (3)$$

and

$$\gamma = \gamma /1 + \gamma = \sigma 2u / \sigma 2 \quad (4)$$

where γ- parameter has a value between 0 and 1. The parameters of the stochastic production frontier model are estimated by the ML method using FRONTIER and STATA.

Technical efficiency is described as the ratio of the actual product to the predicted level of product. The predicted level of the product can be obtained from the corrected vector of residuals.

$$e_i = \log Y_i - \log Y_i^* \quad (5)$$

$$e_i \leq 0$$

Technical Efficiency (TE) exp (e_i) $Y_i / Y^* \leq 0$

Technical Efficiency lies between 1 and 0 with inverse relation to the effect of inefficiency and is predicted based on the conditional expectation of Ui, given composed error $\varepsilon i = (Vi + Ui)$. It can be attained with the use of inefficiency term expectation, conditional on the estimation of the whole composed error. At individual farm level, technical efficiency inferences are drawable by the conditional Ui distribution given the fitted value of parameters and ε_i (Jondrow *et al*.,1982; Kalirajan and Flinn, 1983)

$$E\ (U_i\ /\ \varepsilon_i = \sigma_v\ \sigma_u/\sigma\ [\{f\ (e_i\lambda/\sigma)/1-\ F((e_i\lambda/\sigma)\}\ -\ e_i\lambda/\ \sigma\ ] \quad (6)$$

Where f ($e_i\lambda/\sigma$) and F(($e_i\lambda/\sigma$) are the standard normal density function (pdf) and cumulative distribution function (cdf) respectively evaluated at the value of

$$\varepsilon_i\lambda/\sigma\ (\lambda) = \sigma_v/\sigma_u\ (\sigma 2) = \sigma 2+\sigma 2$$

The same procedure was adopted to estimate the technical efficiency of the farmers in milk production. The Cobb-Douglas production function was applied to data as,

$$\ln Y = \ln \beta_0 + \beta_1 \ln RFA + \beta_2 \ln KFA + \beta_3 \ln ANMU + \beta_4 \ln MLSL + \beta_5 \ln TREXPA + \beta_6 \ln TREXPA + \beta_7 \ln SUPM + \beta_8 \ln FW + \beta_9 \ln OWL + (V_i - U_i) \quad (1)$$

where

In = Natural Logarithm
Y = Productivity in litres/milking animal
RFA = Rabi fodder area (acres)
KFA = Kharif fodder area (acres)
ANMU = Total animal units(no.)
MLSL = Milk sale Litres/day(no.)
TREXPA = Treatment expenditures (PKR/animal/year)
SUPM = Supplements quantity (kgs/milking animal/month)
FW = Full-time farm workers (no.)
OWL = Owned land (acres)
Vi = A random variable which is assumed to be independently and normally distributed with mean 0 and constant variance σ_v^2.
Ui = A non-negative technical inefficiency effect which is assumed to have half normal distribution.

The same as the citrus efficiency effect model was fitted for milk productivity.

$$U_i = \alpha_0 + \alpha_1\ EDU + \alpha_2\ FEXP + \alpha_3\ MICTU + \alpha_4\ ICTU + \mu_i \quad (2)$$

where EDU represents education of the farmer in years, FEXP is the farmer experience in years, MICT is the modern ICT use in agriculture(1= mostly agriculture and 0 = mostly personal), and ICTU represents (any ICT use from a set of ICT=1 and no use of ICT at all=0)

4.8.2 Qualitative Data Analysis

The qualitative research approach offers plenty of data about people and conditions (De Vaus, 2014; Leedy & Ormrod, 2014) that helps to provide an in-depth understanding of research ideas. Qualitative data analysis is the procedure to break down data following significance and logical explanation (Hennink et al., 2020). The belief in words as primary data, not the numeric values, provides appropriate descriptive and factual information (Johnson & Christensen, 2012, p29-37). In the qualitative approach, the close interaction of the researcher and respondent enhances the contribution to the research outcome (Eyisi, 2016).

Although the qualitative data methods, such as the FGDs, deliver a clear and collective viewpoint on research problems. The qualitative methods, particularly the FGDs, gathers extensive data set in comparison to quantitative research studies (Hennink, 2013). Mainly, there are two approaches to FGD data analysis: first, how the respondents talked about the issue, and second, what is stated in the discussion (Morgan, 2010).

To analyse qualitative data from FGDs, transcriptions of the raw data were made. All the responses of different stakeholders were written in specific categories. The recordings were listened to several times to ensure information accuracy shared by the respondents after phrasing sentences and phrases. This keen involvement lets the researcher pinpoint various research support views. For each stakeholder FGDs, the typical arguments and statements were put together under established research themes. Every research opinion or finding was considered and re-analysed relating to original data to avoid any ambiguities that could affect the validity of the research outcome. Then the research findings were arranged in a logical sequence to present every stakeholder's perspective.

4.9 Hypotheses Testing in Relation to ICT with Livelihood Capitals' Perspective

Hypothesis testing is a critical part of empirical research. The initiation of the research process is based on hypothesis generation, which is tested critically by experimentation and observations (Mourougan & Sethuraman, 2017). A hypothesis is considered the statement to describe the relationship between independent and dependent variables (Creswell, 1994). Considering the importance of this aspect of the research process and keeping in mind the research problem, hypotheses were developed in detail with the due reflection of the main formal statement, including all relevant aspects. To understand the comprehensive, interchangeable relationships between independent and dependent variables, the following hypotheses were developed to accept or reject, based on the outcomes of the quantitative or qualitative analysis;

a) Hypothesis 1a: Financial capital is positively related to adoption and ICT usage for agriculture

Characteristics of Financial Capital		Expected influence on adoption & usage
Farm income	(amount)	+
Non-Farm income / Nonbusiness income	(amount)	+
Access to number of finance institutions	(no.)	+/?
Citrus production	(maunds)*	+
Citrus productivity	(maunds/ha)	+
Other------------		

*One maund=40 Kg

b) Hypothesis 1b: Human capital is positively related to adoption and ICT usage for agriculture

Characteristics of Human Capital		Expected influence on adoption & usage
Education of respondent*	(Years)	+
Age	(Years)	+/-/?
Experience	(Years)	+/-/?
Family size of farmers	(no.)	+
Farm/ business workers of family	(no.)	+/?
Citrus management training	(no.)	+
Other------------		

*Person who is actively involved in farming/citrus business activities

c) Hypothesis 1c: Social capital is positively related to adoption and ICT usage for agriculture

Characteristics of Social Capital	Expected influence on adoption & usage
Interaction with fellow farmers for agricultural activities (Yes)	+
Interaction with other relevant stakeholders in agriculture (Yes)	+
Active interaction with other farmers for social activities (Yes)	+
Contacts in markets (no.)	+
Other------------	

d) Hypothesis 1d: Natural capital is positively related to adoption and ICT usage for agriculture

Characteristics of Natural Capital	Expected influence on adoption & usage
House Area (Sq.ft)	+
Landholding (ha)	+
Citrus Area (ha)	+
Other------------	
Other------------	

e) Hypothesis 1e: Physical capital is positively related to adoption and ICT usage for agriculture

Characteristics of Physical Capital	Expected influence on adoption & usage
Tractor (Yes)	+
Trolley (Yes)	+/?
Spray machine (Yes)	+/?
Car (Yes)	+
Motor Bike (Yes)	+/?
Refrigerator (Yes)	+/?
Livestock strength (no.)	+/?
Other------------	
Other------------	

f) Hypothesis 2a: ICT use in citrus/agriculture improves timely decision making of farmers

Characteristics	Expected influence (Agree= + Disagree= -)
Ploughing /Pruning	+/?
Fertilizer Application	+/?
Pesticide Application	+/?
Irrigation Application	+/?
Contract out orchard	+
Harvesting of orchards	+
Arrangement of labour/Transport	+
Supply/Demand of citrus in different markets	+
Volume of sale	+
Other	

g) Hypothesis 2b: ICT use decreases risk factor across citrus/agriculture value chain

Characteristics	Expected Impact (Increase= + Decrease= -)
Weather	-
Pest and disease attack	-
Illness or loss of labor	-
Volatile prices of inputs like fertilizers, pesticides	-
Inputs availability problem	-
Volatile citrus produces prices	-
Market supply/demand situation	-
Other	-

h) Hypothesis 3: ICT use decreases transaction costs across citrus/agriculture value chain

Characteristics	Expected Impact (Increase= + Decrease= -)
Non-Observable Transaction Costs	
Cost of visit to other farmers	-
Cost of visit to agriculture extension staff	-
Cost of finding machinery	-
Cost of finding labour	-
Cost of finding quality inputs including fertilizers, pesticides	-
Cost of traveling to purchase inputs including fertilizers, pesticides	-
Cost of finding markets/market prices	-
Cost of finding labour for marketing activities	-
Cost of finding and traveling to purchase packaging material	-
Cost of finding transport.	-
Cost of bargaining	-
Other	-
Observable Transaction Costs	-
Cost of transport	-
Cost of handling citrus	-
Cost of packaging	-
Cost of storage	-
Cost of spoilage	-
Other	-

i) Hypothesis 4: ICT use is positively related to improving the livelihood capitals of farmers

Characteristics of Livelihood Capitals	**Expected impact**
Citrus Productivity	+
Other Crops productivity	+
Citrus Quality	+
Total Income	+
Profitability	+
Market Access	+
Bargaining Power	+
Collaboration among fellow farmers/businessmen	+
Credit use (investment)	+/?
Inter-household Collaboration	+
Intra-household Collaboration	+
Capacity building	+
Trust	+
Other------------	

4.10 Ethical Consideration

This research has been carried out in line with the University of Canberra’s Human Ethics Research Guidelines. The Human Ethics Research Committee approval Project number is 17-231. The following ethical considerations have been taken care of while conducting this research:

1. Informed consent. It is an essential aspect of research ethics, and the researcher must ensure that the research respondents are aware of, and understand, the study and the research procedure. Therefore, the researcher distributed the information sheet to literate participants and explained it to the less literate respondents. Verbal consent was acquired from the participants before any kind of data collection.
2. Participants’ rights. The researcher ensured that the research participants knew their rights, which included the right to withdraw from the research without feeling

threatened of being fined, the right to be protected, and the right to have access to any publication of the study that they are involved in.

3. Confidentiality. The researcher informed the participants that any information about them would be treated confidentially.

Chapter Five: Results

This research aims to assess the potential of ICT to enhance citrus farmers' livelihood by investigating the role of ICT in improving small- and large- holder citrus farmers' livelihoods in the Punjab, Pakistan, and explore the optimizing and limiting factors on their use. The contribution of ICT in information acquisition and impact on livelihood capitals' improvement was assessed. It also explored small- and large- holder citrus farmers' perceptions of the value and impact of ICT on their farming practices, focusing on the key factors influencing ICT use.

To address the research objectives broadly and research questions specifically, many different analytical techniques were used. The analysis was carried out using two categories. The first category of farmers was based on landholding, smallholders (< 8 hectares), and large holders (≥8 hectares). The second category of farmers was based on the education level, less educated (< 10 years of education) and more educated (≥10 years of education). The variables of interest were cross-tabulated against the categories of farm size, smallholders (142) vs large holders (58) and education level, less educated (81) vs more educated (119). The null hypothesis was that there would be no difference in the variables of interest. That is, these variables were uniformly distributed across the farm size and education level. In cases of violation of the normality or homogeneity of variance assumptions, recommended statistical procedures using Welch t test instead of independent t test were followed to rectify the problem.

This chapter is divided into four major sections. The first three each addressing one of the research objectives with the fourth section describing the outcomes of focus group discussions.

A. Objective One, to investigate factors optimising and limiting the awareness, adoption, and patterns of ICT use in farm business by small- and large- holder citrus farmers in the Punjab, Pakistan.

In the first section of this chapter, the citrus farmers' socio-economic characteristics were analysed using descriptive statistics, independent *t*-test, and Welch's *t*-test statistics. The same techniques were used to analyse the key underlying factors affecting the competence in use, importance in agriculture, and level of various types of ICT use. The determinants of ICT awareness, adoption, and agriculture usage were found using logistic regression. In this section, the limiting factors on using ICT for agriculture were evaluated using descriptive statistics, independent *t*-test, and Welch's *t*-test statistics. Factor analysis was also carried out for the limiting factors to explore key issues.

5.1. Factors Optimising and Limiting the Awareness, Adoption, and Patterns of ICT Use

5.1.1. Socio-Economic Characteristics

Data on the socio-economic characteristics including age, education, farming experience, family size and its composition, education status of the family members, house area, the involvement of family members in farming and other off-farm activities, total and operational land holdings, and the area allocated to citrus fruit were collected (Tables 5.1 and 5.2). In Pakistani culture, the household head is responsible for making decisions regarding day to day household activities. For the survey interviews, males actively involved in the agricultural enterprise were selected. Accordingly, the results, which focus on age, education, farming experience, and total and operational landholdings are specific to actively involved males.

Table 5. 1: Comparison of Household Characteristics of the Respondents Across Categories

Characteristics	Categorization on Farm Size			Categorization on Education			Overall
	Small< 8 (142)	Large ≥8 (58)	Sig.	< 10 (81)	≥10 (119)	Sig.	
Age (Years)	47.38	47.78	0.860	49.91	45.85	0.042**	47.50
Respondent Education (Years)	9.37	10.38	0.064*	6.60	11.75	.000***	9.67
Farming Experience (Years)	21.46	22.45	0.600	25.27	19.34	.001***	21.75
Family Size (No)	7.55	9.21	.007***	8.27	7.87	0.480	8.03
Male < 18 years (No)	1.44	1.74	0.250	1.69	1.42	0.260	1.53
Female < 18 years (No)	1.13	1.76	0.011**	1.40	1.26	0.500	1.32
Male > 18 years (No)	2.54	3.05	.028**	2.62	2.74	0.570	2.69
Female >18 years (No)	2.43	2.66	0.320	2.57	2.45	0.560	2.50
Highest Education Male (Years)	11.88	12.83	0.032**	10.72	13.13	.000***	12.16
Highest Education Female (Years)	10.30	11.26	0.160	9.28	11.46	.001***	10.58
House Area (Marlas)#	17.49	31.26	.000***	20.36	22.24	0.41	21.48

Note: Independent t test and Welch t test was used considering the homogeneity of variance assumption. The results are significantly different from zero at ***, **, * 1, 5, and 10 percent levels, respectively. # (one hectare=395 marlas)

The respondents' average age was about 47 years, with no statistical difference across the farm size. The average years of schooling were nine years for smallholder farmers and ten years for large holder farmers, and this difference was not statistically significant. The average years of schooling across the education level were significantly different. Based on educational categories, average years of schooling were almost 7 for less educated and 12 years for more educated farmers. Significant differences in the highest years of education were observed for male members across the categories of farm size and years of education. While a nonsignificant difference in years of highest education was noted for female members across the farm size, this difference was significant for females across the education level category.

According to the Pakistan Demographic Survey (2015), a family or household can be defined as all those persons who live and share their meals together. The average family size in the area was 7.55 and 9.21 persons, respectively, for small- and large- holders households and 8.27 and 7.87 persons for less educated and more educated respondents' households, in contrast to the average family size of the country (6.96 persons) and Punjab province 6.43 persons. Larger family size in the study area indicates that farm families could provide more family labour for farm production and marketing activities.

Table 5.2: Comparison of Farm Characteristics of the Respondents Across Categories

Characteristics	Categorization on Farm Size (hectares)			Categorization on Education (years)			Overall
	Small<8	Large ≥8	Sig.	< 10	≥10	Sig.	
Fulltime farm workers (Male)	1.32	1.64	.009***	1.42	1.40	0.87	1.41
Fulltime farmworkers (Female)	0.08	0.09	0.86	0.17	0.02	.003***	0.08
Part time farm workers (Male)	0.70	0.83	0.23	0.73	0.74	0.91	0.74
Part time farm workers (Female)	0.10	0.14	0.51	0.06	0.14	0.105	0.11
Off farm workers (Male)	0.76	0.72	0.80	0.67	0.81	0.28	0.75
Off farm workers (Female)	0.70	0.14	0.266	0.07	0.09	0.71	0.09
Monthly off farm income (Males) PKR	31774	26051	0.53	23074	34908	0.16	30115
Monthly off farm income (Females) PKR	1937	2672	0.60	2099	2185	0.95	2150
Land owned (ha)	3.58	13.64	.000***	5.84	6.94	0.18	6.50
Operational Land (ha)	3.77	12.70	.000***	5.81	6.74	0.21	6.36
Citrus area (ha)	2.12	7.23	.000***	3.36	3.37	0.42	3.61

Note: Independent t test and Welch t test was used considering the homogeneity of variance assumption. The results are significantly different from zero at ***, **, * 1, 5, and 10 percent levels, respectively.

Therefore, full-time male workers across the small- and large- holder categories in the area were 1.32 and 1.64, respectively, while full-time male workers across the categories based on education were 1.42 and 1.40, respectively. The difference in full-time farmworkers was statistically significant across the farm categories but not significant for classifications based on education.

The land was one of the primary influences on production, which determines access to other factors. Operated land (i.e., farm size) was calculated as the sum of rented-in and owned minus rented-out area. The results showed a statistically significant difference in total owned and operational landholdings between small- and large- holder farmers.

On the other hand, these differences were not significant between less educated and more educated farmers but, a significant difference was noted in the citrus area for smallholder (2.12 hectares) and large holder (7.23 hectares) farmers. In comparison, a nonsignificant difference was noted in the citrus area between less educated (3.61 hectares) and more educated (3.36 hectares) farmers' households.

In essence, the large holder farmers are better off than the smallholders in all reported socio-economic characteristics. They significantly differ in some key characteristics of particular relevance for agricultural enterprises, such as respondents' education, family size, fulltime farmworkers and, not unexpectedly, in landholding and area under citrus cultivation ("citrus area"). A significant difference was observed in respondents' age, education, farming experience, highest education of male and female, and fulltime female farm workers across the education level category. The more educated farmers were ahead in the majority of reported socio-economic characteristics.

5.1.2. Awareness and Adoption of ICT

Table 5.3 summarises the awareness of normal mobile (as distinct from smartphone) existence and adoption by the respondents. All respondents had an awareness of normal mobile across all the categories although availability at home varied across the categories; for example, 94 and 90 percent of small- and large- holder farmers, respectively, had normal mobile at their homes. The categories across the years of education showed that 94 percent of the less educated respondents, while 92 percent of the more educated farming households kept normal mobile at home. It does not mean that smallholders and less educated farmers had more access to mobile technology; the reason was that large holders and more educated farmers had more access to the smartphone.

Table 5.3: Awareness and Adoption of Normal Mobile

	Categorization on Farm Size (hectares)			Categorization on Education (years)			Overall
	Small<8	Large ≥8	Sig.	< 10	≥10	Sig.	
	Percent						
Awareness	100	100	--	100	100	--	100
Availability at Home	94(133)	90(55)	0.372	94(76)	92(112)	0.466	93(188)
Quantity per household (No)	1.75	2.24	0.098*	1.96	1.84	0.565	1.89
Adoption level	74(105)	66(38)	0.123	77(62)	68(81)	0.091*	72(143)
Average Time Spent (Hrs/day)	1.15	1.26	0.499	1.06	1.27	0.103	1.18
Awareness Sources							
- Friends/Fellow Farmer	86	89	0.476	90	85	0.420	87
-Radio	00	00		00	00		00
-TV	04	00		04	03		03
-Internet	00	00		00	00		00
-Print Media	04	04		01	05		04
-Other Specify	06	07		05	08		07

Note: Independent t test and Welch t test was used considering the homogeneity of variance assumption. The results are significantly different from zero at ***, **, * 1, 5, and 10 percent levels, respectively. Figures given in parentheses are frequencies (number of farmers).

The number of normal mobiles per household was almost the same (about 2) across the categories, while the adoption level differs across the categories. The adoption level was higher (74 percent) for smallholders than that of the large holder farmers (66 percent). Similarly, the adoption level was higher (77 percent) for less-educated farmers than 68 percent for more educated farmers. All the respondents across all the categories spent almost the same time (approximately one hour per day) using the normal mobile. The primary source of awareness for normal mobile was friends and fellow farmers (86 and 89 percent respectively for small- and large- holder farmers and 90 and 85 percent for less educated and more educated farmers, respectively) followed by television, print media, and other sources.

Table 5.4 explains the awareness of the smartphone/internet existence and adoption by the respondents. The results showed a significant difference across small- and large- holder farm categories in the research area. The data showed that 86 percent of the smallholders and 95 percent of the large holders were aware of the smartphone and the internet. Similarly, a significant difference was noted between less educated and more educated farmers (80% vs 94%). While availability at home differed significantly across the categories, e.g., 71 and 87 percent of small- and large- holder farmers had smartphones and internet at their homes, respectively. Similarly, a significant difference was observed across the education level, where 61 percent of less educated respondents reported having smartphones and internet at home while 85 percent of the more educated farmers had smartphones and internet at home. The large holder and educated farmers have more ICT devices at their homes with significant differences compared with respective farming categories of smallholders and less educated farmers.

Table 5.4: Awareness and Adoption of Smart Phone/Internet

	Categorization on Farm Size (hectares)			**Categorization on Education(years)**			**Overall**
	Small<8	Large ≥8	Sig.	< 10	≥10	Sig.	
	Percent						
Awareness	86	95	0.073*	80	94	0.002***	89
Availability at Home	71 (87)	87 (48)	0.000***	61 (40)	85(95)	0.000***	76 (135)
Quantity per household (No)	1.28	2.24	0.003***	1.14	1.81	0.002***	1.56
Adoption level	32 (45)	41 (24)	0.099*	19 (15)	45(54)	0.000***	35 (69)
Average Time spent (Hrs/day)	2.32	2.57	0.299	2.25	2.45	0.576	2.41
Awareness Sources							
- Friends/Fellow Farmer	74	87	0.299	86	74	0.180	78
-Radio	00	00		00	00		00
-TV	14	08		05	15		12
-Internet	00	00		00	00		00
-Print Media	13	06		10	11		10
-Other Specify	00	00		00	00		00

Note: Independent t test and Welch t test was used considering the homogeneity of variance assumption. The results are significantly different from zero at ***, **, * 1, 5, and 10 percent levels, respectively. Figures given in parentheses are frequencies (number of farmers).

The adoption level of smartphones and the internet was lower (32 percent) for smallholder than large holder farmers (41 percent). Similarly, the adoption level of smartphones and the internet was lower (19 percent) for less-educated farmers than for more educated farmers (45 percent). The degree of significance across the education level category was higher than the farm size category. It implies that educated farmers use advanced mobile technology more frequently. All respondents across all the categories spent approximately two hours per day using their smart mobile, and this was higher than for normal mobiles. As for the normal mobile, the awareness of the smartphone and the internet was via friends and fellow farmers, followed by television.

Table 5.5 illustrates the awareness of the computer existence and adoption by the respondents. In the research area, results on awareness of computers showed a significant difference across small- and large- holder categories and less educated and more educated farmers. The results showed that 70 percent of the smallholder and 83 percent of the large holder farmers were aware of the computer. Data regarding awareness of computers for categories based on years of education showed that 63 and 81 percent of the farmers with less and more education respectively were aware of the computer. Data on the availability of computers at home showed that farmers across all the categories had fewer than one computer.

Table 5.5: Awareness and Adoption of Computer

	Categorization on Farm Size (hectares)			Categorization on Education (years)			Overall
	Small<8	Large ≥8	Sig.	< 10	≥10	Sig.	
	Percent						
Awareness	70	83	0.057*	63	81	0.005***	74
Availability at Home	33 (33)	48 (23)	0.013**	25 (13)	45 (43)	0.000***	38 (56)
Quantity per household (No)	0.40	0.60	0.119	0.31	0.55	0.057*	0.47
Adoption Respondents level	6 (9)	9 (5)	0.294	1 (1)	11 (13)	0.000***	7 (14)
Internet use in computer at home	64 (21)	78 (18)	0.008***	54 (7)	74 (32)	0.000***	70 (39)
Average Time spent (Hrs/week)	5.78	7.6	0.303	4	6.62	0.432	6.43
Awareness Sources							
- Friends/Fellow Farmer	92	93	0.427	96	91	0.241	93
-Radio	00	00		00	00		00
-TV	00	02		00	01		02
-Internet	01	00		00	02		01
-Print Media	06	05		02	08		06
-Other Specify	00	00		00	00		00

Note: Independent t test and Welch t test was used considering the homogeneity of variance assumption. The results are significantly different from zero at ***, **, * 1, 5, and 10 percent levels, respectively. Figures given in parentheses are frequencies (number of farmers).

The computer adoption level was low among the farmers. As shown in Table 5.5, six and nine percent of smallholders and large holder farmers adopted computers, respectively. Of the farming households owning a computer, 64 and 78 percent across the small- and large- holder farm categories used the internet on their computers. Similarly, only 1 percent of the farmers fall in less educated category adopted a computer, while the adoption level was 11 percent among the more educated farmers. In more educated farmers' category 74 percent farming households who had the computer at home were using internet on the computer. All the respondents across all the categories who adopted a computer spent time on the computer. Time spent on the computer was lower (5.78 hrs per week) for smallholder farmers than for large holder farmers (7.6 hrs per week). Likewise, computer time was lower (4 hrs per week) for less-educated farmers than for more educated farmers (6.62 hrs per week). In the case of the computer, the primary source of awareness was friends and fellow farmers (92 and 93 percent respectively for small- and large- holder farmers and 96 and 91 percent, respectively for farmers having less education and more education), followed by print media (six and five percent respectively for small- and large- holder farmers and two and eight percent, respectively for farmers having less education and more education).

Table 5.6 describes the awareness of fixed-line phone existence and adoption by the respondents.

Table 5.6: Awareness and Adoption of Fixed-Line Phone

	Categorization on Farm Size (hectares)			Categorization on Education(years)			Overall
	Small<8	Large ≥8	Sig.	< 10	≥10	Sig.	
	Percent						
Awareness	89	98	0.028**	79	100	.000***	92
Availability at Home	13 (17)	14 (8)	0.365	13 (9)	14 (16)	0.309	13 (25)
Quantity per household (No)	0.15	0.17	0.906	0.16	0.16	0.940	0.16
Respondents Personal Use	3 (4)	5 (3)	0.232	4 (3)	3 (4)	0.449	4 (7)
Average Time spent (Hrs/week)	1.25	2.33	0.620	2.67	1.1	0.444	1.71
Awareness Sources							
- Friends/Fellow Farmer	97	98	.426	97	97	.304	97
-Radio	00	00		00	00		00
-TV	02	00		03	01		02
-Internet	00	00		00	00		00
-Print Media	01	02		00	02		01
-Other Specify	00	00		00	00		00

Note: Independent t test and Welch t test was used considering the homogeneity of variance assumption. The results are significantly different from zero at ***, **, * 1, 5, and 10 percent levels, respectively. Figures given in parentheses are frequencies (number of farmers).

Fixed-line phone awareness differed significantly between small- and large- holder farmers. The data showed that 89 percent of the smallholder and 98 percent of the large holder farmers were aware of the fixed-line phone. A significant difference in phone awareness was also noted for less educated and more educated farmers (72 and 100 respectively), while 13 and 14 percent of small- and large- holder farmers respectively had a fixed-line telephone at their homes.

The categories across the years of education show that 13 percent of the respondents having less education had a fixed-line phone at home compared to 14 percent with more. The average number of fixed-line telephones per household was less than one for all the categories based on farm sizes and education level. Data on the personal use of fixed-line phones showed that only 3 and 5 percent of the respondents belong to categories of small- and large- holder farmers, respectively, used the fixed-line telephone for personal use. While 4 and 3 percent of respondents belonging to less educated and more educated, respectively, used the fixed-line phone for personal use. Data on average time spent in hours per week show that smallholder farmers spent 1.25 hrs, and large holder farmers spent 2.33 hrs on using the fixed-line phone. Like others, in the fixed-line telephone, the primary source of awareness was a friend and fellow farmers for all categories.

Table 5.7 shows the awareness and adoption of TV.

Table 5.7: Awareness and Adoption of TV

	Categorization on Farm Size (hectares)			Categorization on Education(years)			Overall
	Small<8	Large ≥8	Sig.	< 10	≥10	Sig.	
	Percent						
Awareness	100	100	----	100	100	----	100
Availability at Home	89(125)	93 (53)	0.232	80 (65)	96 (114)	0.000***	89 (178)
Quantity per household (No)	0.97	1.36	0.002***	0.98	1.16	0.040**	1.09
Respondents Personal Use	83(118)	90 (52)	0.098*	78 (63)	90 (107)	0.012**	85 (170)
Average Time spent (Hrs/day)	1.71	1.63	0.590	1.73	1.68	0.340	1.69
Awareness Sources							
- Friends/Fellow Farmer	100	100	----	100	100	----	100

Note: Independent t test and Welch t test was used considering the homogeneity of variance assumption. The results are significantly different from zero at ***, **, * 1, 5, and 10 percent levels, respectively. Figures given in parentheses are frequencies (number of farmers).

All respondents were aware of the TV, and there was no significant difference in the availability of TV at the homes of small and large landholders. On the other hand, there was a significant difference in television availability at the homes of less educated and more educated farmers (80 percent and 96 percent, respectively). Overall, farmers across all the categories averaged 1.09 in their homes, and 83 percent and 90 percent of small- and large- holder farmers, respectively, used the TV for personal use. Of these farmers having a TV, 78 percent and 90 percent across the small- and large- holder farming categories used the TV for personal use. All respondents spent time watching TV, and the amount of time did not differ significantly across the categories. The only source of awareness was friends and fellow farmers across all the categories.

Table 5.8 summarises the awareness and adoption of Radio by the respondents.

Table 5.8: Awareness and Adoption of Radio

	Categorization on Farm Size(hectares)			Categorization on Education(years)			Overall
	Small<8	Large ≥8	Sig.	< 10	≥10	Sig.	
	Percent						
Awareness	100	100	----	100	100	----	100
Availability at Home	2.10 (3)	1.70 (1)	0.426	2.5 (2)	1.7(2)	0.352	2 (4)
Quantity per household (No)	0.02	0.02	0.860	0.02	0.02	0.698	0.02
Respondents Personal Use	1 (1)	2 (1)	0.290	2 (2)	0 (0)	0.076	1 (2)
Average Time spent (Hrs/day)	1	0.5	----	0.75	0	----	0.75
Awareness Sources							
- Friends/Fellow Farmer	100	100	----	100	100	----	100

Note: Independent t test and Welch t test was used considering the homogeneity of variance assumption. The results are significantly different from zero at ***, **, * 1, 5, and 10 percent levels, respectively. Figures given in parentheses are frequencies (number of farmers).

In the research area, all the respondents were aware of radio, but only two percent of the farmers owned radio at their homes. Thus, radio has almost lost its relevance among the farming community as an information communication source.

Table 5.9 presents data on the awareness and adoption of social media and website browsing. 38 percent of smallholder and 50 percent of large holder farmers were smartphone and computer users. while 20 percent of the less educated and 56 percent of the more educated farmers were smartphone and computer users. Among small- and large- holder farmers, 29 percent and 36 percent, respectively, were social media users.

Table 5.9: Awareness and Adoption of Social Media and Websites

	Categorization on Farm Size (hectares)			Categorization on Education (years)			Overall
	Small<8	Large ≥8	Sig.	< 10	≥10	Sig.	
	Percent						
Smartphone and Computer users	38 (54)	50 (29)	0.061*	20 (16)	56 (67)	0.000***	42 (83)
Social Media Users	29 (41)	36 (21)	0.160	15 (12)	42 (50)	0.000***	31 (62)
Agri. websites Users	25(36)	31 (18)	0.211	12 (10)	37 (44)	0.000***	27 (54)
Data Storage Devices							
Awareness	11	21	.057*	04	20	.001**	14
Sensor Networks							
Awareness	01	02	.868	01	02	.799	02
Satellite							
Awareness	06	17	.009**	00	15	.000***	09

Note: Independent t test and Welch t test was used considering the homogeneity of variance assumption. The results are significantly different from zero at ***, **, * 1, 5, and 10 percent levels, respectively. Figures given in parentheses are frequencies (number of farmers).

Similarly, 31 percent of farmers belonging to both the categories based on education were social media users, while 25 percent of the smallholder and 31 percent of the large holder farmers were surfing websites related to agriculture. Similarly, 12 percent of the less educated and 37 percent of the more educated farmers were surfing websites related to agriculture for relevant information.

Data further revealed that few farmers were aware of data storage devices, sensor networks, and satellites, although the levels of awareness were higher among large holder and educated farmers.

In summary, the findings revealed that all the farmers, both smallholder and large holder, were aware of mobile technology. Ninety-nine percent of farmers had at least one kind of mobile, either normal or smartphone, at their homes. The smallholder and less educated farmers were making more use of normal mobile, but had less awareness, adoption of smartphones, internet, and computers. The radio almost had lost its presence. The large holders and educated farmers were well ahead in the awareness and use of social media and websites.

5.1.3. Competence in the Use of ICT, Importance, and Level of Use in Agriculture

Data on competence level in ICT use were collected from the respondents, where 1=not competent, 2=somewhat competent, 3=competent, and 4=very competent. Data on the importance of given ICT gadgets in agriculture were collected and given values of 1 to 5 respectively for not at all, a little important, somewhat important, very important, and critically important. For the level of use of these gadgets, values of 1 to 4 were assigned to all personal, mostly personal, half personal and half agriculture, and mostly agriculture, respectively.

Table 5.10 describes the respondents' competence in normal mobile use, its importance in agriculture business, and agricultural enterprise usage. Respondents in the smallholders' category, 74 percent had a normal mobile, and in the large holder farmers' category, 66 percent had adopted (personal use) a normal mobile. The scores on competence in the use of normal mobile showed that, on average, farmers in both size categories were somewhat competent. Respondents in the less-educated farmers' category, 77 percent had adopted a normal mobile, and in the more educated farmers' category, 68 percent respondents had adopted normal mobile. For the competence in the use of normal mobile, farmers in both education categories were somewhat competent to competent, although there was a slight, but significant difference.

Table 5.10: Competence, Importance and level of ICT Use (Normal Mobile)

	Categorization on Farm Size (hectares)			**Categorization on Education(years)**			**Overall**
	Small<8	Large ≥8	Sig.	< 10	≥10	Sig.	
Normal Mobile (Percent)	74	66		77	68		72
Competence in use#	2.30	2.29	0.892	2.10	2.46	0.000***	2.30
Importance in Agri.##	3.29	3.69	0.001***	3.23	3.52	0.011**	3.40
Level of Use###	2.33	2.68	0.004***	2.40	2.44	0.711	2.43
#Score Not competent=1, Somewhat competent=2, Competent=3, Very competent=4 ## Not at all=1, A little important=2, Somewhat important=3, Very important=4, Critically important=5 ###All personal=1, Mostly Personal=2, Half personal & Agriculture=3, Mostly Agri.=4							

Note: Independent t test and Welch t test was used considering the homogeneity of variance assumption. The results are significantly different from zero at ***, **, * 1, 5, and 10 percent levels, respectively.

Farmers across all categories considered the use of normal mobiles to be somewhat important to agricultural practices. Although the differences were slight between small and large holders and more and less educated farmers, there was a statistically significant difference between categories. The difference in the level of use of normal mobiles across the farm sizes was statistically significant with relatively more use for agricultural purposes among the large holder farmers. Across the education levels, there was no significant difference in level of personal use.

Table 5.11 shows the respondents' competence in smartphone use, its importance in the agriculture business, and usage for the agricultural enterprise. Data regarding smartphone explained that out respondents in the smallholder farmers' category 32 percent had adopted a smartphone, and respondents in the large holder farmers' category 41 percent had adopted a smartphone.

Table 5.11: Competence, Importance, and level of ICT Use (Smartphone)

	Categorization on Farm Size (hectares)			Categorization on Education (years)			Overall
	Small<8	Large ≥8	Sig.	< 10	≥10	Sig.	
Smartphone (Percent)	32	41		19	45		35
Competence in use#	2.73	2.82	0.477	2.53	2.84	0.040**	2.77
Importance in Agri.##	3.72	3.76	0.704	3.47	3.82	0.044**	3.74
Level of Use###	2.49	2.74	0.055*	2.53	2.61	0.594	2.59
#Score Not competent=1, Somewhat competent=2, Competent=3, Very competent=4 ## Not at all=1, A little important=2, Somewhat important=3, Very important=4, Critically important=5 ###All personal=1, Mostly Personal=2, Half personal & Agriculture=3, Mostly Agri.=4							

Note: Independent t test and Welch t test was used considering the homogeneity of variance assumption. The results are significantly different from zero at ***, **, * 1, 5, and 10 percent levels, respectively.

Similarly, respondents in the less educated farmers' category, only 19 percent had adopted a smartphone, and in more educated farmers' category, 45 percent respondents had adopted a smartphone. Scores on the competence in the use of smartphones showed that farmers in all categories of both size and education were competent to competent with although there was a significantly higher score for the more educated vs less educated farmers. Similarly, all groups considered smartphones somewhat to very important for agricultural practice, but again with a significantly higher score for the more educated vs less educated farmers. The difference in the level of use of smartphones across the farm sizes and education categories was fairly uniform (2.49-2.74), although the difference was statistically significant for smallholders vs. large holders.

Table 5.12 explains the respondents' competence in computer use, its importance in the agriculture business, and usage for the agricultural enterprise. Data regarding computers reveal, respondents in the smallholder farmers' category, only 6 percent had adopted a computer, and respondents in the large holder farmers' category, only 9 percent had a computer. Similarly, in the less educated farmers' category, only one percent had a computer, and in the more educated farmers category, 11 percent respondents had adopted a computer. Score on competence in the use of computers revealed that farmers across all groups are somewhat competent to competent with no significant differences.

Table 5.12: Competence, Importance and level of ICT Use (Computer)

	Categorization on Farm Size (hectares)			**Categorization on Education(years)**			**Overall**
	Small<8	Large ≥8	Sig.	< 10	≥10	Sig.	
Computer (Percent)	6	9		1	11		7
Competence in use#	2.67	2.77	0.785	2.00	2.80	----	2.71
Importance in Agri.##	3.22	3.60	0.183	3.00	3.38	----	3.36
Level of Use###	2.56	2.80	0.400	2.00	2.69	----	2.64

#Score Not competent=1, Somewhat competent=2, Competent=3, Very competent=4
Not at all=1, A little important=2, Somewhat important=3, Very important=4, Critically important=5
All personal=1, Mostly Personal=2, Half half personal & Agriculture=3, Mostly Agri.=4

Note: Independent t test and Welch t test was used considering the homogeneity of variance assumption. The results are significantly different from zero at ***, **, * 1, 5, and 10 percent levels, respectively.

Data on the importance of computers in agriculture described that both small- and large- holder farmers were considering the use of computers somewhat important to very important for agricultural practices. The difference in the level of use of computers across the farm sizes was statistically insignificant. The same data across education levels showed that more educated farmers were ahead in all aspects. It was not logical to report the significant difference comparing 1 percent less educated and 11 percent more educated farmers.

Table 5.13 describes the respondents’ consideration of fixed-line phone importance in the agriculture business and usage for the agricultural enterprise.

Table 5.13: Importance and level of ICT Use (Fixed-line Phone)

	Categorization on Farm Size (hectares)			**Categorization on Education(years)**			**Overall**
	Small<8	Large ≥8	Sig.	< 10	≥10	Sig.	
Fixed line Phone (Percent)	3	5		4	3		4
Importance in Agri.##	3.50	2.00	0.333	3.00	3.00	1.000	3.00
Level of Use###	2.25	1.67	0.211	1.67	2.25	0.211	2.00
## Not at all=1, A little important=2, Somewhat important=3, Very important=4, Critically important=5							
### All personal=1, Mostly Personal=2, Half personal & Agriculture=3, Mostly Agri.=4							

Note: Independent t test and Welch t test was used considering the homogeneity of variance assumption. The results are significantly different from zero at ***, **, * 1, 5, and 10 percent levels, respectively.

Respondents in the smallholder farmers’ category considered a fixed-line phone to be somewhat important to agriculture while respondents in the large holder farmers’ category believed it to be of little importance. Both education categories considered fixed-line phones to be somewhat important. The difference in the level of use of fixed-line phones across the farm sizes was not statistically significant. Farmers in the smallholder’s category used the fixed-line phone mostly for personal use while farmers in the large holder category used fixed-line phone for personal use only. The same data across the education levels showed that less educated and more educated farmers showed no significant difference and used the fixed-line phone for all personal and mostly personal use, respectively.

Table 5.14 illustrates the respondents’ consideration of TV, Radio, social media, and agricultural websites' importance in the agriculture business and usage for the agricultural enterprise. Data on the importance of television (TV) to agriculture explained that farmers in both the small- and large- holder categories considered TV somewhat important to agriculture. The same data for the categories based on education showed that less educated and more educated farmers considered TV somewhat important for agriculture. The difference in the level of TV use across the farm sizes and education years was not statistically significant, and the use of TV was mostly personal.

Table 5.14: Importance and level of other ICT Use in Agriculture

	Categorization on Farm Size (hectares)			Categorization on Education(years)			Overall
	Small<8	Large ≥8	Sig.	< 10	≥10	Sig.	
TV (Percent)	83	90		78	90		85
Importance in Agri.##	2.98	2.88	0.448	2.86	3.00	0.224	2.95
Level of Use###	1.92	1.85	0.425	1.94	1.88	0.532	1.90
Radio	1	1		2	0		01
Importance in Agri.##	3.00	3.00	-----	3.00	-----	-----	3.00
Level of Use###	2.00	2.00	-----	2.00	-----	-----	2.00
Social Media importance in Agri.##	3.18	3.05	-----	3.12	3.17	-----	3.13
Agri. websites importance ##	3.64	3.61	-----	3.5	3.66	-----	3.63
## Not at all=1, A little important=2, Somewhat important=3, Very important=4, Critically important=5 ###All personal=1, Mostly Personal=2, Half half personal & Agriculture=3, Mostly Agri.=4							

Note: Independent t test and Welch t test was used considering the homogeneity of variance assumption. The results are significantly different from zero at ***, **, * 1, 5, and 10 percent levels, respectively.

Farmers across all the categories considered social media and agricultural websites somewhat important in agriculture.

To conclude, the large holder and more educated farmers exhibited more ICT competence, considered it to be more important in agriculture, and had a higher level of agricultural usage for all kinds of ICT. There was a significant difference in the competence of use with the education level. The large holder farmers considered mobile technology important for agricultural enterprises and made more use of it for farming purposes than the smallholder farmers.

5.1.4. Determinants of ICT Awareness4

Table 5.15 describes the estimated logistic regression results to find the determinants of modern ICT awareness. Logit regression was carried out to assess the contribution of education (years), age (years), farming experience (years), interaction in input-output markets, house area (sq. ft), citrus area (acre), and family size (No.) to modern ICT awareness by citrus farmers.

[4] 100 percent of respondents are aware of normal mobile while 91 percent respondents are either aware of smart phone or computer/internet. To get some logical information about awareness of modern ICT, respondents (91 %) who are aware of either smartphone or computer/internet are taken in consideration for analysis purpose.

Table 5.15: Logistic Regression for the Determinants of Modern ICT Awareness

Variables	Coefficient	S.E.	P>z	Odds Ratio	Margins
Education (Years)	0.240	0.083	0.004***	1.272	0.006
Age (Years)	-0.021	0.037	0.566	0.979	-0.001
Farming Experience (Years)	-0.037	0.041	0.374	0.964	-0.001
Interaction with input and output markets	1.054	0.554	0.057*	2.870	0.026
House Area	-0.020	0.023	0.395	0.980	0.000
Citrus Area (Acres)	0.150	0.073	0.042**	1.161	0.004
Family Size (No)	0.199	0.106	0.059*	1.221	0.005
Constant	-2.390	2.143	0.265	0.092	
Observation					200
LR chi2(7)					39.460
Prob > chi2					0.000
Log-likelihood					-40.778
Pseudo R2					0.326

The results are significantly different from zero at ***, **, * 1, 5, and 10 percent levels, respectively.

All 200 observations were used in the analysis. The value of likelihood ratio chi-square (39.46 with a p-value of 0.000) shows that the model fits significantly. Coefficients of the explanatory variables, their standard errors (SE), associated p-values of z-statistic, odd ratios, and respective margins are presented in Table 5.15. Education (years), interaction with input and output markets, citrus area (acres), and family size (No) were statistically significant. The coefficients of the explanatory variables show that a one-unit increase brings an increase of 0.240, 1.054, 0.150, and 0.199 in the log odds of education (years), interaction with input and output markets, citrus area (acres), and family size (No), respectively in the awareness of modern ICT (normal mobile, smart mobile, computer, and internet).

The odds ratios in the table suggests that for a one-unit increase in education (years), interaction with input and output markets, citrus area (acres), and family size (No), the odds of being aware of modern ICT in agriculture increases by 1.272, 2.870, 1.161, and 1.221 times.

Margins show the predicted probabilities of the model holding all other variables in the model at their means. Thus, the predicted probabilities of being aware of modern ICT are 0.006 for education (years), 0.026 for interaction with input and output markets, 0.004 for the citrus area (acres), and 0.005 for family size (No) at their means.

To summarize, education level, farmers’ interaction with relevant stakeholders, family size, and the area allocated for the citrus crop are the key factors contributing to the awareness of ICT. The older and more experienced farmers are less aware of modern ICT.

5.1.5. Determinants of ICT Adoption

A farmer switches from traditional to modern technology only if the utility achieved from the latter is higher than the former. Logit regression was estimated to find the determinants of adoption of ICT (normal mobile, smartphone, computer, fixed-line phone, and TV). The adoption level of ICT was examined by taking education (years), age (years), farming experience (years), interaction in input-output markets, highest education male (years), house area (Sq. ft), citrus area (acres), as explanatory variables.

Table 5.16 shows the estimated logistic regression results for determinants of ICT adoption. All 200 observations were used in the analysis[5]. The value of the likelihood ratio (chi-square = 15.510 with a p-value of 0.030) shows that the model overall fits significantly. Based on the p-values, only education (years) was statistically significant and determines the adoption of ICT.

Table 5.16: Logistic Regression for the Determinants of All ICT Adoption

Variables	Coefficient	S.E.	P>z	Odds Ratio	Margins
Education (Years)	0.243	0.095	0.010**	1.275	0.006
Age (Years)	-0.001	0.048	0.991	0.999	0.000
Farming Experience (Years)	-0.020	0.055	0.719	0.980	0.000
Interaction with input and output markets	0.582	0.651	0.371	1.790	0.014
House Area	-0.015	0.023	0.516	0.985	0.000
Citrus Area (Acres)	0.062	0.066	0.342	1.064	0.001
Family Size (No)	0.052	0.104	0.612	1.054	0.001
Constant	-0.492	2.632	0.852	0.611	
Observation					200.000
LR Chi^2 (7)					15.510
Prob > Chi^2					0.030
Log-likelihood					-81.819
Pseudo R^2					0.087

The results are significantly different from zero at ***, **, * 1, 5, and 10 percent levels, respectively.

Odds ratios for education (years) in the model suggest that for a one-unit increase, the probability of adopting ICT in agriculture increases by a factor of 1.275. That is, the odds of adopting ICT in agriculture increases by 27.5 percent. Data on margins shows the predicted probabilities of the model, holding all other variables in the model at their means. The predicted probabilities of adopting ICT in agriculture were 0.006 for education (years).

[5] In the study area 6 percent of the respondents do not adopt ICT for agriculture while the remaining 94 adopt ICT for agriculture purposes.

Table 5.17 presents the estimated logistic regression results to find the determining factors of modern ICT adoption using all 200 observations. The value of chi-square (likelihood ratio = 25.10) with a p-value of 0.000 showed that the model fits significantly. The results presented include the coefficients, standard errors (SE), associated p-values of z-statistic, odd ratios, and respective margins. Based on the p-values, it is confirmed that only education (years) and citrus area (acres) were statistically significant. The coefficient of education in years suggests that a one-unit increase increases the log odds of adoption of modern ICT (normal mobile, smart mobile, computer, and internet) in agriculture (versus not using ICT in agriculture) by 0.226. On the same line, the coefficient of citrus area (acres) suggests that unit increase in the citrus area increases the log odds of the adoption of modern ICT in agriculture by 0.136.

Odds ratios in the model indicate that for a one-unit increase in education (Years), the probability of adopting modern ICT in agriculture increases by 1.254 times and the increase in odds is 25.4 percent, while a one-unit increase in citrus area (acres) increases the probability of adopting modern ICT in agriculture by 1.146 times. Margins show the predicted probabilities of the model holding all other variables in the model at their means. In the table, the predicted probabilities of adopting ICT in agriculture are 0.007 for education (years) and 0.004 for the citrus area (acres) at their means.

Table 5.17: Logistic Regression for the Determinants of Modern ICT Adoption

Variables	Coefficient	S.E.	P>z	Odds Ratio	Margins
Education (Years)	0.226	0.083	0.006***	1.254	0.007
Age (Years)	-0.013	0.038	0.728	0.987	0.000
Farming Experience (Years)	-0.034	0.043	0.436	0.967	-0.001
Interaction with Input and Output Markets	0.764	0.531	0.150	2.147	0.022
House Area	-0.007	0.023	0.748	0.993	0.000
Citrus Area (Acres)	0.136	0.071	0.057*	1.146	0.004
Family Size (No)	0.000	0.078	0.996	1.000	0.000
Constant	-0.580	2.108	0.783	0.560	
Observation					200
LR chi2(7)					25.100
Prob > chi2					0.001
Log-likelihood					-40.725
Pseudo R2					0.236

The results are significantly different from zero at ***, **, * 1, 5, and 10 percent levels, respectively.

In summary, other than the educational level, the citrus area significantly contributes to adopting modern ICT. Again, the older and more experienced farmers were less inclined to adopt ICT.

5.1.6. Determinants of ICT Use in Agriculture

ICT are multipurpose usage technologies. In the previous section, determinants in respect of adoption were either farmer use for personal or business purposes. In the following analysis, a logit model was used to get information on the determinants of ICT (normal mobile, smartphone, fixed-line phone, computer, and TV) use in agriculture. For this purpose, ICT instrument use in agriculture are evaluated using education (years), age (years), farming experience (years), interaction in input-output markets, citrus area (acres), house area (sq. ft), and total family size as independent variables.

Table 5.18 describes the estimated logistic regression results to assess the relative contribution of all factors in ICT usage. All 200 observations were used in the analysis.

Table 5.18: Logistic Regression for the Determinants of All ICT Use in Agriculture

Variables	Coefficient	S.E.	P>z	Odds Ratio	Margins
Education (Years)	0.097	0.050	0.053*	1.102	0.024
Age (Years)	-0.027	0.018	0.136	0.974	-0.007
Farming Experience (Years)	0.016	0.022	0.467	1.016	0.004
Interaction with Input and Output Markets	0.465	0.246	0.059*	1.592	0.114
House Area	0.028	0.014	0.054*	1.028	0.007
Citrus Area (Acres)	0.050	0.023	0.028**	1.052	0.012
Family Size (No)	-0.010	0.041	0.812	0.990	-0.002
Constant	-2.029	1.036	0.050	0.131	
Observation					200
LR Chi^2 (7)					30.370
Prob > Chi^2					0.000
Log-likelihood					-122.444
Pseudo R^2					0.110

The results are significantly different from zero at ***, **, * 1, 5, and 10 percent levels, respectively.

The value of chi-square (likelihood ratio = 30.37) with a p-value of 0.000 shows that model as a whole fits significantly. The results presented include the coefficients, standard errors (SE), associated p-values of z-statistic, odds ratios, and respective margins. Based on the p-values, it is confirmed that education (years), interaction with input and output markets, house area (sq. ft), and citrus area (acres) are statistically significant. The coefficients of these variables suggest that a one-unit increase in education (years), interaction with input and output markets, house area, and citrus area (acres) increase the log odds of using ICT in agriculture (versus not using ICT in agriculture), respectively by 0.097, 0.465, 0.028 and 0. 050.

Odds ratios in the model suggest that for a one-unit increase in education (years), the probability of using ICT in agriculture increase by a factor of 1.102 and the increase in odds is 10.2 percent. Similarly, a one-unit increase in interaction with input and output markets, house area, and citrus area (acres) increase the probability of using ICT in agriculture by 1.592, 1.028, and 1.052, times respectively.

Margins show the predicted probabilities of the model holding all other variables in the model at their means. In the table, the predicted probabilities of using ICT in agriculture are 0.024 for education (years), 0.114 for interaction with input and output markets, 0.007 for house area, and 0.012 for the citrus area (acres) at their means.

Table 5.19 describes the estimated logistic regression results to find the determinants of modern ICT use in agriculture. In the case of using modern ICT (mobile phones, both normal and smart, computer, and internet) in agriculture, all 200 observations were used in the analysis.

Table 5.19: Logistic Regression for the Determinants of Modern ICT Use in Agriculture

Variables	**Coefficient**	**S.E.**	**P>z**	**Odds Ratio**	**Margins**
Education (Years)	0.112	0.052	0.033**	1.118	0.028
Age (Years)	-0.036	0.019	0.057*	0.964	-0.009
Farming Experience (Years)	0.020	0.023	0.374	1.021	0.005
Interaction with Input and Output Markets	0.563	0.255	0.027**	1.756	0.141
House Area	0.032	0.015	0.032**	1.032	0.008
Citrus Area (Acres)	0.073	0.025	0.003***	1.076	0.018
Family Size (No)	-0.022	0.043	0.606	0.978	-0.006
Constant	-2.477	1.076	0.021	0.084	
Observation					200
LR Chi^2 (7)					43.840
Prob > Chi^2					0.000
Log-likelihood					-116.702
Pseudo R^2					0.158

The results are significantly different from zero at ***, **, * 1, 5, and 10 percent levels, respectively.

The model fits well as shown by the significant value of the likelihood ratio (the value of chi-square = 43.84 with a p-value of 0.000). Based on the p-values, it is confirmed that education (years), age (years), interaction with input and output markets, house area (square feet), and citrus area (acres) are statistically significant. The coefficients of education (years), age (years), interaction with input and output markets, house area (sq.ft), and citrus area (acres) suggest that a one-unit increase brings an increase in log odds of using ICT in agriculture (versus not using ICT in agriculture) by 0.112 factor, -0.036 factor, interaction with input and output markets by 0.563 factor, house area (sq. ft.) by 0.032 factor, and citrus area (acres) by 0.073 factor, respectively.

Odds ratios in the table suggest that for a one-unit increase in education (years), age (years), interaction with input and output markets, house area (sq.ft), and citrus area (acres), the probability of using ICT in agriculture increases by a factor of 1.118, 0.964, 1.756, 1.032, and 1.076, respectively. Similarly, a one-unit increase in interaction with input and output markets, house area, and citrus area (acres) increases the probability of using ICT in agriculture by 1.592, 1.028, and 1.052 times, respectively.

The predicted probabilities (margins) of using modern ICT in agriculture in the model at their means are 0.028, -0.009, 0.141, 0.008, and 0.018 for education (years), age (years), interaction with input and output markets, house area, and citrus area (acres).

Overall, farmers' education level, interaction with relevant agricultural enterprise stakeholders, the house area as a notion of wealth, and the citrus area were significant contributors to the ICT usage for agriculture. As expected, the size of the house area was found to be negatively correlated to awareness and adoption of ICT. In addition, the respondent's age was found to be negatively related to ICT usage in agriculture but with more significant effect than the other negatively impacting factors.

5.1.7. Limiting Factors in the Use of ICT for Agriculture

The farmers were asked about the limiting factors regarding using ICT for agriculture across all the categories of smallholder vs large holder farmers and less educated vs more educated farmers. Information was collected on lack of awareness about ICT, lack of knowledge about the impact of ICT, the poor resource base of the farmers, high cost of ICT, high cost of ICT services, no interest in ICT usage, lack of conviction to ICT usage, language problem in ICT usage, the format of communication method, and timing of information delivery.

Table 5.20 explains the results of limiting factors in the use of ICT for agriculture. It is clear from the results that farmers viewed all factors except lack of awareness about ICT, and lack of knowledge had some limiting impact on the use of ICT for agriculture across the small- and large- holder farm categories, while a lack of awareness about ICT and lack of knowledge had a reasonably limiting impact on the use of ICT for agriculture across the education categories. It is worth noting that farmers' resource base, high cost of ICT, and high cost of ICT services, lack of conviction to ICT usage, and timing of information delivery significantly differed across the small- and large- holder farm categories. The impact of constraining factors was high among smallholder farmers. On the same lines, information was recorded for classifications based on education.

Table 5.20: Limiting Factors on Use of ICT for Agriculture

Limiting Factors	Categorization on Farm Size (hectares)			Categorization on Education(years)			Overall
	Small<8	Large ≥8	Sig.	< 10	≥10	Sig.	
Lack of ICT awareness	3.20	3.04	0.232	3.40	2.98	0.001***	3.15
Lack of ICT knowledge	3.23	3.05	0.195	3.43	3.01	0.001***	3.18
Poor resource base	2.40	1.81	0.001***	2.52	2.03	0.005***	2.23
High cost of ICT	2.13	1.57	0.001***	2.20	1.81	0.010**	1.97
High cost of ICT services	2.06	1.60	0.006***	2.23	1.73	0.002***	1.93
No interest in CTs usage	2.29	2.21	0.614	2.41	2.17	0.111	2.27
Lack of conviction about ICT usage	2.40	2.09	0.076*	2.44	2.22	0.179	2.31
Language problem in ICT usage	2.41	2.31	0.525	2.57	2.26	0.041**	2.38
Method of communication	2.52	2.36	0.323	2.63	2.37	0.079*	2.47
Timing information delivery.	2.44	2.00	0.013**	2.58	2.13	0.007***	2.31

Scale: No Impact = 1, Some Impact = 2, Moderate Impact = 3, Great Impact = 4

Note: The results are significantly different from zero at ***, **, * 1, 5, and 10 percent levels, respectively.

Farmers across the education categories considered all factors except lack of awareness about ICT and lack of knowledge had some limiting impact on the use of ICT for agriculture, and lack of awareness about ICT and lack of knowledge have a moderate limiting impact. In the categories based on education, farmers' responses significantly differed for lack of awareness about ICT, lack of knowledge about the impact of ICT, the poor resource base of the farmers, high cost of ICT, and high cost of ICT services. The limiting factors impacted more on less-educated farmers.

5.1.8. Factor Analysis of Limiting Factors in ICT Use

Factor analysis was carried out to draw inference after items reduction and simplifying data. The above-mentioned constraining factors with no impact to great impact were subjected to principal component analysis (PCA) using SPSS. Before conducting PCA, the suitability of the factors was assessed using a correlation matrix. This revealed the existence of numerous coefficients of .3 and above. The Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy indicated that the strength of the relationships among variables was high (KMO = 0.82), exceeding the advised value of .6 (Kaiser 1970,1974); thus, it was acceptable to proceed with the analysis. Bartlett's test of sphericity, which determined whether the overall significance of all correlations within the correlation matrix was significant, indicated the appropriateness to use the factor analytic model on this set of data (χ^2 = 1222.557, p=XXXX). A series of factor analyses was conducted, which indicated that three factors give the most interpretable solution. Both oblimin and varimax with Kaiser Normalization rotation were performed with factors correlation consideration.

Table 5.21a: Factor loading of Limiting Factors in ICT Use

Sr. No.	Limiting Factors	Mean*	Factors** 1	Factors** 2	Factors** 3	Communalities
1	Lack of ICT awareness	3.15	-0.058	**0.935**	0.065	0.891
2	Lack of ICT knowledge to use	3.18	0.037	**0.958**	-0.056	0.901
3	Poor resource base of the farmer	2.23	**0.798**	0.067	0.044	0.714
4	High cost of ICT	1.97	**0.969**	-0.007	-0.020	0.917
5	High cost of ICT services	1.93	**0.952**	-0.056	0.017	0.894
6	No interest of farmers in ICT use	2.27	0.208	0.113	**0.589**	0.594
7	Lack of conviction of ICT usage	2.31	-0.131	0.129	**0.862**	0.729
8	Language problem in ICT usage	2.38	0.268	0.059	**0.588**	0.623
9	Methods of communication using ICT	2.47	0.267	0.121	**0.498**	0.537
10	Timing of information delivery with ICT	2.31	-0.041	-0.151	**0.890**	0.683
	Eigen Values	------	4.98	1.49	1.02	------
	Total Variance Experienced (Percent)	------	49.75	14.88	10.19	------
	Cumulative variance experienced (Percent)	------	49.75	64.63	74.82	------

Observations= 200   Bartlett's test of Sphericity $\chi2$ = 1222.557*** KMO= 0.821
Extraction Method: Principal Component Analysis
Rotation Method = Oblimin with Kaiser Normalization
* 1 = No Impact, 2 = Some Impact, 3 = Moderate Impact, and 4 = Great Impact

Factors:**
1. **ICT are unaffordable for poor resource base farmers**
2. **Lack of knowledge and awareness impacts ICT usage**
3. **Poor communication ways and lacking interest in ICT impacts ICT effectiveness**

Table 5.21a shows the PCA results with oblimin rotation. The first factor was robust, with a high eigenvalue of 4.98, and it accounts for 49.75% of the variance in the data. Factor two had an eigenvalue of 1.49 and accounts for a further 14.88% of the variance. The eigenvalue for factor three was 1.02, accounting for 10.19% of the total variance.

Table 5.21b describes the PCA results with varimax rotation. No difference was found in eigenvalues and variance extraction in both rotations' types. No difference was found in the three factors, only the reshuffling of items positions with the same meaning under factors sequence. Factor analysis of the items used in the current study revealed three factors were sufficient to explain the limiting factors in ICT use. The pattern matrix in Table 5.21a using oblimin rotation revealed factor one to consisted of three items. This factor was labelled ICT are unaffordable for poor resource base farmers, reflects a high internal consistency. The second factor consisted of two items and labelled as a lack of knowledge and awareness impacts ICT usage. Factor three contained five items relating to poor communication, and lack of interest in ICT usage impacts its effectiveness. Poor communication comprised the language problem, communication method, and information delivery timing. The internal consistency of this item was also high.

Table 5.21b: Factor loading of Limiting Factors in ICT Use

Sr. No.	Limiting Factors	Mean*	Factors**			Communalities
			1	2	3	
1	Lack of ICT awareness	3.15	0.089	0.223	**0.913**	0.891
2	Lack of ICT knowledge to use	3.18	0.151	0.138	**0.927**	0.901
3	Poor resource base of the farmer	2.23	**0.784**	0.270	0.163	0.714
4	High cost of ICT	1.97	**0.921**	0.242	0.101	0.917
5	High cost of ICT services	1.93	**0.907**	0.262	0.056	0.894
6	No interest of farmers in ICT use	2.27	**0.370**	**0.637**	0.225	0.594
7	Lack of conviction of ICT usage	2.31	0.121	**0.809**	0.245	0.729
8	Language problem in ICT usage	2.38	**0.421**	**0.643**	0.180	0.623
9	Methods of communication using ICT	2.47	**0.404**	**0.568**	0.226	0.537
10	Timing of information delivery with ICT	2.31	0.176	**0.807**	-0.012	0.683
	Eigen Values	------	4.98	1.49	1.02	------
	Total Variance Experienced (Percent)	------	49.75	14.88	10.19	------
	Cumulative variance experienced (Percent)	------	49.75	64.63	74.82	------

Observations=200 Bartlett's test of Sphericity $\chi2 = 1222.557^{***}$ KMO= 0.821
Extraction Method: Principal Component Analysis
Rotation Method = Varimax with Kaiser Normalization
* 1 = No Impact, 2 = Some Impact, 3 = Moderate Impact, and 4 = Great Impact

Factors:**

1. **ICTs are unaffordable for poor resource base farmers**
2. **Poor communication ways and lacking interest in ICT impacts ICT effectiveness**
3. **Lack of knowledge and awareness impacts ICT usage**

Table 5.21b using varimax rotation revealed factor one consisted of six items. This factor was labelled as ICT are unaffordable for poor resource base farmers and based on the three items strongly loaded reflects a high internal consistency. The other three items loading was high in the second factor. The second factor consisted of five items and labelled as poor communication, and lack of interest in ICT usage impacts its effectiveness. The third factor consisted of two items and was labelled as a lack of knowledge and awareness impacts ICT usage. With both rotations, the same conclusion was drawn only the change in the sequence of labelled factors.

Table 5.21c describes the comparative analysis of factor scores based on the farm size and education level categories. Factor scores were calculated using different methods. In this analysis, the Anderson-Rubin method was used. Scores obtained with this method were not correlated with the other factors and uncorrelated with the factor scores. A 0 score on a factor describes the respondent’s rating of the value of the related characteristics is near to the average. A positive score implies that the respondent gives higher importance than the average. Negative score value means that the respondent’s response lies below the average score.

Score values of factor, ICT were unaffordable for weak resource base farmers, were significantly different between the small- and large- holder farmers. The smallholder farmers' positive value illustrated that they had more impact in less ICT usage due to affordability and poor resource base compared to large holder farmers. This finding was validated with both oblimin and varimax rotation methods of PCA. The result was the same for the other two factors; lack of knowledge and awareness impacts ICT usage and poor communication methods and lack of interest in ICT. These two factors affect the effectiveness between the small- and large- holder farmers with both the rotation methods. The results clarified that the lack of knowledge, awareness, and poor communication impacted smallholder farmers in less ICT usage than large holder farmers, but not significantly.

The difference in perception for these three factors was substantial and differed significantly between the less educated and more educated farmers. The positive score values for less-educated farmers clearly indicated that the factors played a greater role in limiting the use of ICT than for the more educated farmers. All three factors; affordability and poor resource base, lack of knowledge and awareness, and poor communication conferred a greater constraint on less-educated farmers. Both the rotation methods supported the findings with the same consistency, except the poor communication factor not differed across education categories significantly with the varimax rotation method.

Table 5. 21c: Factor Scores Comparison Based on Farm Size and Education Level

Sr. No	Factors	Factor Score Comparison (Oblimin Rotation)									
		Categorization on Farm Size (hectares)					Categorization on Education (years)				
		Small<8	**Large ≥8**	Mean Diff.	t value	Sig.	**< 10**	**≥10**	Mean Diff.	t value	Sig.
		Average Score					Average Score				
1	F1. ICT are unaffordable for poor resource base farmers	0.142	-0.348	0.489	3.186	0.002***	0.256	-0.168	0.423	2.961	0.003***
2	F2. Lack of knowledge and awareness impacts ICT usage	0.048	-0.117	0.165	1.051	0.295	0.281	-0.184	0.465	3.272	0.001***
3	F3. Poor communication ways and lacking interest in ICT impacts ICT effectiveness	0.072	-0.176	0.247	1.581	0.116	0.199	-0.13	0.329	2.28	0.024**
		Factor Score Comparison (Varimax Rotation)									
1	F1. ICT are unaffordable for poor resource base farmers	0.136	-0.334	0.469	3.05	0.003***	0.207	-0.136	0.343	**2.385**	0.018**
2	F2. Poor communication ways and lacking interest in ICT impacts ICT effectiveness	0.034	-0.082	0.116	0.736	0.463	0.112	-0.073	0.185	1.271	0.205
3	F3. Lack of knowledge and awareness impacts ICT usage	0.024	-0.058	0.081	0.517	0.606	0.238	-0.156	0.394	2.752	0.006***

The results are significantly different from zero at ***, **, * 1, 5, and 10 percent levels, respectively.

To conclude, the factor analysis results illustrate that the impact of limiting factors varied across the farm size and education level categories. ICT affordability, lack of awareness and knowledge, and poor communication methods were the most important limiting factors with more impact on the smallholder and less educated farmers.

Section 5.1 has explored the first research objective and revealed that the socioeconomic characteristics varied across the farmers' categories based on farm size and education level. The large holder farmers were more advantaged in all reported socioeconomic characteristics compared with smallholder farmers. More educated farmers were also more advantaged in the majority of reported characteristics, except the age, and farming experience. The large holders and more educated farmers had relatively higher competence levels in ICT use, and valued ICT importance and usage in agriculture within their respective categories. The education level and citrus area (farm size) emerged as important elements in the awareness, adoption, and use of ICT for agricultural purposes. The farmers' interaction with relevant stakeholders also contributed significantly to the awareness and usage of ICT for agriculture. Many of the older and experienced farmers were unaware of the adoption and usage of modern ICT, specifically the smartphone, internet, and computers. The critical constraining factors in ICT adoption and usage for agriculture were lack of awareness and knowledge, unaffordability of modern ICT, and poor communication in the ways of information transmission. The smallholders and less educated farmers were more affected by these factors.

B. Objective Two, examining the contribution of ICT use to small- and large- holder citrus farmers in agriculture

In the second section, the research questions related to the second objective were addressed. The effect on information acquisition, cost, and time spent getting information for agricultural purposes by small- and large- holder farmers was explored using descriptive statistics, Z Score, independent *t*-test, and Welch's *t*-test statistics. To analyse the impact of ICT on small- and large- holder citrus farmers in innovative information acquisition and adoption of new technologies, OLS Regression, Poisson Regression, and a Stochastic Production Frontier Model were used.

5.2. Contribution of ICT Use in Agriculture for Citrus Farmers

5.2.1. Change in Information and Communication Sources for Citrus Using ICT

This analysis was carried out to examine the change in information acquisition for citrus management practice among the small- and large- holder farmers. The farmers were explicitly asked for citrus enterprise-related information acquisition to compare the recent past (10 years back) and the current era. Although it was a memory test, the experienced farmers were mindful of explaining the difference in information acquisition frequency, information sources, and present and recent past communication sources.

Table 5.22a illustrates that information acquisition improved for all production and marketing practices, and this was statistically significant in many production and marketing practices of citrus management among the farmers comparing two eras.

The marginal increase in information attainment for certain citrus management practices like citrus pruning, weather, plant protection, information availability/quality, and market prices were higher in smallholder farmers than the large holders. This finding signified the contribution of ICT for the smallholder farmers as well as large holders.

Table 5.22b illustrates the change in information acquisition between small- and large- holder farmers before the modern ICT era and the current era. Results showed that for all measures, information acquisition levels were higher for large holders, both in the previous era and currently, however the levels improved for both small- and large- holder citrus farmers over this time period.

Table 5.22a: Change in Information Acquisition in Citrus Enterprise

Sr. No	Production and Marketing Practices	Smallholders				Large holder				Overall			
		Before Modern ICT Era	Current Era	Z Score	P Value	Before Modern ICT Era	Current Era	Z Score	P Value	Before Modern ICT Era	Current Era	Z Score	P Value
		Percent				Percent				Percent			
1	Citrus variety/Nursery	21	28	1.382	0.084*	28	43	1.772	0.038*	23	33	2.134	0.016*
2	Hoeing/pruning	27	41	2.402	0.008**	33	43	1.154	0.124	29	42	2.639	0.004**
3	Water management	11	13	0.556	0.289	21	22	0.226	0.411	14	16	0.568	0.285
4	Weather	49	87	7.546	0.000***	72	100	4.701	0.000***	56	92	8.818	0.000***
5	Plant protection	55	80	4.742	0.000***	69	88	2.553	0.005**	59	83	5.347	0.000***
6	Inputs quality/availability	54	73	3.400	0.000***	67	76	1.034	0.151	58	74	3.425	0.000***
7	Market prices	44	75	5.597	0.000***	57	90	4.291	0.000***	48	79	6.913	0.000***
8	Post-Harvest management	8	12	1.197	0.116	14	18	0.514	0.304	10	14	1.233	0.109

The results are significantly different from zero at ***, **, * 1, 5, and 10 percent levels, respectively.

Table 5.22b: Change in Information Acquisition in Citrus Enterprise

Sr. No	Production and Marketing Practices	Before Modern ICT Era				Current Era				Overall			
		Smallholders	Large holder	Z Score	P Value	Smallholders	Large holder	Z Score	P Value	Before Modern ICT Era	Current Era	Z Score	P Value
		Percent				Percent				Percent			
1	Citrus variety/Nursery	21	28	0.951	0.171	28	43	1.986	0.023**	23	33	2.134	0.016*
2	Hoeing/pruning	27	33	0.734	0.231	41	43	0.293	0.384	29	42	2.639	0.004**
3	Water management	11	21	1.713	0.034**	13	22	1.584	0.056*	14	16	0.568	0.285
4	Weather	49	72	3.204	0.000***	87	100	4.540	0.000***	56	92	8.818	0.000***
5	Plant protection	55	69	1.904	0.028**	80	88	1.409	0.079*	59	83	5.347	0.000***
6	Inputs quality/availability	54	67	1.747	0.042**	73	76	0.389	0.348	58	74	3.425	0.000***
7	Market prices	44	57	1.714	0.043**	75	90	2.771	0.002**	48	79	6.913	0.000***
8	Post-Harvest management	8	14	1.196	0.115	12	18	0.931	0.175	10	14	1.233	0.109

The results are significantly different from zero at ***, **, * 1, 5, and 10 percent levels, respectively.

Table 5.23a explains the transformation of information sources in comparison to the two eras and farmers' category. Due to inefficient agricultural extension systems, fellow farmers have been the primary information source for the majority of farmers, especially the smallholders, however a transformation of information sources was observed in this study. Information acquisition from the informal[6] sources, including the fellow farmers and the pre-harvest contractor, decreased from 52 percent to 38 percent for the smallholder farmers but remained the primary information source. A significant increase was observed in formal[7] sources of information (including authenticated government research and development departments). The position of formal cum informal[8] sources did not change substantially for smallholder or large holder farmers between the two eras, but here was a significant increase in formal sources and a decrease in informal sources. A significant difference was noted between small- and large-holder farmers in a decrease of informal information sources, but the difference between the small- and large- holder farmers for formal and formal cum informal information sources was almost the same.

Table 5.23b explains the transformation of communication sources in comparison to two eras and farmers' category. The transformation mentioned above in information sources was due to modern[9] ICT, including mobile and internet technologies. A significant change was found in the means of communication. Personal[10] communication was decreased significantly with the introduction and use of modern ICT across the small- and large- holder farmers. Old[11] ICT, including radio and Tv, were still information communication sources but were substantially reduced.

Modern ICT contribution was prominent in ease of communication and change in to get access to formal information sources. The use of modern ICT as and information communication source was higher among the large holder farmers than the smallholder farmers. The results revealed a significant difference between the small- and large- holder farmers in a decrease in personal interaction and an increase in modern ICT as communication sources.

---

[6] Fellow Farmers, friend, relatives and Pre-harvest Contractors

[7] Agricultural extension, Agricultural Research, Agricultural universities/colleges, Meteorological Department, Agricultural websites, Authenticated Social Media Forums

[8] Private seed/ pesticide companies, Private Agricultural Consultancy Firms, Commission Agents etc

[9] Normal Mobile/Smartphone, Internet using Smartphone, Internet using computer, Multimedia CDs and USB etc. using computer, Other farmer using ICT

[10] Personal visit by farmer, Personal visit by expert

[11] TV, Radio, Fixed-line phone, Newspapers/Agricultural Magazines/brochures etc.

Table 5. 23a: Change in Information Acquisition Sources in Citrus Enterprise

Sr. No	Information Sources	Smallholders				Large holder				Overall			
		Before Modern ICT Era	Current Era	Z Score	P Value	Before Modern ICT Era	Current Era	Z Score	P Value	Before Modern ICT Era	Current Era	Z Score	P Value
		Percent				Percent				Percent			
1	Informal	52	38	-2.41	0.008***	43	28	-1.77	0.038**	50	35	-2.97	0.002***
2	Formal cum Informal	25	26	0.14	0.446	27	26	-0.21	0.417	25	27	3.05	0.001***
3	Formal	23	**36**	2.51	0.006***	**29**	**45**	1.75	0.040**	**26**	**38**	2.58	0.005***
Sr. No	Information Sources	**Before Modern ICT Era**				**Current Era**				**Overall**			
		Smallholders	Large holder	Z Score	P Value	Smallholders	Large holder	Z Score	P Value	Before Modern ICT Era	Current Era	Z Score	P Value
		Percent				Percent				Percent			
1	Informal	52	43	-1.164	0.122	38	28	-1.461	0.071*	50	35	-2.97	0.002***
2	Formal cum Informal	25	27	0.323	0.373	26	26	-0.028	0.488	25	27	3.05	0.001***
3	Formal	23	29	0.977	0.164	**36**	**45**	1.161	0.122	**26**	**38**	2.58	0.005***

The results are significantly different from zero at ***, **, * 1, 5, and 10 percent levels, respectively.

Table 5.23b: Change in Information Communication Sources in Citrus Enterprise

Sr. No	Communication Sources	Smallholders				Large holder				Overall			
		Before Modern ICT Era	Current Era	Z Score	P Value	Before Modern ICT Era	Current Era	Z Score	P Value	Before Modern ICT	Current Era	Z Score	P Value
		Percent				Percent				Percent			
1	Personal Interaction	89	48	-8.23	0.000***	83	32	-6.59	0.000***	87	43	-10.39	0.000***
2	Old ICT	11	8	-0.79	0.213	17	9	-1.39	0.082*	13	9	-1.45	0.073*
3	Modern ICT	0	44	10.49	0.000***	0	60	9.39	0.000***	0	49	13.72	0.000***
Sr. No	Communication Sources	**Before Modern ICT Era**				**Current Era**				**Overall**			
		Smallholders	Large holder	Z Score	P Value	Smallholders	Large holder	Z Score	P Value	Before Modern ICT	Current Era	Z Score	P Value
		Percent				Percent				Percent			
1	Personal Interaction	89	83	-1.062	0.144	48	32	-2.283	0.011**	87	43	-10.39	0.000***
2	Old ICT	11	17	1.062	0.144	8	9	0.039	0.484	13	9	-1.45	0.073*
3	Modern ICT	0	0	--	---	44	60	2.179	0.014**	00	49	13.72	0.000***

The results are significantly different from zero at ***, **, * 1, 5, and 10 percent levels, respectively.

In summary, a considerable increase in information acquisition among the small- and large-holder farmers was observed when comparing the two periods. The results also indicated a slight decrease in the information gap between the small- and large- holder farmers in most citrus management practices. Both the small- and large- holder farmers were in progression to acquire information from formal information sources with the ease of modern ICT usage; large holder farmers were relatively ahead in more and better use of ICT, especially the modern technologies.

5.2.2. Cost of Information Acquisition Using ICT and Personal Visit

Table 5.24 illustrates the cost comparison of information acquisition between the two eras for the different farm sizes and education levels. Results showed that smallholder farmers, on average, had reportedly acquired 205 times information regarding citrus crops compared to 273 for large holders. This was statistically significant. The same data for categories on education showed that less-educated farmers made significantly fewer visits than more educated farmers (184 vs 252).

Smallholder farmers, on average, reported significantly fewer visits to acquire information regarding citrus crops before modern ICT than large holders (93 vs 139).

On average, smallholder farmers spent significantly less than large holder farmers on acquiring information on citrus crops using ICT (PKR 1577 vs PKR 2790). Smallholder farmers also spent significantly less time acquiring this information (10.25 vs 15.57 hours). These results reflect the economies of the size of the citrus enterprise and affordability ICT for large holder farmers.

The number of visits was not significantly different between more and less educated farmers before modern ICT.

Less-educated farmers, on average, expended PKR 1349 to acquire information regarding citrus crops using ICT compared to PKR 2323 for more educated farmers. This difference was statistically significant. Similarly, less educated farmers spent fewer hours than more educated farmers acquiring information regarding citrus crops using ICT (9.36 vs 13.44). It suggests that education gives confidence in the use of ICT.

Table 5.24: Cost of Information Acquisition for Citrus Using ICT and Personal Visit

	Categorization on Farm Size (hectares)			**Categorization on Education(years)**			**Overall**
	Small< 8	Large ≥8	Sig.	< 10	≥10	Sig.	
Information acquisition frequency currently	205	273	0.007***	184	252	0.003***	224
Information acquisition frequency for before modern ICT	93	139	0.035**	110	105	0.803	107
Cost of information acquisition for using ICT	1577	2790	0.001***	1349	2323	0.001***	1928
Time spent for information (hrs) using ICT	10.25	15.57	0.007***	9.36	13.44	0.026**	11.79
Time spent for information (hrs) in personal visit	20.56	11.47	0.013**	23.41	14.18	0.030**	17.92
Total time spent for information (hrs)	30.80	27.03	0.334	32.77	27.63	0.238	29.71
Time spent in personal visit for information before modern ICT (hrs)	31.41	30.59	0.868	35.74	28.06	0.088*	31.17
Opportunity cost of personal visit for information (PKR)	2056	1147	0.013**	2341	1418	0.030**	1792
Opportunity cost of personal visit before modern ICT for information (PKR)	3141	3059	0.844	3574	2806	0.088*	3117
Yield (Maunds Per Hectare)	346	452	0.019**	350	372	0.341	363

Note: Independent t test and Welch t test was used considering the homogeneity of variance assumption. The results are significantly different from zero at ***, **, * 1, 5, and 10 percent levels, respectively.

In summary, all the farmers across both categories based on farm size and education level increased information acquisition for their citrus enterprise. However, this increase was greater for large holders and more educated farmers.

5.2.3. Awareness/Adoption of Innovative Farming Practices

Table 5.25 explains the role of ICT in the awareness and adoption of innovative farming practices. A farmer switches from traditional to modern technology only if the latter's utility is higher. Farmers of the area were asked if they became aware of, or adopted, innovative technologies in the last two years. Results revealed that 66 percent of the smallholders were familiar with or had adopted innovative technologies compared to 72 percent of large holders. In total, 68 percent of farmers were aware or had adopted innovative technologies. The sources of information regarding the spread of innovative technologies play an essential role. Information from reliable sources is very important for agricultural productivity (Reganold et al., 2011).

Table 5.25: Effect of ICT on Awareness/Adoption of Innovative Farming Practices

	Categorization on Farm Size (hectares)		Categorization on Education(years)		Overall
	<8	≥8	<10	≥10	
Awareness/Adoption of Innovative Technologies	94(66)	42(72)	27(33)	109(92)	136(68)
Information Source:					
Formal	70 (74)	37 (88)	22 (81)	85 (78)	107 (79)
Informal	24 (26)	5 (12)	5 (19)	24 (22)	29 (21)
Communication Source:					
ICTs	36 (38)	20 (48)	4 (14)	52 (48)	56 (41)
Others	58 (62)	22 (52)	23 (86)	57 (52)	80 (59)

Note: Figures in parentheses are percentages

In the study area, sources of information for smallholder (74 percent), large holder (88 percent), and overall (79 percent) were formal sources while the rest of the farmers received information from informal sources. For farmers belonging to small- and large- holder farm categories, and on an overall basis, ICT remained the communication source for 38 percent, 48 percent, and 41 percent, respectively.

The same information based on education categories showed that 27 (33 percent) out of 81 farmers having less education were aware or had adopted innovative technologies, while 92 percent (109 out of 119) of farmers belonging to more education category were familiar or have adopted innovative technologies, although formal sources of information for less educated and more educated farmers were similar (81 vs 78 percent). However, the rest of the farmers (19 percent of less education category and 22 percent in more education category) received information from informal sources. ICT remained the communication source for 14 percent of less educated and 48 percent of more educated farmers for awareness or adoption of innovative technologies, whereas 86 percent of the farmers in the less education category and 52 percent in more education category used other sources of communication.

To summarise, the awareness and adoption level of innovative technologies in the large holder and more educated farmers was higher than the smallholder and less educated farmers. The formal sources of information remained the key sources across all farming categories based on farm size and education, while the ICT contribution was lower than the other communication sources for awareness and adoption of innovations.

5.2.4. Gross Margin with ICT Use in Agriculture

Enterprises are undertaken to gain some benefits on the investment made. However, some entrepreneurs are innovative in using the latest available techniques and adopting new technologies. The same was the case for citrus growers in the research area; farmers in the area had access to ICT, but only 110 farmers out of the total 200 used ICT for mostly agricultural purposes, and the rest used ICT mostly for personal purposes. The results explain the gross margin (in PKR per acre where one acre = 0.404 hectares) of the citrus growers with some different citrus crop and livestock interacted combinations. The gross margin is the difference between the gross income received from enterprise minus the variable costs (input costs) required for production.

Table 5.26 illuminates the gross margin comparison for different agricultural enterprises or combination of enterprises with ICT usage (mostly for personal purposes vs mostly for agricultural purposes) between the farmers and education level categories.

Gross margins for citrus growers across the small- and large- holder farm categories, using ICT mostly for personal purposes, were estimated respectively as PKR 59457 per acre and PKR 74569 per acre. The gross margin of citrus growers using ICT mostly for agricultural purposes were estimated respectively as PKR 78837 per acre and PKR 81384 per acre for small- and large- holder farm categories. A significant difference exists in the gross margin of citrus growers who were using ICT for agricultural purposes and personal purposes.

To examine the differences in gross margin based on total operational land holding, gross margin obtained from the citrus crop was divided by operational area to check for disparities in income realized by ICT users for personal and agricultural purposes. The results revealed no statistically significant difference; however, arithmetic differences were noted across the categories of small- and large- holder farmers; farmers using ICT for personal purposes were receiving less income than that of the farmers using ICT mostly for agricultural purposes.

To reveal the impact of ICT on the gross margin from the whole farm excluding livestock, results indicated a statistically significant difference between the farmers using ICT for mostly personal purposes and agricultural purposes. Farmers using ICT in agricultural operations were receiving more income than farmers using ICT for personal purposes. Smallholder farmers using ICT for personal purposes were receiving a lower gross margin than smallholder farmers using ICT for agricultural purposes. Similarly, large holder farmers using ICT for personal purposes were receiving a lower gross margin than large holder farmers using ICT for agricultural purposes.

Table 5.26: Gross Margin (PKR/Acre) with ICT Use (1 Acre = 0.404 Hectare)

	Mostly Personal		Mostly Agriculture			Mostly Personal		Mostly Agriculture		
	Categorization on Farm Size (hectares)					Categorization on Education (years)				
	<8	≥8	<8	≥8	Sig.	<10	≥10	<10	≥10	Sig.
Gross margin citrus[1]	59457	74569	78837	81384	0.001***	59026	64512	78639	80598	0.001***
Gross margin citrus[2]	31213	34431	33930	45146	0.119	29621	33530	35352	40008	0.119
Gross margin Citrus and Crops[3]	44455	55970	48645	61088	0.086*	47095	45771	51921	54417	0.086*
Gross margin Citrus, Crops and ivestock[4]	78323	73398	82145	79925	0.486	80016	75399	83132	80218	0.486

[1] (Gross income from Citrus – Total production cost of citrus)/Citrus Area

[2] (Gross income from Citrus – Total production cost on citrus)/Operational Area

[3] (Gross income from Citrus + Total income from crops except fodder – Total production cost of citrus-total production cost of all crops)/Operational Area

[4] (Gross income from Citrus + Total income from crops except fodder + Total income from livestock – Total production cost of citrus-total production cost of all crops-total cost of livestock except fodder)/Operational Area

Note: ***, **, * show results are significantly different from zero at 1, 5 and 10 percent levels, respectively.

The gross margins from the whole farm, including livestock, were calculated. Farmers using ICT in agricultural operations were receiving more gross margin than farmers using ICT for personal purposes. Smallholder farmers using ICT mostly for agricultural purposes were receiving a higher gross margin than the smallholder farmers using ICT mostly for personal purposes. Similarly, large holder farmers using ICT for agricultural purposes were receiving a higher gross margin than the large holder farmers using ICT for personal purposes.

Results showed that 90 farmers (41 in less education category and 49 in more education category) were using ICT mostly for personal purposes, and the remaining (110) farmers (40 in less education category and 70 in higher education category) were using ICT for mostly agricultural purposes. The gross margin for less-educated citrus growers, who were using ICT mostly for personal purposes, was less than farmers in the same category, using ICT for mostly agricultural purposes. It is worth noting that a significant difference exists in the gross margins of citrus growers who were using ICT for agricultural purposes and personal purposes.

Results of gross margin based on total operational land holding showed no statistically significant difference between ICT users for personal and agricultural purposes. However, arithmetic differences are noted across the categories of less education, and in more education, farmers using ICT for personal purposes were receiving less income than that of the farmers using ICT for agricultural purposes. The gross margin for less-educated citrus growers, who were using ICT mostly for personal purposes, was less than farmers having less education and using ICT for mostly agricultural purposes.

The results presented in the table also showed the gross margin from the whole farm, excluding livestock, based on the operational area. A statistically significant difference was observed between the farmers using ICT for mostly personal purposes and those using ICT mostly for agricultural purposes, the latter receiving more income. Less-educated farmers using ICT for personal purposes were receiving less gross margin than the farmers who were using ICT mostly for the agricultural purposes. Similarly, more educated farmers using ICT mostly for personal purposes were receiving less gross margin than the farmers at the same level of education and using ICT mostly for agricultural purposes.

Table 5.26 further revealed that the gross margin from the whole farm analysis, including livestock, was statistically insignificant across the farm size and education level categories. However, farmers using ICT in agricultural operations were receiving more income than farmers using ICT for personal purposes. Farmers having less education and using ICT for personal purposes were receiving slightly less gross margin than the farmers at the same level of education and using ICT for agricultural purposes. Similarly, farmers having more education and using ICT for personal purposes were receiving a less gross margin than the more educated farmers using ICT for agricultural purposes.

To summarize, the results signify the contribution of ICT in increasing farm income. Farmers, who mostly used ICT for agricultural enterprises across all the categories based on farm size and education level, earned more than the farmers who mostly used ICT for personal purposes. The large holder farmers' gross margin was higher than the smallholder farmers in all agricultural enterprises' combinations excluding livestock, irrespective of using ICT mostly for agriculture or mostly for personal purposes. However whole-farm analysis, including livestock, made smallholder farmers more beneficial per unit of analysis.

5.2.5. Access and Interaction with Relevant Stakeholders

Table 5.27a and 5.27b show the access to and interaction of farmers with relevant stakeholders using ICT. Strong connection with fellows and relevant stakeholders improves the social capital and awareness of interest. Results revealed that a strong correlation between modern ICT as a communication source reflects the significant contribution to enhancing access and interaction with the relevant stakeholders. Farmers using ICT as communication sources had a strong association with formal information sources. Modern ICT adoption and interaction within the farming community showed a strong association. The results revealed that farmers with modern ICT as communication sources had better interaction with the agricultural input-output market stakeholders. Farmers had better access to get enterprise-specific information from relevant formal sources with the use of modern ICT. Concisely, the farmers who use modern ICT as communication sources have better access and interaction with agricultural enterprise relevant stakeholders.

Table 5.27a: Access and Interaction with Relevant Stakeholders

	Variables	1	2	3	4	5	6
1	Formal information sources for citrus	---					
2	Modern ICT source of communication for citrus	**.539****	---				
3	Formal information sources for crops	.255**	.262**	---			
4	Modern ICT source of communication for crops	.360**	.411**	**.615****	---		
5	Formal information sources for livestock	-.065	-.048	.127	.080	---	
6	Modern ICT source of communication for livestock	.235**	.320**	.256**	.356**	**.433****	---

** and* show significance at the 0.01 and 0.05 level (2-tailed).

There is a significant correlation between ICT use and formal sources of information. In some below mentioned regression analysis, only ICT use related variables were included to avoid multicollinearity problems with formal information sources.

Table 5.27b: Social Interaction

	Variables	1	2	3
1	Adoption of modern ICT	---		
2	Interaction within the farming community	**.218****	---	
3	Interaction in input and output markets	**.150***	**.544****	---

** and* show significance at the 0.01 and 0.05 level (2-tailed).

5.2.6. Determinants of Citrus Area

Table 5.28 shows Poisson regression results for a number of potential predictor variables on the area of citrus farmed. All 200 observations were used in the regression to know the determinants of the citrus area. The LR test statistic showed that the model was overall a good fit and at least one predictor variable regression coefficient was not equal to zero in the model. Pseudo R^2 is McFadden's pseudo-R-squared, as Poisson regression does not generate an equivalent to the R-squared. The estimated coefficients for the Poisson regression for the model were the log of the expected count as a function of the predictor variables. The coefficients of farming experience (years), interaction with input and output markets, house area, family size (No), modern ICT use in agriculture, and ICT use in citrus are statistically significant. *Ceteris paribus*, a unit increase in farming experience (years), interaction with input and output markets, house area, family size (No), modern ICT use in agriculture, and ICT use in citrus, the difference in the logs of expected counts were predicted to increase by 0.006 unit, 0.086 unit, 0.010 unit, 0.019 unit, 0.409 unit, and 0.236 unit, respectively.

Table 5.28: Poisson Regression for the Determinants of Citrus Area (Acres)

Variables	Coefficient	S.E.	P>z	IRR	Margins
Education (Years)	0.009	0.008	0.248	1.009	0.075
Farming Experience (Years)	0.006	0.002	0.009***	1.006	0.046
Interaction with input and output markets	0.086	0.039	0.028**	1.090	0.711
House Area	0.010	0.001	0.000***	1.010	0.082
Family Size (No)	0.019	0.006	0.001***	1.019	0.156
Modern ICT use in Agriculture[12]	0.409	0.052	0.000***	1.505	3.392
ICTs use in Citrus[13]	0.236	0.058	0.000***	1.266	1.958
Constant	0.935	0.148	0.000	2.547	
Observation					200
LR $Chi^2(7)$					271.720
Prob > chi^2					0.000
Log Likelihood					-910.920
Pseudo R^2					0.129

The results are significantly different from zero at ***, **, * 1, 5, and 10 percent levels, respectively.

The margins showed the predicted number of events for farming experience (year) was 0.046. The predicted number of events for interaction with input and output markets, house area, family size (No), modern ICT use in agriculture, and ICT use in citrus were 0.711, 0.082, 0.156, 3.392, and 1.958, respectively.

[12] Modern ICT use variable is based on the perception of farmers. Farmers use modern ICT (Normal mobile, smartphone, computer and internet) mostly for agriculture=1 and mostly personal=0

[13] ICT use for citrus variable is based on if farmers use ICT to get information relating to citrus yes=1and No=0

Therefore, ICT use for agricultural enterprises is correlated with the area of citrus crop, an important high-value crop with critical socio-economic associations.

5.2.7. Determinants of Citrus Yield

Table 5.29 presents OLS regression results for a number of potential predictor variables on citrus yield. The quantitative observations were transformed in its logarithmic form.

The p-value associated with F statistics confirms that the independent variables are significant predictors of the citrus yield. R^2 indicates that almost 24% of the variation in citrus yield was attributable to the predictor variables, although it does not reflect the relative contribution of any particular independent variable.

Estimates showed the relationship between the independent variables and the dependent variable as the quantitative variables were in log form and represent the elasticities, i.e., a proportionate change in citrus yield with a 1 percent change in independent variables.

Table 5. 29: Determinants of Citrus Yield (All Farmers)

ln Yield/Acre	Coefficient	S.E.	P>t	[95% Confidence	Interval]
Quantity of Cultivation Practices	-0.078	0.064	0.226	-0.204	0.049
Total fertilizers (bags)	0.150	0.076	0.051*	0.000	0.301
No of Irrigations	0.033	0.084	0.695	-0.132	0.198
Total Labour (hrs)	0.113	0.108	0.300	-0.101	0.326
Citrus Area (acre)	0.114	0.037	0.002***	0.041	0.186
Education (years)	-0.066	0.057	0.250	-0.179	0.047
Farming Experience (years)	0.020	0.046	0.670	-0.071	0.110
Modern ICT use in agriculture	0.208	0.060	0.001***	0.089	0.326
ICTs use in citrus	0.184	0.070	0.010**	0.045	0.323
Constant	3.921	0.542	0.000	2.853	4.990
Number of observations					185
F (9, 175)					5.960
Prob > F					0.000
R-squared					0.235
Adj R-squared					0.195

The results are significantly different from zero at ***, **, * 1, 5, and 10 percent levels, respectively.

The p-values indicate that the coefficients of total fertilizers (bags), citrus area (acre), modern ICT use in agriculture, and ICT use in citrus are significantly different from zero. It was estimated that keeping all the other variables constant, a one percent change in total fertilizers (bags) brings a proportionate change of 15 percent in citrus yield. Likewise, a one percent increase in citrus area (acre) is associated with an 11 percent increase in citrus yield, while a one percent change in the use of modern ICT in agriculture and ICT use in citrus proportionately increase output by 20 percent and 18 percent, respectively.

Table 5.30 shows the OLS regression results for a number of potential predictor variables on the citrus yield of large holder farmers. The quantitative observations were transformed in its logarithmic form.

The F statistics were highly significant (p=0.002), indicating that the independent variables reliably estimate the dependent variable. The R^2 indicates that a 40 percent variation in citrus yield is explained by the independent variables.

Based on p-values, it was predicted that the coefficients of the quantity of cultivation practices for citrus orchard, modern ICT use in agriculture, and ICT use in citrus are significantly associated with citrus yield. Keeping all the other variables constant, one percent change in the respective coefficients of modern ICT use in agriculture, and ICT use in citrus brought a proportionate increase of 15 percent and 22 percent, respectively. The over irrigation and increase in number of cultivation practices had impacted yield negatively for the large holder farmers.

Table 5.30: Determinants of Citrus Yield (Large Holder Farmers)

In Yield/Acre	**Coefficient**	**S.E.**	**P>t**	**[95% Confidence**	**Interval]**
Quantity of Cultivation Practices	-0.189	0.086	0.033**	-0.362	-0.016
Total fertilizers (bags)	0.124	0.094	0.192	-0.064	0.312
No of Irrigations citrus	-0.150	0.108	0.170	-0.367	0.067
Total Labour (hrs)	0.006	0.132	0.967	-0.261	0.272
Citrus Area (acre)	0.097	0.059	0.107	-0.022	0.216
Education (years)	0.086	0.074	0.249	-0.062	0.235
Farming Experience (years)	0.049	0.056	0.391	-0.065	0.162
Modern ICT use in agriculture	0.175	0.079	0.032**	0.015	0.335
ICTs use in citrus	0.221	0.102	0.036**	0.015	0.427
Constant	4.659	0.698	0.000	3.255	6.063
Number of observations					58
F (9, 48)					3.480
Prob > F					0.002
R-squared					0.395
Adj R-squared					0.282

The results are significantly different from zero at ***, **, * 1, 5, and 10 percent levels, respectively.

Table 5.31 presents the estimated OLS regression results to find the contributing factors in smallholder farmers' citrus yield. To estimate the determinants of citrus yield for smallholder farmers, per acre yield of citrus was regressed the independent variables mentioned above. The quantitative observations were transformed in its logarithmic form, and the estimates showed elasticities.

The significant value of F statistics confirmed that the independent variables consistently forecast the dependent variable. R^2 explains the percentage variation in citrus yield predicted by the independent variables. In this case, almost 20% of the variation in citrus yield was explained by independent variables.

Based on p-values, it was predicted that the coefficients of citrus area (acre), modern ICT use in agriculture, and ICT use in citrus were significant determinants of citrus yield for smallholder farmers. It was estimated that keeping all the other variables constant, one percent change in the citrus area (acre) increases a 17 percent increase in citrus yield, while one percent change in the use of modern ICT in agriculture and ICT use in citrus proportionately increase yield by 23 percent and 18 percent, respectively.

Table 5.31: Determinants of Citrus Yield (Smallholder Farmers)

Ln Yield/Acre	**Coefficient**	**S.E.**	**P>t**	**[95% Confidence**	**Interval]**
Quantity of Cultivation Practices	-0.036	0.086	0.675	-0.207	0.135
Total fertilizers (bags)	0.156	0.106	0.144	-0.054	0.366
No of Irrigations citrus	0.064	0.116	0.585	-0.166	0.293
Total Labour (hrs)	0.166	0.151	0.275	-0.133	0.465
Citrus Area (acre)	0.170	0.061	0.006***	0.049	0.290
Education (years)	-0.115	0.078	0.146	-0.270	0.040
Farming Experience (years)	0.014	0.062	0.826	-0.109	0.136
Modern ICT use in agriculture	0.236	0.082	0.005***	0.073	0.398
ICTs use in citrus	0.182	0.093	0.053*	-0.003	0.366
Constant	3.554	0.722	0.000	2.124	4.984
Number of observations					127
F (9, 117)					3.190
Prob > F					0.002
R-squared					0.197
Adj R-squared					0.135

The results are significantly different from zero at ***, **, * 1, 5, and 10 percent levels, respectively.

These results suggest that the usage of ICT for information acquisition contributed considerably to an increase in citrus yield with other factors of production, as shown in all regression analyses conducted for all farmers together and separately for small- and large-holder farmers. The smallholders with more citrus areas also had higher citrus yield. Over-cultivation practices had a negative impact on citrus yield.

5.2.8. Determinants of Animal Units

Table 5.32 describes the Poisson regression results for a number of potential predictor variables on herd size at the farms. The probability of Chi^2 (LR statistics =597.190) showed that the model was a good fit overall. The coefficients of regression were statistically significant, except for interaction with input and output markets. The coefficients of Poisson regression represent the log of the expected count as a function of the predictor variables. *Ceteris paribus*, a unit increase in education (years), farming experience (years), house area, family size (No), modern ICT use in agriculture, ICT use in livestock, and total land owned, the difference in the logs of projected counts is expected to increase by -0.018, 0.004, -0.005, 0.046, 0.137, 0.404, and 0.024, respectively.

The IRR values represent incidence rate ratios for explanatory variables. The IRR values showed that a unit increase in education (years), farming experience (years), house area, family size (No), modern ICT use in agriculture, ICT use in livestock, and total land owned, animal units are expected to increase by 0.982, 1.004, 0.995, 1.047, 1.147, 1.498, and 1.025 factor, respectively.

Table 5.32: Poisson Regression for the Determinants of Animal Units

Variables	Coefficient	S.E.	P>z	IRR	Margins
Education (Years)	-0.018	0.007	0.011	0.982	-0.158
Farming Experience (Years)	0.004	0.002	0.038**	1.004	0.037
Interaction with input and output markets	0.054	0.036	0.132	1.056	0.481
House Area	-0.005	0.001	0.000***	0.995	-0.048
Family Size (No)	0.046	0.005	0.000***	1.047	0.408
Modern ICT use in Agriculture	0.137	0.051	0.007***	1.147	1.213
ICTs use in Livestock[14]	0.404	0.059	0.000***	1.498	3.578
Total Land Owned	0.024	0.002	0.000***	1.025	0.214
Constant	1.127	0.142	0.000	3.087	
Observation					200
LR Chi^2 (8)					597.190
Prob > Chi^2					0.000
Log Likelihood					-774.838
Pseudo R^2					0.278

The results are significantly different from zero at ***, **, * 1, 5, and 10 percent levels, respectively.

The estimated margins show the predicted response. The impact of ICT usage was recognizable in determining livestock herd size. The landholding, farming experience, and family size as a source of labour for livestock management are also key factors in deciding livestock herd size.

5.2.9. Determinants of Milk Yield

Table 5.33 shows the OLS regression results for a number of potential predictor variables on milk yield.

The p-value associated with F statistics was very small (0.000) and confirmed that the independent variables consistently predicted the dependent variable. The value of R^2 explained the percentage variation in milk productivity explained by the independent variables. Thus almost 21% variation in milk productivity is explained by the independent variables.

Estimates showed the relationship between the dependent and independent variables. The quantitative variables were in log form and represent the elasticities, i.e., a proportionate change in milk yield with a one percent change in independent variables.

[14] ICT use for livestock variable is based on if farmers use ICT to get information relating to livestock management yes=1and No=0

Table 5.33: Determinants of Milk Yield (All Farmers)

Ln Milk Yield/ Milking Animal	Coefficient	S.E.	P>t	[95% Confidence	Interval]
Area under Rabi Fodder (acre)	0.022	0.054	0.680	-0.084	0.129
Area under Kharif Fodder (acre)	0.051	0.052	0.329	-0.052	0.154
Total Animal Units	-0.180	0.063	0.005***	-0.304	-0.056
Average Milk Sale (litre per day)	0.101	0.027	0.000***	0.048	0.154
Treatment Expenditures (PKR per animal)	0.046	0.018	0.010**	0.011	0.081
Milk Supplements (kg per month)	0.058	0.027	0.035**	0.004	0.111
Fulltime farm workers (No.)	0.078	0.064	0.223	-0.048	0.204
ICT for Livestock	0.199	0.062	0.002***	0.077	0.322
Modern ICT use in agriculture	0.036	0.058	0.535	-0.079	0.152
Education (years)	0.014	0.050	0.780	-0.085	0.114
Farming Experience (years)	0.012	0.042	0.776	-0.071	0.095
Constant	1.080	0.252	0.000	0.582	1.577
Number of observations					180
F (11, 168)	=				4.090
Prob > F					0.000
R-squared					0.211
Adj R-squared					0.160

The results are significantly different from zero at ***, **, * 1, 5, and 10 percent levels, respectively.

The coefficients of total animal units, average milk sale (litre per day), treatment expenditures (PKR per animal), milk supplements (kg per month), and ICT for livestock are significantly different from zero. It was estimated that keeping all the other variables constant, one percent increase in total animal units decreases milk yield by 18 percent. In comparison, one percent change in average milk sale (litre per day), treatment expenditures (PKR per animal), milk supplements (kgs per month), and ICT for livestock bring positive change of 10 percent, 4 percent, 5 percent, and almost 20 percent in milk productivity, respectively.

Table 5.34 presents the estimated OLS regression results to find the milk yield's contributing factors for large holder farmers. The F value was significant, confirming that the independent variables consistently forecast the dependent variable. The R^2 indicates that almost 32 percent of the variation in the dependent variable is explained by independent variables.

Estimates showed the elasticities, i.e., proportionate change in milk productivity due to change in the respective coefficient. The p-values in the table confirmed that only total animal units and average milk sales (litre per day) significantly different from zero and affect milk productivity for large holder farmers. Keeping all the other variables constant, a one percent increase in total animal units decreases milk productivity by almost 29 percent, while one percent change in average milk sale (litre per day) increases milk productivity by 10 percent.

Table 5.34: Determinants of Milk Yield (Large Holder Farmers)

Ln Milk Yield/ Milking Animal	Coefficient	S.E.	P>t	[95% Confidence	Interval]
Area under Rabi Fodder (acre)	0.022	0.101	0.825	-0.181	0.225
Area under Kharif Fodder (acre)	0.051	0.095	0.594	-0.140	0.241
Total Animal Units	-0.296	0.089	0.002***	-0.476	-0.115
Average Milk Sale (litres per day)	0.102	0.033	0.003***	0.036	0.169
Treatment Expenditures (PKR per animal)	0.016	0.026	0.547	-0.037	0.068
Milk Supplements (kg per month)	0.056	0.046	0.229	-0.036	0.147
Fulltime farm workers (No.)	0.039	0.095	0.682	-0.152	0.231
ICT for Livestock	0.011	0.145	0.943	-0.282	0.303
Modern ICT use in agriculture	-0.039	0.101	0.699	-0.243	0.164
Education (years)	-0.020	0.089	0.822	-0.200	0.159
Farming Experience (years)	-0.023	0.067	0.735	-0.158	0.112
Constant	2.069	0.436	0.000	1.190	2.948
Number of observations					55
F (11, 43)					2.810
Prob > F					0.002
R-squared					0.316
Adj R-squared					0.141

The results are significantly different from zero at ***, **, * 1, 5, and 10 percent levels, respectively.

Table 5.35 shows the OLS regression results for a number of potential predictor variables on the milk yield for smallholder farmers. The p-value of F statistics showed the model's overall significance and confirmed that the independent variables consistently predicted the dependent variable. The value of R^2 explains that independent variables have explained almost 23 percent variation in the dependent variable.

Estimates in the table were the elasticities and can be described as a proportionate change in milk productivity due to changes in the respective coefficient. The p-values in the table confirmed that only total animal units, average milk sales (litres per day), treatment expenditure (PKR per animal), and ICT for livestock significantly differ from zero and affect milk productivity for smallholder farmers. Keeping all the other variables constant, a one percent increases in total animal units decreases milk productivity by almost 20 percent. While one percent change in average milk sales (litres per day), treatment expenditure (PKR per animal), and ICT for livestock increase milk productivity by 14 percent, 5 percent, and 20 percent, respectively.

Table 5.35: Determinants of Milk Yield (Smallholder Farmers)

Ln Milk Yield/ Milking Animal	Coefficient	S.E.	P>t	[95% Confidence	Interval]
Area under Rabi Fodder (acre)	-0.036	0.071	0.607	-0.177	0.104
Area under Kharif Fodder (acre)	0.055	0.066	0.406	-0.075	0.185
Total Animal Units	-0.198	0.091	0.031**	-0.378	-0.018
Average Milk Sale (litre per day)	0.143	0.044	0.002***	0.055	0.231
Treatment Expenditures (PKR per animal)	0.051	0.023	0.033**	0.004	0.097
Milk Supplements (kg per month)	0.047	0.035	0.180	-0.022	0.115
Fulltime farm workers (No.)	0.086	0.085	0.319	-0.084	0.255
ICT for Livestock	0.204	0.075	0.007***	0.056	0.352
Modern ICT use in agriculture	0.025	0.075	0.737	-0.123	0.174
Education (years)	0.028	0.063	0.651	-0.096	0.152
Farming Experience (years)	0.020	0.054	0.705	-0.086	0.127
Constant	1.004	0.334	0.003	0.343	1.665
Number of observations					125
F (11, 113)					3.030
Prob > F					0.001
R-squared					0.228
Adj R-squared					0.153

The results are significantly different from zero at ***, **, * 1, 5, and 10 percent levels, respectively.

The use of ICT for livestock management practices, commercial base (milk selling), and animal treatment substantially contributed to the milk yield. The ICT usage contribution for large holder farmers was not significant than the smallholder farmers. The contribution of ICT is significant for smallholders because the considerable contribution of livestock to their livelihood requires them make fair use of ICT for needed information acquisition.

5.2.10. Citrus Production Efficiency

The Cobb-Douglas production function was estimated to determine the technical efficiency of citrus growers in the study area. Table 5.36 describes the Maximum Likelihood (ML) and Ordinary Least Square (OLS) results. Based on p-values, it was confirmed that the greater number of cultivation practices for citrus had negative impact on efficiency. Fertilizer application and area under citrus crop had a significant positive affect on efficiency for citrus growers in the area.

Table 5.37 presents the inefficiency model results. Astonishingly, education increased the inefficiency of citrus growers. It might be the reason that citrus production had been the agriculture enterprise for so long that farmers have attained certain citrus production knowledge through learning by doing. While the use of modern ICT in agriculture and ICT use in citrus management decreased the inefficiency of citrus growers revealing a positive role of ICT in agriculture in general and in citrus in particular.

Table 5.36: ML and OLS Estimates of the Production Frontier Function

Parameters	ML Estimates			OLS Estimates		
	Coefficient	Z	P>z	Coefficient	t	P>z
Ln total cultivation practices qty	-0.100	-1.720	0.085*	-0.065	-1.000	0.317
Ln total fertilizers bags qty	0.119	1.770	0.076*	0.189	2.460	0.015**
Ln irrigations citrus (No.)	0.037	0.490	0.625	0.026	0.310	0.756
Ln total labour hours citrus (acre)	0.088	0.860	0.388	0.061	0.540	0.588
Ln Citrus area (acre)	0.121	3.620	0.000***	0.153	4.190	0.000***
Constant	4.579	9.280	0.000	4.150	7.780	0.000
Log likelihood = -72.0711	Prob > chi2 = 0.0003					

The results are significantly different from zero at ***, **, * 1, 5, and 10 percent levels, respectively.

Table 5.37: Estimates of the Inefficiency Model

Parameters	Coefficient	Z	P>z
Ln education (years)	0.657	1.850	0.064*
Ln Farming experience (years)	0.147	0.600	0.552
Modern ICT Use Agriculture	-0.989	-2.770	0.006**
ICTs citrus	-1.300	-3.380	0.001**
Constant	-2.399	-1.930	0.054

The results are significant at ***, **, * 1, 5 and 10 percent levels

Table 5.38 explains the efficiency results in ICT usage. Using ICT showed that overall farmers using ICT were more efficient across small- and large- holder farm categories.

Similarly, Table 5.39 illustrates citrus farmers' efficiency based on information sources. The efficiency associated with formal and informal information sources showed that farmers across small- and large- holder farm categories using formal sources of information were more efficient than farmers who were using informal sources. However, the efficiency with education level (Table 5.40) indicates that more educated smallholder farmers had almost the same efficiency level comparing to less educated farmers while in the case of a large holder farmer's category, more educated farmers were more efficient than the less educated farmers. On an overall basis, it was concluded that more educated farmers were slightly more efficient than less-educated farmers. Education group analysis results were different from the number of education years variable estimates in the technical efficiency calculation.

Table 5.38: Efficiency with the Use of Information Communication Technologies (ICTs)

ICTs use	Small			Large			Total		
	Efficiency (%)	SD	Freq.	Efficiency (%)	SD	Freq.	Efficiency (%)	SD	Freq.
ICTs use	77.38	0.113	86	81.32	0.059	48	78.79	0.099	134
No use	67.78	0.174	41	64.15	0.131	10	67.07	0.166	51
Overall	74.28	0.142	127	78.36	0.099	58	75.56	0.131	185

Table 5.39: Efficiency with Formal and Informal Information Sources

Information Sources	Small			Large			Total		
	Efficiency (%)	SD	Freq.	Efficiency (%)	SD	Freq.	Efficiency (%)	SD	Freq.
Formal	75.90	0.122	93	78.39	0.100	56	76.84	0.114	149
Informal	69.84	0.183	34	77.45	0.118	02	70.26	0.179	36
Overall	74.28	0.142	127	78.36	0.099	58	75.56	0.131	185

Table 5.40: Efficiency with the Education Level

Education Level	Small			Large			Total		
	Efficiency (%)	SD	Freq.	Efficiency (%)	SD	Freq.	Efficiency (%)	SD	Freq
More educated	74.24	0.149	75	81.52	0.057	39	76.73	0.130	114
Less educated	74.34	0.133	52	71.87	0.133	19	73.68	0.133	71
Overall	74.28	0.142	127	78.36	0.099	58	75.56	0.131	185

Overall, results revealed that ICT usage for citrus enterprise enhances citrus productivity efficiency. The farmers who are using ICT for citrus were more efficient among the small- and large- holder farmers. The large holder farmers were more efficient than smallholder farmers. The farmers who are acquiring information from formal sources were also more efficient than the others.

5.2.11. Milk Production Efficiency

On the same lines, citrus growers' technical efficiency for milk productivity in the study area was estimated using the Cobb-Douglas production function. Table 5.41 illustrates the Maximum Likelihood (ML) and Ordinary Least Square (OLS) results.

Table 5. 41: ML and OLS Estimates of the Production Frontier Function

Parameters	ML Estimates			OLS Estimates		
	Coefficient	Z	P>z	Coefficient	t	P>z
Ln Rabi Fodder Area (acre)	0.000	-0.010	0.993	0.002	0.030	0.973
Ln Kharif Fodder Area (acre)	0.011	0.230	0.816	0.008	0.150	0.882
Ln Total Animal Units	-0.215	-3.480	0.001***	-0.211	-3.180	0.002***
Ln Average milk sale per day	0.100	3.990	0.000***	0.108	3.940	0.000***
Ln treatment expenditure per animal	0.042	2.620	0.009***	0.046	2.590	0.010**
Ln Milk supplements	0.050	2.040	0.041**	0.056	2.060	0.041**
Ln fulltime farmworkers	0.050	0.850	0.393	0.041	0.660	0.510
Ln land owned (acre)	0.088	1.890	0.059*	0.130	2.580	0.011**
Constant	1.556	8.280	0.000	1.131	6.190	0.000
Log likelihood = -53.864	Prob > chi2 =	0.0000				

The results are significantly different from zero at ***, **, * 1, 5, and 10 percent levels, respectively.

Based on p-values, it was confirmed that total animal units, average milk sales per day, treatment expenditure per animal, milk supplements, and land owned by the farmers significantly affect the efficiency of milk productivity for citrus growers in the area.

Table 5.42 describes the inefficiency model results in milk productivity. It was confirmed that ICT use in livestock management significantly decreased farmers' inefficiency in livestock management. This shows the positive role of ICT in milk productivity.

Table 5.42: Estimates of the Inefficiency Model

Parameters	Coef.	Z	P>z
Ln education in years	-0.116	-0.340	0.732
Ln Farming experience	-0.277	-0.960	0.338
Modern ICT use agriculture	-0.706	-1.640	0.100*
ICTs citrus	-1.126	-2.400	0.016**
Constant	-0.128	-0.100	0.924

The results are significant at ***, **, * 1, 5 and 10 percent levels

Further, Table 5.43 shows that farmers using ICT were more efficient across small- and large-holder farm categories and overall, than those who were not using it. Similarly, Table 5.44 shows the efficiency in comparison to information sources. Farmers across small- and large-holder farm categories using formal sources of information were more efficient than farmers who were using informal sources of information. On the same lines, Table 5.45 describes the results based on education level. The efficiency with education level showed that for farmers across smallholder, large holder categories, and overall, more educated farmers were slightly efficient than the less educated farmers.

Table 5.43: Efficiency with the Use of Information Communication Technologies (ICTs)

ICTs use	Small			Large			Total		
	Efficiency (%)	SD	Freq.	Efficiency (%)	SD	Freq.	Efficiency (%)	SD	Freq.
ICTs use	80.48	0.088	81	83.88	0.053	49	81.76	0.078	130
No use	71.25	0.126	43	79.55	0.078	6	72.27	0.123	49
Overall	77.28	0.111	124	83.40	0.057	55	79.16	0.102	179

Table 5.44: Efficiency with Formal and Informal Information sources

Information Sources	Small			Large			Total		
	Efficiency (%)	SD	Freq.	Efficiency (%)	SD	Freq.	Efficiency (%)	SD	Freq.
Formal	78.32	0.103	111	83.53	0.058	47	79.87	0.095	158
Informal	68.37	0.139	13	82.64	0.059	8	73.81	0.133	21
Overall	77.28	0.111	124	83.40	0.057	55	79.16	0.102	179

Table 5.45: Efficiency with the Education Level

Education Level	Small			Large			Total		
	Efficiency (%)	SD	Freq.	Efficiency (%)	SD	Freq.	Efficiency (%)	SD	Freq.
More educated	77.75	0.110	71	83.94	0.048	37	79.87	0.098	108
Less educated	76.64	0.114	53	82.30	0.073	18	78.07	0.107	71
Overall	77.28	0.111	124	83.40	0.057	55	79.16	0.102	179

In summary, the results illustrate a significant contribution of ICT in increasing milk production efficiency. In livestock management, farmers who made good use of ICT were more efficient than those who did not. The farmers' experience and education also enhanced milk productivity efficiency but not considerably. The farmers who got information from formal information sources were more efficient in livestock management that impacts on milk productivity.

Section 5.2 investigated objective two and considered the contribution of ICT. The information acquisition for citrus management practices and frequency of information acquisition increased with improving access to formal information sources among the small- and large- holder farmers. From an overall perspective, the considerable difference between small- and large-holder farmers were retained by reducing the information gap in certain practices in comparing the two eras, currently and before access to modern ICT. The large holder and more educated farmers made more use of modern ICT compared to smallholder and less-educated farming categories. The large holder and more educated farmers had relatively better awareness and adoption of innovative technologies, with formal sources of information being the primary source. ICT contribution was lower than the other communication sources in making farmers innovative. Farmers making more use of ICT for agricultural enterprises earned more income than farmers who made more use of ICT for personal purposes, across all farm categories based on farm size and education level. Research findings emphasized the considerable impact of ICT with other contributing factors in citrus area allocation, citrus productivity, animal herd size, and milk productivity, for small- and large- holder farmers. The results highlighted ICT contribution in increasing the efficiency of citrus and livestock production. The ICT user farmers for agricultural enterprises (citrus and livestock) were more efficient across all farming categories based on farm size and education. The smallholder farmers were less efficient in both agricultural enterprises than the large holder farmers.

C. Objective Three, to explore small- and large- holder citrus farmers' perceptions of the value and impact of ICT on their farming practices.

This section relates to the third objective, addressing the research question about the perceived benefits to small- and large- holder farmers using ICT for agriculture. The analytical techniques included independent *t*-test and Welch's *t*-test statistics. To draw the key aspects, factor analysis using principal component analysis (PCA) was conducted with the oblimin and varimax rotations available in statistical software.

5.3. Perceptions of the Value and Impact of ICT

5.3.1. Awareness/Attitude Perception Measurement about ICT Possible Contribution

Table 5.46 describes the farmers' attitude/perception of ICT contribution. Data were collected from farmers to seek their insight into ICT, based on their knowledge capacity and how they value the contribution of ICT to farming enterprise. They were asked to respond to 20 ICT related statements. Results revealed that farmers across both categories of farming and education agreed or agreed some extent about ICT the contribution 13of the variables, while for two others, their perception ranged from disagreeing to agreeing to some extent. For the negatively stated variables their perception ranged from strongly disagree to disagree.

Importantly, all farmers response for the positive stated aspects for ICT possible contribution from some extent agree to agree, the disagreement was higher among the smallholder and less educated farmers than the large holder and more educated farmers. The same result was observed for other three positively stated aspects from disagreeing to agreeing some extent across both farmers categories based on the farm size and education level. For the negatively stated aspects like the ICT cannot meet location-specific needs of the farmers, illiteracy will not deter farmers in accessing ICT services, existing infrastructure of ICT is not enough to meet needs of farming community, ICT is a valuable tool, but it will never influence farmers' own decision making and only resourceful farmers can get the benefit of the ICT, the disagreement was higher among the large holder and more educated farmers.

There was a statistically significant difference in perception of ICT contribution in the adoption of innovative technologies, increasing income due to market information, development of the knowledgeable farming community, cheaper storage and retrieval information and ICT are for only resourceful farmers across the small- and large- holder farm categories and education categories. Perceptions were significantly different regarding the ICT increase the adoption of innovations, ICT improve social interaction, buying less priced quality inputs, acquisition of firsthand information from scientist between the small- and large- holder farmers.

Thus, considering the awareness, attitude, and perception of ICT possible contribution in agriculture enterprise, large holder farmers and more educated farmers exhibited a relatively more positive attitude.

Table 5.46: Awareness/Attitude Perception Measurement about ICT Possible Contribution

Perceptions regarding ICT	Categorization on Farm Size (hectares)			Categorization on Education (years)			Overall
	Small <8 (1	Large ≥8		<10	≥10		
	Average Score		Sig.	Average Score		Sig.	Avg. Score
1. ICT increase adoption of innovative technologies/new farming practices	3.54	3.81	0.041**	3.36	3.79	0.012**	3.62
2. ICT improve market access for produce	3.46	3.66	0.261	3.37	3.62	0.108	3.52
3. ICT increase farmers income with market price information and negotiation	3.43	3.71	0.044**	3.33	3.63	0.086*	3.51
4. ICT increase access to financial sources	2.56	2.50	0.797	2.31	2.70	0.063*	2.54
5. ICT improve farm management practices	3.51	3.66	0.335	3.44	3.63	0.241	3.56
6. ICT improve social interaction among farmers which contributes to efficiency	3.68	3.95	0.041**	3.65	3.82	0.264	3.76
7. ICT reduce dependency on agriculture extension services	3.18	3.29	0.535	3.14	3.27	0.416	3.22
8. ICT based extension services assist farmers in planning and decision-making	3.36	3.36	0.987	3.20	3.47	0.109	3.36
9. Easy and cheaper access to accurate and timely information	3.44	3.62	0.264	3.26	3.66	0.023**	3.50
10. Farmers can get low prices and quality of inputs using ICT.	3.23	3.50	0.056*	3.19	3.39	0.219	3.31
11. Phone-in-live with scientists gives first-hand information about queries.	3.41	3.69	0.056*	3.33	3.60	0.100	3.49
12. ICT based extension services to build a skilled and Knowledge community.	3.27	3.64	0.012**	3.16	3.52	0.027**	3.38
13. Weather forecasting through ICT assists farmers in timely decisions.	3.67	3.76	0.584	3.49	3.83	0.025**	3.70
14. ICT provide possible solutions to the present agricultural situation.	3.22	3.47	0.168	3.00	3.49	0.003***	3.29
15. Cheaper and Better Storage and Retrieval of information	2.36	2.84	0.062*	1.88	2.92	0.000***	2.50
16. ICT cannot meet location specific needs of the farmers	1.81	1.67	0.458	1.73	1.80	0.694	1.77
17. Illiteracy will not deter farmers in accessing ICT services.	2.45	2.53	0.613	2.26	2.62	0.017**	2.48
18. Existing infrastructure of ICT is not enough to meet needs of farming community.	1.68	1.55	0.457	1.58	1.69	0.505	1.65
19. ICT is a valuable tool, but it will never influence farmers' own decision making.	1.99	1.90	0.490	2.01	1.93	0.538	1.97
20. Only resourceful farmers can get the benefit of the ICT	1.96	1.64	0.006***	2.02	1.76	0.031**	1.87
Score Undecided/don't know=0, Strongly Disagree=1, Disagree=2, To some extent agree=3, Agree=4, Strongly Agree=5							

The results are significantly different from zero at ***, **, * 1, 5, and 10 percent levels, respectively.

5.3.2. Factor Analysis of Perceptions Regarding the Perceived Benefits of ICT Usage for Agriculture

The responses to the 20 statements above were analysed by principal component analysis (PCA) using SPSS. Before conducting PCA, the suitability of the data was assessed using a correlation matrix. The matrix revealed numerous coefficients ≥0.3. The Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy indicated that the strength of the relationships among variables was high (KMO = 0.943), exceeding the advised value of 0.6; thus, it was acceptable to proceed with the analysis. Bartlett's test of sphericity, the overall significance of all the correlations within the correlation matrix, was significant (χ^2 = 2898.738, p=XX), indicating that it was appropriate to use the factor analysis model on these data. A series of factor analyses were conducted, which indicated that three factors account for a substantial proportion of the variance. An oblimin and with Kaiser Normalization rotation was performed since factors are expected to be correlated.

Table 5.47a explains the PCA results with oblimin rotation. The first factor was robust, with a high eigenvalue of 10.30, and it accounted for 51.48 % of the variance in the data. The second factor had an eigenvalue of 1.77 and accounted for a further 8.86 % of the variance. The eigenvalue for factor three was 1.16, accounting for 5.79 % of the total variance. There was no difference in eigenvalues and variance extraction between the rotation types in all three factors in number sequence, only reshuffling of items positions with the same meaning under factors sequence. Factor analysis of the items used in the current study revealed three factors were sufficient to explain the perceived benefits of ICT use. The pattern matrix in Table 5.47a revealed factor one consisted of thirteen items. Some items had loaded in more than one factor with a minimal value of 0.3, but the more coefficient value was considered as a part of a particular factor. This factor, labelled 'ICT are helpful in improving social capital, and farm business' reflects a high internal consistency. The second factor consisted of four items and labelled as 'ICT affordability and access help farmers in reaping ICT benefits across distant locations. The third factor contained three items that explain that 'illiteracy has a moderate impact on accessing ICT services such as data storage, data retrieval, and financial access'.

Table 5.47b describes the PCA results with varimax rotation. The results were the same with both rotation methods. The results using varimax rotation also reveals factor one consisted of thirteen items. This factor, labelled as 'ICT are helpful in improving social capital, and farm business' reflects a high internal consistency, as for the oblimin rotation method. The second factor consisted of four items and was labelled ‘ICT affordability, and existing infrastructure is enough to access and influence farmers to reap the ICT benefits across distant locations’. The third factor consisted of three items and was labelled ‘Illiteracy has a moderate impact on accessing ICT services such as data storage, retrieval information, and financial access’. With both rotations, the conclusion is the same, with minor differences in the values of coefficients in factor loading, that ‘farmers’ perceptions/attitude confirm that ICT use is beneficial in the improvement of social and financial capitals of livelihood’.

Table 5.47a: Factor Loading Regarding Perceived Benefits of ICT Usage (Oblimin Rotation)

Sr.No	Perceptions regarding ICT	Mean*	Factors** 1	2	3	Communalities
1	ICTs increase adoption of innovative technologies/new farming practices	3.62	**0.838**	-0.007	0.038	0.724
2	ICTs improve market access for produce	3.52	**0.715**	0.093	0.069	0.604
3	ICTs increase farmers income with better market price information and negotiation	3.51	**0.852**	-0.098	0.057	0.723
4	ICTs increase access to financial sources	2.54	0.263	0.142	**0.566**	0.550
5	ICTs improve farm management practices	3.56	**0.862**	0.009	-0.065	0.709
6	ICTs improve social interaction between farmers which contributes to efficiency	3.76	**0.911**	-0.114	-0.164	0.691
7	ICT based extension services assist farmer in better planning and decision-making	3.36	**0.786**	0.154	0.070	0.765
8	Easy and cheaper access to accurate and timely information	3.50	**0.848**	0.058	0.021	0.766
9	Farmers can get low prices and quality of inputs using ICT.	3.31	**0.753**	0.054	0.215	0.766
10	Phone-in-live with scientists gives first-hand information.	3.49	**0.822**	0.010	0.012	0.689
11	ICTs based extension services provide opportunity to build skilled and Knowledge community	3.38	**0.834**	-0.033	0.104	0.756
12	Weather forecasting through ICT assists farmers in timely decisions.	3.70	**0.845**	-0.041	-0.043	0.668
13	ICTs provide possible solutions to the present agricultural situation.	3.29	**0.760**	-0.016	0.197	0.723
14	Cheaper and Better Storage and Retrieval of information	2.50	0.137	0.143	**0.667**	0.570
15	ICTs cannot meet location specific needs of the farmers	1.77	0.297	**0.605**	-0.062	0.555
16	ICTs reduce dependency on agriculture extension services	3.22	**0.730**	0.064	0.097	0.629
17	Illiteracy will not deter farmers in accessing ICT services	2.48	0.051	-0.154	**0.745**	0.601
18	Existing infrastructure of ICT is not enough to meet the needs of farming Community.	1.65	0.034	**0.745**	0.244	0.644
19	ICT is a valuable tool, but it will never influence farmers' own decision making.	1.97	**0.349**	**0.522**	**-0.304**	0.513
20	Only resourceful farmers can get the benefit of the ICT	1.87	-0.229	**0.799**	-0.014	0.579
	Eigen Values	------	10.30	1.77	1.16	
	Total Variance Experienced (Percent)	------	51.48	8.86	5.79	
	Cumulative variance experienced (Percent)	------	51.48	60.34	66.13	

Observations= 200 Bartlett's test of Sphericity $\chi 2$ =2898.738* KMO=0.943**

Extraction Method: Principal Component Analysis

Rotation Method=Oblimin with Kaiser Normalization

*Scale Undecided/Don't Know=0 Strongly Disagree =1 Disagree =2 To Some Extent Agree=3 Agree = 4 Strongly Agree =5

Factors**
1. **ICT are helpful in improving social capital and farm business**
2. **ICT affordability and existing infrastructure is enough to access and influence farmers to reap the ICT benefits across distant locations**
3. **Illiteracy has moderate impact in availing ICT services including data storage/retrieval and financial access**

Table 5.47 b: Factor Loading Regarding Perceived Benefits of ICT Usage (Varimax Rotation)

Sr.No	Perceptions regarding ICT	Mean*	Factors** 1	2	3	Communalities
1	ICTs increase adoption of innovative technologies/new farming practices	3.62	**0.812**	0.134	0.217	0.724
2	ICTs improve market access for produce	3.52	**0.713**	0.210	0.226	0.604
3	ICTs increase farmers income with better market price information and negotiation	3.51	**0.816**	0.045	0.234	0.723
4	ICTs increase access to financial sources	2.54	**0.379**	0.153	**0.619**	0.550
5	ICTs improve farm management practices	3.56	**0.818**	0.159	0.122	0.709
6	ICTs improve social interaction between farmers which contributes to efficiency	3.76	**0.829**	0.051	0.030	0.691
7	ICT based extension services assist farmer in better planning and decision-making	3.36	**0.791**	0.282	0.246	0.765
8	Easy and cheaper access to accurate and timely information	3.50	**0.827**	0.201	0.205	0.766
9	Farmers can get low prices and quality of inputs using ICT.	3.31	**0.772**	0.170	**0.375**	0.766
10	Phone-in-live with scientists gives first-hand information about queries.	3.49	**0.794**	0.150	0.189	0.689
11	ICTs based extension services provide opportunity to build skilled and Knowledge community	3.38	**0.817**	0.103	0.280	0.756
12	Weather forecasting through ICT assists farmers in timely decisions.	3.70	**0.799**	0.106	0.138	0.668
13	ICTs provide possible solutions to the present agricultural situation.	3.29	**0.766**	0.103	0.355	0.723
14	Cheaper and Better Storage and Retrieval of information	2.50	0.277	0.127	**0.691**	0.570
15	ICTs cannot meet location specific needs of the farmers	1.77	**0.357**	**0.653**	0.033	0.555
16	ICTs reduce dependency on agriculture extension services	3.22	**0.729**	0.182	0.255	0.629
17	Illiteracy will not deter farmers in accessing ICT services	2.48	0.168	-0.186	**0.734**	0.601
18	Existing infrastructure of ICT is not enough to meet the needs of farming Community.	1.65	0.181	**0.729**	0.283	0.644
19	ICT is a valuable tool, but it will never influence farmers' own decision making.	1.97	**0.350**	**0.593**	-0.197	0.513
20	Only resourceful farmers can get the benefit of the ICT	1.87	-0.113	**0.752**	-0.024	0.579
	Eigen Values	------	10.30	1.77	1.16	
	Total Variance Experienced (Percent)	------	51.48	8.86	5.79	
	Cumulative variance experienced (Percent)	------	51.48	8.86	5.79	

Observations= 200 Bartlett's test of Sphericity $\chi2$ =2898.738* KMO=0.943**
Extraction Method: Principal Component Analysis
Rotation Method=Varimax with Kaiser Normalization
*Scale Undecided/Don't Know=0 Strongly Disagree =1 Disagree =2 To Some Extent Agree=3 Agree = 4 Strongly Agree =5

Factors**
1. **ICT are helpful in improving social capital and farm business**
2. **ICT affordability and existing infrastructure is enough to access and influence farmers to reap the ICT benefits across distant locations**
3. **Illiteracy has a moderate impact in availing ICT services including data storage/retrieval and financial access**

Table 5.47 c: Factor Scores Comparison Based on Farm Size and Education Level

Sr. No	Factors	Factor Score Comparison (Oblimin Rotation)									
		Categorization on Farm Size (hectares)					Categorization on Education (years)				
		Small<8	Large ≥8	Mean Diff.	t value	Sig.	< 10	≥10	Mean Diff.	t value	Sig.
		Average Score					Average Score				
1	ICTs improve social capital and farm business	-0.07	0.16	-0.227	-1.460	0.146	-0.18	0.12	-0.301	-2.107	0.036**
2	ICTs affordability and access influence farmers to reap ICT benefits	0.09	-0.22	0.304	1.964	0.049**	0.07	-0.05	0.120	0.829	0.408
3	Illiteracy has moderate impact in availing ICT services	-0.04	0.11	-0.152	-0.973	0.332	-0.32	0.22	-0.534	-3.835	0.000***
		Factor Score Comparison (Varimax Rotation)									
1	ICTs improve social capital and farm business	-0.08	0.20	-0.280	-1.806	0.072*	-0.14	0.10	-0.235	-1.638	0.103
2	ICTs affordability and access influence farmers to reap ICT benefits	0.10	-0.25	0.350	2.270	0.024**	0.11	-0.07	0.178	1.236	0.218
3	Illiteracy has moderate impact in availing ICT services	-0.02	0.06	-0.081	-0.516	0.606	-0.29	0.20	-0.490	-3.493	0.001***

The results are significantly different from zero at ***, **, * 1, 5, and 10 percent levels, respectively.

Table 5.47c describes the comparative analysis of factor scores based on farm size and education level. Factor scores were calculated using the Anderson-Rubin method. Scores obtained with this method were not correlated with the scores of other factors and uncorrelated with the factor scores. A zero score on a factor indicates that the respondent's rating of the value of the related characteristics is near to the average. A positive score implies that the respondent is inclined towards agreement with the factor statement while a negative score value means that the respondent is inclined towards disagreement with the statement.

Score values for the factor **'ICT** improve social capital and farm business' differed between the small- and large- holder farmers. The negative value recorded for small holder farmers to the statement, 'ICT improve social capital, and farm business for the smallholder farmers' reflected the fact that their perception ranged from to some extent agree to disagree. The positive value for large holder farmers reflected agreement that 'ICT improve the social capital and farm business'. This finding was validated with both oblimin and varimax rotation methods of PCA. The difference of perception between small- and large- holder farmers was more significant with the varimax rotation method. The factor score values were opposite between small- and large- holder farmers for the second-factor statement that 'ICT affordability and access influence farmers to reap its benefits'. The negative value for the large holder farmers reveals that ICT affordability and access is not a barrier to obtaining benefits from ICT. The positive value for the smallholder farmers reflected their concerns about ICT affordability and access, due to a weak resource base. These different perceptions regarding affordability and access were apparent using both the rotation methods. The negative value for smallholders in the third factor indicated that illiteracy impacts much more on their ability to access ICT services in comparison to large holder farmers. The result was the same with both the rotation methods except some variation in factor score values.

The factor scores followed the same pattern for less educated and more educated farmers as with the earlier comparison of small- and large- holder farmers. A variation in the factor score values and significance with both the oblimin and varimax rotation method was observed. The perception regarding the first factor between the less educated farmers and more educated farmers was significantly different. The more educated farmers' judgment was more towards agreement that 'ICT improve the social capital and farm business compared to the less educated farmers. The second factor score values explain that ICT affordability and access were more of a concern to less educated farmers. For the third factor relating to literacy, a significant difference in scores was observed across the categories based on education with both rotation methods; the less educated farmers considered illiteracy to have a greater impact on accessing ICT services than more educated farmers.

Hence, the factor analysis regarding the perceived benefits was built around three key considerations but varied across farming categories. Firstly, farmers perceived that ICT contributes to improving social capital and farm business. Secondly ICT' affordability and illiteracy limit the ICT' advantages. Finally, the smallholder and less educated farmers are relatively less optimistic about the perceived contribution of ICT.

5.3.3. Farmers Preferred Means for Obtaining Technical Information

Table 5.48 shows farmers' preferences for various means of communication to get information relating to farm enterprises.

Table 5.48: Farmers Preferred Means for Obtaining Technical Information

Sr. No	Communication ways	Smallholder Farmers		Large holder Farmers		Overall	
		Percent	Priority	Percent	Priority	Percent	Priority
1	Mobile Call to relevant expert	47	1	39	1	45	1
2	Agricultural Programs on TV	20	2	17	2	19	2
3	Seminar/trainings using ICT visual preference	10	3	13	3	11	3
4	MMS (video in local language)	9	4	11	4	10	4
5	SMS text in Urdu/local language	5	5	8	5	6	5
6	Agri.websites etc using internet	5	6	7	6	6	6
7	MMS (Audio in local language)	2	7	1	7	1	7
8	Social media, Facebook etc using interne on mobile/computer	0	8	4	8	1	8
9	Agricultural Programs on Radio	0	9	1	9	0	9

The farmers were more comfortable with personal communication via mobile as the preferred way to communicate with the experts. Among some other possible communication ways, they gave more preference to the broadcasting of agricultural programs on TV, and seminars with ICT aids could contribute effectively to the information acquisition process. The priorities were the same for the small- and large- holder farmers for effective and efficient communication. As reported in section 5.3, all farmers recognised the value of ICT in contributing to information communication, enhancing the social capital and farm businesses, improving farmers' knowledge, skills, innovations' adoption, and possibly all farm business-related aspects. However, the smallholder and less educated farmers had a less positive perception of ICT's potential contribution. They were more concerned about constraining factors such as ICT affordability and illiteracy. All the farmers prioritized personal communication with the relevant stakeholder as a preferred way of communication for information acquisition, followed by TV programs and seminars with ICT aids.

D. Focus Group Discussions' Results

The section describes the results from the Focus group Discussions (FGDs) conducted with relevant stakeholders of the citrus value chain including, agricultural research officers, agricultural extension agents, input dealers, citrus pre-harvest contractors, commission agents, citrus exporters, and transporters. The insight of these stakeholders regarding ICT use and contribution in their businesses and farmers' perspective is explained. The relationship between age and ICT use for agriculture is also considered in this section. At the end of this chapter, hypotheses developed on different livelihood capitals are addressed with the research outcome of ICT's role and contribution in agricultural enterprises.

5.4. Focus Group Discussion

Focus group discussions were held to gain insight into the perception of the citrus value chain stakeholders regarding ICT contribution to their businesses and the limiting factors affecting its effectiveness. Focus Group Discussions (FGDs) were conducted with employees of agricultural research and agricultural extension, officials from agricultural marketing, input suppliers, citrus pre-harvest contractors, commission agents, transporters, and youth in the research area. The participants in every FGD were informed about the purpose of research before conducting FGD.

5.4.1. Agricultural Research and Extension Experts

The FGD was conducted with officials from the Citrus Research Institute (CRI) and agricultural extension officers of the study area. The agricultural officers were present at CRI for training purposes which provided an excellent opportunity to get the insights of both research and extension officers into ICT's role in an agricultural enterprise. Seven people participated in this discussion. The following important responses were noted:

- Officials and officers of the Agricultural Extension Department and Agricultural Research were also in communication through social media groups. Using these social media groups, experts communicate issues within the system. With the use of ICT, attendance of the agricultural officials was ensured, and efficiency/performance had also increased. Also, now feedback was available to officials regarding crop conditions.
- It was revealed that the Government of Punjab planned to distribute smartphones to selected smallholder farmers, supplemented with Apps including Zarai Mashware (Agricultural Consultation), Zarai Jentry, Kasht (Farming) Calculator, Kissan (Farmers') TV, Kissan Dokan (Farmers' Shop), Maqami Mausam (Local weather), and Mandi (Market). Agricultural commodity rates were available, and farmers could make free calls, voice messages and MMS for various inquiries. The intention was that farmers would be able to receive expert opinion/advice within the shortest possible time using these Apps. Through these apps, experts also used to provide region specific information for crops.
- Besides these apps, the Punjab Information Technology Board (PITB) had also developed an Agri Smart app, where information was available with GPS location, picture, and relevant literature for farmers' guidance.
- App development was in progress through a joint venture between the Agriculture Department of Punjab province and the Telenor mobile company where farmers would be able to make free calls, voice messages, short messages, and multimedia messages regarding crop condition and diseases among other things. Experts would be bound to reply to every query on a regional basis.
- Agricultural experts revealed that, on average, they were receiving 3-4 calls daily from farmers regarding different aspects of crop production.
- ICT had made it easy to search the literature on a range of issues, helping to get information about the latest technologies. Farmers from far-flung areas could send photos of their infested crop, and make calls, and send emails, SMS and MMS to identify the issue and obtain advice about possible remedies. Previously, extension agents were usually consulted by the farmers, but this communication improved the link between agricultural institutes and farmers. Now researchers and extension agents

were equally engaged through ICT. The use of ICT also strengthened the link between extension agents, researchers, and farmers.

- Researchers and extension agents used to record videos and upload them on different media for the guidance of interested farmers. In some groups, farmers were also connected with agricultural research and extension experts for receiving timely information on agricultural practices and issues. Mobile was the primary source of communication between agricultural experts and farmers. The smallholder farmers were also part of the groups. Farmers shared their issues with these groups, and experts provide suggestions for the solution of problems. These groups were also used to gather farmers for field days and other activities arranged for the farming community within a specific region. With the use of social media, more of the farmers became informed, and participation in the events also increased.

Employees of Citrus Research Institute (CRI) regarded ICT highly. They were using the internet to get updated knowledge about new farming practices and techniques. ICT were time saving, and helped in identification of different infestations on crops and detailed information about different diseases. They had also formed a social media group for sharing information within employees and farmers. Further, employees of CRI were also members of other groups where they could share information. They were also sharing advice on SMS, MMS, mobile calls and emails.

In summary, the researchers and agricultural extension agents were convinced that ICT were contributing positively to their official responsibilities and for farmers. Certain initiatives to boost the effectiveness of ICT and apprise smallholder farmers with the latest information were in progress. The research and extension officials were well connected via mobile and social media apps among themselves and with the farming community.

5.4.2. Input Dealer

Two FGDs were organized with input dealers, who were dealing with most of the farm inputs, to get their opinions about how ICT were benefiting them in developing business volume and liaison with farmers. Mainly farmers and input dealers communicate for the availability, quality and price of farm inputs, quality marketing. Input dealers were using ICT to connect with experts about new developments in the field and possible solutions for different issues.

The following were the important responses noted during Focus Group Discussions:

- Mobile was used by farmers to get availability and price information on different inputs.
- Farmers were getting the price from different dealers and could buy inputs of their choice at the best-offered price. Smallholders were also benefiting with ICT usage in input market.
- Though pesticide companies appoint the technical workforce to visit farmers' fields, many farmers were using social media to get information on the use of pesticides and the application of other inputs at the proper stage of crops.
- Input dealers also were using ICT for to reply to farmers' queries regarding input use and correct diagnosis of disease.
- The use of ICT had also increased the business volume for input dealers.
- ICTs were bridging information gaps, especially for educated farmers, while other farmers convince only seeing practical demonstrations.

One input dealer had opened a fertilizer business in 1990 and included pesticides in 2011. He believed that modern ICT played a large role in farm enterprise; with the application of ICT, farmers bargaining power, knowledge and productivity had increased. ICT also helped in the timely application of inputs, as farmers use ICT to get latest information about farm practices from different sources e.g. internet, social media groups, etc.

In summary, input dealers believed that the input market had developed better linkages with the farming community via mobile communication, bringing mutual benefits. Farmers, including the smallholders, were less exploited in the input market when buying quality inputs at reasonable prices. The input dealers had increased business and knowledge through better access to relevant experts.

5.4.3. Citrus Pre-harvest Contractors

Citrus pre-harvest contractors hold an important position in the citrus supply chain. They are linked with the farmers, commission agents in different fruit markets, transporters, labour, input dealers, and other pre-harvest contractors. To investigate the role of ICT in their business, two FGDs were conducted. At the start of the discussion, they were uncomfortable sharing their experience due to a lack of trust, but they started to take an interest as the conversation progressed. The critical views noted during the discussion are described below:

- Mobile was making a significant contribution to their business. They visit farmers' citrus orchard once, and bargaining discussion continues via mobile to come up with the final deal or decision. Previously, without mobile, they had to visit one orchard many times leading to a wastage of time and resources.

- Before mobile adoption, they had been unaware of the existence of many citrus orchards from which they could purchase fruit. Now this was not the issue; to make citrus orchard contract or leave, it was contractors' decision. They had increased business volume from 25 to 50 percent with mobile use.
- Mobile communication had made their lives comfortable in labour and transport arrangements. As citrus harvesting contractors mainly hire labour outside the district, they could easily manage labour on a need's basis considering the time and number of labours. They could arrange the required vehicle with one mobile phone call and remain connected with drivers during citrus produce transportation from field to market. They could also address other issues during the transportation of produce.
- They were well connected with the exporters in near and remote markets all over the country using mobile. They were updating themselves daily with the price and supply-demand situation of citrus through mobile calls, SMS, or through social media such as WhatsApp group, Facebook groups, and websites of marketing departments. They make their decisions accordingly to fetch a good price.
- Modern ICT had made their money transactions very easy. Some were using internet banking, and most of the contractors were using facilities provided by different cellular companies such as 'Easy paisa' first branchless bank mobile service. They were making transactions with farmers, commission agents, exporters, and among themselves without fear of theft.
- Frequent interaction using mobile also increase the trust and confidence among different stakeholders of the citrus value chain.
- All the participants agreed that modern ICT, especially mobile, are benefitting both small and large holder farmers greatly. Farmers had attained a better bargaining position with mobile adoption. Farmers kept themselves aware of every critical aspect of their farming business, and especially the selling of citrus. Now they could contact other fellow farmers, contractors, exporters, and commission agents of different markets to know the price trend in the current season before making the citrus orchard contract-out decision. In the past contractors used to get the advantage in purchasing citrus orchard due to the lack of awareness of the farmers about the prevailing price in the

area. Awareness with better communication encouraged farmers for self-marketing of citrus to earn more rather than to contract out on less price.

Hence, citrus contractors, believed that with the communication revolution using mobile, every player in the citrus value chain, including smallholder farmers, was now more advantaged than fifteen years previously.

5.4.4. Transporters

Focus Group Discussion (FGD) was held with six citrus transporters. The purpose of the discussion was explained to the group before starting the discussion and recording of information. Every member of the group took a keen interest in the talk due to their role in the citrus supply chain. Transporters appreciated this research work because it was the first time that someone was discussing their role and contribution to the citrus supply chain. The key observations noted during the discussion are described below:

- Transporters in the area were mainly operating the small vehicles with a loading capacity of 60-65 maunds (1 maund = 40 Kgs). They explained that some years back, large vehicles with a loading capacity of more than 400 maunds were used, as only big markets were accessible for domestic marketing of citrus. Transporting a large volume of citrus is still a viable option, but more risk is involved due to price fluctuation.
- Transport commission agents were improving their services. Transport commission agents for arranging transport had established shops and had been working since the start of domestic marketing. They were also arranging and/or providing labour with the vehicle to farmers and pre-harvest contractors. Transport commission agents were earning PKR 400 per vehicle arrangement. They were responsible for providing guarantees to farmers and contractors regarding any issue related to transport and labour.
- Mobile communication had increased access to small markets. It had also increased the demand for small vehicles with more employment opportunities. Better communication was giving the double advantage to transporters that before they arrived at destination carrying citrus, they could arrange for another commodity to bring back. If they had any problem during travelling, they handled it economically and quickly via communication through mobile. Mobile communication was saving the time of every stakeholder of the citrus value chain.

- With the adoption of ICT, the business volume had increased, resulting in an increase of transporters' income. Transporters were of the view that now PKR 15000-20000/vehicle/month earning has increased in the citrus season.
- Considering the farmers' perspective, transporters were convinced that even smallholder farmers had enhanced their bargaining power in price negotiation even if they were making pre-harvest contracts. In the past, farmers, especially smallholder farmers, had been exploited by middlemen, but now, they were very aware of the market situation at any time, even when working in the field. Also, farmers were making citrus selling decisions based on the weather forecast. With better communication, the trend of self-marketing among farmers was encouraged. Transport commission agent services were also encouraging farmers to take self-marketing decisions. Sometimes farmers were unable to travel with the product and they asked drivers to show the market auction process live on WhatsApp through voice or video communication. In a real sense, farmers were reaping the benefits of communication advancement, especially mobile.

> One 45-year-old transporter was involved in this business for the last 20 years. He was convinced that use of mobile had made farmers and transport just a call away. Most of the times farmers arranged vehicles via mobile phone to transport their produce to different markets of the country. He viewed that the use of mobile in this business has increased his income many folds.

> “Communication advancement had increased the income of every player of the citrus value chain. Now, consumers of small towns and villages of distant places from Sargodha were tasting fresh quality citrus” Respondent 3.

Thus, the transporters believe that mobile phone has revolutionized the communication process. Mobile phones contributed to the transport business with increasing income and ease of management. They are now well connected through mobile with every citrus value chain stakeholder, including farmers, which has resulted in increasing mutual benefits.

5.4.5. Agricultural Marketing

A detailed discussion was carried out with the four marketing officials of district Sargodha. The important points of discussion are described here.

- The Agricultural Marketing wing of government using recent developments in information communication was providing better services in the collection and dissemination of market information. The Agricultural Marketing Department was releasing price information for different markets using electronic and other media daily.
- The Agricultural Marketing Department had managed to display commodity prices in many wholesale markets. The Department was delivering predicted price information for agricultural commodities through SMS to 30,000 farmers across the province. Some citrus farmers of Sargodha district were also gaining an advantage with this price information. Exploitation by middlemen was decreasing with the availability of predicted price information.
- The Department was planning to share price information with the majority of farmers at the district level using mobile as a communication source. App development was in progress to benefit as many farmers as possible without discriminating between small and large holder farmers.
- Marketing department officials believed that fast communication was impacting to some extent on the stability of supply-demand of commodities in markets. Sellers and buyers were not facing the shocks that they were 10 years ago.
- Officials' efficacy was improving with modern ICT, with better monitoring of higher authorities and ease in delivering information effectively for farmers and other market stakeholders.
- They believe that the exploitation of farmers was decreasing. Farmers were aware of the supply-demand situation in the market, and prices in different markets. Farmers were receiving better prices of their produce. Awareness of modern ICT, especially mobile, was proving a good source of encouragement for the farmers to shift from a pre-harvest contract marketing system to self-marketing to grow more income that would otherwise have gone to the pre-harvest contractors. They believed that ICT, especially the mobile, was very valuable for the well-being of the farming community.

The marketing officials thus emphasize that ICT related market department initiatives and ICT self-use by citrus value chain actors has conferred an advantage on everyone from producer to consumer. Fast communication now supports stable supply-demand of commodities with decreasing exploitation of farmers due to price awareness in different markets.

5.4.6. Commission Agent

Two FGDs were conducted with Commission Agents, comprising five participants in each discussion. The participants showed a profound interest in the discussion. The following key observations were noted.

- The use of mobile phones was timesaving because, in the past, the contractors and commission agents had to repeatedly visit farmers' fields to monitor crops quality and production. They were now paying only one or two visits in the season and then coordinating with the concerned parties on the mobile phone.
- The use of mobile had increased the timely sharing of market information. They have boosted up working relations in different markets that help in making some profit.
- ICTs had improved communication at different levels; commission agents inform farmers and contractors about the market situation to decide on crop harvesting and supply to the market.
- Weather forecast information through modern ICT was also a key determinant for decision making about harvesting and transportation of citrus produce.
- Commission agents were less optimistic regarding the increase in their volume of business due to ICT.
- The use of the online banking systems had also improved the ease of making transactions for everyone in the citrus supply chain; even a small farmer could make transactions anywhere.
- The group pointed out that educated farmers, either smallholder or large holder, had increased their production and income with the use of modern ICT. In contrast to previous practices of waiting for a fellow farmer to sell out their produce, now farmers were getting price information, watching the live auction at the market, and becoming involved in self-marketing. Farmers could track the movements of their produce and be well aware of the market situation. In the case of glutted markets, farmers could easily divert their product to other markets to get a better price. In this way, farmers realized the benefits of ICT in the production, management, and marketing of their produce. Mobile was used for coordinating of labour and transport, to know the location of vehicles/produce, and communicate market position and price information. Also, with the use of modern ICT, farmers were now aware of price information in the international market.

A 47 years respondent had been working as a commission agent in Sargodha Market for the last eight years. He was educated up to 12th grade. He believed that before modern ICT, commission agents benefitted substantially, but by using ICT farmers were benefitting from knowledge of the market situation. He considered that mobile had made life easier for commission agents. Rather than relying on personal visits to different orchards, commission agents were now in a close loop with contractors and farmers. In this way, commission agents were saving time and money. He said that farmers had increased the area under citrus crop and that yield had increased over time due to the introduction and adoption of modern management practices. He also believed that educated farmers could reap the real benefit of ICT.

Therefore, the commission agents recognized the contribution of ICT and that the mobile has made doing business easier in terms of time and cost. The business volume has decreased owing to the shift of citrus produce to distant markets as a consequence of fast communication. They believed both the small- and large- holder farmers gained an advantage with the rise of modern ICT.

5.4.7. Exporters/Processing Factory

In the research area, citrus processing plants have been installed with the increase in productivity and demand for citrus and its products. FGD was conducted with the managers/owners of processing plants. Their viewpoint is described below:

- All the participants were of the view that ICT are used to get weather information.
- ICT were used to get price information about the national and international markets. Also, information about supply and demand was acquired at a national and international level.
- The recent advances in communication linkages at domestic and international markets have resulted in increasing business. They were well connected with the pre-harvest contractors and farmers which helps in business efficiency.
- The group viewed that with the use of modern ICT, farmers were improving their management practices and getting a better harvest. Nowadays, farmers were aware of market positions and made decisions accordingly about the different destinations of

their produce and prices. With the use of modern ICT, the trend of self-marketing among the farmers had increased, generating more profit.

- During the FGD, participants stressed the need for guidance from the government to improve processing and consequent exports.

Overall, the citrus exporters acknowledged the contribution of ICT to their business. They have developed their linkages in national as well as international markets. ICT usage has enabled farmers to make informed decisions, resulting in increased income.

5.4.8. Youth

Young people are more familiar with modern era ICT. Two focus group discussions were conducted comprising seven participants in each FGD. The focus of the discussion was to get youth insight about the modern ICT contribution to agriculture and their possible contribution to assist their elders in using the latest technology for information acquisition.

Before starting, participants were made aware of the purpose of the FGD. The youth of the area participating in FGD were very enthusiastic and eager to contribute.

- All the participants watched TV for drama and different sports before the introduction of mobile phones. Now they only to watched sports on TV.
- All the participants adopted ICT, and most of them were aware of the different packages offered by various companies.
- ICT connected most of the youth on Facebook, WhatsApp, YouTube, and surf search engines for information on different issues, including agriculture.
- Youth were also helping their elders who were unable to use ICT to get information from different sources.

Youth in the research area are convinced of ICT importance in agriculture. Also, they believed they could help their elders search for and acquire new technologies with the use of modern ICT.

Participants of the Focus Group Discussions identified the following common issues related to ICT and put forward some suggestions:

- Need interventions and dedication of government officials and agencies.
    - To form and develop social media groups at the district or union council level and share information according to the crop requirement at different stages of production cycle
    - To register farmers and to update information
- Farmers were getting information, but timely information and crop specific information links were still missing.
- There was no control of information; some information is specific to a particular area and not suitable for other areas. Therefore, there should be an authenticated source for the region-specific flow of information.
- Information should also be delivered through a video link to address farmers' issues.
- Research and extension at the district level and agricultural officers at the union council level can assist in linking the farmers.
- Input dealers also benefited from the views and discussion with researchers, extension agents and farmers.
- Farmers also identified problems regarding understanding the English language; most of the materials are written and available in English but should be translated into the local language so the farmers can understand better.
- It is the farmers' view that radio and TV programs are still effective, however, they need to be improved by being better aligned with farmers' free time and the requirements of the specific district.
- Need for training in the use of smartphones and the internet.
- Farmers search for information but could not get the desired information because the websites are not user-friendly.
- The low level of literacy is hindering the reaping of the actual benefits of ICT.
- Through SMS, MMS, and Urdu, translation of important information will help farmers.
- There should be a focus on information regarding mechanization of the farm, drip irrigation, high-density plantations, and different cropping patterns.

To summarize section 5.4, all the participating citrus value chain stakeholders in FGDs appreciated the ICT contribution to their business. They pointed out that they are now better-connected across citrus value chain stakeholders, especially with the farmers, a key component of the citrus value chain. All the stakeholders believed that modern ICT usage has made a considerable contribution to their businesses. ICT have eased their business management with time and cost-effectiveness, and mainly peace of mind. They perceived that advantages gained by farmers are no less than to other citrus enterprise stakeholders. Farmers with ICT usage, especially the mobile, made more informed decisions from production to marketing of their citrus produce. They are now not exploited by market intermediaries compared to 10-15 years ago. They posited that farmers' literacy level, ICT cost, and information communication sources still hinder smallholder farmers from maximising benefits from ICT usage for agricultural enterprises.

5.5. Hypotheses Testing in Relation to ICT Usage and Livelihood Capitals Aspects

Hypotheses were developed to understand comprehensively the interchangeable relationship between different livelihood capitals' characteristics in ICT usage for agricultural enterprises, mainly citrus (Section 4.9 p.102). This section describes in detail the outcomes of this research in relation to these hypotheses.

The impact of ICT usage in agriculture on financial capital is explained in Table 5.49.

The findings show that ICT adoption and usage for agricultural enterprises positively impact farm productivity and income. The farmers also have better access to financial institutions.

Table 5.49: Financial capital is positively related to adoption and ICT usage for agriculture (Hypothesis 1a, p.103)

Characteristics of Financial Capital	Expected influence on adoption & usage	Research Outcome
Farm income (amount)	+	Positive Relation
Non-Farm income	+	Positive Relation
Access to number of finance institutions (no)	+/?	Positive Relation
Citrus production (maunds)	+	Positive Relation
Citrus productivity (maunds/ha)	+	Positive Relation
Other------------		

Table 5.50 explains the relationship between ICT usage and human capital characteristics. ICT usage in agriculture has a positive relationship with the farmers' education and family size. The older and more experienced farmers are not so aware of ICT usage. ICT positively contributed to improving farmers' knowledge.

Table 5.50: Human capital is positively related to adoption and ICT usage for agriculture (Hypothesis 1b,p.103)

Characteristics of Human Capital	**Expected influence on adoption & usage**	**Research Outcome**
Education of respondent* (Years)	+	Positive Relation
Age (Years)	+/-/?	Negative Relation
Farm Experience (Years)	+	Negative Relation
Family size of farmers (no)	+	Positive Relation
Farm/ business workers of family (no)	+/?	Positive Relation
Citrus management training (no)	+	Positive Relation
Other------------		

***Person who is actively involved in farming/citrus business activities

ICT usage had a positive relation in the social capital perspective (Table 5.51). ICT adoption and usage enhanced development of linkages with fellow farmers and other agricultural value chain stakeholders in the business as well as the social perspective.

Table 5.51: Social Capital is Positively Related to Adoption and ICT Usage for Agriculture (Hypothesis 1c, p.104)

Characteristics of Social Capital	**Expected influence on adoption & usage**	**Research Outcome**
Interaction with fellow farmers for agricultural activities (Yes)	+	Positive Relation
Interaction with other relevant stakeholders in agriculture (Yes)	+	Positive Relation
Active interaction with other farmers regarding social activities (Yes)	+/?	Positive Relation
Contacts in markets (no)	+	Positive Relation
Other------------		

The results in Table 5.52 illustrates that the natural capital characteristics influence the ICT adoption and usage in agriculture. ICT usage contributed positively to enhancing farmers' natural capital.

Table 5.52: Natural Capital is Positively Related to Adoption and ICT Usage for Agriculture (Hypothesis 1d, p.104)

Characteristics of Natural Capital	Expected influence on adoption & usage	Research Outcome
House Area (Sq.ft)	+	Positive Relation
Landholding (ha)	+	Positive Relation
Citrus Area (ha)	+	Positive Relation
Other------------		
Other------------		

The ownership of farm assets and household assets represents the livelihood condition of farmers. All the reported physical assets (Table 5.53) have a positive relation in ICT adoption and usage except the refrigerator, being the necessity item of every household.

Table 5.53: Physical Capital is Positively Related to Adoption and ICT Usage for Agriculture (Hypothesis 1e, p.104)

Characteristics of Physical Capital	Expected influence on adoption & usage	Research Outcome
Tractor (Yes)	+	Positive Relation
Trolley (Yes)	+/?	Positive Relation
Spray machine (Yes)	+/?	Positive Relation
Car (Yes)	+	Positive Relation
Motor Bike (Yes)	+/?	Positive Relation
Refrigerator (Yes)	+/?	Negative Relation
Livestock strength (no)	+/?	Positive Relation
Other------------		

The research findings in (Table 5.54 & 5.55) clarify the ICT contribution to timely decision making and decrease in risk factors in the execution of agricultural activities. ICT usage in citrus production and marketing practices supported farmers in making timely informed decisions that impact on the profitability of the farming business. ICT usage reduced the risk element in citrus/agricultural management practices.

Table 5. 54: ICT Use in Citrus/Agriculture Improves Timely Decision Making of Farmers (Hypothesis 2a, p.105)

Characteristics	**Expected influence (Agree= + Disagree= -)**	**Research Outcome**
Ploughing /Pruning	+/?	Agree
Fertilizer Application	+/?	Agree
Pesticide Application	+/?	Agree
Irrigation Application	+/?	Agree
Contract out orchard	+	Agree
Harvesting of orchards	+	Agree
Arrangement of labour/Transport	+	Agree
Supply/Demand of citrus in markets	+	Agree
Volume of sale	+	Agree
Other		

Table 5.55: ICT Use Decreases Risk Factor across Citrus/Agriculture Value Chain (Hypothesis 2b, p.105)

Characteristics	**Expected Impact (Increase= + Decrease= -)**	**Research Outcome**
Weather	-	Decrease in Risk
Pest and disease attack	-	Decrease in Risk
Volatile prices of inputs like fertilizers, pesticides	-	Decrease in Risk
Inputs availability problem	-	Decrease in Risk
Volatile citrus produces prices	-	Decrease in Risk
Market supply/demand situation	-	Decrease in Risk
Other	-	

ICT's role in decreasing the transaction costs across the citrus/agricultural value chain was appreciable (Table 5.56). ICT have improved communication both in a time and cost perspective. Farmers' in-person visits to acquire information relating to production and marketing practices or finding farm implements, labour, etc. from relevant stakeholders have decreased significantly. Farmers made favourable negotiations with relevant input and output market stakeholders, saving time and cost. In brief, ICT have contributed considerably to almost all types of transaction costs including search, travelling, and negotiation.

Table 5.56: ICT Use Decreases Transaction Costs Across Citrus/Agriculture Value Chain (Hypothesis 3, P.106)

Characteristics	Expected Impact (Increase= + Decrease= -)	Research Outcome
Non-Observable Transaction Costs		
Cost of visit to other farmers	-	Decrease Cost
Cost of visit to agriculture extension staff	-	Decrease Cost
Cost of finding Machinery	-	Decrease Cost
Cost of finding Labour	-	Decrease Cost
Cost of finding quality inputs like fertilizers, pesticides etc	-	Decrease Cost
Cost of traveling to purchase inputs like fertilizers, pesticides etc.	-	Decrease Cost
Cost of finding markets/market prices	-	Decrease Cost
Cost of finding labour for marketing activities	-	Decrease Cost
Cost of finding and traveling to purchase packaging material	-	Decrease Cost
Cost of finding transport.	-	Decrease Cost
Cost of bargaining	-	Decrease Cost
Other	-	
Observable Transaction Costs	-	Decrease Cost
Cost of transport	-	Decrease Cost
Cost of handling citrus	-	Decrease Cost
Cost of packaging	-	Decrease Cost
Cost of storage	-	Decrease Cost
Cost of spoilage	-	Decrease Cost
Other	-	

Results in Table 5.57 briefly illustrate the ICT impact on improving the livelihood capitals of small- and large- holder farmers. The farmers who use ICT or made more use of ICT for citrus/agricultural activities gained a greater benefit. ICT assisted farmers in acquiring innovative information, improving farmers' human capital. ICT have exhibited considerable contribution to linkage development among all citrus/agriculture value chain stakeholders, both from a social and business perspective. The latest/innovative information enhanced farmers' ability to make timely informed decisions relating to citrus/agricultural management activities, increasing farm productivity and income. The increasing farm business income builds the physical and natural capitals of the farming community over time.

Table 5.57: ICT Use is Positively Related to Improving the Livelihood Capitals of Farmers (Hypothesis 4, p.107)

Characteristics of Livelihood Capitals	Expected impact	Research Outcome
Citrus Productivity	+	Positive relation
Other Crops productivity	+	Positive relation
Citrus Quality	+	Positive relation
Total Income	+	Positive relation
Profitability	+	Positive relation
Market Access	+	Positive relation
Bargaining Power	+	Positive relation
Collaboration among fellow farmers/businessmen	+	Positive relation
Credit use (investment)	+/?	Positive relation
Inter-household Collaboration	+	Positive relation
Intra-household Collaboration	+	Positive relation
Capacity building(knowledge)	+	Positive relation
Trust	+	Positive relation
Other------------		

To summarize section 5.5, the various livelihood capitals' characteristics influenced the adoption and usage of ICT in citrus/agricultural enterprises. ICT usage in agriculture improved the farmers' decision making and decreased the risk factor in different citrus/agriculture management activities. ICT played a considerable role in reducing the transaction costs of the farmers. The ICT made a substantial contribution to improving the farming community's livelihood capitals across the farming categories of small- and large- holder farmers. Concisely, the livelihood capitals contribute in the adoption of technologies as ICT, results in the increase of livelihood capitals due to ICT contribution.

5.6. Chapter Summary

This chapter extended findings on all research objectives/questions studied in this thesis using quantitative and qualitative data.

The socioeconomic impacts varied across the farmers' categories based on farm size and education level. The large holder farmers are more advantaged in all reported socioeconomic characteristics compared to smallholder farmers. The large holder and more educated farmers have relatively high competence levels in ICT use, ICT importance in agriculture, and ICT usage in agriculture within their respective categories. Education, citrus area (farm size) and farmers' interaction with relevant stakeholders are key contributors to the awareness, adoption, and usage of ICT for agricultural purposes. Older and experienced farmers are unaware of the adoption and use of modern ICT, specifically the smartphone, internet, and computer. The lack of awareness and knowledge, unaffordability of modern ICT, and poor communication ways of information dissemination were key constraining factors in ICT adoption and usage for agriculture. Smallholders and less educated farmers were more affected by these constraining factors.

Regarding the ICT contribution, the information acquisition level for citrus management practices has increased with improving access to formal information sources among the small- and large- holder farmers. From an overall perspective, the considerable difference between the small- and large- holder farmers before the inflow of modern ICT persists, despite the reduction of the information gap in certain practices. The large holder and more educated farmers made more use of modern ICT compared with smallholder and less educated farming categories. The large holder and educated farmers were relatively more innovative with better access to formal sources of information. ICT contribution fell behind the other communication sources in making farmers innovative. The income level is high among the farmers who made more use of ICT across all farm categories based on farm size and education level. Research findings emphasized the considerable impact of ICT, along with other contributing factors, in citrus area allocation, citrus productivity, animal herd size, and milk productivity for small- and large- holder farmers. The results indicate an ICT contribution in increasing the efficiency of citrus and livestock. ICT user farmers for agricultural enterprises (citrus and livestock) were more efficient across all farming categories based on farm size and education. The smallholder farmers were less efficient in both agricultural enterprises than the large holder farmers.

All the farmers recognised the value of ICT's possible contribution to information communication and to enhancing the social capital and farm business of the farming community. ICT affordability and literacy level influenced its effectiveness. Smallholders and less educated farmers exhibited a less positive attitude toward ICT's potential contributions. They were more concerned about constraining factors such as ICT affordability, and illiteracy. The farmers were more comfortable with personal communication via mobile with experts and visual information content delivery as preferred ways of communicating information. The priorities were the same for the small- and large- holder farmers for effective and efficient communication.

All the participating citrus value chain stakeholders in FGDs appreciated ICT contribution to their business. They pointed out that they are now better connected among themselves and with the farmer, a key actor of the citrus value chain. All the stakeholders believed that modern ICT usage has a considerable impact on their businesses, increasing volume with time and cost-saving. They perceived that farmers' advantages are no less than other citrus enterprise stakeholders. Farmers with ICT usage made more informed decisions in citrus/agricultural enterprises. They are now not exploited by market intermediaries compared to pre-ICT times. Famers' literacy level, ICT cost, and information communication methods still hinder the smallholder farmers from gaining the potential benefits of ICT usage for agricultural enterprises.

In conclusion, livelihood capitals' characteristics influenced the adoption and usage of ICT in citrus/agricultural enterprises. ICT usage in agriculture improved the farmers' decision-making, decreasing the risk factor and transaction costs in different citrus/agriculture management activities. ICT's role and impact were recognizable in improving the farming community's livelihood capitals, but smallholder farmers remained relatively disadvantaged in accessing the potential benefits of ICT usage. A more in-depth discussion of these findings follows.

Chapter Six: Discussion

This study explored the role and impact of ICT in the livelihood improvement of small- and large- holder citrus farmers and assessed the potential and importance of ICT for citrus producers. This chapter discusses the determinants of ICT adoption and usage, explores ICT's role and contribution in livelihood improvement of farmers, and develops implementable recommendations for policymakers to improve farm productivity through effective use of ICT. This chapter also provides an in-depth understanding of ICT capabilities and issues to develop effective strategies that include timely and better dissemination and accessing of information, integrated and better production, and marketing planning.

This chapter discusses results in the light of pre-set objectives. Results are also discussed in the context of findings of different studies, conducted mainly in developing countries. The chapter is organized into three sections.

Part one will address the first objective, which is: to investigate the factors optimising and limiting the awareness, adoption and patterns of ICT use in the farm business by small and large holder citrus farmers. Part one considers the citrus growers' socio-economic characteristics and awareness about ICT, and its availability, adoption, and usage of ICT for agricultural purposes. It explains the rationale of variation and influence of socio-economic characteristics in ICT availability, adoption and usage for agriculture among the small- and large- holder farmers. Part one further discusses the interpretation of the determinants of ICT awareness, its adoption, and use in agriculture. It provides a discussion on the key factors that affect the ICT recognition among the farmers. The limiting factors constraining ICT's effectiveness in farm business are also discussed. It explains the reasoning of varying constraining factors effect between the small- and large- holder farmers, and for farmers with different education levels.

Part two addresses the second objective, which is: to examine the contribution of ICT use in agriculture for small- and large- holder citrus farmers. It presents a discussion of the ICT contribution to change in information acquisition, the cost comparison of information acquisition using ICT and personal visit, awareness, and adoption of innovative farming practices. This part further provides a rationale for comparing gross margin received across the farmers' categories based on the farm size and education level. Discussion of the factors determining the citrus area and yield, determinants of animal units, and milk yield is also included. This part also discusses the efficiency of citrus and milk production. It discussed the reasons for varying efficiency levels between the small- and large- holder farmers based on the ICT usage agricultural enterprises, information sources, and education level.

Part three refers to the third objective: to explore small- and large- holder citrus farmers' perceptions of the value and impact of ICT on their farming practices, focusing on the key factors influencing ICT use. This part discusses perceived benefits to small- and large- holder citrus farmers using ICT for different aspects of agricultural enterprise, farmers' livelihood capacity, and issues related to ICT related infrastructure availability. The rationale for the farmers' preferred means of obtaining technical information is also discussed.

6.1. Discussion of Factors Optimising and Limiting the Awareness, Adoption, and Patterns of ICT Use

This section discusses the optimising and limiting factors that determine the awareness, adoption, and pattern of ICT use. It includes the following aspects: citrus growers' socio-economic characteristics, ICT awareness, availability, adoption, and usage for agricultural purposes.

6.1.1. Socio-economic and Farm Characteristics of Citrus Growers

Accurate, needs-based, reliable, and timely information is essential for consistent growth in agricultural production. Improvement in agricultural output cannot result if farmers' access to essential information is not assured. Understanding of required information is an essential part of the delivery of need-based and applicable information to farmers. It has been pointed out that "in order to achieve relevance, the information needs of communities must be assessed, and the correct stocks and services put in place" (Zaverdinos-Kockott, 2004, p.13). For the assessment of the information need, socio-economic- and farm-characteristics of farmers play a pivotal role.

Socio-economic characteristics, including but not limited to, family size and composition, education, age, and farming experience, play an essential role in adopting new technology. Of these, literacy is considered one of the crucial characteristics of farmers that influence the attitude towards the adoption of new technology. Education offers a platform for households to gain employment and raise income for reducing poverty and inequality. Again, educated households are more resilient to adverse shocks (Malik, 2014).

In the study, citrus farmers had nine to ten years of education on average. Differences in years of education were statisitcally significant for male family members but not for female family members. Thus, education level suggests that innovative activities, especially technology distribution and adoption, are expected to be relatively easy in the area based on literacy rate. Currently, farmers in the area were not fully exploiting the potential use of ICT and lacking productivity. Low levels of education and unawareness are the major hurdles in seeking information (Dutta, 2009). The use of ICT is increasing with the increase in the education level of the farmers (Kalusopa, 2005; Krishna et al., 2005; Mwakaje, 2010). Human capital is considered a critical factor in enhancing ICT's efficacy (Patil et al., 2008), and education is a crucial element of this livelihood capital.

Generally, younger farmers are enterprising and willing to take more risk to increase their farm income compared to their older counterparts. The younger generation quickly adopts ICT for obtaining information on different farm practices (Aleke et al., 2011; Mwakaje, 2010). Results showed that citrus farmers were well skilled with farm practices but lacking in the latest technologies. Older farmers are reluctant to adopt novelties (Diederen et al., 2003) which is consistent with these research findings that older farmers lack in adoption and use of ICT. However, introducing new technologies, techniques, and timely delivery of information may help farmers take steps towards higher production.

The land is one of the primary factors of production, which determines access to other factors, as farmers having more land are in a better position to adopt new technology. They may have better access to information and resources. Large holding farmers are more likely to adopt farm and ICT based technologies (Alvarez & Nuthall, 2006; Isgin et al., 2008; Rahelizatova & Gillespie, 2004). Farmers with more land usually are the early adopters of technology and have the capacity to absorb shock, if any.

Smallholder farmers with no access to recent developments in agriculture and other facilities in rural areas are affected the most, which limits their productivity and contribution to economic growth (Dutta, 2009). The current research findings support the above arguments that large holder farmers were ahead in adopting ICT. ICT in the current era are readily available and more easily accessible for smallholder farmers than other agricultural innovative technologies. The role of ICT could be significant in the flow of information and creating awareness in the transfer of technology about modern farming practices.

Socio-economic characteristics impact the adoption of agricultural innovations and household characteristics affect ICT adoption A difference in age, income, schooling, etc. is more likely to have an effect on ICT adoption for the acquisition of information (Das, 2014). Rural people need information for day-to-day farm activities (Dutta, 2009). According to Sabo (2007), and Zhang and Yu (2009), farmers living in rural areas need information on credit availability, farm management, soil management, weather, besides information on agricultural insurance, animal health, fertilizer application, future market prices, improved seedlings, insecticides availability, land tenure, and vaccination for animals, and the like for better production.

The research findings show that socio-economic characteristics impacted ICT adoption and usage for information acquisition. Age and farming experience were negatively related to the adoption and use of modern ICT and innovative practices. These results are consistent with Khan et al. (2019) that farm experience reflects the farmers' age, and aged farmers make less mobile use.

The educated, large holder farmers and sociable farmers interacting in input and output markets were more inclined to innovative technologies.The importance of socio-economic factors was also explored by researchers, and Grover (2007) found that age, education, landholding, and caste contributes to technology adoption. It was confirmed by Waqar et al. (2018) that age, education, and landholding contribute to ICT presence among the farming community. Numerous research studies, described in the literature review, validate the socio-economic factors with some variation in local contexts, influencing innovative technology adoption such as ICT, from the research outcomes reported in this thesis.

6.1.2. Awareness and Availability of ICT

Awareness is an essential precondition for the adoption of new technology. According to Diagne and Demont (2007), when technology is unique, but the target population remains unexposed to it, the actual population adoption rate is not a consistent estimator of the observed sample adoption rate. Omolayole (2002) points out that factors including a general lack of awareness, poor telecommunications infrastructure, low level of computer culture affect the use of ICT. Adequate information and adoption are vital for up-to-date technology to make individuals psychologically convincing to adopt the new technology.

This study found all the citrus growers were aware of normal mobile, but normal mobile owners were more likely to be smallholders and less educated farmers, because of their affordability and ease of use. Moreover, the awareness level of smartphones and the internet among the smallholders and less educated farmers were low compared to large holder farmers. The same trend applied to the adoption and use of smartphones and the internet. The large holder and more educated farmers had more awareness and access to computers than smallholder and less educated farmers. Thus, large holders and more educated farmers can quickly access information and use ICT in citrus farming.

However, data regarding social media use show that a limited number of small- and large-holder farmers were social media users. The same was the case for surfing websites related to agriculture for relevant information. It indicated that in the area, farmers had access to ICT, but their use for agriculture purposes was limited. It was noted that some larger or more educated farmers do use ICT for acquiring information on different agricultural practices and other relevant information. The same observation was reported by (Dutta, 2009; Kalusopa, 2005; Krishna et al., 2005; Mwakaje, 2010).

6.1.3. Adoption and Usage of ICT in Agriculture

People acquire the capacity to develop the attitude, make choices, introduce and affirm the implementation of inventions (Talukder, 2012). Feder et al. (1985) defined adoption as the decision to use innovation, given the information's full potential.

The place of knowledge, skill, and attitude has a significant impact on adopting improved technologies. With the recent upsurge of ICT, farmers search for techniques to expand their crop yield. ICT help farmers in decision making with information about sowing time and method, seasonal variation in weather and variable climatic conditions such as drought and floods, pest control and disease attack, soil fertility, and the best prices for their output to improve their livelihoods.

In the absence of this information, farmers face difficulties in such matters even if they are exceptionally skilled. Armstrong et al. (2010, 2011, 2012a,2012b)) opined that the use of ICT for acquiring information in the field of agriculture is fit and well phased, because it is a known fact that informed decisions translate into better production, leading to farmers generating more profit. Kalusopa (2005), Krishna et al. (2005), and Mwakaje (2010) also observed that the use of ICT including mobile phones and computer, have increased in recent years for obtaining information about farming. However, its effectiveness depends upon factors such as language, political will, and traditional constraints (Aleke et al., 2011). It is common that development in skill, knowledge, attitude, and perceptions affect farmers' adoption of modern techniques (Meijer et al., 2015). So too, adequate information and a positive attitude are crucial for an individual to adopt advanced technology.

Keeping in view the above vital aspects that influence the adoption and usage of ICT, this research found that large holders and educated farmers were ahead in using modern ICT compared with smallholder and less educated farmers. The results revealed that for farmers, more natural capital elements, human capital, and financial capitals were a stimulus in the adoption and higher use of ICT for agriculture. The results are inconsistent with the Grover (2007), and Armstrong and Gandhi (2012) findings that more educated and large farm-sized/income-level farmers have more adoption and usage of ICT, especially the modern ones.

The conventional or old ICT (radio, TV, and fixed-line phone) adoption and usage are largely unaffected by possession of certain livelihood assets, such as large landholdings and higher education. The use of fixed-line phone and TV for agricultural purposes was higher due to fewer skills requirements and the cheapest and more diffused technologies. The radio almost has lost its identity and availability generally as well among the farming community. This research indicated that the lack of region-specific broadcasting of informative agricultural programs was the main reason for the negligible radio availability with the farming community.

6.1.4. Determinants of ICT Awareness

Awareness of ICT was determined by education (years) of farmers, farmers' interaction with input and output markets, area (acres) under citrus crop, and family size (No). The older and more experienced farmers were not very aware of ICT. Although average education level (schooling years) was low, still education was a key determinant, as farmers having more education were more aware than farmers having less education. These findings support the results of other studies (Dutta, 2009; Kalusopa, 2005; Krishna et al., 2005; Mwakaje, 2010; Okello et al., 2014).

Similarly, farmers who interact with input and output markets for day to day farm activities, availability and prices of inputs, supply situation in the different output markets, and prevailing rates were more aware of ICT than those with less interaction with input-output markets. The area under citrus crop is an indicator of the scale of citrus farming. Farmers who cultivate more of their operational land under citrus crops, were more aware of ICT, and were concerned about various farm operations and disposal of their product as observed and noted by Dutta (2009). These study findings are also in line with Ashraf et al. (2015), who found that education and cultivated area have a significant positive effect on the awareness of ICT.

This research imparts that family size and social interaction in agricultural enterprise relevance also contribute significantly to modern ICT awareness.

6.1.5. Determinants of ICT Adoption

The diffusion of new technology varies across regions depending on specific regional characteristics, including access to technology, domestic absorptive competence of the respondents, economic size, and specialization of the firm (Keller, 2004). The use of ICT is imperative in agriculture to meet the farmers' and other stakeholders’ requirements on time and within the limited available resources. ICT can be of great help in exchanging information to all stakeholders. Effective use of ICT contributes to establishing a database, providing networks, and exchanging information electronically. ICT also enhances efficient association and synchronization between different partners. ICT offers a comprehensive platform for exchanging and sharing information/knowledge, synchronizing events, and backing businesses at national and international levels (Blurton, 1999). Despite its importance, the recognition of ICT in Pakistan's agriculture sector remains weak. Information is not exchanged efficiently due to factors including, but not limited to, the cost of acquiring information, culture, and government policy.

ICT adoption is based on farmers' willingness to try new ideas, practices, and technologies. Generally, farmers adopt new technology only if the benefits are higher than the previous technology. ICT are adopted only by educated farmers as education is an approximation to human capital. There is an understanding that knowledge accumulation through education is crucial for economic development (Ozturk, 2008). Education is assumed to increase agricultural output by enhancing the farmers' ability to harvest more from given resources and improve their capacity to obtain and analyse information and fine-tune swiftly to uncertainties (Pudasaini, 1983).

Educated farmers are anticipated to accomplish specific tasks with higher efficiency and are more likely to adopt new technologies in a shorter period than uneducated people. Educated people can collect, manage, and translate all available information, distinguish between promising and unpromising investment areas, and make decisions more quickly with relatively small errors. Previous studies (Asfaw et al., 1997; Mekuria, 1995; Tadesse, 2000; Yirga et al., 1996) also consider education one of the factors affecting the adoption of new technologies. The decision-making process mostly lies with the household's educated adult members, demonstrating that education and socio-economic environments could be substitutes in modern settings and complementary in traditional ones. It implies that education expansion in traditional areas might be more attractive than in developed areas since education is usually the only means to enhance the farmers' ability to acquire, synthesize, and respond to innovations.

This research supports the above-discussed facts that education was a critical element in the adoption of ICT. Education contributed significantly to adopting modern ICT or analysing the determinants of all ICT, including TV, radio, and fixed-line phone.

The adoption of ICT is subject to a wide range of social, economic, technical, and physical aspects of farming. This research found that the interaction with input and output markets also affected the adoption of modern ICT. Modern ICT, especially mobile telephony, improves the efficacy of the farmers' communication with the relevant stakeholders. Large family size facilitated the adoption of modern ICT. Modern ICT facilitates effective connectivity among the farming masses.

The citrus area was also a key contributor to adopting modern ICT and conventional ICT because farmers' citrus area reflects the farmers' overall farm area and financial strength. Need, along with financial capability supports the adoption of innovations, as in the case of modern ICT. Easy and effective communication across the citrus value chain stakeholders using modern ICT, especially mobile technology, helps farmers better manage their citrus orchards. The results are consistent with other research that indicates that education and landholding are the vital determinants of ICT adoption (Armstrong & Gandhi, 2012; Ashraf et al., 2015; Grover, 2007). This research found that family size and social interaction in agricultural enterprise relevance also play a part in ICT adoption but not significantly.

6.1.6. Determinants of ICT Use in Agriculture

Generally, no difference is made in the adoption and usage of any technology. For ICT, this understanding may vary due to the multipurpose usage of these communication technologies. The usage patterns of these technologies vary among the farmers from more personal to more agricultural purposes. This observation indicates a separate finding of the determinants of ICT use in agriculture.

It is evident that the use of ICT reduces the costs of managing information and allows individuals to carry out information linked tasks efficiently. ICT also allows production innovations to be best handled in an agricultural enterprise. The research findings described variations among farmers based on their socio-economic and farm characteristics, including education (years), interaction with input and output markets, house area, and citrus area (acres) for ICT usage in agricultural purposes.

Understanding the factors linked with ICT adoption and use in agriculture supports approaches to encourage ICT acceptance. It intensifies the efficiency and usefulness of the information in the agriculture sector (Kurtenbach & Thompson, 2000). As expected, ICT use was higher among educated farmers than those less educated. The same findings have been observed elsewhere (Dutta,2009; Krishna et al., 2005; Kalusopa, 2005; Mwakaje,2010). This research found that schooling level increases ICT usage in agriculture in general and citrus farming. As discussed earlier, interaction with input and output markets make the farmers use ICT for agricultural purposes.

The house area of the farmers is taken as a proxy to represent their wealth and financial status. Farmers with more house area used ICT for agricultural purposes more than others. It also means that the usage of ICT is widespread among farmers who are well off in society. Along the same lines, farmers allocating more area to citrus crops also were using ICT. Citrus growers use ICT to get information about citrus cultural practices, pest attack, disease incidence, and input and output market information. The results are in line with Waqar et al. (2018), who identified age, education, and landholdings as the main factors affecting ICT usage. Nyamba and Mlozi (2012) reported that respondents' socio-economic attributes influence ICT usage, and Kezi et al. (2012) found that low education, older age, and lower-income limit the use of mobile phones, email, and computer as an information source. Increasing age of farmers decreases the ICT usage for agriculture. This finding is consistent with Khan et al. (2019) that an increase in the farmers' age has a negative relationship with mobile use. Young farmers are more comfortable with making use of ICT in agriculture. Youth is more enthusiastic and comfortable to communicate with modern ICT (Saravanan & Suchiradipta, 2015), and Tekin (2013) also found that age limits ICT usage.

To sum up, this research revealed that in addition to factors identified by other researchers including education, age, and farm size, the farmers' interaction in input-output markets and affluence make considerable contribution for more use of modern ICT for agriculture.

6.1.7. Factors Limiting the Use of ICT in Agriculture

The spread of ICT is constrained by several factors, which include the gap between technology preference and current technology that is used, poor telecommunications infrastructure, low level of computer culture, and general lack of awareness affecting the use of ICT (Omolayole, 2002).

This research study found that ICT related factors limit the positive impact of its use across the small- and large- holder farmers. Smallholder farmers are weak resources based on all livelihood capitals' perspectives. The research finding highlighted the limited use of ICT for agricultural purposes among the smallholder farmers in comparison to large holder farmers in all explored limiting aspects. Citrus growers were still not aware of ICT, that impact on agricultural productivity. Many resource-poor farmers considered ICT affordability a crucial limiting factor. ICT cost and low education affect its efficacy (Kante et al., 2017). Farmers identify language problems as a cause of their inability to use ICT. Most of the farmers have nine years of schooling and cannot read and benefit from the information mainly shared in English. Language and illiteracy are significant constraints to hinder ICT effectiveness (Saravanan & Suchiradipta,2015).

The factor analysis summarized the limiting factors in three areas: ICT are unaffordable for poor resource farmers; lack of knowledge and awareness impacts ICT usage; weak communication methods, and lack of interest impact ICT effectiveness. These results reflect the situation for poor smallholder farmers who make nearly 90 percent of the farming community in the country. The study findings are consistent with the Khan et al. (2019) that lack of awareness and interest in ICT based information services, and Mwakaje (2010) explored that lack of knowledge, acquisition cost, and accessibility limit ICT usage. The results are also consistent with Matto (2018), who pointed out that lack of awareness, knowledge to operate, and affordability hinders ICT usage.

Provision of these facilities in regional languages through innovative production of efficient and affordable ICT would enhance their use by rural farmers (Armstrong et al., 2012b). In order to strengthen and encourage farmers' groups to use ICTs such as the internet, home phones need facilitation.

To conclude, the results are consistent with the literature review. This research concisely illustrates the three key challenges and impact intensity on smallholder farmers using various analytical techniques.

To summarize, the discussion emphasised, following the current study and previous research, that education is a critical factor in the awareness adoption and usage of ICT. Educated farmers are more optimistic about using ICT and more confidence in the contribution of ICT to farm enterprises. The older farmers are less familiar with ICT's importance. Farm size as a notion of farmers' financial capacity is also a primary determinant in adopting and using ICT to benefit from these modern-day gadgets. Lack of awareness and knowledge, affordability, and communication methods hinder ICT effectiveness in the farm business, impacting smallholder and less educated farmers.

6.2. Discussion on Contribution of ICT Use in Agriculture for Citrus Farmers

This section presents a discussion on ICT contribution to agricultural enterprises in the following subsections. The subsections consist of a change in information acquisition, a cost comparison of information acquisition using ICT, awareness, and adoption of innovative farming practices, comparison of gross margin received with ICT use in agriculture, factors the citrus area and yield, determinants of animal units and milk production, and efficiency of citrus and milk production.

6.2.1. Using ICT to Change Information and Communication Sources for Citrus Production

The conventional agricultural extension systems unable to deliver innovative information to the smallholder farmers in Pakistan. The qualified agricultural extension personnel and farmer ratio is widening over time. The financial hurdles aid further negative impact on the performance of the existing agricultural extension system. The emergence of mobile technology and the internet with other sets of modern ICT provide the possibility to overcome the inefficiency of present information dissemination systems, results in the productivity enhancement of farming systems, including small-scale agricultural enterprises.

The study results revealed that farmers' information acquisition for citrus management practices was significantly higher in this modern ICT era compared to the recent past. The findings also provided a comparison between small- and large- holder farmers in both technological periods. Results were in agreement with Oladele (2011) that ICT have had a profound impact on agricultural information acquisition. The findings validate the observation made by Chapota et al. (2014) that ICT potentially increase farmers' access to required agricultural information. The ICT revolution is strongly linked to farmers' knowledge and could enrich them in essential information on pesticides, various diseases, weather forecasts, and seeds (Deininger & Byerlee, 2012).

The large holder farmers were ahead in information acquisition compared to the smallholder farmers due to economies of size in the citrus enterprise. Financial capacity stimulates them to be more informed on the effective use of ICT. Notably, the study found that the marginal increase in information attainment among smallholders was higher than the large holder farmers in all the citrus management practices except the citrus variety/nursery related information. The marginal effect was higher in more crucial aspects like the weather, plant protection, inputs quality, and market prices. Smallholder farmers concentrate on getting information on the weather forecast, plant protection, and market prices, considered most crucial among the variety of available information (Mittal et al., 2010). Also, ICT are frequently used in agricultural information services, including but not limited to, input accessibility, input quality, input prices, contacting intermediaries for commodity marketing, pest, and disease control (Syiem & Raj, 2015).

The research findings highlighted the contribution of ICT to obtaining information on critical aspects, and detected a slight reduction in the information gap between small- and large- holder farmers. Mittal and Mehar (2012) argued that mobile phone ICT embedded information distribution mechanisms can eliminate the information gap between large and smallholder farmers. The study results align with Qaisar (2011) that ICT initiatives provide effective means to offer farming information appropriately and revamp agricultural knowledge for smallholders.

Before the introduction of modern ICT, farmers were dependent on informal information and communication sources. A number of studies have confirmed that a decade earlier, farmers had mainly been dependent on relatives/friends, fellow farmers, and media including radio and TV for information (Abbas et al., 2009; Chaudhry et al., 2008; Dutta, 2009; Sadaf et al., 2006; Nosheen et al., 2010; Zhao & Zhang 2009). To acquire agricultural information, a formal source of information has been minimal.

The study results revealed that farmers had increased their access to formal sources of information due to modern ICT prevalence. In the recent past, large holder farmers benefitted more from formal sources of information due to their economic positioning and agricultural extension system' biases for the large holder farmers. Although the study results were consistent with the previous literature, large holders have better access to formal sources. A significant increase among the smallholder farmers was found in accessing formal sources of information for citrus management related information. ICT assimilation with agricultural extension will aid in bridging knowledge gaps among extension staff and farmers (Mabe & Oladele, 2012). Study results further explained that the increasing connectivity helped farmers to acquire the latest information from other formal sources such as agricultural extension, research, and agricultural academic institutes.

ICT, including mobile phones, web portals, and social media, have been adopted broadly by agricultural stakeholders to develop communication among the farmers' agricultural extension and researchers (Saravanan & Suchiradipta, 2015). The modern ICT have revolutionized the communication system. Up to the recent past, personal interaction has been the leading information communication source.

The study found a significant decrease in in-person communication among large holders and smallholder farmers. Farmers had increased the use of mobile technology to communicate with relevant stakeholders. ICT promote new means for information transfer to enhance knowledge capacity among various people. ICT allow switching and strengthening the current information transferring system and networks (Chhachhar & Hassan, 2013). The use of modern ICT has made communication easier. Previous information communication methods have been expensive, with less reach to the target community. The ICT embedded extension model is inexpensive with an extensive range in numbers compared to conventional extension approaches such as field days, training and farmer field schools (FFS) (Cox & Sseguya, 2015).

The study results are consistent with the previous research findings regarding the ICT contribution to improving the information communication mechanism. These results provide empirical evidence that smallholder farmers have gained less advantageous from ICT due to certain constraints, but they are not far behind the large holder farmers in information access from reliable resources.

6.2.2. Cost of Information Acquisition Using ICT and Personal Visit

ICT usage in agriculture is crucial to deliver accurate and timely information on farmers' queries about inputs availability, its use, and prices, how to access markets, adapt to weather conditions, and increase yield. According to Chisenga (2006), ICT speed up agricultural operations and improve farm productivity and income through efficient information flow.

The literature review revealed that ICT link different stakeholders through mobile phones, computers, instant messaging, the internet including email, video conferencing and social networking websites, radio, satellite technology, and television for speedy, timely, and cost-effective communication. ICT acquisition centres on farmers' inclination towards its perceived benefits. Despite its significance, the adoption of ICT in the agriculture sector is still low because of the cost of ICT and ICT services, among other factors.

The study found that the difference in the cost of acquiring information between small- and large- holder farmers and education categories was statistically significant. The frequency of information acquisition by large holder farmers and more educated farmers was higher than those with fewer years’ education. Similarly, the difference in the information acquisition before and after introducing ICT across the categories on-farm and education was significant. Although the smallholder farmers had increased the frequency of information acquisition, the difference was wider with the large holder farmers than in the conventional ICT era.

The time spent using ICT for information acquisition was significantly higher among large holder and more educated farmers. Smallholders and less educated farmers were still devoting time to personal visits to approach relevant stakeholders for information acquisition. This implies that smallholder and less educated farmers make limited use of ICT due to a weak resource base either in the shape of finance or knowledge.

Overall findings indicated that with the introduction of ICT, time consumption on personal visits significantly decreased per farmer in the citrus season, saving their limited resources. ICT save time and cost in attaining information (Chavula, 2014). The study results revealed that information acquisition costs had decreased significantly. This result highlights the importance of ICT use and is consistent with the other researchers' findings that ICT provide cost-effective information acquisition for agricultural practices and reduces risk. Mobile phones considerably lower the cost of information communication (Adamides & Stylianou, 2013). The cost of information acquisition and dissemination has decreased with increased number and speed in the computer era (Hall et al. 2003). ICT agriculture embedding enhances information acquisition, essential for risk reduction, getting inputs and credit, and lessening transaction costs (Chikaire et al., 2016). Using ICT can reduce information management costs gradually, allowing individuals and companies to carry out information related tasks effectively (Adegbidi et al., 2012).

A significant difference was also noted in the cost of acquiring information regarding different farm operations (de Silva & Ratnadiwakara, 2010). Working on the value of receiving information de Silva and Ratnadiwakara (2010) argued that farmers could grow high-value crops and alleviate poverty in rural areas if easy access to market information is provided. The same authors further pointed out that the cost of acquiring market information in subsistence farming is a critical issue. However, the current boom in ICT has made information affordable to farmers as ICT have reduced the high costs of information acquisition in terms of traveling and time.

Previous research mainly hypothesized the future ICT contribution to transaction costs reduction in agricultural enterprises. This research empirically describes the change in cost and time effective information acquisition of citrus farmers across the farming categories and two eras of technology.

6.2.3. Awareness/Adoption of Innovative Farming Practices

Farmers are the best evaluators of any new technology. Farmers adopt new technology if it is lucrative and fits within their given circumstances (Viatte, 2001). In this study, large holder citrus farmers were generally more aware than smallholder farmers due to more use of ICT for information acquisition and better access to formal information sources. Usually, large holder farmers have more resources and, therefore, access to information that makes them aware of agriculture development.

Farmers who are aware of new developments can also adopt new technology. Because of their farm size, they can spare some land to test and adopt that technology. On the same lines, farmers who have more years of schooling are aware of recent developments and have adopted new agriculture techniques more than those who have less schooling. Results revealed that awareness and adoption of innovative technologies in the more educated farming category were higher than those of the less educated farmers' category.

The sources of information regarding the spread of innovative technologies play an essential role. Generally, people give weight to information from authentic and reliable sources. The majority of the large holder farmers and some of the smallholder farmers receive information about farming and new technologies from formal sources. In formal sources, despite its importance and ease, ICT contribute for less than half of the farmers as communication source; this needs the concerned authorities' attention. These results contrast with Bhattacharjee & Saravanan (2013) that ICT provide an exciting opportunity to move from traditional farming to innovative farming methods for poor resource farmers.

Similarly, ICT was the primary source of information communication for almost fifty percent of the farmers having a high education level, while this figure was below 20 percent for less-educated farmers. Notably, the use of ICT in innovation awareness and adoption was higher among the large holder and educated farmers. The study findings agree with Karim et al. (2020), and Asif et al. (2017) that mobile phone is an important communication technology among modern ICT makes access to agricultural innovations. These findings are further supported by Chhachhar et al. (2013) that ICT offer innovative access and methods for rural development to the various communities' advantage.

However, farmers cannot tap ICT potential properly to acquire innovative information about new seed, weather, pesticide, and market. This study finding and previous research support the argument that ICT could benefit the smallholders in innovations awareness and adoption because the existing extension systems for general agriculture and livestock are biased towards the large holder farmers.

6.2.4. Gross Margin with ICT Use in Agriculture

Agriculture is a vital sector of the economy and a source of livelihood for the population, mainly living in the country's rural areas. The adapted traditional agricultural approaches have various challenges in production, marketing, and profit, among others. These challenges are addressed significantly by ICT usage, which has a vital role in improving rural smallholder farmers' livelihoods. ICT provide the opportunity to use mobile information services, exchange capital that give access to critical, targeted information on weather, commodity prices, disease outbreaks, and helpline services providing key tips and real-time advice.

Studies on the usage of ICT, confirm that ICT can transform the farming sector, and the entire farming community, including smallholder farmers, can benefit. ICT speeds up agricultural operations and brings improvements in farm productivity and income through the efficient flow of information (Chisenga, 2006). It is evident that ICT have the potential to facilitate smallholders in access and exchange of information and through ICT transmitted agricultural advisory services have benefit smallholder farmers (Palmer, 2012). ICT related initiatives for agriculture have enhanced production and farming practices by improving the knowledge of smallholder farmers (Technical Centre for Agricultural and Rural Cooperation [CTA], 2015).

This research found that half of the citrus growers in this study used ICT mostly for agricultural purposes. The gross margin for citrus growers, who used ICT mostly in agriculture, was significantly higher than those who used ICT mostly for personal purposes among the smallholders and moderately higher among large holder citrus farmers. It implies that the marginal increase in gross income for the citrus enterprise was considerably higher among the smallholder farmers than the large holder farmers who made more use of ICT for agriculture. The large holder farmers' income was relatively higher than the smallholders in both ICT use situations in the citrus enterprise. The same difference was observed for citrus farmers across the education categories. The finding on the gross margin from the whole farm, excluding livestock, showed a statistically significant difference between the farmers using ICT for mostly personal purposes and agricultural purposes. Farmers using ICT mostly for farm operations received more gross margin than farmers using ICT mostly for personal purposes. Farm gross margins were higher where ICT were used for agricultural purposes rather than personal use alone. The results are consistent with (Chhachhar & Hassan, 2013; Ferroni & Zhou, 2012; Karim et al., 2020; Nyamba & Mlozi, 2012; Raj et al., 2011) who found that ICT use has a positive relationship with the income increase. Inadequate communication services result in restricted information access that results in revenue loss (Adamides & Stylianou, 2013).

The whole farm analysis reemphasized the importance of livestock for smallholders. The gross margin over the entire farm per acre basis was slightly higher among the smallholder farmers compared to large holder farmers. These results highlight the contribution of ICT for the smallholder farmers as well. Results are consistent with Hassan et al. (2009), and Donner (2007) that ICT usage positively correlates with small-scale agricultural enterprises' income. Appropriate information enables smallholder farmers to fetch a high price with better bargaining power (Dagne & Oguamanam, 2018).

Previous research findings mainly concentrated on the positive relationship between ICT usage through planned interventions and farm income but did not quantify the ICT contribution. This study empirically validates the importance of ICT use in agriculture by analysing the existing situation rather than gauging the impact of certain ICT related interventions for the farmers. Therefore, investments in innovation and information through ICT use may increase productivity and, consequently, the farmers' income to gain the full benefit of innovations. One promising trend is that as more farmers with access to mobile phones will be capable of obtaining a range of information, from weather reports to current market prices. ICT also contributes to the operation of agricultural produce markets, lowers intermediation costs and reduces the costs of providing agricultural extension and enhancing its effectiveness, which ultimately leads to a reduction in the resource-poor farmers' costs.

6.2.5. Access and Interaction with Relevant Stakeholders

Strong interaction improves the social capital and awareness of interest. Findings show that ICT contribute significantly to developing linkages with relevant stakeholders. Modern ICT adoption and usage have increased the connection among the farming community. Farmers developed better linkages with the agricultural input-output market stakeholders. Farmers had better access to enterprise-specific information from relevant formal sources such as the agricultural extension, research department, marketing department, and agricultural universities/colleges with the use of modern ICT. The research findings are consistent with the findings of other researchers, that ICT boost professional relationships among different stakeholders (Blurton, 1999).

ICT offer a forum to connect with the majority of farmers in the quickest possible time to share knowledge, thus improving interaction among farmers, extension agents, and research stations in a variety of areas such as availability of inputs, market information, suggested practice, among others, to boost agricultural activities and farm harvests (Nnenna et al., 2015). ICT help farmers better market their products with the latest information, getting reasonable prices by avoiding market intermediaries' exploitation (Anoop et al., 2015). Due to its interactive way of communication, modern ICT contributes to bridging the gap between extension workers and farming communities (Chavula, 2014). The significant contribution of ICT in social interaction enhancement is a resource to the farming community's social and human capital development. This argument is supported by Onwuemele (2011) who found that mobile phones have a significant impact on particular human and social rural livelihood capitals. ICT has assisted in driving social change (Karim et al., 2020).

6.2.6. Determinants of Citrus Area

Citrus is the leading fruit of Pakistan, famous across the globe for its taste and quality. Area allocation to a crop is influenced by various factors, including the farmers' socio-economic and farm characteristics and the area's suitability to that crop. This study found that farming experience (years), interaction with input and output markets, house area, family size (No), modern ICT use in agriculture, and ICT use in citrus statistically significantly determine the area under citrus crop.

The reason is that farmers having experience in farming have allocated more areas to citrus crops. Experienced farmers were aware of the importance of the citrus crop and its value; therefore, they allocate more area to citrus crops. Farmers who were in contact with the input and output market also allocated more area to citrus crop. Market information about input and output made them coordinate input supply and output disposal, putting them in a better position to decide about the area allocated to citrus crop. As previously mentioned, the house area serves as a proxy for the wealth of the farmers. Farmers who had bigger houses having more agricultural land could afford the comparatively higher citrus crop cost and spare more land to citrus. Like other fruit crops, citrus planting and management need more labour, and larger family sizes also contributed to a larger area for citrus crop. Information is critical in the development of agriculture as it helps in assessing the trends and shaping decisions of the farmers. ICT are valuable sources of linkages and information dissemination.

In the modern world, ICT have replaced the extension services to some extent, and farmers connect now with research and extension services and other farmers through ICT. Therefore, ICT are crucial for the agricultural development of a country. Farmers who use ICT for agriculture in general and citrus cropping are well informed and allocate more area to citrus crop because of the profitability and long-term increasing returns to investment due to export potential. Mwombe et al. (2014) found that banana acreage impacts ICT use intensity significantly, and Adegbidi et al. (2012) found a similar result with rice crops. However, this study findings add to research that the ICT use in agriculture contributes to creating awareness among the farmers and scaling up the high-value agricultural enterprises rather than persisting with traditional crops, as the case of citrus.

6.2.7. Determinants of Citrus Yield

Pakistan is the 12th largest citrus producer in the world (FAO, 2019). The crop is among the major export commodities of the country. Its yield not only determines the farmers' income but is also a source of foreign exchange earnings. This research found that citrus yield was influenced significantly by fertilizers, citrus area (acre), modern ICT use in agriculture and ICT use in citrus. Other variables, such as cultivation practices (no), irrigation(no), labour (hrs), and farming experience, did not make a significant contribution to citrus yield. This does not mean that these variables are not important, but their citrus yield role is not statistically significant.

However, in large holder farmers, the citrus yield was significantly determined by cultivation practices, modern ICT use in agriculture and ICT use in citrus. The overuse of cultivation practices by large holder farmers had a significant negative impact on citrus yield. A separate analysis of large holders and smallholder farmers determined the productivity factors differently. In smallholder farmers, the citrus acreage was an additional significant contributor with a significant contribution of modern ICT use in agriculture in determining citrus yield in the area. It indicates the role of ICT in the yield of citrus crops. It means that timely and accurate information about farm practices, input availability and prices, and output market information may increase citrus yield. These findings are consistent with other research as rural producers have improved their productivity, market access, and options using mobiles (Jansen et al., 2006). Mobile phones are an inexpensive source of information transmission concerning the production and marketing of agricultural produce (Jehan et al., 2014). Mobile usage increases farm output (Ogbeide & Ele, 2015). Munyua and Adera (2009) found that modern ICT embedded capacity can enhance agricultural production by communicating information to farming communities.

Through text messages, agricultural advice has increased 11.5 percent yield of smallholder farmers than non-users of technical advice (Casaburi et al., 2014). This study found that the ICT use for citrus enterprise contributed 18 percent in yield. The ICT contribution for smallholders in citrus productivity was similar to that for large holder farmers. The results are consistent with Lashgarara (2011) who reported that ICT leave a modest contribution to agricultural product marketing, leading to yield improvement, with improved linkages among the researchers, extensionists, and farmers. Dagne and Oguamanam (2018) found that ICT interventions impact agricultural production with better information distribution and technical knowledge exchange (Dagne & Oguamanam, 2018).

This research validates the findings the other researchers, but with empirical evidence comparing small- and large- holder farmers. This highlights the need for agencies responsible for agriculture promotion in-country to invest in ICT for the betterment of citrus producers, especially smallholder farmers.

6.2.8. Determinants of Animal Units

The livestock sector has played a crucial role in improving the socio-economic status of farmers. The livestock contribution is more substantial for smallholders' livelihood. They consider livestock herd size as a bank balance because they meet their urgent needs by selling the animals. Therefore, it is essential to have appropriate technological development programs and disseminate improved animal husbandry practices to improve success.

The research findings revealed that education (years), farming experience (years), house area, family size (No), modern ICT use in agriculture, ICT use in livestock, and total land owned contributed significantly in deciding the herd size. The level of education was an important factor in productivity and adopting improved animal husbandry practices by dairy farmers. Higher education and house area, as a wealth, were not contributors in determining herd size. Ingole et al. (1988), in their work, reported that most livestock owners have either primary or secondary education. However, Mote et al. (1997), in their study, observed that one-third of the dairy farmers were educated up to college level, with only 10.87 percent illiterate.

In contrast, Sidhu et al. (1997) observed that the majority (86.6 percent) of the dairy farmers have a medium level of education. Family size is also a significant contributor to herd size. More of farmworkers are required for livestock management as it is labour intensive agricultural enterprise. Sikhweni et al. (2014) also found that family size affects the determination the herd size. The majority of the respondents from the dairy group have a joint family system and belong to medium size families, as observed by (Gour, 2002; Nayak et al., 1986; Patel,1984).

Farm experience is an essential characteristic in livestock enterprise amongst farming communities. Aged or experienced farmers prefer large herd sizes. De Bruyn et al. (2001) argued that old farmers tend to keep larger herds. Two to three decades ago, large herd size was a social status symbol rather than a commercial venture among the majority of the farmers. More recently, the business aspect has gained more consideration due to overtime awareness of the potential contribution in livelihood earning and economic pressure. This research found a valuable citrus/livestock interaction in farm enterprises. Landholding contributed significantly to determining the livestock herd size. The results are aligned with Rahman et al. (2001), and Sikhweni et al. (2014) that livestock herd size is affected by the farm size. In the present information age, communication services, especially ICT, could help the farming community improve its production capabilities and overall quality of life. A breakthrough in animal husbandry is not possible without adequate communication support to disseminate the research findings. Speedy dissemination of technological know-how and information to farmers is essential for bridging the gap between the scientists and the farmers.

Therefore, modern ICT use in agriculture and ICT use in livestock contribute directly to determining a farm's herd size. The results of this study confirm the importance of information. The use of ICT in information acquisition had a significant impact on maintaining herd size. These results are consistent with Rajoria et al. (2018), who found that farmers have a positive attitude, and herd size affects ICT usage. ICT provide an easy way for the farming community to share livestock-related information among themselves. Improved and efficient communication could lead to livestock sector growth (Saravanan, 2010). This research adds to the literature documenting the considerable effect of ICT usage in determining herd size at the farm and enhancing livestock enterprise profitability.

6.2.9. Determinants of Milk Yield

Pakistan is among the top milk-producing countries, but milk yield is low and lagging compared to other countries in the region; thus, tremendous potential exists for an increase in dairy producers' productivity and income. The dairy sector is predominantly occupied by smallholder and marginal farmers and landless labourers, whose dependence on dairying for subsistence is substantial.

The study found that milk yield for citrus growing farmers was mainly determined by total animal units (herd size), average milk sale, treatment expenditures, milk supplements, and ICT for livestock. Large herd size had a significant negative relationship to productivity, but milk selling, livestock treatment, and feed supplements contributed considerably to milk productivity. In large holder farmers, milk productivity was determined only by total animal units which had a significant negative contribution, and average milk sales with a significant positive contribution.

In contrast, milk yield for smallholder citrus farmers was negatively correlated with total animal units, but positively correlated with average milk sale, treatment expenditure, and ICT use for livestock purposes. According to Mansoor et al. (2012), milk production has increased over time due to a larger animal population, however, the national average yield is far below the levels achieved under the best farming practices. They further argue that milk sales or the price offered to milk producers also determine milk yield. With a reasonable, guaranteed price, farmers are willing to invest and ultimately achieve high productivity.

Research results revealed that expenditure on animal health and supplement purchases also played a significant role in milk productivity. Livestock herd size affected yield. It leads to the rationalization of the herd size with quality breeds animals. Further, a balanced utilization of supplements and livestock treatment is required to enhance the milk yield. Smallholder farmers' support in these areas could significantly improve their income, livestock being an integral part of the smallholding farming systems.

The study found that the contribution of ICT to accessing the latest livestock management information was more significant for smallholder farmers compared to large holder farmers. It indicated that ICT had increased smallholder farmers' access to the latest livestock management information, especially treatments to improve milk productivity. With the existing veterinary extension system, smallholder farmers usually lack access to the latest information. The study findings validate the observation of Angello (2015) that ICT can improve livestock management, thus improving productivity. The role of ICT is vital for livestock management in making farmers aware of the latest developments in the dairy sector, and essential inputs use for increased productivity. Systematic management using ICT can make livestock farming economically viable (Kim et al., 2014).

In developing countries, women's contribution to livestock management is noteworthy. However, the social and cultural environment does not support women in acquiring knowledge through the existing veterinary extension system. ICT could allow women to use innovative livestock management practices to increase livestock productivity. To reduce the information gap based on gender, modern ICT could significantly raise livestock production (Saghir et al., 2013). ICT is one way to remove or tackle these social impediments to knowledge acquisition for women, allowing them to contribute productively (Lin & Heffernan, 2010).

This research provides empirical evidence supporting the contribution of ICT as a communication source in increasing milk production and better livestock management.

6.2.10. Citrus Production Efficiency

Productivity improvement can come through adopting new technologies and/or an increase in production efficiency. It is also well established that increasing efficiency is more cost-effective than introducing new technology, mainly if the producers are not efficient in using the existing technology (Belbase & Grabowski, 1985; Dey et al., 2000; Shapiro, 1983). If the producers are reasonably efficient, technology and new inputs would be required to shift the production frontier upward (Ali & Chaudhary, 1990; Ali & Byerlee, 1991).

This research found that an increase in the number of cultivation practices decreases the efficiency in citrus production. An increase in fertilizer application and more area under citrus had a positive effect on efficiency enhancement of citrus growers. The inefficiency analysis showed that education increases the inefficiency of citrus growers. These results align with (Rahman & Haque, 2008; Sadiq et al., 2009) that inefficiency is higher for more educated farmers. This may be the reason that citrus production has been an agriculture enterprise for so long in the study area; farmers have achieved a certain level of citrus production knowledge through learning by doing, implying that a certain level of education is enough to run an agricultural enterprise. The research results showed that the use of modern ICT in agriculture and ICT use in citrus management decreases citrus growers' inefficiency, showing a decisive role for ICT in agriculture in citrus and more generally. Large holder farmers' efficiency was higher than the smallholder farmers because of better access to and viability of other production resources.

ICT, including mobile phones, the internet, radio, and television, disseminate timely and relevant information to efficiently make use of available resources (Ekbia & Evans, 2009; Ommani & Chizari, 2008). Further, the efficiency of small- and large- holder citrus enterprises was greater on an overall basis for those who were using ICT. These results provide empirical support and are consistent with other researchers' observations; for example, Chikaire et al. (2016) observed that ICT assimilation in agriculture enhances farmers' efficiency, Mwalupaso (2019) noted that mobile use increases farm enterprise efficiency, and Jensen (2010) showed that ICT can improve production performance by offering extension services remotely. ICT holds immense potential to enhance farmers' livelihoods by increasing farm productivity and efficiency (Adamides et al., 2013; Sangeetha et al., 2015). ICT efficacy can increase agricultural productivity, efficiency, and farmers' profit through generating more knowledge and interest (Rao, 2007).

Similarly, data on efficiency with the formal and informal information sources showed that farmers across small- and large- holder farm categories using formal sources of information are more efficient. These results are consistent with Dessale (2019), and Mango et al. (2015) who reported that farmers' contact with the extension officials increases crop production efficiency. ICT usage had a strong association with interaction with formal sources of information such as extension officials.

However, smallholder farmers with less or more education were almost equally efficient. In contrast, in large holder farmers, more educated farmers were more efficient than less educated farmers. This implies that, in addition to education, farmers' financial capacity is also vital to agricultural enterprise efficiency. Education group analysis results were different from the number of education years variable estimates in the technical efficiency calculation. On an overall basis, ICT usage made farmers efficient across small and large holder categories.

6.2.11. Milk Production Efficiency

The findings of this study highlighted that total animal units (herd size), average milk sale, treatment expenditure per animal, milk supplements, and land owned by the farmers significantly affect milk productivity efficiency. The large herd size decreased milk production efficiency. It implies the rationality of keeping productive herd size at a farm. Milk selling, use of supplements, and animals' treatment from the qualified veterinary staff reflect the importance of dairy enterprise and farmers' commercial orientation; these factors contributed significantly to enhancing milk production efficiency.

Results of the inefficiency model for milk productivity verified that ICT use in livestock management substantially decreases milk production inefficiency. The study findings support the previous research that recognizes ICT as vital in livestock farming (Nwagwu & Opeyemi, 2015; Williams & Agbo, 2013). New ICT developments have yielded substantial contributions to livestock sector efficiency (Senapati et al., 2016). ICT facilitate information exchange to enhance livestock farming competitiveness and efficiency (Nwagwu & Opeyemi, 2015).

Further, farmers using ICT were more efficient across small- and large- holder farm categories and on an overall basis than those who were not using it. The efficiency of large holder farmers was six percent higher than the smallholder farmers. This finding is probably a consequence of the smallholder farmers' inadequate financial capacity, which hinders their ability to make use of milk supplements, and expend money on treatment, which are both significant contributors to milk productivity. This study found that in addition to the considerable contribution of ICT in inefficiency reduction in milk production, farmers' experience and education also contributed to inefficiency reduction, which is contrary to the results for citrus production. This is consistent with the findings of Fita et al. (2013), Nganga et al. (2010), and Reddy et al. (2008) that higher education increases milk production efficiency. Fita et al. (2013), and Nganga et al. (2010) found that farming experience also contributes to enhancing milk production efficiency. The reason is, in this era, educated farmers using ICT have increased access to attain innovative information.

Farmers with experience improve livestock management dealing with specific breed milking animals for many years. In the past indigenous knowledge of farmers has been a leading contributor to livestock management. Mobile phone contribution as information communication technology appears to be important in livestock linked value chains. Mobile phones make it easier to access information from the dairy value chain's relevant stakeholders and to get information on innovation, production and marketing, to avoid the exploitation from the input suppliers and output collectors. Farmers are exploited by the middlemen to sell produce at cheaper rates due to lack of market information and conveyance management problems (FAO, 2001).

Similarly, farmers across small- and large- holder farm categories using formal sources of information were more efficient than farmers who used informal information sources. Along the same lines, data on efficiency with education level showed that farmers across all categories with more education were slightly more efficient than those with lower education levels.

This research adds to scarce empirical evidence on ICT usage for agriculture and agricultural enterprise efficiency.

To conclude, the discussion on the ICT contribution for citrus farmers reveals that ICT improves information acquisition and reduces the information gap between the small- and large- holder farmers, due to cost and time effective communication. The discussion reveals that ICT also facilitates innovation. This study, along with previous research illustrates the contribution of ICT in enhancing agricultural enterprise productivity and better market access in input and output markets. The smallholder farmers are a little behind the large holder farmers in reaping ICT benefits due to the constraints discussed. Farmers have improved interaction with other relevant stakeholders in addition to increasing contact with the farming community.

6.3. Discussion on Perceptions of the Value and Impact of ICT

This section discusses the perceptions of the value and impact of ICT.

6.3.1. Perception about ICT Possible Contribution in Farm Business

Attitudes towards emerging ICT depend on the extent to which users believe that technology will boost producers' social capital, finance capital, and human resources. This then determines how much users intend to embrace the technology (Wei et al., 2012). The awareness, adoption, and use vary among the farming communities depending on ICT knowledge and financial considerations. The perceived benefits of ICT include, but are not limited to, timely and updated delivery of information on the emergence of new threats such as diseases, commodity prices, supply and demand, information on new varieties and innovative production practices, and weather forecasts. Therefore, ICT are critical to improving the livelihoods of farmers, especially smallholder citrus farmers. Also, globalization and integration of food markets have strengthened competition and the usefulness of ICT in agriculture.

Farmers were asked how they perceive the potential ICT contribution to current and future agriculture enterprises, keeping in mind the importance of agriculture in the livelihood earnings of the majority rural population.

The study found that farmers perceive ICT as a means to increase efficiency, productivity, and sustainability. Farmers get market information on inputs-output prices and make informed decisions about future farming practices and the best place and time to buy inputs and sell output. The majority of the farmers agreed that mobile and internet might prove to be a valuable information acquisition source (Aldosari et al., 2019). Farmers have a positive perception about ICT use to attain agricultural input related information based on the simplicity, relative advantage, and compatibility (Kante et al., 2017)

The study results found that farmers recognize the potential contribution of ICT in aspects of adopting innovations, market access, market price negotiation, and farm management. ICT also fosters social interaction with the farming community, reduces dependency on agricultural extension, and assists better planning and decision making. Better and time-saving information, availability of lesser-priced quality inputs, live first-hand information acquisition, development of a skilled, knowledgeable farming community, weather information, and provision of possible solutions related to farming can also result from embracing ICT. The results are in agreement with Blommesten et al. (2006), Hashemi Nejad and Ghanji (2009), and Matani (2007), who perceive that ICT contribute by developing markets, raising incomes, providing access to market-related policy updates, and decreasing waste. They further recognize that ICT accelerates information flows, increasing producers' knowledge of prospects, and enhancing their farming operative skills to help the marketing of agricultural products.

Sekabira et al. (2012) also found that farmers believe ICT empowers farmers to acquire agricultural information, such as weather conditions, pest control, mobile money, and other data necessary to make critical decisions. Okello et al. (2010) noted that unlike the old-style agricultural information communication approaches, ICT have the advantage of presenting a low-cost method of i) empowering farmers to bargain better prices, ii) enhancing farmers' access to markets and agricultural credit, iii) establishing and enabling interaction among farmers, iv) transferring information, which are all consistent with the findings in this current research. Knowledgeable farmers perceive that ICT enhances the technology adoption rate, decreases information acquisition costs, and saves time (Ajayi et al., 2018).

Research findings revealed that farmers' perceptions ranged from disagreeing to some extent agreeing on aspects of ICT contribution to finance access, cheaper storage, and retrieval information. The observations and belief of large holder farmers and educated farmers were more positive in the perception of ICT contribution in agriculture compared to poor resource base farmers. This highlights the significance of financial and human capital in perception and practical use of innovative technologies. These research results are consistent with Peansupap and Walker (2005) and Opata et al. (2011), who showed that positive opinions about ICT correlate with its development and usage.

The factor analysis condensed farmers' perception on different characteristics into three key factors, i) ICT assists in improving social capital and farm business, ii) ICT affordability and existing infrastructure are enough to access and influence farmers to reap the benefits across distant locations, iii) illiteracy has a moderate impact in availing ICT services including data storage/retrieval and financial access. The smallholder and less educated farmers were less optimistic about the potential contribution of ICT. To address this, policymakers need to devise strategies to build positive perceptions and confidence among the poor resource farmers.

6.3.2. Farmers Preferred Means for Obtaining Technical Information

As mentioned earlier, all the farmers had mobile phones to get in touch with relevant experts for suggestions on agricultural issues. They preferred to interact personally verbally with technical experts, which gives confidence in decision-making about farm activities. Mobile phones provide the opportunity for information sharing among the farming community (Khan, 2013). Farmers with phones also prefer to receive and share MMS and SMS for information on different issues regarding crop production and management. SMS based technical advice increased the crops' yield (Casaburi et al., 2014). Also, farmers in the study area gave priority to watching agricultural programs on TV. Less education and a better understanding of visual led agricultural information's were the reason to give second priority across the farmers' categories. Smallholders' language and literacy issues make television programs and some other forms of ICT of more value for transferring technologies (Akter & Kabir, 2011). In south Asian countries, TV is the preferred medium of communication for learning and obtaining information on different agricultural techniques (Nazari, 2010). Farmers' preference validates the finding of Armstrong and Gandhi (2012) that mobile and TV use equip the farmers to access quality information for improving practices to promote better agricultural output. Access to the Internet has made it easier for farmers to access and share information on different global agricultural issues, and it is now the preferred means. Educated and informed farmers also prioritize social media groups considering them an easy and effective forum to discuss daily farming issues. Farmers also share clips and photos of different diseases and pest attacks on social media to get instant opinions from relevant experts.

To summarize, farmers generally recognize the potential contribution of ICT, but smallholder farmers are relatively less positive owing to their poor resource base. The discussion further highlights the importance of personal communication with relevant stakeholders on mobile as farmers' preferred means of communication, followed by TV which is more popular among less educated farmers.

6.4 Chapter Summary

This research has confirmed the literature review's main themes, with quantified empirical evidence relevant to Pakistan. It reveals that citrus farmers in the Punjab province in Pakistan share much in common with other farmers globally, especially the developing countries where most farmers are smallholders with a reduced resource base. The study has highlighted that education is a critical factor in the awareness adoption and usage of ICT. Educated farmers are more confident in its use and more positive about the contribution of ICT to farm enterprises. Farmers' financial capacity is also a key determinant in adopting and using ICT in reaping the benefits from these modern era gadgets.

Lack of awareness and knowledge, affordability, and communication methods hinder ICT effectiveness in the farm business, particularly in the case of smallholder and less educated farmers. ICT use is bridging the gap between the authenticated information sources and farmers. Farmers have enhanced their access to get innovative information as part of crop production technologies and updated information for inputs purchase and output disposal. This increases agricultural enterprise productivity and limits exploitation from market intermediaries. Farmers have improved their access and social interaction with relevant stakeholders, which has a positive impact on their agricultural productivity. Farmers recognize the ICT role and impact in developing interaction and social relations with relevant stakeholders and improving agricultural enterprises with some concerns. The smallholder farmers are relatively less optimistic about the ICT potential impact due to their weaker resource base.

Overall, this research highlights the significance of ICT in benefitting farmers, including smallholder farmers who make up the majority in Pakistan's agriculture. The research findings suggest that policymakers and relevant organizations/departments should that develop strategies to ensure the benefits of ICT to the farming community are realised. The policy implications derived from this research are discussed in chapter six.

Chapter Seven: Conclusions and Implications

This chapter draws conclusions from the salient findings of this research, identifies implications of the study, and makes recommendations for developing policy and practices based on current and future prospects for ICT in Pakistan's agriculture sector. This study's limitations and suggestions for future research in ICT perspective are also discussed.

7.1 Conclusions

The research was designed to explore the ICT contribution to innovative information acquisition and improving the livelihood of citrus farmers, especially smallholders, due to the speedy growth of mobile technology, the internet, and computer. This research was further motivated by the existing gap in empirical research regarding the impact of ICT on innovative information acquisition and farmers' income. Innovative information access is one of the significant structural problems among the farming community, especially for smallholders in developing countries like Pakistan. Dissemination of needs-based, accurate, reliable, and timely information to farmers is vital for consistent agricultural growth. Based on this research, the following conclusions are presented.

As subsections 5.1.2 and 5.1.3 indicate the adoption of normal mobile is promising, but other modern ICT (e.g. smartphones, computers, internet) use is low among the farming community. Modern ICT adoption, competency in using ICT, ICT importance, and use in agriculture are relatively high among the large holder and more educated farmers due to their financial and human capital. Social media use for agricultural purposes is low among farmers generally. As an established ICT, television is still popular but with minimal value for farming purposes due to its generalised nature, and because broadcasting is not region-specific. Radio has almost lost its presence among the farming community, even though there exist regional-based FM stations.

The education level, financial capacity, agricultural business size, and communication with relevant stakeholders are the key elements in ICT awareness, adoption, and agricultural usage as sub-sections 5.1.4 to 5.1.6 indicated. Though the farming community's mainstays, older farmers are not very aware of ,or familiar with ICT usage for personal and agricultural purposes. This argues for the importance of conventional ICT such as TV and radio for older and less educated farmers.

Modern ICT usage has increased significantly for information acquisition for citrus management practices among the farmers. ICT fulfils a recognizable role in bridging the information gap and developing linkages with reliable information sources. Reliance on fellow farmers for innovative information acquisition switches towards the formal information sources like the extension agents, research departments, and others with the ICT use reflected in sub-section 5.2.1. ICT as indicated in 5.2.2 provides cost and time effective information acquisition to the farming community. Modern ICT use for information acquisition and access to reliable information sources is lower among smallholder farmers than large holder farmers.

ICT usage in agricultural enterprises reveals at 5.2.4 a considerable contribution to improving the livelihood of farmers. More use of ICT in agriculture is a source of increasing farm income, increasing production, and avoiding exploitation in input-output markets. ICT usage impact is significant in enhancing the citrus and livestock enterprises' efficiency with other production factors as shown at 5.2.10 and 11. Smallholder farmers are less efficient in agricultural enterprises than large holder farmers due to resource constraints that influence ICT usage and other inputs balanced use in agricultural enterprises.

Farmers with awareness and experience have developed attitudes/perceptions about the potential contribution ICT. Farmers' attitudes shown at 5.3.1 are overall positive but vary on specific aspects. Smallholder and less educated farmers are less optimistic about the contribution of ICT currently and in the future due to the constraining factors discussed above and revealed at subsection 5.1.7.

Farmers' have a consensus that certain factors limit the effectiveness of ICT among the farming community. Farmers consider that ICT are unaffordable, that they lack awareness and knowledge, and there exists poor communication (methods and language), all of which impact ICT effectiveness. Smallholders and less educated farmers are more concerned about the effectiveness of ICT due to limitations of finance and knowledge. Based on empirical evidence from specific research sites, these limitations may be a broad reflection of the farming community across the country.

Farmers indicated at 5.3.3 that they give priority to verbal interaction with relevant experts/stakeholders through mobile calls to make farm decisions. Despite the existence of more modern technologies, farmers still give importance to television because of its visual component. Less educated and poor farmers prefer visual and audio delivered information for better understanding. However, TV and radio, do not deliver region-specific information on agricultural innovation. Less educated and poor farmers also prefer participating in seminars, farmers' meetings with ICT aiding the provision of innovative expert knowledge. Farmers prefer region/crop specific information in their local or national language ‘Urdu.’

The youth of the farming community revealed in discussions (5.4) that they are familiar with modern ICT. The majority have a smartphone and are frequent users of the internet. They are connected among themselves on Facebook, WhatsApp, YouTube, and surf search engines for information on many issues, including agriculture. Some help their elders who are unable to use ICT, and almost all are convinced that they could help elders acquire innovative information using modern ICT.

7.2 Policy Implications

The research findings recognize the contribution of ICT across both categories of farmers, suggest some actions that may maximize benefits and overcome the smallholder farmers’ concerns with useful ICT related measures. To address these constraints will require practical efforts from relevant stakeholders, including the government and non-government organizations, to improve the livelihoods of the farming community, especially the smallholders.

Awareness campaigns by relevant government departments and cellular companies are required to address the problems, mainly among smallholders, of being less competent in the use of modern ICT, and using it less than other farmers. This will enhance farmers' familiarity and knowledge regarding ICT use for agricultural purposes.

To overcome the barriers presented by lower education and greater age in ICT adoption and usage for agricultural enterprises, introducing certain short courses and diplomas programs would be beneficial. Agricultural training institutes and technical education and vocational institutes at the district level can contribute in this regard. The establishment of community service centers (CSCs), equipped with modern ICT tools for training and as an information hub in rural areas, could enhance innovative information access without discriminating among the farming community. The participants should be provided with modern ICT tools such as smartphones and tablets to keep their interests intact.

Decreasing the information gap and achieving optimal efficiency levels among smallholders, calls for the government, cellular companies, and other relevant stakeholders' to make a joint effort. It necessitates developing a digital information system related to crop management advice, weather forecasts, and market information related to farm inputs and output. The integration of relevant agencies including government agricultural institutes (e.g. extension, research, academia), cellular companies, and the private agricultural services sector will provide authenticated innovative information as a one-stop solution, using these ICT related platforms. Smallholder farmers' financial support with ICT related intervention could boost their farm productivity.

The limiting factors in ICT adoption and usage, and indifferent perceptions of small- and large-holder farmers demand intensive efforts to capitalize on ICT potential benefits in agricultural enterprises. Lack of awareness and knowledge requires consistent persuasion from the government and other relevant agencies to apprise the farming community with ICT attendant benefits, especially among the smallholders. Government and other relevant agencies should provide modern ICT embedded with agricultural applications and agricultural-based social media platforms considering literacy constraints and language concerns, with no cost or subsidized rates to smallholder farmers.

Farmers' preference for effective communication methods implies that the less educated and older farmers require personal communicative platforms and visual information dissemination from relevant developmental agencies. Two-way communicative ICT platforms such as toll-free helplines at the district level are options for farmers to communicate with the relevant experts. Information dissemination embedded with visual content delivery using a smartphone may contribute effectively to the smartphone adopting farmers. PEMRA should instruct the public and private TV channels for agricultural programs broadcasting both on terrestrial and cable networks with due consideration of timing, regional crops specific information, and language. Radio still could be an essential communication source, using the broader FM network in the majority of districts to broadcast region-specific agricultural programs, using mobile sets with a headset if needed.

Thus, lower financial and educational resources should be a key consideration by the relevant stakeholders in devising any program for ICT use. In order to improve the innovative information delivery mechanism for farmers, especially smallholders, a significant future financial investment is required.

The familiarity and adoption of modern ICT among the rural youth are a potentially important resource for the relevant stakeholders.Youth need to be encouraged and incentivized with the provision of subsidized modern ICT. This could assist elders in acquiring innovative information from different information sources for agricultural enterprises, in addition to benefit for their formal education. It could further enhance the youth's interest in agriculture to contribute by increasing farm profitability with innovative farming techniques.

7.3 ICT Assessment Framework for Improving ICT Effectiveness in Agriculture

The research conclusion articulates that ICT have a significant contribution to the livelihood improvement of the farming community. Some farmers are currently unable to reap all the potential benefits, especially from modern ICT. Of more significant concern is the adoption and usage of ICT for agricultural purposes of smallholder farmers due to their weak resource base. These research findings are based on the situation analysis of ICT adoption and utilization for agricultural activities. There were no prior specific ICT related interventions from the government institutes to assess the ICT interventions contribution.

The research findings have policy and practice implications in improving the effectiveness of both modern and conventional ICT. The following assessment frameworks for improving ICT effectiveness in agriculture are described separately for modern and conventional technologies. The focus is specifically on smallholders owing to their weak resource base in terms of all livelihood capitals. The assessment framework is adapted from (Coggins et al., 2020) and modified according to this research perspective. The assessment framework is presented in Table 7.1 for the conventional ICT, and Table 7.2 provides the assessment framework for modern ICT.

Table 7.1 presents the assessment framework regarding conventional ICT. While TV is still the second most demanded media of communication across the farming community, either small or large holders, the contribution of TV innovative information dissemination is negligible. Radio has become obsolete, but the revival of radio as a communication source for the farming community is possible with concerted efforts, by making FM radio stations responsible. The existence of FM radio stations in many districts provides the opportunity to disseminate region/district-focused agricultural information. There is a need to make farmers aware of how to access radio via mobile and additional ICT-related products such as headsets, if the mobile does not have an inbuilt antenna.

Table 7.1: ICT Assessment Framework and Implications of Conventional ICT (Tv and Radio)

Evaluation Aspect	Success Element	Success Component	Doable	Research findings (Concerns/Issues)	Desired Actions for Effectiveness/Remarks	Actions/ Responsibilities
Contextual appropriateness	Farming Community especially smallholder farmers	ICTS availability/ access	High access	High access to TV but very low access to radio	Need to broadcast crop and region-specific agricultural programs on Tv and radio to stop losing Tv and radio's identity and effectiveness. Farmers could switch on radio through mobile if they find broadcasted information worthwhile. Regional FM radio stations could contribute.	Government or Public Institutes (Media houses and FM services for radio)
		Digital ability	Familiar	No issue	No specific action is required	-
		Literacy	Even no or low level	Low	No specific action is required	-
		Agricultural knowledge	Even low is workable	Low	Innovative research developments dissemination TV and radio	Public/private Institutes
		Attitude	Passively interested	low interest	Useful information broadcasting including entertaining script	Public/ Private Institutes
	Digital infrastructure	Availability of terrestrial and cable networks	Accessible, reliable, and affordable	Extensive and quality broadcasting coverage	Provision of quality networking facilities on both terrestrial and cable networks	Government and private broadcasting corporations
	Government Policy	Government and Non-government advisory providers	Public-private partnerships	Government lacks in taking information communication initiatives	The government should make compulsory to public and private institutes/channels to fix a suitable time for broadcasting agricultural programs both on Terrestrial and cable networks	Public/private organizations
Information/ Service adoptability	Authentic information/ service delivery	Authenticated and validated information/ service	Recognizable	Increase in Information influx without authenticity	Need to reflect responsible behavior to deliver authentic information/ service, not just commercial motive on advertising agricultural products	Public/private Institutes
	Ease in use	User friendly	Highly user friendly	No issue	No specific action is required	-
	Consumable advice	Local/national language	Familiar	Unavailability of innovative research outcomes in	Broadcasting of Innovative research outcomes in local/national language by the public and private institutes	Public/private Institutes

Evaluation Aspect	Success Element	Success Component	Doable	Research findings (Concerns/Issues)	Desired Actions for Effectiveness/Remarks	Actions/ Responsibilities
				local/national language		
		Visual	Visualizable advice	Lack of practical visual advice aspect in information broadcasting through Tv.	Visual advice attains more attention. For illiterate or low level educated farmers need practically demonstrated visual content embedment in the information broadcasting process	Public/private Institutes
	Interactive advice	Addressing issues	Answering the issues/queries by experts	No proper interactive advice mechanism. Generic information is answered without consulting relevant experts.	The low educated farming community is comfortable with interpersonal communication. Relevant expert base interactive advice system is vital. Agricultural programs host should provide contact numbers for queries and clarifications	Public/private Institutes
	Relevant advice	Information dissemination considering farmers priorities	Critical issues of production and marketing	Supply-driven advice	Need consideration of critical aspects and farmer's priorities in information dissemination	Public/private Institutes
		Relevant to farm	Region specific	No reflection of regional conditions	Need to deliver crop-specific and region-specific information	Public/private Institutes
		Relevant timing	Referable advice	Supply-driven timing	Farmer's free time should be a consideration in agricultural information broadcasting.	Public/private Institutes
Information communication scalability	Possibility of scaling up	Operational efficiency	Cost effective	No issue	Crop and region-specific information could impact farmers free time consideration	Public/private Institutes
Information communication sustainability	Economic	Cost effective	Cost effective information delivery	No issue	Need to consider the demand-driven information aspect.	Public/private Institutes
Ethical responsibility	Inclusive	Inclusion without discrimination of small or large holder, castes and geographic isolations	Access to everyone	No issue	Consideration of values and norms of the farming community	Public/private Institutes

Table 7.2: ICT Assessment Framework and Implications for Modern ICT (Normal Mobile, Smartphone, Computer, and Internet)

Evaluation Aspect	Success Element	Success Component	Doable	Research findings (Concerns/Issues)	Desired Actions for Effectiveness/Remarks	Actions/ Responsibilities
Contextual appropriateness	Farming Community especially smallholder farmers	ICTS availability/ access	High access	Moderate access	Need to support/provide smartphones/tablets to smallholder farmers embedded with agricultural apps	Government or Public Institutes
		Digital ability	Familiar	Inexperienced	Farmers training in the use of modern ICT	Public Institutes
		Literacy	Moderate	Low	Farmers' training/short courses in the use of ICT to overcome low literacy aspects. Information content in the national and local languages. Voice messaging.	Public Institutes
		Agricultural knowledge	Moderate	Low	Innovative research developments dissemination using ICT	Public Institutes
		Attitude	Passively interested	Moderate interest	Modern ICT use and effectiveness demonstrations	Public/ Private Institutes
	Digital infrastructure	Cellular companies' networks G3, G4 service	Accessible, reliable, and affordable	Some networks coverage problems	Provision of quality networking facilities	Cellular Companies
	Government Policy	Government and Non-government advisory providers	Public-private partnerships	Government lacks in taking ICT based information communication initiatives	Public/private partnerships consisting of public institutes, cellular companies, and other Agri. service provider companies benefiting the farming community and taking care of private companies profit motives	Public/private organizations
		Farmer and farm data	Access to government institutions	Misuse of personal data	Strict rules to ensure data use for Agri. Business	Public Institutes/ Cellular Companies
Information/ Service adoptability	Authentic information/ service delivery	Authenticated and validated information/ service	Recognizable	Increase in Information influx without authenticity	Need to reflect responsible behavior at the individual and institution level to deliver authentic information/service	Public/private Institutes

Evaluation Aspect	Success Element	Success Component	Doable	Research findings (Concerns/Issues)	Desired Actions for Effectiveness/Remarks	Actions/ Responsibilities
	Ease in use	User-friendly apps or platforms (e.g. WhatsApp)	Moderate, user-friendly	Requires training Unfamiliar	Requires training in the use of ICT and related apps.	Public/private Institutes
	Consumable advice	Local/national language SMS	Familiar	Unavailability of innovative research outcomes in local/national language	Dissemination of Innovative research outcomes in local/national language by the public and private institutes	Public/private Institutes
		Visual	Visualizable advice	Lack of practical visual advice aspect in information dissemination.	Visual advice attains more attention. For illiterate or low level educated farmers need practically demonstrated visual content embedment in the information dissemination process	Public/private Institutes
	Interactive advice	Addressing issues	Answering the issues/queries by experts	No proper interactive advice mechanism	The low educated farming community is comfortable with modern ICT based interpersonal communication. Relevant expert base interactive advice system is critical.	Public/private Institutes
		Information sharing using ICT (Multimedia, videos) followed by a discussion with the farming community	Moderate Effectiveness	ICTs use in farming community meeting is not much prevalent.	ICTs based information dissemination followed by discussion is also useful and desirable for farmers. Experts need to follow this method considering the time and travel constraints.	Public/private Institutes
	Relevant advice	Information dissemination considering farmers priorities	Critical issues of production and marketing	Supply-driven advice by government institutes and cellular company (Telenor)	Need consideration of critical aspects and farmers' priorities in information dissemination	Public/private Institutes
		Relevant to farm	Region specific	No reflection of regional conditions	Need to deliver crop-specific and region-specific information	Public/private Institutes

Evaluation Aspect	Success Element	Success Component	Doable	Research findings (Concerns/Issues)	Desired Actions for Effectiveness/Remarks	Actions/ Responsibilities
		Relevant timing	Referable advice	Supply-driven timing	Information delivery timing is essential, although modern ICT have information retention capability.	Public/private Institutes
Information communication scalability	Possibility of scaling up	Operational efficiency	Cost-effective	No judicious use of ICT, personal communication preference	Need to compile farmer and farm data for comprehensive access to farmers.	Public/private Institutes
Information communication sustainability	Economic	Relatively cheap ICT services	Cost-effective information delivery	The majority are poor resource base farmers	Initially, farmers need to subsidize modern ICT and ICT services. Later, by increasing productivity would be able to sustain modern ICT based services. Reliable groups on social media, including Facebook and WhatsApp, etc., administered by professionals from government/or reputable private institutes.	Public/private Institutes
Ethical responsibility	Inclusive	Includes weak resource base, smallholder farmers, without discrimination among farmers' categories and geographic isolations	Important considering farmers' preferences without biases	Smallholder farmers have comprehensions in use of ICT comparing to large holder farmers	Efforts require to make the best benefits of modern ICT across the farming community, considering norms and values.	Public/private Institutes

The framework describes a number of different measures under the five key technology evaluation aspects, to enhance the value of these cost-effective, one-way conventional communication technologies that are well-accepted among poor and less educated farmers. The five key evaluation aspects of technologies are contextual appropriateness, information/service adaptability, information communication scalability, information communication sustainability, and ethical responsibility. This framework further explains the success elements around each evaluation aspect relating to conventional ICT. In relation to each success component, what are the realistic possibilities to maximize conventional ICT effectiveness, and what are the concerns/issues resulted from the research findings. This framework's last column describes the actions required to address the problems and suggesting the responsibility for the execution of actions.

Table 7.2 presents the assessment framework regarding for modern ICT. It provides a description of the research outcome and possible measures to improve modern ICT effectiveness. Farmers are making efforts on their own to benefit from innovative/latest information acquisition with the gradual improvement in ICT adoption and usage in agriculture. For better resourced farmers, modern ICT and related technological advancements like the establishment of social media platforms are interesting and useful for agriculture and social interactions, but farmers with low education, low income, and lack of awareness of modern ICT potential cannot gauge, let alone realise the actual potential.

This framework explains the process of enhancing modern ICT effectiveness targeting smallholder farmers, in the context of the five key evaluation aspects of technologies described above for conventional ICT, including contextual appropriateness, information/service adaptability, information communication scalability, and information communication sustainability, and ethical responsibility. The assessment framework for modern ICT provides a detailed understanding of the issues and execution of possible actions with the responsible stakeholders identified.

7.4 Limitations of the Study

Extensive efforts were made to execute this research with clear planning and an objective approach to data collection and analysis. Nevertheless, the study has some limitations:

1. The first limitation of the study is that it trusted the self-reported views of the respondents. The satisfaction level regarding any service or technology varies among individuals with different socio-economic characteristics. It is not easy to find a uniform sample of appropriate size for analysis.
2. The sample size and specificity of the study location might be not be sufficient to generalize this study outcome to other districts of Pakistan. The country's topography varies from coastal to mountainous, and there is considerable variation in agricultural systems across country. Farmers' socio-economic attributes vary with resource access and cultural influences that impact the adoption and usage of technologies.
3. The third limitation reflects the development and implementation of the research instrument. The research instrument was developed, incorporating both directive and indirective questions. A recommended procedure was followed to implement a research instrument in the field. A reasonable number of farmers were interviewed before the final data collection. However, there may have been deficient instrument development to allow the inclusion of indirect information and respondents' behaviour at an interview, which potentially compromised research reliability.

Despite the listed limitations, due thought was given to research planning and execution under advised research protocols. The mixed-methods approach used in data collection included survey, informal discussion with key farmers, and focus group discussions with relevant stakeholders to substantiate and confirm the respondents' responses.

7.5 Future Research Directions

In this research, the existing situation analysis explored ICT adoption, role, and impact, and efforts were made to fill the research gaps in the field and follow the literature review. Future research studies are essential to overcome the methodological limitations in dealing with so many socio-economic characteristics and technological changes over time; especially in this technological era, the emergence of IT or ICT innovations and its contribution changes rapidly.

The federal and provincial governments like Punjab have taken specific initiatives to provide tablets to smallholder farmers equipped with agricultural information. An assessment of this kind of intervention is required to replicate and promote the benefits to the farming community.

Private cellular companies have also launched individual agricultural information dissemination initiatives in a different region. A careful examination is essential to evaluate the information content and dissemination process.

A longitudinal research design should be followed to assess the role and impact of ICT. It will be helpful to gauge ICT potential for enabling long-term sustainable livelihoods. This research activity will generate a detailed set of possible implementable and replicable sets of ICT related measures in different resource-limited environments.

Future research is needed to analyse the ICT adoption patterns, and its and contribution from the whole family perspective, and particularly for women and youth, to improve farmers' family livelihood, especially in the case of smallholders.

Detailed research on social media effectiveness and constraints is required on an urgent basis to develop policy implications. Social media is increasing day by day, providing a plethora of information. The potential dissemination of inaccurate data may affect the importance and value of ICT.

The capability and working of different relevant institutes are also a matter of concern. Research should be conducted to investigate ICT aided options to improve their capability, ultimately developing the farming community's ability.

This research gauged important implications for the farming community in district Sargodha. This research needs to be replicated with further methodological improvement across all provinces of the country due to variation in the agroclimatic zones and diversity in agricultural systems, variation in socio-economic characteristics, and the cultural context of different farming communities.

7.6 Concluding Remarks

There can be little doubt that ICT contribute positively to farmers' livelihood and it is pertinent to note that farmers' awareness, adoption, and usage of ICT for agriculture is encouraging. However, there is a lack of availability of ICT related interventions such as the establishment of individual platforms to disseminate specific information/technical advice and applications of agricultural technologies from the government and private sector. Farmers' efforts to make ample use of available ICT are admirable. These research findings recognize the contribution of livelihood capitals in the adoption and usage of ICT in agriculture and, in turn, improvement of livelihood capitals with the frequent use of ICT, mainly the modern ICT for agricultural business. Smallholder farmers are also making progress in reaping the benefits of modern ICT, but a weak resource base is a hurdle in realising the maximum potential benefits. All farmers agree that ICT are contributing and will contribute effectively to overcome the production and marketing efficiencies relating to updated/innovative information availability. Government departments, other relevant non-government organizations (NGOs), and cellular companies need to step forward to equip the farming community, especially the smallholders, with emerging ICT advancements materially and competently.

The developed world agriculture benefits from ICT advancements using geographic information system (GIS) technologies, artificial intelligence (AI), remote sensing, and the like. Relevant and responsible stakeholders need to start urgently addressing farmers' concerns to adopt ICT for precision and productive agriculture. Smallholders are among the most important contributors in developing economies and must not be left behind in the effort to realise global food security.

References

Abbas, M., Hassan, S. A., & Lodhi, T. E. (2009). Role of extension services in promoting agroforestry in district Bahawalpur. *Journal of Agricultural Research 47(2),* 211. https://agris.fao.org/agris-search/search.do?recordID=PK2009001066

Abbas, M., Lodhi, T. E., Bashir, A., & Mahmood, M. A. (2008). Dissemination of wheat production technologies and interface of out-reach efforts with farmers. *Journal of Agricultural Research, 46(1),99-108.* https://agris.fao.org/agris-search/ search. do?recordID =PK2008001085

Abid, M. E. A., Scheffran, J., Schneider, U. A., & Ashfaq, M. (2015). Farmers' perceptions of and adaptation strategies to climate change and their determinants: the case of Punjab province, Pakistan. *Earth System Dynamics, 6(1), 225-243.* https:/ /doi.org/ 10.5194/esd-6-225-2015.

Adamides, G., & Stylianou, A. (2013). ICT and mobile phone use for agricultural knowledge sharing by Cypriot farmers. *In AGRIS on-line Papers (Ed.), Economics and Informatics, 5, 3-10.* DOI: 10.22004/ag.econ.152686

Adamides, G., Stylianou, A., Kosmas, P. C., & Apostolopoulos, C. D. (2013). Factors affecting PC and internet usage by the rural population of Cyprus. *Agricultural Economics Review, 14, 16-36.* DOI 10.22004/ag.econ.253535.

Addi, H., & Williams, L. J. (2010). Principal component analysis. *Wire Computational Statistics, 2(4),* 433-459. https://doi.org/10.1002/wics.101.

Adegbidi, A., Mensah, R., Vidogbena, F., & Agossou, D. (2012). Determinants of ICT use by rice farmers in Benin: from the perception of ICT characteristics to the adoption of the technology. *Journal of Research in International Business and Management, 2(11), 273-284.* http://www.interesjournals.org/JRIBM

Adom, D., Adu-Gyamfi, S., Agyekum, K., Ayarkwa, J., Dwumah, P., Abass, K., & Osei-Poku, P. (2016). Theoretical and conceptual framework: Mandatory ingredients of quality research. *Journal of Education and Human Development, 5(3),* 158-172. https://www.researchgate.net/publication/32220415.

Afzal, M., Naqvi, A. N., WFP, K. L., & Balochistan, P. I. (2004). Livestock resources of Pakistan: Present status and future trends. *Quarterly Science Vision, 9 (1), 3-4.*

Ågerfalk, P. J. (2013). Embracing diversity through mixed methods research. *European Journal of Information Systems, 22(3),* 251-256. https://doi.org/10.1057/ejis.2013.6.

Agrahari, A., Tripathi, S., & Tripathi, D. S. (2012). A theoretical framework for development of decision support system for agriculture. *International Journal of Engineering and Science, 1(6),* 50-55. http://www.researchinventy.com/papers/v1i6/F016050055.pdf.

Ahmad, W., Noor, M. A., Afzal, I., Bakhtavar, M. A., Nawaz, M. M., Sun, X., & Zhao, M. (2016). Improvement of sorghum crop through exogenous application of natural growth-promoting substances under a changing climate. Sustainability, 8(12), https://doi.org/10.3390/su8121330

Ajani, E. N. (2014). Promoting the use of information and communication technologies (ICTs) for agricultural transformation in Sub-Saharan Africa: Implications for policy. *Journal of Agricultural & Food Information, 15(1), 42-53.* https: //doi.org/ 10.1080/10496505.2013.858049

Ajayi, A. O., Alabi, O. S., & Okanlawon, B. I. (2018). Knowledge and perception of farmers on the use of information and communication technology (ICT) in Ife-Central Local Government Area of Osun State: Implications for rural development. *Journal of Agricultural Extension and Rural Development, 10(3), 44-53.* DOI:10.5897/JAERD2013.0519.

Ajzen, I. (1985). From intentions to actions: A theory of planned behavior. In Kuhl J., Beckmann J. (eds) Action Control. SSSP Springer *Series in Social Psychology*. Springer, Berlin, Heidelberg. https://doi.org/10.1007/978-3-642-69746-3_2.

Aker, J. C., & Mbiti, I. M. (2010). Mobile phones and economic development in Africa. *The Journal of Economic Perspectives, 24(3), 207-232.* DOI: 10.1257/jep.24.3.207.

Akhtar, W., Akmal, N., Shah, H., Niazi, M. A., & Tahir, A. (2013). Export competitiveness of Pakistani horticultural products. *Pakistan Journal of Agricultural Research, 26(2).* https://www.cabi.org/gara/FullTextPDF/2013/20133358757.pdf.

Akintoye, A. (2015). Developing Theoretical and Conceptual Frameworks. Retrieved from https://doczz.net/doc/6786378/akintola-akintoye_developing-theoretical-and-conceptual.

Akter, N., & Kabir, W. (2011). Empowering Farmers through Mass Media: A Success Story of Mati-O-Manush Television Program in Bangladesh. In Hazelman, N., & Attaluri, S. (Eds) *Success Stories on ICT/ICM in AR4D in Asia and the Pacific Region.* Food and Agriculture Organization & Asia-Pacific Association of Agricultural Research Institutions Bangkok, Thailand.(37-48).http://www.apaari.org/wp-content/ uploads/ 2011/06/Success%20Stories%20on%20ICTICM%20in%20AR4D%20in%20AP%20 Region%202011.pdf.

Aldosari, F., Al Shunaifi, M. S., Ullah, M. A., Muddassir, M., & Noor, M. A. (2019). Farmers' perceptions regarding the use of Information and Communication Technology (ICT) in Khyber Pakhtunkhwa, Northern Pakistan. *Journal of the Saudi Society of Agricultural Sciences, 18(2),* 211-217. https://doi.org/10.1016/j.jssas.2017.05.004.

Aleke, B. (2010). Developing a model for information and communication technology diffusion among small and medium sized agribusiness enterprises in Southeast Nigeria. *Unpublished doctoral dissertation, University of Northumbria, Newcastle, UK.* http://dx.doi.org/10.1108/17410391111097438

Aleke, B., Ojiako, U., & Wainwright, D. W. (2011). ICT adoption in developing countries: perspectives from small-scale agribusinesses. *Journal of Enterprise Information Management, 24(1),* 68-84. DOI:10.1108/17410391111097438

Alene, A. D. (2007). Improved production technology and efficiency of smallholder farmers in Ethiopia: Extended parametric and non-parametric approaches to production efficiency analysis. *Unpublished doctoral dissertation, University of Pretoria*. http://hdl.handle.net/2263/28652

Ali, J. (2012). Factors affecting the adoption of information and communication technologies(ICTs) for farming decisions. *Journal of agricultural & food information, 13(1),* 78-96. https://doi.org/10.1080/10496505.2012.636980.

Ali, J., & Kumar, S. (2011). Information and communication technologies (ICTs) and farmers' decision-making across the agricultural supply chain. *International Journal of Information Management, 31(2),* 149-159. DOI:10.1016/j.ijinfomgt.2010.07.008.

Ali, M., & Byerlee, D. (1991). Economic efficiency of small farmers in a changing world: A survey of recent evidence. *Journal of International Development, 3(1),* 1-27. https://doi.org/10.1002/jid.4010030102S.

Ali, M., & Chaudhry, M. A. (1990). Inter-regional farm efficiency in Pakistan's Punjab: a frontier Production function study. *Journal of Agricultural Economics, 41(1),* 62-74. https://doi.org/10.1111/j.1477-9552.1990.tb00619.x.

Ali, T. (2004). Marketing of citrus fruit in Pakistan. *Unpublished Doctoral Dissertation, University of Karachi, Karachi*. http:/ /173. 208.131. 244:9060/ xmlui/handle/ 123456789/6876.

Allahyari, M. S. (2008). Extension mechanisms to support sustainable agriculture in Iran context. *American Journal of Agricultural and Biological Sciences, 3(4),* 647-655. https://www.academia.edu/792689/Extension_mechanisms_to_support_sustainable_agriculture_in_Iran_context.

Allison, P. D. (2012). Logistic regression using SAS: Theory and application. *SAS Institute.*

Alvarez, J., & Nuthall, P. (2006). Adoption of computer-based information systems: The case of dairy farmers in Canterbury, NZ, and Florida, Uruguay. *Computers and Electronics in Agriculture, 50(1),* 48-60. DOI:10.1016/j.compag.2005.08.013.

Angello, C. (2015). Exploring the use of ICT in learning and disseminating livestock husbandry knowledge to urban and peri-urban communities in Tanzania. *International Journal of Education and Development using Information and Communication Technology, 11(2).* http://www.suaire.sua.ac.tz/handle/123456789/3314.

Anoop, M., Ajjan, N., & Ashok, K. R. (2015). ICT based market information services in Kerala–determinants and barriers of adoption. *Economic Affairs, 60(1),* 117-121. DOI: 10.5958/0976-4666.2015.00016.9.

Anushree, B., & Mohan, D. G. M. (2018). The farmers' view towards the use of information and communication technology in agriculture: A study among farmers in the NER (North-eastern Region) of India. *Journal of Emerging Technologies and Innovative Research (JETIR), 5(11)*. www.jetir.org (ISSN-2349-5162).

Arif, M. (2018). ICT and Development in Pakistan: A Review. *Journal of Innovations and Sustainability, 4(3)*,7-25.ISSN:2367-8151 https:// www. researchgate. net/publication/ 328718444_ICTs_and_Development_in_Pakistan_A_Review.

Armstrong, L. J., Diepeveen, D. A., & Gandhi, N. (2011). Effective ICT in agricultural value chains to improve food security: An international perspective. In World Congress on Information and Communication Technologies (WICT), Mumbai, India. DOI:10.1109/WICT.2011.6141422.

Armstrong, L. J., Diepeveen, D. A., & Tantisantisom, K. (2010). An eAgriculture-based decision support framework for information dissemination. *International Journal of Human Capital and Information Technology Professionals (IJHCITP), 1(4),* 1-13. DOI:10.4018/jhcitp.2010100101

Armstrong, L. J., Gandhi, N., & Lanjekar, K. (2012, May). Use of information and communication technology (ICT) tools by rural farmers in Ratnagiri district of Maharastra, India. In *Proceedings of 2012 International Conference on Communication Systems and Network* Technologies (pp. 950-955) Rajkot, India. DOI: 10.1109/CSNT.2012.202

Armstrong, L., & Diepeveen, D. (2008). Developing an information-driven ICT framework for Agriculture. *World Conference on Agricultural Information and IT 2008.* IAALD AFITA WCCA. http://researchrepository.murdoch.edu.au/id/eprint/12974

Armstrong, L., & Gandhi, N. (2012). Factors influencing the use of information and communication technology (ICT) tools by the rural farmers in Ratnagiri district of Maharashtra India. In *Proceedings of the Third National Conference on Agro Informatics and Precision Agriculture* (pp.58-63). https: //ro.ecu. edu.au/ cgi/ viewcontent. cgi?article=1104&context=ecuworks2012

Asfaw, N., Gunjal, K., Mwangi, W., & Seboka, B. (1997). Factors affecting the adoption of maize production technologies in Bako Area, Ethiopia. *Ethiopian Journal of Agricultural Economics, 1(2)*,52-73.https://www.semanticscholar.org/paper/Factors-affecting-the-adoption-of-maize-production-Negasa-unjal/6611d11d5d5945b9fd6a1229045edb1807a2875c

Asghar, S. (2014). Farming system analysis of irrigated farms in Faisalabad, Pakistan. *Unpublished Doctoral dissertation, CIRAD*. https://agritrop.cirad.fr/575602

Ashraf, I., Muhammad, S., Mahmood, K., Idrees, M., & Shah, N. (2009). Strengths and Weaknesses of Extension System as Perceived by Extension Field Staff. *Sarhad Journal of Agriculture, 25(1),* 131-134. ISSN : 1016-4383

Ashraf, S., Khan, G. A., Ali, S., & Iftikhar, M. (2015). Socio-economic determinants of the awareness and adoption of citrus production practices in Pakistan. *Ciência rural, 45(9),* 1701-1706. https://doi.org/10.1590/0103-8478cr20131227

Asif, A. S., Uddin, M. N., Dev, D. S., & Miah, M. A. M. (2017). Factors affecting mobile phone usage by the farmers in receiving information on vegetable cultivation in Bangladesh. *Journal of Agricultural Informatics, 8(2), 33-43.* DOI : 10.17700/jai.2017.8.2.376

Askenazy, P. (2000). The consequences of new workplaces practices in the United States: the neo-stakhanovism. mimeo.

Badar, H. (2014). Value chain performance improvement for sustainable mango industry development in Pakistan. *Unpublished doctoral dissertation, University of Queensland, Australia.* .https://doi.org/10.14264/uql.2015.430

Balaji, V., Meera, N., & Dixit, S. (2007). ICT-enabled knowledge sharing in support of extension: addressing the agrarian challenges of the developing world threatened by climate change, with a case study from India. *Journal of SAT Agricultural Research, 4(1),* 1-18. http://oar.icrisat.org/id/eprint/2604

Baliamoune-Lutz, M. (2003). An analysis of the determinants and effects of ICT diffusion in developing countries. *Information Technology for development, 10(3),* 151-169. https://doi.org/10.1002/itdj.1590100303

Balnaves, M., & Caputi, P. (2001). Introduction to quantitative research methods: An investigative approach. *Sage publishers. London*

Banker, R. D., & Natarajan, R. (2008). Evaluating contextual variables affecting productivity using Data envelopment analysis. *Operations research, 56(1),* 48-58. https:// doi.org/ 10.1287/ opre.1070.0460

Banmeke, T. O. A., & Olowu, T. A. (2005). Accessibility of women farmers to agricultural information in South Western Nigeria. *South African Journal of Agricultural Extension, 34*, 237-246.

Baqir, M. N. (2009). A qualitative inquiry of ICT based socio-economic development in developing countries: The case of Pakistan. *The University of North Carolina at Greensboro.*

Bartholomew, D. J., Knott, M., & Moustaki, I. (2011). Latent variable models and factor analysis: A unified approach. John Wiley & Sons, (904).

Bashir, A., Abbas, M., Sheikh, A. D., & Mahmood, K. (2006). Citrus marketing system in the Punjab. Pakistan. *Journal of Life and Social Sciences, 4(1-2),* 27-33.

Battese, G. E., & Coelli, T. J. (1995). A model for technical inefficiency effects in a stochastic frontier production function for panel data. *Empirical economics, 20(2),* 325-332. https://doi.org/10.1007/BF01205442

Baye, M. R., Morgan, J., & Scholten, P. (2006). Information, search, and price dispersion. *Handbook on Economics and Information Systems, 1,* 323-375. DOI:10.1016/S1574-0145(06)01006-3

Bayo-Moriones, A., & Lera-López, F. (2007). A firm-level analysis of determinants of ICT adoption in Spain. *Technovation, 27(6-7),* 352-366. https:// doi.org/ 10.1016/j. technovation. 2007.01.003

Bedi, A. S. (1999). The role of information and communication technologies in economic development: a partial survey. In *ZEF–Discussion Papers on Development Policy, (7).* http://dx.doi.org/10.2139/ssrn.3318589

Begley, C. M. (1996). Using triangulation in nursing research. *Journal of Advanced Nursing, 24(1),* 122-128.DOI: 10.1046/j.1365-2648.1996.15217.x

Belbase, K., Grabowski, R., & Sanchez, O. (1985). The marginal productivity of inputs and agricultural production in Nepal. *The Pakistan Development Review*, 51-60. https://www.jstor.org/stable/41258692

Bell, S. (1986). Information systems planning and operation in less developed countries. Part 1: Planning and operational concerns. *Journal of Information Science, 12(5),* 231-245. https://doi.org/10.1177/016555158601200503

Bello, O. A., & Aderbigbe, F. (2014). ICT in agricultural sustainability and food security. *International Journal of Emerging Technology and Advanced Engineering, 4(3),* 508-513.

Berger, S. C. (2009). Self-service technology for sales purposes in branch banking: The impact of personality and relationship on customer adoption. *International Journal of Bank Marketing, 27(7),* 488-505. https://doi.org/10.1108/02652320911002322

Bernard, R., Dulle, F., & Ngalapa, H. (2014). Assessment of information needs of rice farmers in Tanzania. A case study of Kilombero District, Morogoro. *Library Philosophy and Practice (e-journal), 1–34.* http://www.suaire.sua.ac.tz/handle/123456789/1164

Beshir, H. (2016). Technical efficiency measurement and their differential in wheat production: The case of smallholder farmers in South Wollo. *IJEBF, 4(1),* 1-16. ISSN: 2327-8188

Bhattacharjee, S., & Saravanan, R. (2013). Youth and ICT for Agricultural Development. In Narayanagowda, K., Nataraju, M.S. & Veerabhdraiah, V. (Eds.). Youth in Agriculture and Rural Development. *New India Publishing Agency, New Delhi*. https://www.researchgate.net/publication/328225722_Youth_and_ICTs_for_Agricultural_Development

Bhattacherjee, A. (2012). Social science research: Principles, methods, and practices. (2nd ed.). https://digitalcommons.usf.edu/cgi/viewcontent.cgi?article=1002&context=oa_textbooks

Binam, J. N., Tonye, J., Nyambi, G., & Akoa, M. (2004). Factors affecting the technical efficiency among smallholder farmers in the slash and burn agriculture zone of Cameroon. *Food policy, 29(5),* 531-545. https:// doi.org/ 10.1016/j. foodpol. 2004.07.013

Black, T. R. (1999). Doing quantitative research in the social sciences: An integrated approach to research design, measurement and statistics. *Sage.* https://uk.sagepub.com/en-gb/eur/doing-quantitative-research-in-the-social-sciences/book205869

Blaxter,L.(2010). How to research. McGraw-Hill Education (UK). https:// www. mheducation. com/highered/ category. 11205.research-methods.html

Blommestein, N., Krogt, S., Lamourex, L., Morrow, K., & Neuman, F. (2006). ICT for agricultural livelihoods. In Gerard, A., & Morrow K. *ICT for Agricultural Livelihoods: Impacts and Lesson Learned from IICD Supported Activities.* https:/ /www. bibalex. org/search4dev/files/287780/118686.pdf.

Blurton, C. (1999). New directions in education. *The world communication and information,* 46-61. DOI: 10.4236/oalib.1103405

Boon, J.A. (1992). Information and development: some reasons for failure. *Information Society, 8(3),* 227-241. https://doi.org/10.1080/01972243.1992.9960122

Boyd, B. K., & Solarino, A. M. (2016). Ownership of corporations: A review, synthesis, and research agenda. *Journal of Management, 42(5),* 1282-1314. https: //doi. org/10. 1177/0149206316633746

Bresnahan, T. F., Brynjolfsson, E. & Hitt, L. M. 2002. Information Technology, Workplace Organization, and the Demand for Skilled Labor: Firm-Level Evidence. *Quarterly Journal of Economics, 117,* 339-376. https://doi.org/10.1162/003355302753399526

Brohi, N. (2010). Gender and land Reforms in Pakistan. Working paper (No. 17). Sustainable Development Policy Institute (SDPI), Islamabad, Pakistan. http:// arks. princeton. edu/ark: /88435/dsp01m039k7276

Bryman, A. (2001). Social research methods. *New York: Oxford University Press*. DOI: 10.4236/oalib.1107411

Bryman, A. (2007). Barriers to integrating quantitative and qualitative research. *Journal of Mixed Methods Research, 1(1),* 8-22. https://doi.org/10.1177/2345678906290531

Bryman, A. (2012). Social research methods. 4th edition. *New York: Oxford University Press*. https://www.academia.edu/38228560/Alan_Bryman_Social_Research_Methods_4th_Edition_Oxford_University_Press_2012_pdf

Bryman, A. (2016). Social research methods. *Oxford University Press.*

Brynjolfsson, E. & Hitt, L. M. 1995. Information technology as a factor of production: the role of differences among firms. *Economics of Innovation and New Technology, 3,* 183-199. https://doi.org/10.1080/10438599500000002

Buabeng-Andoh, C. (2012). An exploration of teachers' skills, perceptions and practices of ICT in teaching and learning in the Ghanaian second-cycle schools. *Contemporary Educational Technology, 3(1),* 36. DOI:10.30935/cedtech/6066

Burton, M., Fileccia, T., Gulliver, A., Qamar, M. K., & Tayyab, A. (2012). Pakistan: priority areas for investment in the agricultural sector. Food and Agriculture Organization (FAO) Investment Centre. http://www.fao.org/3/i2879e/i2879e.pdf

Bwala, M. A., Kokoye, H. S. E., & Yegbemey, R. N. (2015). Technical efficiency of cereal production in north-central Nigeria: a case for maize, rice and sorghum farmers. *Journal of Agricultural Science and Environment, 15(1),* 25-34.

Calvo, A., & Rahrig, K. (1997). Diffusion of Innovations. University of South Florida

Cameron, A. C., & Trivedi, P. K. (2013). Regression analysis of count data. Cambridge university press. http://cameron.econ.ucdavis.edu/racd/count.html

Caribbean Agricultural Research and Development Institute (CARDI). (2014). Regional synthesis of ICT uptake and usage in agricultural value chains in the Caribbean. Strengthening ICTs in Value Chains in the Caribbean. http://www.cardi.org/wp-content/ uploads/downloads/2014/11/Regional-synthesis-of-ICT-uptake-and-usage-in-agriculturalvalue-chains-in-the-Caribbean.-FINAL-Submitted-15-Oct-2014.pdf

Casaburi, L., Kremer, M., Mullainathan, S., & Ramrattan, R. (2014). Harnessing ICT to increase agricultural production: Evidence from Kenya. *Harvard University*. https://pedl.cepr.org/publications/harnessing-ict-increase-agricultural-production-evidence-kenya

Cassim, K. M., & Obono, S. E. (2011). On the factors affecting the adoption of ICT for the teaching of word problems. In Proceedings of the World Congress on Engineering and Computer Science (Vol. 1, pp. 19-21). http:/ /www. iaeng. org/ publication/ WCECS2011/ WCECS2011_pp269-276.pdf

Chambers, S., Lobb, A., Butler, L., Harvey, K., & Traill, W. B. (2007). Local, national and imported foods: a qualitative study. *Appetite, 49(1),* 208-213. https://doi.org/10.1016/j.appet.2007.02.003

Chapota, R., Fatch, P., & Mthinda, C. (2014). The Role of radio in agricultural extension and advisory services–experiences and lessons from farm radio programming in Malawi–. *MEAS Case Study, 8.* DOI:10.4314/jdcs.v4i1.4

Chatfield, A., Gillian J., Andrea F., & Neal L. (2015). The CommCare evidence base - CommCare: The most evidence-based mobile tool for frontline workers. *Dimagi Corporation. Washington, DC: CommCare.* https:// lib. digitalsquare. io/bitstream/ handle/123456789/77309/CommCare%20Evidence%20Base%20 % 20 % 20 March % 20 2015 .pdf?sequence=1&isAllowed=y

Chaudhry, K. M., Muhammad, S., Saghir, A., & Ashraf, I. (2008). Rural women's access to various sources of information in tehsil Faisalabad. *Journal of Animal and Plant Sciences 18 (*2-3). ISSN:1018-7081. https: //www. researchgate. net/ publication /267948926_Rural_women's_access_to_various_sources_of_information_in_tehsil_Faisalabad

Chaudry, M. S. (2004). Opportunities and constraints in the production, marketing and export of citrus in Punjab. *Unpublished Doctoral dissertation, University of Agriculture, Faisalabad.*

Chavula, H. K. (2014). The role of ICTs in agricultural production in Africa. *Journal of Development and Agricultural Economics, 6(7),* 279-289. DOI: 10. 5897/ JDAE2013.0517

Chhachhar, A. R., & Hassan, M. S. (2013). Information communication technology for agriculture development. *Journal of American Science, 9(1),* 85-91. (ISSN: 1545-1003).

Chhachhar, A. R., & Memon, B. (2019). Challenges in usage of mobile phone regarding agricultural and marketing information among farmers in Sindh, Pakistan. *Indian Journal of Science and Technology, 12(6).* DOI: 10.17485/ijst/2019/v12i6/141300

Chhachhar, A. R., & Omar, S. Z. (2012). Use of mobile phone among fishermen for marketing and weather information. *Archives Des Sciences, 65(8),* 107-119. https://www.researchgate.net/publication/233741193_Use_of_Mobile_Phone_among_Fishermen_for_Marketing_and_Weather_information

Chhachhar, A. R., Makhijani, H. B., Khushk, G. M., & Maher, Z. A. (2013). Information and communication technologies for rural development in developing countries. *Journal of American Science, 9(9).*

Chhachhar, A. R., Qureshi, B., Khushk, G. M., & Ahmed, S. (2014). Impact of information and communication technologies in agriculture development. *Journal of Basic and Applied Scientific Research, 4(1),* 281-288. (ISSN: 1545-1003).http://www.jofamericanscience.org.

Chhachhar, A. R., Qureshi, B., Khushk, G. M., & Maher, Z. A. (2014). Use of mobile phone among farmers for agriculture information. *European Journal of Scientific Research, 119(2),* 265-271.

Chikaire, J. U., Tijjani, A. R., & Abdullahi, K. A. (2016). Perceived role of information and communications technology in improving agricultural livelihoods of rural farmers in Imo State, Nigeria. *International Journal of Agricultural Policy and Research, 4(2),* 29-34.

Child, D. (2006). The essentials of factor analysis. *A&C Black.*

Chisenga, J. 2006. Information and communication technologies: Opportunities and challenges for national and university libraries in Eastern, Central and Southern Africa. *Keynote paper presented at the standing conference of African National and University libraries of Eastern, Central and Southern Africa (SCANUL-ECS) The courtyard Hotel, Dar es Salaam, Tanzania*. http://eprints.rclis.org/9579/1/Chisenga_SCANUL_2006.pdf

Chong, A., Galdo, V., & Torero, M. (2009). Access to telephone services and household income in poor rural areas using a quasi-natural experiment for Peru. *Economica, 76(304*), 623-648.

Clarke, R. (1999). A primer in diffusion of innovation theory. Retrieved from: http://www.rogerclarke.com/SOS/InnDiff.html

Coggins, S., Sharma, R., McCampbell, M., Sharma, A., Haefele., S., Karki, E., Hetherington, J., Brown, B. (2020). Assessment framework for digital extension tools. Retrieved from: http://dx.doi.org/10.13140/RG.2.2.35692.59520.

Colby, C. L., & Parasuraman, A. (2001). Techno-ready marketing: how and why customers adopt technology. *Simon and Schuster.*

Connolly, P. (2007). qualitative data analysis in education: A critical introduction using SPSS. *London: Routledge.*

Consolata, A. (2017). Urban agriculture and the use of ICT in accessing and disseminating livestock husbandry information in urban areas of Tanzania. *A Review of Related Literature. Library* Philosophy and Practice (e-journal). 1489. http://digitalcommons.unl.edu/libphilprac/1489.

Cox, A. J., & Sseguya, H. (2015). ICT supported extension services in conservation agriculture information access for small holder farmers in Laikipia County, Kenya. *IEEE International Symposium on Technology and Society (ISTAS)* (pp. 1-6). https://www.ruforum.org/sites/default/files/ISTAS_Paper_ref_42_420__ACHORA%5B1%5D.pdf

Coxe, S., West, S. G., & Aiken, L. S. (2009). The analysis of count data: A gentle introduction to poisson regression and its alternatives. *Journal of Personality Assessment, 91(2),* 121-136.

Creswell, J. W. (1994). Research design: qualitative & quantitative 71e approaches. *Thousand Oaks, CA Sage.*

Creswell, J. W. (2003). Research design: Qualitative, Quantitative and Mixed Methods Approaches (2nd ed.). SAGE Publications. Retrieved from: https://www.ucg.ac.me/skladiste/blog_609332/objava_105202/fajlovi/Creswell.pdf.

Crossman, A. (2017). Social System. Retrieved from: *https: //www .thoughtco. com/renaissance-rhetoric-1691908*.

CSF (2011). The state of Pakistan's competitiveness report 2010-2011. *The Competitive Support Fund (CSF), Ministry of Finance, Government of Pakistan, Islamabad.*

CTA, (2015). Why invest in ICT for agriculture? *The Technical Centre for Agricultural and Rural Cooperation (CTA) Discussion Paper*. www.cta.int

Cullen, R. (2001). Addressing digital divide. IFLA proceedings of 67th Council and General Conference. Boston: IFLA.

Dagne, T. W., & Oguamanam, C. (2018). ICT in agricultural production and potential deployment in operationalising geographical indications in Uganda. *Ottawa Faculty of Law Working Paper, (2018-24).*

Das, B. (2014). ICT adoption for accessing agricultural information: Evidence from Indian agriculture. *Agricultural Economics Research Review, 27*(347-2016-17125), 199-208.

David, P. A. (1969). A contribution to the theory of diffusion. *Research Center in Economic Growth, Stanford University.*

David, S., Nigel, S., Christopher, G., Jain, R., & Ophelia, M. (2005). The economic impact of telecommunications on rural livelihoods and poverty reduction: A study of rural communities in India (Gujarat), Mozambique and Tanzania. Working Paper (No. 2005-11-04). Indian Institute of Management Ahmedabad, Research and Publication Department.

Davis, F. D. (1989). Perceived usefulness, perceived ease of use, and user acceptance of information technology. *MIS quarterly,* 319-340.

Davis, K., Swanson, B., Amudavi, D., Mekonnen, D. A., Flohrs, A., Riese, J., lamb,C. & Zerfu, E. (2010). In-depth assessment of the public agricultural extension system of Ethiopia and recommendations for improvement. *Discussion Paper, (1041), International Food Policy Research Institute (IFPRI).*

De Bruyn, P., De Bruyn, J. N., Vink, N., & Kirsten, J. F. (2001). How transaction costs influence cattle marketing decisions in the northern communal areas of Namibia. *Agrekon, 40(3),* 405-425.

De Silva, H., & Ratnadiwakara, D. (2008). Using ICT to reduce transaction costs in agriculture through better communication: A case-study from Sri Lanka. *LIRNE Asia, Colombo, Sri Lanka.*

De Silva, H., & Ratnadiwakara, D. (2010). ICT Policy for agriculture based on a transaction cost approach: Some lessons from Sri Lanka. *International Journal of ICT Research and Development in Africa (IJICTRDA), 1(1),* 51-64.

De Tarde, G. (1903). The laws of imitation. *H. Holt.*

De Vaus, D. A. (2014). Surveys in social research. *(6th ed). Australia: UCL Press.*

Deininger, K., & Byerlee, D. (2012). The rise of large-scale farms in land-abundant countries: Do they have a future. *World Development, Elsevier, vol. 40(4), pages 701-714.* DOI: 10.1016/j.worlddev.2011.04.030

Delacre, M., Lakens, D., & Leys, C. (2017). Why psychologists should by default use Welch's t-test instead of Student's t-test. *International Review of Social Psychology, 30(1).*

Dessale, M. (2019). Analysis of technical efficiency of smallholder wheat-growing farmers of Jamma district, Ethiopia. *Agriculture & Food Security, 8(1),* 1.

Dessale, M., Beshir, D., & Tegegne, D. (2017). Technical efficiency in teff production: the case of smallholder farmers in Jamma District, South Wollo Zone, Ethiopia. *Unpublished Doctoral dissertation, Haramaya University*.

Dey, B. L., Prendergast, R., & Newman, D. (2008). How can ICT be used and appropriated to address agricultural information needs of Bangladeshi farmers? *GlobDev 2008, 21.* http://aisel.aisnet.org/globdev2008/21

Dey, M. M., Paraguas, F. J., Bimbao, G. B., & Regaspi, P. B. (2000). Technical efficiency of tilapia grow out pond operations in the Philippines. *Aquaculture Economics & Management, 4(1-2),* 33-47.

Diagne, A., & Demont, M. (2007). Taking a new look at empirical models of adoption: Average treatment effect estimation of adoption rates and their determinants. *Agricultural Economics, 37(2-3),* 201-210.

Diederen, P., van Meijl, H., & Wolters, A. (2002). Innovation and farm performance: the case of Dutch agriculture. In A. Kleinknecht, & P. Mohnen (Eds.), *Innovation and firm performance* (pp. 73-85). https://research.wur.nl/en/publications/innovation-and-farm-performance-the-case-of-dutch-agriculture.

Diederen, P., Van Meijl, H., Wolters, A., & Bijak, K. (2003). Innovation adoption in agriculture: innovators, early adopters and laggards. Cahiers d'Economie et de Sociologie Rurales, INRA Editions, 2003, 67, pp.29-50. https://hal.archives-ouvertes.fr/hal-01201041/document.

Donner, J. (2007). Customer acquisition among small and informal businesses in urban india: comparing face-to-face and mediated channels. the electronic journal of information systems in developing countries, 32(1), 1-16.

Driouchi, A., Azelmad, E. M., & Anders, G. C. (2006). An econometric analysis of the role of knowledge in economic performance. *The Journal of Technology Transfer, 31(2),* 241-255.

Duncombe, R., & Boateng, R. (2009). Mobile phones and financial services in developing countries: a review of concepts, methods, issues, evidence and future research directions. *Third World Quarterly, 30(7),* 1237-1258.

Dutta, S. (Ed.). (2009). Global information technology report 2008-2009. *World Economic Forum.*

Eden, B. L., & Kalusopa, T. (2005). The challenges of utilizing information communication technologies (ICTs) for the small-scale farmers in Zambia. *Library Hi Tech, 23 (3).* DOI:10.1108/07378830510621810

Edwards, A.L. (1957). Techniques of attitude scale construction. *Vakils, Feffer and Simons Private Ltd., 9 Sport Road, Ballard Estate, Bombay (Mumbai).*

Ekbia, H. R., & Evans, T. P. (2009). Regimes of information: Land use, management, and policy. *The Information Society, 25(5),* 328-343.

El Bilali, H., & Allahyari, M. S. (2018). Transition towards sustainability in agriculture and food systems: Role of information and communication technologies. *Information Processing in Agriculture, 5(4),* 456-464.

Elizabeth, S. (2007). Participatory assessment of the impact of women in agriculture programme of Borno State, Nigeria. *Journal of Tropical Agriculture, 44*, 52-56.

Epple, D., Gordon, B., & Sieg, H. (2010). A new approach to estimating the production function for housing. *American Economic Review, 100(3),* 905-24.

Erceg-Hurn, D. M., & Mirosevich, V. M. (2008). Modern robust statistical methods: an easy way to maximize the accuracy and power of your research. *American Psychologist, 63(7),* 591.

Esen, M., & Erdogmus, N. (2014). Effects of technology readiness on technology acceptance in e-HRM: Mediating role of perceived usefulness. *The Journal of Knowledge Economy & Knowledge Management, 9, 7-21.*

ESRF, (2008). Enhancing the livelihoods of the rural poor through ICT: A knowledge MAP. Tanzania country study, *Working Paper (14). Economic and Social Research Foundation (ESRF).*

Esterberg, K. G. (2002). Qualitative methods in social research. *McGraw-Hill, Boston*

Estevão, M. M. (2004). Why is productivity growth in the Euro area so sluggish? *IMF Working Papers*, *2004*(200), A001. Retrieved Oct 8, 2021, from: https://www.elibrary.imf.org/view/journals/001/2004/200/article-A001-en.xml

Evans, M. (2007). Recent research (2000–2006) into applied linguistics and language teaching with specific reference to L2 French. *Language Teaching, 40(3),* 211-230.

Eyisi, D. (2016). The Usefulness of qualitative and quantitative approaches and methods in researching problem-solving ability in science education curriculum. journal of education and practice, 7(15), 91-100.

Ezell, S., & Andes, S. (2010). ICT R&D policies: An international perspective. *IEEE Internet Computing, 14(4),* 76-80.

Fabrigar, L. R., & Wegener, D. T. (2011). Exploratory factor analysis. *Oxford University Press*.

Fafchamps, M., & Hill, R. V. (2005). Selling at the farmgate or traveling to market. *American Journal of Agricultural Economics, 87(3),* 717-734.

FAO, & ITU. (2016). E- Agriculture Strategy Guide, Piloted for Asia -Pacific Countries. *Food and Agriculture Organization (FAO) of the United Nation and International Telecommunication Union (ITU).*

FAO, (2017). Information and communication technology (ICT) in agriculture: a report to the G20 agricultural deputies. *Food and Agriculture Organization of the United Nations Rome, 2017.*

FAO. (2001). Knowledge and information for food security in Africa from traditional media to the internet. *Communication for Development Group, Sustainable Development Department, Food, and Agricultural Organization (FAO), Rome*.

FAO. (2005). Year Book. *FAO, Rome, Italy.*

FAOSTAT. (2019). Food and agriculture data. *United Nation's Food and Agricultural organization.*

Faridi, M. Z. (2012). Contribution of agricultural exports to economic growth in Pakistan. *Pakistan Journal of Commerce & Social Sciences, 6(1).*

Farooq, A., Ishaq, M., Shah, N. A., & Karim, R. (2010). Agriculture extension agents and challenges for sustainable development. *Sarhad Journal of Agriculture, 26(3)*, 419-426.

Farooq, U. (2015a). Population and urbanization projections in Pakistan. Background Chapter, Vision 2050: Addressing Challenges to the Agriculture Sector in Pakistan. *Social Sciences Division, Pakistan Agricultural Research Council, Islamabad.*

Farooq, U. (2016). Revolutionizing Pakistan agriculture by increasing the use of knowledge, science and technology and ICT. In Khalid Z. (Ed.), Building Knowledge-Based Economy of Pakistan: Learning from Best Practices (pp. 112-143). Islamabad, Pakistan: Islamabad Policy Research Institute.

Farrimond, H. (2012). Doing ethical research. *Macmillan International Higher Education*.

Fawole, O. P., & Olajide, B. R. (2012). Awareness and use of information communication technologies by farmers in Oyo State, Nigeria. *Journal of agricultural & food information, 13(4),* 326-337.

Feder, G., Just, R. E., & Zilberman, D. (1985). Adoption of agricultural innovations in developing countries: A survey. *Economic Development and Cultural Change, 33(2),* 255-298.

Ferroni, M., & Zhou, Y. (2012). Achievements and challenges in agricultural extension in India. *Global Journal of Emerging Market Economies, 4(3),* 319-346.

Fita, L., Trivedi, M. M., Patel, A. M., Tassew, B., & Joshi, C. G. (2013). Determinants of technical efficiency of the dairy farmers in Ada'a district of Oromia State, Ethiopia. *Aranian Journal of Applied Animal Sciences,3(1),* 59-65.

Flick, U. (2018). An introduction to qualitative research. *Sage Publications Limited*.

Forestier, E., Grace, J., & Kenny, C. (2002). Can information and communication technologies be pro-poor? *Telecommunications Policy, 26(11),* 623-646.

Franklyn, C., & Tukur, A. (2012). Problems and prospects of adopting ICT in agriculture: some comments. *African Journal of Agricultural Research and Development, 5(3),* 39-47.

Franzese, M., & Iuliano, A. (2019). Correlation analysis.

Freeman, K., & Mubichi, F. (2017). ICT use by smallholder farmers in rural mozambique: A case study of two villages in central Mozambique. *Journal of Rural Social Sciences, 32(2),* 1.

Gagnon, D. R., Doron-LaMarca, S., Bell, M., O'Farrell, T. J., & Taft, C. T. (2008). Poisson regression for modelling count and frequency outcomes in trauma research. *Journal of Traumatic Stress, 21(5),* 448-454.

Gay L.R., Mills, G. E., & Airasian P. (2013). Educational research competencies for analysis and application (10th ed.). *USA: Pearson Education, Inc.*

George, T., Bagazonzya, H., Ballantyne, P., Belden, C., Birner, R., Del Castello, R., & Treinen, S. (2011). ICT in agriculture: Connecting smallholders to knowledge, networks, and institutions. *Working Paper (64605) The World Bank.*

Gerald, B. (2018). A brief review of independent, dependent and one-sample t-test. *International Journal of Applied Mathematics and Theoretical Physics, 4(2),* 50-54.

Ghafoor, U., Muhammad, S., & Chaudhry, K. M. (2008). Constrains in availability of inputs and information to citrus (Kinnow) growers of tehsil Toba Tek Singh. *Pakistan Journal of Agricultural Sciences, 45,* 520-522.

Giunta, A., & Trivieri, F. (2007). Understanding the determinants of information technology adoption: evidence from Italian manufacturing firms. *Applied Economics, 39(10),* 1325-1334.

Goddard, W., & Melville, S. (2004). Research methodology: An introduction. Juta and Company Ltd.

Gottret, M. V. (2007). Rural innovation and smallholders' livelihoods: modes of intervention in hillside communities of Latin America. *International Institute of Social Studies, Den Haag.* http://hdl.handle.net/1765/32626.

Gour, A. K. (2002). Factors influencing adoption of some improved animal husbandry practices of dairying in Anand and Vadodara districts of Gujarat State. Unpublished Doctoral dissertation, AAU, Anand, India.

Government of Pakistan (GOP). (2000). Pakistan Census of Agriculture. Ministry of Food, Agriculture and Livestock, Islamabad, Pakistan.

Government of Pakistan (GOP). (2006). Fruits, vegetables and condiments. *Ministry of Food, Agriculture and Livestock (MINFAL). Islamabad, Pakistan.*

Government of Pakistan (GOP). (2006). Livestock Census, Agriculture Census Organization, Bureau of Statistics, Islamabad, Pakistan.

Government of Pakistan (GOP). (2010). Agriculture Census, Statistical Division. *Agricultural Census Organization. Islamabad, Pakistan.*

Government of Pakistan (GOP). (2012). Pakistan Economic Survey 2011-12. *Ministry of Finance. Islamabad, Pakistan.*

Government of Pakistan (GOP). (2013). Curriculum for Citrus Processing (NVQF Level 2). *National Vocational & Technical Training Commission (NAVTTC). Islamabad, Pakistan.*

Government of Pakistan (GOP). (2016). Pakistan Economic Survey 2015-16. *Ministry of Finance. Islamabad, Pakistan.*

Government of Pakistan (GOP). (2019). Pakistan Economic Survey 2018-19. *Ministry of Finance. Islamabad, Pakistan.*

Government of Pakistan (GOP). (2020). Pakistan Economic Survey 2019-20. *Ministry of Finance. Islamabad, Pakistan.*

Greenan, N., Mairesse, J. & Bensaid, T. (2001). Information technology and research and development impacts on productivity and skills, looking for correlations on French firm level data. *Cambridge, MA: NBR*

Grover, I. (2007). Adoption of information and communication technologies by farming households in Haryana, India. *Congress on Computers in Agriculture (Vol. 2, p. 5).*

Gummagolmath, K. C., & Sharma, P. (2011). ICT Initiatives in Indian agriculture-an overview. *Indian Journal of Agricultural Economics, 66*.

Gupta, O. (2006). Encyclopaedia of India, Pakistan and Bangladesh. *Gyan Publishing House.*

Haji, J., & Andersson, H. (2006). Determinants of efficiency of vegetable production in smallholder farms: The case of Ethiopia. *Acta Agriculturae Scand Section C, 3(3-4),* 125-137.

Halcomb, E. J. (2010). Mixed Methods Research. *Bachelor of Nursing (Hons) Seminar, (July).* http://doi.org/10.4135/9781412963909.n269.

Hall, B. H., & Khan, B. (2003). Adoption of new technology. Working Paper (9730). National Bureau of Economic Research. Massachusetts Avenue Cambridge. http://www.nber.org/papers/w9730.

Haller, S. A., & Siedschlag, I. (2011). Determinants of ICT adoption: Evidence from firm-level data. *Applied Economics, 43(26*), 3775-3788.

Hanif, M. S., Yunfei, S., & Hanif, M. I. (2018). Growth prospects, market challenges and policy measures: Evolution of mobile broadband in Pakistan. *Digital Policy, Regulation and Governance, 20 (1)* pp. 42-61. https://doi.org/10.1108/DPRG-04-2017-0014

Hanushek, E. A., & Jackson, J. E. (2013). Statistical methods for social scientists. *Academic Press*.

Hardy, A. P. (1980). The role of the telephone in economic development. *Telecommunications policy, 4(4),* 278-286.

Harris, P. J. C., Browne, A. W., Barrett, H. R., & Cadoret, K. (2001). Facilitating the inclusion of the resource-poor in organic production and trade: Opportunities and constraints posed by certification. *Department for International Development.* ftp://ftp3.us.freebsd.org/pub/misc/cd3wd/1004/_ag_certification_487_skat_dup_en_105020_.pdf

Harrison, L., & Startin, N. (2013). Political Research: An introduction. *Routledge.*

Hart, C. (2018). Doing a literature review: Releasing the research imagination. *Sage.*

Hassan, M. S., Shaffril, H. M., Hassan, M. A., & D'Silva, J. L. (2009). Developing agriculture in Malaysia: Internet utilization among Malaysian youth agro-businessman. *European Journal of Social Sciences, 11(2),* 215-224.

Hayat, Z., Luqman, M., Nasir, S., Ashraf, E., Shahbaz, B., & Iqbal, Z. (2017). Constraints to livestock production in the Punjab, Pakistan: a case study of district Sargodha. *Journal of Agricultural Research, 55(1).*

Heeks, R. (2010). An ICT4D journal ranking table. *Information Technologies & International Development, 6(4),* pp-71.

Hennink, M. M. (2013). Focus group discussions. *Oxford University Press.*

Hennink, M., Hutter, I., & Bailey, A. (2020). Qualitative research methods. *SAGE Publications Limited.*

Henson, R. K., & Roberts, J. K. (2006). Use of exploratory factor analysis in published research: Common errors and some comment on improved practice. *Educational and Psychological measurement, 66(3),* 393-416.

Hilbe, J. M. (2009). Logistic regression models. *CRC press*.

Hosmer Jr, D. W., Lemeshow, S., & Sturdivant, R. X. (2013). Applied logistic regression, 398. *John Wiley & Sons.*

Howell, K. E. (2013). Constructivist and participatory paradigms of inquiry: introducing action research'. *KE Howell, An introduction to the philosophy of methodology, 88-100*.

Howland, F. C., Muñoz, L. A., Staiger, S., Cock, J., & Alvarez, S. (2015). Data sharing and use of ICT in agriculture: working with small farmer groups in Colombia. *Knowledge Management for Development Journal, 11(2),* 44-63.

Huang, Y. P. (2012). Diffusion of innovation, perceived usefulness, perceived ease of use, and user acceptance of information technology. In *Proceedings of the International Conference on e-Learning, e-Business, Enterprise Information Systems, and e-Government*. The Steering Committee of The World Congress in Computer Science, Computer Engineering and Applied Computing (WorldComp). http://worldcomp-proceedings.com/proc/p2012/EEE3490.pdf

Hutcheson, G. D. (2011). Ordinary least-squares regression. In Moutinho, L., & Hutcheson, GD. *The SAGE Dictionary of Quantitative Management Research, 224-228.*

Idiegbeyan-Ose, J., & Akpoghome, T. (2009). Information as an effective tool in rural development. *International Journal of Library and Information science, Vol.1(3),* pp. 022-028. https://doi.org/10.5897/IJLIS.9000054

Igwenagu, C. (2016). Fundamentals of research methodology and data collection. *LAP LAMBERT Academic Publishing.*

Ikram-ul-Haq, M. A., Ali, T., & Zafar, M. I. (2009). An analysis of farm services centre (FSC) approach launched for agricultural extension in NWFP, Pakistan. *Pakistan Journal of Agricultural Sciences, 46(1),* 69-72.

Imenda, S. (2014). Is there a conceptual difference between theoretical and conceptual frameworks?. *Journal of Social Sciences, 38(2),* 185-195.

Ingole, N. O., Saigaonkar, P. B., & Kothekar, M. D. (1988). Adoption of improved animal husbandry practices by owners of cross bred cattle under ICDP. *Indian Research Journal of Extension Education, 24(2&3),* 56-62.

International Telecommunication Union. (2016). Measuring the information society report 2016.

Iqbal, S., Sial, M. H., & Hussain, Z. (2009). Technical efficiency of citrus production in Sargodha district, Punjab. *International Journal of Agricultural Applied Sciences, 1(2).*

Irani, Z., Dwivedi, Y. K., & Williams, M. D. (2009). Understanding consumer adoption of broadband: an extension of the technology acceptance model. *Journal of the Operational Research Society, 60(10),* 1322-1334.

Irawan, T. (2014). ICT and economic development: comparing ASEAN member states. *International Economics and Economic Policy, 11(1-2),* 97-114.

Irungu, K. R. G., Mbugua, D., & Muia, J. (2015). Information and Communication Technologies (ICTs) attract youth into profitable agriculture in Kenya. *East African Agricultural and Forestry Journal, 81(1),* 24-33.

Isgin, T., Bilgic, A., Forster, D. L., & Batte, M. T. (2008). Using count data models to determine the factors affecting farmers' quantity decisions of precision farming technology adoption. *Computers and Electronics in Agriculture, 62(2*), 231-242.

Islam, M. S., & Grönlund, Å. (2011). Factors influencing the adoption of mobile phones among the farmers in Bangladesh: theories and practices. *ICTer, 4(1).*

Islam, M. S., & Grönlund, Å. (2012). Applying design science approach in ICT4D research: mobile phone based Agriculture Market Information Service (AMIS) in Bangladesh. In M. Helfert, & B. Donnellan (Eds.), *Communications in Computer and Information Science (pp. 132–143*). Berlin: Springer.

Jain, L., Kumar, H., & Singla, R. K. (2015). Assessing mobile technology usage for knowledge dissemination among farmers in Punjab. *Information Technology for Development, 21(4),* 668-676.

Jamaluddin, N. (2013). Adoption of e-commerce practices among the Indian farmers, a survey of Trichy District in the State of Tamilnadu, India. *Procedia Economics and Finance, 7,* 140-149.

Jamie Hale, M.S. (2018). The 3 basic types of descriptive research methods. *Retrieved from* https://psychcentral.com/blog/the-3-basic-types-of-descriptive-research-methods

Jansen, H. G., Pender, J. L., Damon, A., & Schipper, R. A. (2006). Rural development policies and sustainable land use in the hillside areas of Honduras: A quantitative livelihoods approach. *Working Paper (147). International Food Policy Research Institute.*

Jehan, N., Aujla, K. M., Shahzad, M., Hussain, A., Zahoor, M., Khan, M., & Bilal, A. (2014). Use of mobile phones by farming community and its impact on vegetable productivity. *Pakistan Journal of Agriculture. Research. 27(1).*

Jensen, R. T. (2010). Information, efficiency, and welfare in agricultural markets. Agricultural *Economics*, *41*, 203-216.

Jimma, E. (2017). The Role of Information Communication Technology for Agricultural Extension Service in Ethiopia. *Masters Dissertation, Rural Development and Agricultural Extension Department, Jimma University, Jimma, Ethiopia*.

John, A., & Barclay, F. P. (2017). ICT usage and effects among rural farming communities. *Journal of Media and Communication, 1(1),* 100-136.

Johnson, B. & Christensen, L. (2012). Educational research, qualitative, quantitative and mixed approach. (4th ed). *California: SAGE Publication*.

Johnson, B. D., Dunlap, E., & Benoit, E. (2010). Organizing "mountains of words" for data analysis, both qualitative and quantitative. *Substance use & misuse, 45(5),* 648-670.

Johnson, R. B., & Christensen, L. (2019). Educational research: Quantitative, qualitative, and mixed approaches. *SAGE Publications, Incorporated.*

Johnson, R. B., Onwuegbuzie, A. J., & Turner, L. A. (2007). Toward a definition of mixed methods research. *Journal of Mixed Methods Research, 1(2)*, 112-133.

Jolliffe, I. T., & Cadima, J. (2016). Principal component analysis: a review and recent developments. *Philosophical Transactions of the Royal Society: A Mathematical, Physical and Engineering Sciences, 374(*2065)

Jondrow, J., Lovell, C. K., Materov, I. S., & Schmidt, P. (1982). On the estimation of technical inefficiency in the stochastic frontier production function model. *Journal of Econometrics, 19(2-3)*, 233-238.

Jorgenson, D. W., Ho, M. S., & Stiroh, K. J. (2003). Lessons from the US growth resurgence. *Journal of Policy Modeling, 25(5)*, 453-470.

Joshi, P. K., Gulati, A., & Cummings, R. W. (2007). Agricultural diversification and smallholders in South Asia. *Academic Foundation. New Dehli, India*

Kabir, S. M. (2016). Methods of Data Collection. *Retrieved from:* https://www.researchgate.net/publication/325846997_methods_of_data_collection

Kalirajan, K. P., & Flinn, J. C. (1983). The measurement of farm specific technical efficiency. *Pakistan Journal of Applied Economics, 2(2)*, 167-180.

Kangai, C. (2012). In Higher Education: A Critical Analysis of Methodological *Issues and Emerging Trends at the Zimbabwe Open University. In P. A. Lopez-Varela (Ed.), Theoretical and Methodological Approaches to Social Sciences and Knowledge Management.* http://doi.org/DOI: 10.5772/38306.

Kante, M., Oboko, R., & Chepken, C. (2016). Factors affecting the use of ICT on agricultural input information by farmers in developing countries. *AIMS Agriculture and Food.1(3)*, pp. 315-329. DOI: 10.3934/agrfood.2016.3.315

Kante, M., Oboko, R., & Chepken, C. (2016). Factors affecting the use of ICTs on agricultural input information by farmers in developing countries. *AIMS Agriculture and Food, 1(3),* 315-329. doi: 10.3934/agrfood.2016.3.315

Kante, M., Oboko, R., & Chepken, C. (2017). ICT' Model for Cereal Farmers in the Access and Use of Agricultural Input Information in Developing Countries: Questionnaire Validation Using SEM. American Journal of Information Systems, 5(1), 1-12. DOI:10.12691/ajis-5-1-1

Kante, M., Oboko, R., Chepken, C., & Hamunyela, S. (2017, May). Farmers' perceptions of ICT and its effects on access and use of agricultural input information in developing countries: Case of Sikasso, Mali. *IST-Africa Week Conference (IST-Africa).* DOI: 10.23919/Istafrica.2017.8101973

Kaphle, S., Chaturvedi, S., Chaudhuri, I., Krishnan, R., & Lesh, N. (2015). Adoption and usage of mHealth technology on quality and experience of care provided by frontline workers: observations from rural India. *JMIR mHealth and uHealth, 3(2),* e61. doi: 10.2196/mhealth.4047

Karim, M. R., Meem, M. A., Rahman, M. S., Noman, M. R. F., & Huda, S. (2020). Use and role of mobile phone for information services in agricultural activities. *Asian Journal of Agricultural Extension, Economics & Sociology,* 102-110. DOI: 10.9734/AJAEES/2020/v38i230316

Katsicas, S. K. (2009). Computer and information security handbook. *Elsevier Inc. p. 605.* https://www.sciencedirect.com/book/9780128038437/computer-and-information-security-handbook

Keller, W. (2004). International technology diffusion. *Journal of Economic Literature, 42(3),* 752-782. DOI: 10.1257/0022051042177685

Kezi, D. M., Ajala, M. K., Musa, M. W., & Ayuba, N. A. (2012). Influence of socio-sconomic characteristics on the use of information communication technologies (ICTs) in income generation among small ruminants' farmers in Kaduna State. *Nigerian Journal of Rural Extension and Developmen,6(1).*

Khan, F. U., Khan, N., & Abdullah, Z. (2012). Impact of kinnow (mandarin) yield losses on socio-economic conditions of the farming community in Punjab, Pakistan. *Pakistan Journal of Agricultural Research, 25(1).* https: //agris. fao. org/ agris-search /search. do?recordID =PK2012000769

Khan, H. (undated). Telecommunication in Pakistan. *Institute of Management Studies, University of Peshawar, Peshawar.*

Khan, H. undated. Telecommunication in Pakistan, Class assignment of the 4th-semester student, Institute of Management Studies, University of Peshawar, Peshawar. [Presentation present on slide share].

Khan, M. Z., Khalid, N., and Khan, M. A. (2006). Weeds related professional competency of agricultural extension agents in NWFP, Pakistan. *Pakistan Journal of Weed Science Research, 12(4):* 331-337. https ://agris. Fao .org/agris-search /search. do?recordID=PK2008000529

Khan, N. A., Qijie, G., Ali, S., Shahbaz, B., & Shah, A. A. (2019). Farmers' use of mobile phone for accessing agricultural information in Pakistan. *Ciência Rural, 49(10).* DOI:10.1590/0103-8478cr20181016

Khan, N. A., Qijie, G., Sertse, S. F., Nabi, M. N., & Khan, P. (2020). Farmers' use of mobile phone-based farm advisory services in Punjab, Pakistan. *Information Development, 36(3),* 390-402. https://doi.org/10.1177/0266666919864126

Khan, Y. (2013). Analysis of teacher training and education program of pakistan for ict integration in Pakistan. in a case study: 27th AAOU Annual Conference, AIOU, Islamabad. Pakistan Journal of Education 29(1). DOI:10.30971/pje.v29i1-2.388

Kim, H., Jeong, S., Yoe, H., Kim, N., Lee, S., & Wen-zheng, Y. (2014). Design and implementation of ICT-based system for information management of livestock farm. *International Journal of Smart Home, 8(2),* 1-6. DOI:10.14257/ijsh.2014.8.2.01

Kim, T. K. (2015). T-test as a parametric statistic. *Korean Journal of Anaesthesiology, 68(6*), 540. DOI: 10.4097/kjae.2015.68.6.540

Kiplang'at, J., & Ocholla, D. N. (2005). Diffusion of information and communication technologies in communication of agricultural information among agricultural researchers and extension workers in Kenya. *South African Journal of Libraries and Information Science, 71(3*), 234-246. DOI:10.7553/71-3-591

Kiveu, M., & Ofafa, G. (2013). Enhancing market access in Kenyan SMEs using ICT. *Global Business and Economics Research Journal, 2(9),* 29-46. https://www.semanticscholar.org/paper/Enhancing-Market-Access-in-Kenyan-SMEs-using-ICT-Kiveu-Ofafa/aa0829a5d30ac1b79f54c06b82bd4f8debf63e93

Kolshus K., Pastore A., Treinen S., & Van der Elstraeten A. E. (2015). Agriculture 10 year Review Report: Implementation of the World Summit on the Information Society (WSIS) Action Line C7. *ICT applications: e-agriculture. Rome.* www.fao. org/3/a-i4605e.pdf.[33] challenges

Korkmaz, M., GÜNEY, S., & YİĞİTER, Ş. (2012). The importance of logistic regression implementations in the Turkish livestock sector and logistic regression implementations/fields. *Harran Tarım ve Gıda Bilimleri Dergisi, 16(2),* 25-36.

Kothari, C. R. (2004). Research methodology: Methods and techniques. *New Age International*.https://books.google.com.pk/books?hl=en&lr=&id=hZ9wSHysQDYC&oi=fnd&pg=PA2&dq=Research+methodology:+Methods+and+techniques&ots=1tWauJd_A0&sig=n8H4ARhrVhpO6RLCizuIvzZ9uzQ

Kozma, R. B. (2005). National policies that connect ICT-based education reform to economic and social development. *Human Technology: An Interdisciplinary Journal on Humans in ICT Environments.* DOI:10.17011/ht/urn.2005355

Krueger, R. A., & Casey, M. A. (2014). Focus groups: A practical guide for applied research. *Sage publications. https://us.sagepub.com/en-us/nam/focus-groups/book243860*

Kumar, P. G., & Ratnakar, R. (2016). A scale to measure farmers' attitude towards ICT-based extension services. *Indian Research Journal of Extension Education, 11(21),* 109-112. DOI: http://dx.doi.org/10.18782/2582-2845.8132

Kurtenbach, T., & Thompson, S. (2000). Information technology adoption: implications for agriculture. Retrieved from; https://www. ifama. org/conferences.

Kwee-Meier, S. T., Bützler, J. E., & Schlick, C. (2016). Development and validation of a technology acceptance model for safety-enhancing, wearable locating systems. *Behaviour & Information Technology, 35(5),* 394-409. https:// doi.org/10. 1080/0144929X.2016. 1141986

Lal, K. (1999). Determinants of the adoption of information technology: a case study of electrical and electronic goods manufacturing firms in India. *Research Policy, 28(7),* 667-680. https://doi.org/10.1016/S0048-7333(99)00014-1

Lal, K. (2007). E-business and manufacturing sector: A study of small and medium-sized enterprises in India. *Information and Communication Technologies in the Context of Globalization (pp. 16-33), Springer*. http://hdl.handle.net/10986/26553

Langmia, K. (2006). The role of ICT in the economic development of Africa: The case of South Africa. *International Journal of Education and Development using ICT, 2(4).* http://ijedict.dec.uwi.edu/include/getdoc.php?id=1703&article=200&mode=pdf

Lans, W., & Van Der Voordt, T. (2002). Descriptive research. Ways to study and research urban, architectural and technical design.

LaRose, R., Gregg, J. L., Strover, S., Straubhaar, J., & Carpenter, S. (2007). Closing the rural broadband gap: Promoting adoption of the Internet in rural America. *Telecommunications Policy, 31*(*6*-7), 359-373. https:/ /doi.org /10.1016/j. telpol.2007.04.004

Larsen, T. J. (1997). Diffusion theory as the basis for understanding information technology related change: True or false. Position statement presented at WG8, 6.

Lashgarara, F., Mohammadi, R., & Omidi Najafaba, M. (2011). ICT capabilities in improving marketing of agricultural production of Garmsar Township, Iran. *Ann. Biol. Res, 2(6),* 356-363. https:// www. researchgate. net/ publication /234114920 _ICT_Capabilities_in_Improving_Marketing_of_Agricultural_Productions_of_Garmsar_Township_Iran

Lastra-Gil, L. E. (2018). The effect of icts on agricultural distribution channels in mexico. *Digital Technologies for Agricultural and Rural Development in the Global South*, 77. DOI : 10.1079/9781786393364.0077

Leedy, P. D., & Ormrod, J. E. (2014). Practical Research: Planning and design. *Pearson Education. NYC: Merril.* https:// www.pearson.com/us/higher-education/ product/ Leedy- Practical-Research-Planning-and-Design-9th-Edition/9780137152421.html

Leeuw, F. L., & Vaessen, J. (2009). Impact evaluations and development: NONIE guidance on impact evaluation. *Network of networks on impact evaluation.*

Lewis, G. A. (1997). Leadership Products as Innovations In The Context Of Rogers' Diffusion Theory (Doctoral dissertation, Virginia Tech). Virginia Polytechnic Institute and State University.

Lichtman, M. (2012). Qualitative research in education: A user's guide. *Sage Publications*

Liebscher, P. (1998). Quantity with quality? Teaching quantitative and qualitative methods in an LIS master's program. *Library Trends, 46(4),* 668–680 http ://hdl .handle .net/2142/8180

Lin, Y., & Heffernan, C. (2010). Creating the livestock guru: ICT to enhance livestock-related knowledge among poor households in Orissa, India. *Tropical animal health and production, 42(7), 1*353-1361. doi: 10.1007/s11250-010-9592-4

Lio, M., & Liu, M. C. (2006). ICT and agricultural productivity: evidence from cross-country data. *Agricultural Economics, 34(3),* 221-228. https://doi.org/10.1111/j.1574-0864.2006.00120.x

Lokeswari, K. (2016). A study of the use of ICT among rural farmers. *International Journal of Communication Research, 6(3),* 232. https://www.semanticscholar.org/paper/A-Study-of-the-Use-of-Ict-among-Rural-Farmers-Lokeswari/db543746a85d1c3b1e417af55b953bf8d1fffa25

Love, P. E., Irani, Z., Ghoneim, A., & Themistocleous, M. (2006). An exploratory study of indirect ICT costs using the structured case method. International. *Journal of Information Management, 26(2),* 167-177. DOI:10.1016/j.ijinfomgt.2005.11.001

Luqman, M., Javed, A. og Asghar, N. (2005). Impact of administrative changes on the working efficiency of extension field staff after decentralization in the punjab, pakistan. *Journal of Agriculture and Social Sciences (Pakistan)*. https://agris.fao.org/agris-search/search.do? recordID=PK2007000959

Luse, A., Mennecke, B. E., & Townsend, A. M. (2012). Selecting a research topic: A framework for doctoral students. *International Journal of Doctoral Studies, 7,* 143. DOI:10.28945/1572

Lwasa, S., Asingwire, N., Okello, J. J., & Kiwanuka, J. (2011). Awareness of ICT-based projects and the intensity of use of mobile phones among smallholder farmers in Uganda: The case of Mayuge and Apac districts. *International Journal of ICT Research and Development in Africa (IJICTRDA), 2(2),* 26-38. DOI:10.4018/978-1-4666-3607-1.ch007

Lwoga, E. T. (2010). Bridging the agricultural knowledge and information divide: The case of selected telecenters and rural radio in Tanzania. *The electronic journal of information systems in developing countries, 43(1),* 1-14. https://doi.org/10.1002/j.1681-4835.2010.tb00310.x

Lwoga, E. T., & Sangeda, R. Z. (2019). ICT and development in developing countries: A systematic review of reviews. The Electronic Journal of Information Systems in Developing Countries, 85(1), e12060. https://doi.org/10.1002/isd2.12060

Ma, Q., & Liu, L. (2004). The technology acceptance model: A meta-analysis of empirical findings. *Journal of Organizational and End User Computing (JOEUC), 16(1),* 59-72. DOI:10.4018/978-1-59140-474-3.ch006

Mabe, L. K., & Oladele, O. I. (2012). Use of information communication technologies tools among extension officers in the North-West Province, South Africa. *Life Science Journal, 9(4),* 3275-3279.

Madden, G., & Savage, S. J. (1998). CEE telecommunications investment and economic growth. *Information Economics and Policy, 10(2),* 173-195. https://mpra.ub.uni-muenchen.de/11843/1/MPRA_paper_11843.pdf

Madon, S. (2009). What do we mean by development?. In E-governance for development (pp. 9-32). Palgrave Macmillan, London.

Mahant, M., Shukla, A., Dixit, S., & Patel, D. (2012). Uses of ICT in agriculture. *International Journal of Advanced Computer Research, 2(1),* 46. https:// www. researchgate. net/publication/ 265351125_Uses_of_ICT_in_agriculture

Maitah, M., & Smutka, L. (2013). Economic analysis of milk production and consumption in the Middle East and North Africa. *Acta Universitatis Agriculturae et Silviculturae Mendelianae Brunensis, 60(4),* 245-254. DOI:10.11118/actaun201260040245

Majeed, M. T., & Ayub, T. (2018). Information and communication technology (ICT) and economic growth nexus: A comparative global analysis. Pakistan *Journal of Commerce and Social Sciences (PJCSS), 12(2),* 443-476. http:// www. jespk. net/ publications/431.pdf

Makorere, R. (2014). An exploration of factors affecting development of citrus industry in Tanzania: Empirical evidence from Muheza District, Tanga Region. International Journal of Food and Agricultural Economics (IJFAEC), 2(1128-2016-92042), 135-154. DOI: 10.22004/ag.econ.168587

Makoza, F., & Chigona, W. (2012). The livelihood outcomes of ICT use in microenterprises: The case of South Africa. *The Electronic Journal of Information Systems in Developing Countries, 53(1),* 1-16. DOI:10.1002/j.1681-4835.2012.tb00374.x

Malhan, I. V., & Rao, S. (2007, August). Impact of globalization and emerging information communication technologies on agricultural knowledge transfer to small farmers in India. *In World library and information congress: 73rd IFLA General conference and Council (pp. 19-23).* http://origin-archive.ifla.org/IV/ifla73/papers/120-Malhan_Rao-en.pdf

Malik, A. U., Hafeez, O., Johnson, P., Campbell, J. A., Amin, M., Saeed, M., & Adeel, J. (2009, November). Toward developing a sea-freight supply chain for delivering Pakistani mangoes to European supermarket: a private-public sector model. Í *International Symposium Postharvest Pacifica 2009-Pathways to Quality: V International Symposium on Managing Quality in 880*. DOI:10.17660/ActaHortic.2010.880.7

Malik, A., Ghani, E., & ud Din, M. (2017). An assessment of Pakistan’s export performance and the way forward. *Pakistan Institute of Development Economics, Islamabad.*

Malik, K. (2014). Human development report 2014: Sustaining human progress: Reducing vulnerabilities and building resilience. *United Nations Development Programme, New York.*

Man, N., & Sadiya, S. I. (2012). Off-farm employment participation among paddy farmers in the Muda Agricultural Development Authority and Kemasin Semerak granary areas of Malaysia. *Asia-Pacific Development Journal, 16(2),* 141-153. DOI: 10. 18356/ be439b1f-en

Mango, N., Makate, C., Hanyani-Mlambo, B., Siziba, S., & Lundy, M. (2015). A stochastic frontier analysis of technical efficiency in smallholder maize production in Zimbabwe: The post-fast-track land reform outlook. *Cogent Economics & Finance, 3(1),* 1117189. https://doi.org/10.1080/23322039.2015.1117189

Maqsood, L. (2015). Use of mobile technology among rural women in Pakistan for agricultural extension information. Michigan State University. *Telecommunication, Information Studies and Media.*

Marsh, D., & Stoker, G. (2002). Theories and methods in political science. *Palgrave.*

Martin, B. L. (2010). Mobile phones and rural livelihoods: An exploration of mobile phone diffusion, uses, and perceived impacts of uses among small-to medium-size farm holders in Kamuli District, Uganda.

Martin, W. J. (1984). The potential for community information services in a developing country. *IFLA Iournal, 10(4),* 385-392. https://doi.org/10.1177/034003528401000408

Matani, A. G. (2007). Information technology improving retail marketing in agriculture. http://hdl.handle.net/2259/627

Matto, G. (2018). Agricultural information access and the use of ICT among smallholder farmers: A Case of Bembeke EPA in Dedza District, Malawi. Research Report Series (RRS). 2(1), https: //www. academia. edu/ 36649539/ Agricultural _Information _Access_and_the_Use_of_ICTs_among_Smallholder_Farmers_A_Case_of_Bembeke _EPA_in_Dedza_District_Malawi

Maxwell, J. A. (2004). Causal explanation, qualitative research, and scientific inquiry in education. *Educational Researcher, 33(2),* 3-11. https:// doi.org/ 10. 3102/ 0013189X033002003

Maxwell, J. A. (2012). Qualitative research design: An interactive approach. *Sage publications.*

McLeod, S.A. (2014). Questionnaires. Retrieved from www. simplypsychology. Org /questionnaires. html

McMillan, J. H., & Schumacher, S. (2010). Research in Education: Evidence-Based Inquiry, *MyEducationLab Series. Pearson.* https://www.pearson.com/us/higher-education /program/ Mc-Millan- Research-in-Education-Evidence-Based-Inquiry-7th-Edition /PGM153294. html

McNamara, K. (2008). Enhancing the livelihoods of the rural poor through ICT-a knowledge map.

Meena, M., Singh, K. M. og Singh, R. (2012). Ict-enabled extension in agriculture sector: Opportunities and challenges in climate change situation. *ICTs for agricultural development under changing climate, KM Singh, MS Meena, eds., Narendra Publishing House.*

Meena, N. C. (2012). A study on ICT exposure regarding animal husbandry practices of dairy farmers in Morar block Gwalior district Madhya Pradesh. *Unpublished Doctoral Dissertation, RVSKVV, Gwalior (MP).* https://www.semanticscholar.org/paper/A-Study-on-ICT-Exposure-Regarding-Animal-Husbandry-Meena/70b965ea7c5f6825d20ad1e043a794666d603923

Mehta, P. K. (2010). Role of information and communication technologies in improving livelihoods*:* A case of mewat. *Working paper series, Sehgal Foundation, Gurgaon.*

Meijer, S. S., Catacutan, D., Ajayi, O. C., Sileshi, G. W., & Nieuwenhuis, M. (2015). The role of knowledge, attitudes and perceptions in the uptake of agricultural and agroforestry innovations among smallholder farmers in sub-Saharan Africa. *International Journal of Agricultural Sustainability*, *13*(1), 40-54. https:// doi.org/ 10. 1080/ 14735903.2014.912493

Mekuria, M. (1995). Technology development and transfer in Ethiopian agriculture: An empirical evidence. In *Annual Conference of the Agricultural Economics Society of Ethiopia, Addis Abeba (Ethiopia), 8-9 Jun 1995. AESE.*

Meuter, M. L., Bitner, M. J., Ostrom, A. L., & Brown, S. W. (2005). Choosing among alternative service delivery modes: An investigation of customer trial of self-service technologies. *Journal of marketing*, *69(2)*, 61-83. DOI:10.1509/jmkg.69.2.61.60759

Meyer, H. W. (2005). The nature of information, and the effective use of information in rural development. *Information Research: An International Electronic Journal*, *10(2)*, 2. http://informationr.net/ir/10-2/paper214.html

Minishi-Majanja, M. K., & Kiplang'at, J. (2005). The diffusion of innovations theory as a theoretical framework in library and information science research. *South African Journal of Libraries and Information Science*, *71(3)*, 211-224. DOI:10.7553/71-3-586

Mittal, S. (2012). Modern ICT for agricultural development and risk management in smallholder agriculture in India. *Socioeconomics Working Paper 3. Mexico, D.F.: CIMMYT.*

Mittal, S., & Mehar, M. (2012). How mobile phones contribute to growth of small farmers? Evidence from India. *Quarterly Journal of International Agriculture, 51*, 227-244. DOI: 10.22004/ag.econ.155478

Mittal, S., Gandhi, S., & Tripathi, G. (2009, August). Impact on small farmers and fishermen through the use of mobiles in India. *In 111th Seminar, June 26-27, 2009, Canterbury, UK (No. 52809). European Association of Agricultural Economists.*

Mittal, S., Gandhi, S., & Tripathi, G. (2010). Socio-economic impact of mobile phones on Indian agriculture. *Working paper. New Delhi: Indian Council for Research on International Economic Relations.*

Mohammed, W. A. (2012). Technical efficiency of sorghum production in Hong local government area of Adamawa State, Nigeria. *Russian Journal of Agricultural and socio-economic Sciences, 6(6).* DOI:10.18551/rjoas.2012-06.02

Mojaverian, S. M., Rasouli, F., & Hosseini-Yekani, S. A. (2014). Citrus marketing channel strategy and its determinants in Mazandaran province of Iran: An application of nested logit model. *Journal of Agricultural Science and Technology, 16(7),* 1469-1479. URL: http://jast.modares.ac.ir/article-23-11728-en.html

Molony, T. (2008). Running out of credit: the limitations of mobile telephony in a Tanzanian agricultural marketing system. *The Journal of Modern African Studies, 46(4),* 637-658. DOI: https://doi.org/10.1017/S0022278X08003510

Molony, T. (2009). Carving a niche: ICT, social capital, and trust in the shift from personal to impersonal trading in Tanzania. *Information technology for development, 15(4),* 283-301. DOI:10.1002/itdj.20127

Mooi, E., & Sarstedt, M. (2011). Chapter 9: Cluster analysis. *A concise guide to market research, 237-84.*

Morgan, D. L. (2007). Methodological implications of combining qualitative and quantitative methods. *Journal of Mixed Methods Research, 1,* 48–76. https:// doi.org/ 10. 1177/ 2345678906292462

Morrow, K., Nielsen, F., & Wettasinha, C. (2002). Changing information flows. *LEISA, 18(2*), 4-5.

Mote, M. G., Tambat, R. V., & Choudhari, M. R. (1997). Influence of selected characteristics of dairy farmers on milk production. *Maharashtra Journal of Extension Education, 16,* 235-240.

Mourougan, S., & Sethuraman, K. (2017). Hypothesis Development and Testing. Journal of *Bussiness Management*, *19*, 34-40. DOI: 10.9790/487X-1905013440

Mugo, F. W. (2002). Sampling in research.

Mugwisi, T., Mostert, J., & Ocholla, D. N. (2015). Access to and utilization of information and communication technologies by agricultural researchers and extension workers in Zimbabwe. *Information Technology for Development, 21(1),* 67-84. https://doi.org/10.1080/02681102.2013.874317

Munack, A., & Speckmann, H. (2001). Communication technology is the backbone of precision agriculture. *Agricultural Engineering International: CIGR Journal*. https://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.200.5134&rep=rep1&type=pdf

Munyua, H., Adera, E., & Jensen, M. (2009). Emerging ICT and their potential in revitalizing small-scale agriculture in Africa. *Agricultural information worldwide, 2(1).* https://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.855.2532&rep=rep1&type=pdf

Murthy, C. (2009). Use of convergent mobile technologies for sustainable economic transformation in the lives of small farmers in rural India. *The Turkish Online Journal of Distance Education, (10),* 1-8. https:// www. researchgate. net/publication

/292265196_Use_of_convergent_mobile_technologies_for_sustainable_economic_transformation_in_the_lives_of_small_farmers_in_rural_India

Muto, M., & Yamano, T. (2009). The impact of mobile phone coverage expansion on market participation: Panel data evidence from Uganda. *World development, 37(12*), 1887-1896. https://doi.org/10.1016/j.worlddev.2009.05.004

Mutula, S., Stilwell, C., & Elia, E. F. (2014). Indigenous knowledge use in seasonal weather forecasting in Tanzania: the case of semi-arid central Tanzania. *South African Journal of Libraries and Information Science, 80(1),* 18-27. DOI:10.7553/80-1-180

Mwakaje, A. G. (2010). Information and communication technology for rural farmers market access in Tanzania. *Journal of Information Technology,10(2),* 111-128. https://www.researchgate.net/publication/266522007_Information_and_Communication_Technology_for_Rural_Farmers_Market_Access_in_Tanzania

Mwalupaso, G. E., Wang, S., Rahman, S., Alavo, E. J. P., & Tian, X. (2019). Agricultural informatization and technical efficiency in maize production in Zambia. *Sustainability*, *11(8),* 2451. DOI:10.3390/su11082451

Mwombe, S. O., Mugivane, F. I., Adolwa, I. S., & Nderitu, J. H. (2014). Evaluation of information and communication technology utilization by smallholder banana farmers in Gatanga District, Kenya. *The Journal of Agricultural Education and Extension, 20(2),* 247-261. DOI:10.1080/1389224X.2013.788454

Myhr, J., & Nordström, L. (2006). Livelihood changes enabled by mobile phones: the case of Tanzanian fishermen. *Unpublished Bachelor Thesis, Department of Business Studies, Uppsala University, Sweden.* https:/ /www. researchgate. net/publication/ 279658773_Livelihood_Changes_Enabled_by_Mobile_Phones_the_case_of_Tanzanian_fishermen

Nakasone, E., Torero, M., & Minten, B. (2014). The power of information: The ICT revolution in agricultural development. *Annu. Rev. Resour. Econ.*, *6(1),* 533-550. https://doi.org/10.1146/annurev-resource-100913-012714

Naveed, M. A., & Anwar, M. A. (2013). Agricultural information needs of Pakistani farmers. *Malaysian Journal of Library & Information Science, 18(3),* 13-23. https://www.researchgate.net/publication/289647665_Agricultural_information_needs_of_Pakistani_farmers

Nayak, H. S., Bajaj, S. S., & Raut, D. R. (1986). Problems of dairy farmers in Ahmednagar district Maharashtra. *Maharashtra Journal of Extension Education*, *5*, 107.

Nayak, L. U., Priest, L., & White, A. P. (2010). An application of the technology acceptance model to the level of Internet usage by older adults. *Universal Access in the Information Society*, *9(4),* 367-374. https://doi.org/10.1007/s10209-009-0178-8

Nazari, M. R. (2010). Impact of television on rural development. http:// eprints.um.edu.my/id/eprint/3342

Nazari, M. R., & Hassan, M. S. B. H. (2011). The role of television in the enhancement of farmers agricultural knowledge. *African Journal of Agricultural Research, 6(4)*, 931-936. DOI: 10.5897/AJAR10.1154

Ndahiriwe, I. (2015). Contribution of ICT on Socio−Economic Development of Rwanda. (Case Study of Mukura and Tumba Sectors in Huye District), *Bachelor Dissertation, University of Rwanda*.

Needle, D. og Burns, J. (2010). *Business in context: An introduction to business and its environment*. South-Western Cengage Learning Boston.

Nejad, A. H., & Ghanji, M. (2009). Role of ICT in rural development. In *Proceeding of the national congress on agricultural extension and education, sustainable development and natural resources*.

Neuman, W. L. (2003). Social research methods: Qualitative and quantitative approaches (5th ed.). *Sydney, Australia: Pearson Education.*

Nganga, S. K., Kungu, J., De Ridder, N., & Herrero, M. (2010). Profit efficiency among Kenyan smallholders' milk producers: A case study of Meru-South district, Kenya. *African Journal of Agricultural Research, 5(5)*, 332-337. http://environmental.ku.ac.ke/images/stories/docs/profit_efficency_among_kenyans.pdf

Niazi, A. Q. K. (1993). To determine the extent of adoption of recommended horticultural practices by mango growers of tehsil Muzaffargarh. M. Sc. (Hons.) *Unpublished Thesis, Department of Agricultural Extension University of Agriculture, Faisalabad.*

Ninsiima, D. (2015). Factors affecting adoption of an information communications technology system for agriculture in Uganda. Michigan State University. https://search.proquest.com/openview/42efda11d493bdb2c15cf5c6913c27a5/1?pq-origsite=gscholar&cbl=18750&casa_token=aS922uQLvtMAAAAA:05t6zjmd7nC8tRKV8fbBNj8JkKR1O-Dt9UWYO08faom3Ms-1v-Xdytp_oySaP1v61O_5vyE_QR5g

Nnenna, E. A., Eze, A. V., & Aleke, B. (2015). Assessment of socioeconomic determinants of access and utilization of ICT among farmers in South-East Nigeria. *International Journal of Agriculture Innovations and Research, 3(4).* https://www.academia.edu/download/53869973/IJAIR-1208_final.pdf

Nonso, F. (2012). Problems and prospects of adopting ICT in agriculture. *African Journal of Agricultural Research and Development, 5(3).* https:// www. researchgate. net/publication/234017770_problems_and_prospects_of_adopting_ict_in_agriculture

Noor Sharifah, S. S. (2003). Model planning on traditional village in Peninsular Malaysia. *Rural Planning Center, Faculty of Alam Bina, and UTM. Penerbit Technology University of Malaysia, Skudai, Johor.*

Noor, M. A., Fiaz, S., Nawaz, A. og Nawaz, M. M. (2018). The effects of cutting interval on agro-qualitative traits of different millet (pennisetum americanum l.) cultivars. *Journal* *of the Saudi Society of Agricultural Sciences*, *17*(3), 317-322.http://dx.doi.org/10.1016/j.jssas. 2016.07.002.

Norton, S. W. (1992). Transaction costs, telecommunications, and the microeconomics of macroeconomic growth. *Economic Development and Cultural Change, 41(1),* 175-196. http://dx.doi.org/10.1086/452002

Nosheen, F., Ali, T., & Ahmad, M. (2010). Analysis of gender-specific sources of information regarding home and farm practices in the Potohar region: A case study. *Journal of Animal & Plant Sciences, 20(1),* 56-59. https:// www. researchgate. net/publication/267807320_Analysis_of_gender_specific_sources_of_information_regarding_home_and_farm_practices_in_potohar_region_A_case_study

Nwagwu, W. E., & Opeyemi, S. (2015). ICT use in livestock innovation chain in Ibadan city in Nigeria. *Advances in Life Science and Technology, 32,* 12-20. https://www.iiste.org/Journals/index.php/ALST/article/viewFile/22242/22588

Nyamba, S. Y., & Mlozi, M. R. (2012). Factors influencing the use of mobile phones in communicating agricultural information: A case of Kilolo District, Iringa, Tanzania http://www.suaire.sua.ac.tz/handle/123456789/1786

O'Farrell, C., Norrish, P. og Scott, A. (1999). Information and communication technologies for sustainable livelihoods. *Intermediate Technology Development Group: Warwickshire.) Available at: http://practicalaction. org*.

Ogbeide, O. A., & Ele, I. (2015). Smallholder farmers and mobile phone technology in Sub-Sahara Agriculture. *Mayfair Journal of Information and Technology Management in Agriculture, 1(1),* 1-19. https://www.researchgate.net/publication/272510110_Smallholder_Farmers_and_Mobile_Phone_Technology_in_Sub-Sahara_Agriculture

Ogutu, S. O., Okello, J. J., & Otieno, D. J. (2014). Impact of information and communication technology-based market information services on smallholder farm input use and productivity: The case of Kenya. *World Development, 64,* 311-321. https://doi.org/10.1016/j.worlddev.2014.06.011

Ojiambo, J. B. (1990). Communication of agricultural information between research scientists, extension personnel and farmers in Kenya. https:// www. cabdirect. org/cabdirect/abstract/19921893099

Okello, J. J., Kirui, O. K., Gitonga, Z. M., Njiraini, G. W., & Nzuma, J. M. (2014). Determinants of awareness and use ICT-based market information services in developing-country agriculture: The Case of smallholder farmers in Kenya. *Quarterly Journal of International Agriculture, 53* 263-282. DOI: 10.22004/ag.econ.195738

Oladele, O. I. (2006). Multilinguality of farm broadcast and agricultural information access in Nigeria. *Nordic Journal of African Studies, 15(2).* http://www.njas.helsinki.fi/pdf-files/vol15num2/oladele5.pdf

Oladele, O. I. (2011). Effect of information communication technology on agricultural information access among researchers, extension agents, and farmers in South-Western Nigeria. *Journal of Agricultural & Food Information, 12(2),* 167-176. https://doi.org/10.1080/10496505.2011.563229

Olaniyi, O. A., Adetumbi, S. I., & Adereti, M. A. (2013). Accessibility and relevance of information and communication technologies (ICTs) among cassava farmers in Nigeria. *African Journal of Agricultural Research, 8(35),* 4514-4522. DOI:10.5897/AJAR2013.7260

Oliner, S. D., & Sichel, D. E. (2003). Information technology and productivity: where are we now and where are we going? *In Technology, Growth, and the Labor Market (pp. 41-94). Springer, Boston, MA.* DOI:10.2139/ssrn.318692

Ommani, A. R., & Chizari, M. (2008). Information dissemination system (IDS) based e-learning in agricultural of Iran (perception of Iranian extension agents). *International Journal of Human and Social Sciences, 2(3),* 129-133. https://www.researchgate.net/publication/242566640_Information_Dissemination_System_IDS_Based_E-Learning_ in_ Agricultural_ of_ Iran_ Perception_ of _Iranian _Extension_agents

Omolayole, O. O. (2002). Electronic services in Nigerian libraries. *A Keynote address presented at the Ogun State chapter of the Nigerian Library Association.*

Omoregbee, F., & Okoedo-Okojie, D. U. (2008). Farmers' characteristics and adoption of recommended practices under the Fadama project scheme in Edo State, Nigeria. *Global Journal of Agricultural Sciences, 7(1),* 45-48. DOI:10.4314/gjass.v7i1.2358

Onwuegbuzie, A. J., & Collin, K. M. T. (2007). A typology of mixed methods sampling designs in social science research. *The Qualitative Report, 12(2),* 281–316. DOI:10.46743/2160-3715/2007.1638

Onwuemele, A. (2011). Impact of mobile phones on rural livelihood assets in rural Nigeria: A case study of ovia norh east local government area. *Journal of Research in National Development, 9(2),* 223-236. https:// www. ajol. info/index. php/jorind/ article/ view /91725

Oosterlaken, I. (2014). Technologies of choice? Icts, development and the capabilities approach. Taylor & Francis.DOI:10.1080/19452829.2013.875737

Opata, P., Nweze, J., & Rahman, M. (2011). The place of information and communication technology in promoting agro-based enterprises in third world countries. *Journal of Agricultural Technology, 7(2),* 207-214. http://www.ijat-aatsea. com/ pdf/ April_v7_n2_11/1%20IJAT2010_25F.pdf

Opolot, H. N., Isubikalu, P., Obaa, B., Ebanyat, P., Okello, D., & Mirembe, D. (2017). The benefits and challenges of using ICTs to strengthen university-farming community engagement in Uganda. *African Journal of Rural Development, 2(1),* 41-53. DOI: 10.22004/ag.econ.263299

Osanloo, A., & Grant, C. (2016). Understanding, selecting, and integrating a theoretical framework in dissertation research: Creating the blueprint for your "house." *Administrative Issues Journal: Connecting Education, Practice, and Research, 4(2),* 7. DOI: 10.5929/2014.4.2.9

Otete, K. S. (2018). The role of ICT in improving livelihoods in Kenya: Perspectives from pastoralists communities. *International Journal of Law, Humanities & Social Science, 2(4),* 51-59. http://www.ijlhss.com/wp-content/uploads/2018/05/IJLHSS-03-18-05done.pdf

Owotogbe, J. S., Adu, B. A. & Adu, B. (2018). The role of robust ICT in fostering agricultural extension, rural development and food security. *International Journal of Science and Research (IJSR),8(10),* 442-445. DOI:10.21275/ART20201751

Ozturk, I. (2008). The role of education in economic development: a theoretical perspective. Retrieved from:. https:// papers. ssrn. com/sol3/ papers. cfm? abstract_id=1137541

Paez-Urdaneta, I. (1989). Information in the third world. *International Library Review, 21(2),* 177-191. https://doi.org/10.1016/0020-7837(89)90006-X

Pakistan Electronic Media Regulatory Authority (PEMRA). (2019). *Annual Report 2015-18.*

Pakistan Software Export Board. (2020). History. Retrieved from: https://www.pseb.org.pk/about-us/pseb-histo

Pakistan Telecommunication Authority. (2017). Telecom indicators. *Pakistan Telecom Industry Report.* Retrieved from https://www.pta.gov.pk/en/telecom-indicators

Palmer, N. (2012). Using ICT to enable agricultural innovation systems for smallholder's ICT innovations.https://www.semanticscholar.org/paper/Using-ICT-to-enable-Agricultural-Innovation-Systems-Palmer-Ciat/6702e7744820d04189c79ec02532f8bddfbfe3e5

Palvia, P., Baqir, N., & Nemati, H. (2018). ICT for socio-economic development: A citizens' perspective. *Information & Management, 55(2),* 160-176. https:// doi. org/10.1016/ j.im.2017.05.003

Pandis, N. (2017). Logistic regression: Part 1. *American Journal of Orthodontics and Dentofacial Orthopedics, 151(4).* DOI:https://doi.org/10.1016/j.ajodo.2017.01.017

PANOS, (2011). South Asia study "Leveling the Playing Field: A Survey of Pakistan's Land Reforms". Published as part of project by Swedish International Development Agency (SIDA).

Parasuraman, A. (2000). Technology readiness index (TRI) a multiple-item scale to measure readiness to embrace new technologies. *Journal of Service Research, 2(4),* 307-320. https://doi.org/10.1177/109467050024001

Parasuraman, A., & Colby, C. L. (2015). An updated and streamlined technology readiness index: TRI 2.0. *Journal of Service Research, 18(1),* 59-74. https://doi.org/10.1177/1094670514539730

Parveen, H. & Showkat, N. (2017). Data collection. Retrieved from: https:// www. Researchgate .net/publication/319128325

Patel, R. K., Singh, C. B., & Dhaka, J. P. (1984). Economic analysis of different species of dairy animals. *Indian Dairyman, 36(7),* 365.

Patil, V. C., Gelb, E., Maru, A., Yadaraju, N. T., Moni, M., Misra, H., & Ninomiya, S. (2008). Adoption of information and communication technology (ICT) for agriculture: An Indian case study. *In IAALD AFITA WCCA 2008. World Conference on Agricultural Information and IT.* http://www.cabi.org/GARA/FullTextPDF/2008/20083298229.pdf

Peansupap, V. og Walker, D. (2005). Factors affecting ict diffusion: A case study of three large Australian construction contractors. *Engineering, construction and architectural management.*DOI:10.1108/09699980510576871

Pendharkar, P. C., Rodger, J. A., & Subramanian, G. H. (2008). An empirical study of the Cobb–Douglas production function properties of software development effort. *Information and Software Technology, 50(12),* 1181-1188. https://doi.org/10.1016/j.infsof.2007.10.019

Peng, C. Y. J., Lee, K. L., & Ingersoll, G. M. (2002). An introduction to logistic regression analysis and reporting. *The Journal of Educational Research, 96(1),* 3-14. https://doi.org/10.1080/00220670209598786

Perrin, R., & Winkelmann, D. (1976). Impediments to technical progress on small versus large farms. *American Journal of Agricultural Economics, 58(5).* http:// hdl. handle. net/ 10.2307/1239988

PHDEB. (2007). Pre-feasibility Study; Establishment of Cold Chain System under National Trade Corridor Improvement Project, Volume-I Horticulture Industry. *By Arch-Vision Consulting Engineers, Environmentalists, and Architects.*

Pilat, D. (2003). ICT and economic growth: evidence from OECD countries, industries and firms. *OECD Publishing.*

Poate, C. D., & Daplyn, P. F. (1993). Data for agrarian development. *CUP Archive.*

Pudasaini, S. P. (1983). The effects of education in agriculture: Evidence from Nepal. *American Journal of Agricultural Economics, 65(3),* 509-515. https://doi.org/10.2307/1240499

Punch, K. F. (2013). Introduction to social research: Quantitative and qualitative approaches. *Sage.*

Puri, S. K. (2007). Integrating scientific with indigenous knowledge: Constructing knowledge alliances for land management in India. *Mis Quarterly*, 355-379. DOI:10.2307/25148795

Qaisar, T. M., Khan, M. A., & Alom, S. (2011). Innovative agricultural information services by ICT projects in India. *International Journal of Trade, Economics, and Finance, 2(4),* 276-279.

Qamar, M. K. (2016). Modernizing national agricultural extension systems: a practical guide for policymakers of developing countries.

Rafea, A. (2009). Managing agriculture knowledge: role of informationand communication technology. In *Science Forum 2009 Workshop: ICTs transforming agricultural science, research and technology generation*. http:// www. fao. org/ docs/ eims/ upload/295346/Rafea Managing Agriculture Knowledge.pdf.

Rahelizatovo, N. C., & Gillespie, J. M. (2004). The adoption of best-management practices by Louisiana dairy producers. *Journal of Agricultural and Applied Economics, 36(1),* 229-240.

Rahman, M., & Haque, E. (2008). Economic efficiency in rice farming in Bangladesh. Pakistan Journal of Agricultural Economics, (1).

Rahman, S. M. R., Hashan, S., Shahjahan, M. D., & Islam, S. (2001). The ownership of livestock in relation to land holding in the semi-arid area of Bangladesh. *Journal of Biological Sciences, 1(10),* 960-962.

Raj, D. A., Murugesan, A. P., Aditya, V. P. S., Olaganathan, S., & Sasikumar, K. (2011). A crop nutrient management decision support system: India. Strengthening rural livelihoods: The impact of information and communication technologies in Asia. *Rugby and Ottawa: Practical Action Publishing and International Development Research Centre*, 33-52.DOI:10.3362/9781780440361.003

Rajoria, S., Rewani, S. K., Singh, V., Singodia, M., Nanda, B., & Bhumra, H. (2018). Attitude of livestock farmers towards the ict based livestock extension services in Jaipur district of Rajasthan, India. *International Journal of Current Microbiology and Applied Sciences, 7(2),* 1014-1021. DOI:10.20546/ijcmas.2018.702.125

Raksha, S. N. M. (2016). Determinants of ICT in agricultural extension system. *Indian Research Journal of Extension Education*, *15(1),* 1-7. http://www.seea.org.in/.../01.pdf

Rao, N. H. (2007). A framework for implementing information and communication technologies in agricultural development in India. *Technological Forecasting and Social Change, 74(4),* 491-518. https://doi.org/10.1016/j.techfore.2006.02.002

Räsänen, M., & Nyce, J. M. (2013). The raw is cooked: data in intelligence practice. *Science, Technology, & Human Values, 38(5),* 655-677. https:// doi. org/10. 1177/ 0162243913480049

Rashid, S., & Sheikh, A. T. (2015). Farmers' Perceptions of agricultural land values in rural *Pakistan. Pakistan Development Review, 54(4),* 809-823. http: //www. pide.org. pk/ pdf /PDR/ 2015/Volume4/809-821.pdf

Ravitch, S. M., & Carl, N. M. (2019). Qualitative research: Bridging the conceptual, theoretical, and methodological. *SAGE Publications, Incorporated*

Raza, M. H., Shahbaz, B., & Bell, M. A. (2017). Review based analysis of adoption gap and training needs of farmers in Pakistan. *International Journal of Agricultural Extension, 4(3),* 185-193.https://journals.esciencepress.net/index.php/IJAE/article/view/2018

Reddy, G. P., Reddy, M. N., Sontakki, B. S., & Prakash, D. B. (2008). Measurement of efficiency of shrimp (Penaeus monodon) farmers in Andhra Pradesh. *Indian Journal of Agricultural Economics, 63*. DOI: 10.22004/ag.econ.204607

Reganold, J. P., Jackson-Smith, D., Batie, S. S., Harwood, R. R., Kornegay, J. L., Bucks, D., & Willis, P. (2011). Transforming U.S. agriculture. *Science*, *332*, 670–671. DOI:10.1126/science.1202462

Rehman, F., Muhammad, S., Ashraf, I., Ch, K. M. & Ruby, T. (2013). Effect of farmers' socioeconomic characteristics on access to agricultural information: Empirical evidence from pakistan. *Young (Up to 35), 52*, 21-67. https://www.researchgate.net/publication/257651911_Effect_of_farmers'_socioeconomic_characteristics_on_access_to_agricultural_information_Empirical_evidence_from_Pakistan

Richardson, D. (2006). Icts–transforming agricultural extension? Report of the 6th consultative expert meeting of cta's observatory on icts. *CTA Working document*. https:// www. semanticscholar. org/paper/ ICTs-%E2%80% 93-Transforming-Agricultural-Extension- Report Richardson/139b28eac3e54ae7c724c15c678b013c610798c5

Riddell, W. C., & Song, X. (2017). The role of education in technology use and adoption: Evidence from the canadian workplace and employee survey. *ILR Review*, *70*(5), 1219-1253.https://doi.org/10.1177/0019793916687719

Rodell, J. B., Breitsohl, H., Schröder, M., & Keating, D. J. (2016). Employee volunteering: A review and framework for future research. *Journal of Management*, *42(1),* 55-84. https://doi.org/10.1177/0149206315614374

Rogers, E. M., & Scott, K. L. (1997). The diffusion of innovations model and outreach from the national network of libraries of medicine to native American communities. Retrieved October 22, 2019.

Rogers, E.M. (2003): Diffusion of innovations (5th Ed.). *New York: Free Press*.

Rogers, EM & Scott, KL. 1999. The Diffusion of innovations model and outreach from the national network of libraries of medicine to native American communities. http://nnlm.gov/pnr/eval/rogers.html. *Retrieved 20 October 2019.*

Rogers, EM. 1983. Diffusion of innovations. (3rd. ed.) *New York: Free Press.*

Röller, L., & Waverman, L. (2001). Telecommunications infrastructure and economic development: A simultaneous approach. *The American Economic Review, 91(4),* 909-923.DOI: 10.1257/aer.91.4.909

Roy, R. (2009). Trends of ICT usage in agriculture and extension. *Bangladesh Research Publication Journal, 2(1),* 307-318. https: //www. academia. edu/6669823/ Trends_of_ICT_usage_in_Agriculture_and_Extension

Rupan, R., Saravanan, R. & Suchiradipta, B. (2018). Climate smart agriculture and advisory services: approaches and implication for future. *Discussion paper 1, Manage- centre for agricultural extension innovations, Reforms and Agripreneurship (CAEIRA), National Institute of Agricultural Extension Management, Hyderabad, India.* DOI:10.13140/RG.2.2.15848.72966

Rutherford, A. (2001). Introducing ANOVA and ANCOVA: a GLM approach. *Sage*. https://www.researchgate.net/publication/246522459_Introducing_ANOVA_and_ANCOVA_a_GLM_approach

Ryan, B., & Gross, N. C. (1943). The diffusion of hybrid seed corn in two Iowa communities. *Rural sociology, 8(1),* 15. https:// search. proquest . com/ openview/ 7de2b2276a089fe888071663de12b6a0/1?pq-origsite =gscholar&cbl=1817355

Sadaf, S., Javed, A., & Luqman, M. (2006). Preferences of rural women for agricultural information sources: a case study of district Faisalabad-Pakistan. *Journal of Agriculture & Social Sciences, 2(3), 1*45-149. https://agris.fao.org/agris-search/ search.do?recordID=PK2007000985

Sadiq, G., Haq, Z., Ali, F., Mahmood, K., & Shah, M. (2009). Inamullah. technical efficiency of maize farmers in various ecological zones of AJK. *Sarhad Journal Agriculture, 25(4),* 607-610.http://www.aup.edu.pk/sj_pdf/TECHNICA...

Saghir, A., Chaudhary, K. M., Muhammad, S., & Maan, A. A. (2013). Role of ICT in bridging the gender gap of information regarding livestock production technologies. *Journal of Animal and Plant Sciences, 23(3),* 929-933. http://www.thejaps.org.pk/.../41.pdf

Saidu, A., Clarkson, A. M., Adamu, S. H., Mohammed, M., & Jibo, I. (2017). Application of ICT in agriculture: Opportunities and challenges in developing countries. *International Journal of Computer Science and Mathematical Theory, 3(1),* 8-18. https://iiardpub.org/get/IJCSMT/VOL.%203%20NO.%201%202017/Application%20of%20ICT.pdf

Salia, M., Nsowah-Nuamah, N. N., & Steel, W. F. (2011). Effects of mobile phone use on artisanal fishing market efficiency and livelihoods in Ghana. *The Electronic Journal of Information Systems in Developing Countries, 47(1),* 1-26. https://doi.org/10.1002/j.1681-4835.2011.tb00334.

Sangeetha, V., Burman, R. R., Dubey, S. K., Sharma, J. P., & Singh, I. (2015). Attitude of agricultural stakeholders on use of short message service (SMS) in transfer of technology. *Indian Journal of Extension Education, 51,,* 60-65.

https://www.indianjournals.com/ijor.aspx?target=ijor:ijee3&volume=51&issue=1and 2&article=010

Sapsford, R., & Jupp, V. (2006). Data Collection and Analysis. *Thousand Oaks, CA: Sage Publications*. DOI: https://dx.doi.org/10.4135/9781849208802

Saravanan, R. (Ed.). (2010). ICT for agricultural extension: Global experiments, innovations and experiences. *New India Publishing.*

Saravanan, R., & Suchiradipta, B. (2015). Role of ICT in family farming: experiences and way forward. Family farming and rural economic development. *New India Publishing Agency, New Delhi*, 215-234. https://www.researchgate.net/publication/328225413_CHAPTER-28_Role_of_ICTs_in_Family_Farming_Experiences_and_Way_Forward

Sattar, K. (2007). A sustainable model for use of ICT in rural Pakistan. *International Journal of Education and Development using Information and Communication Technology, 3(2),* 89. http:// ijedict. dec. uwi. Edu /include/ getdoc. Php ?id= 2390&article=247&mode=pd

Saunders, R., Warford, J., & Wellenieus, B. (1994). Telecommunications and economic development (2 Eds.). *Baltimore, MD: Johns Hopkins University Press*. https://doi.org/10.1080/08109028408628960

Schepers, J., & Wetzels, M. (2007). A meta-analysis of the technology acceptance model: Investigating subjective norm and moderation effects. *Information & Management, 44(1),* 90-103. https://doi.org/10.1016/j.im.2006.10.007

Schmidt, P., & Lovell, C. K. (1979). Estimating technical and allocative inefficiency relative to stochastic production and cost frontiers. *Journal of Econometrics, 9(3),* 343-366. https://doi.org/10.1016/0304-4076(79)90078-2

Schober, P., Boer, C., & Schwarte, L. A. (2018). Correlation coefficients: appropriate use and interpretation. *Anaesthesia & Analgesia, 126(5),* 1763-1768.

Schoonenboom, J., & Johnson, R. B. (2017). How to construct a mixed methods research design. *KZfSS Kölner Zeitschrift für Soziologie und Sozialpsychologie, 69(2),* 107-131. DOI:10.1007/s11577-017-0454-1

Sein, M., Thapa, D., Hatakka, M., & Sæbø, Ø. (2016). What theories do we need to know to conduct ICT4D research? *In SIG GlobDev, Dublin, December 11 2016.* https://www.semanticscholar.org/paper/What-theories-do-we-need-to-know-to-conduct-ICT4D-Sein-Thapa/8a94aacedc6c01d5fb832fc50baa6cfe7d3b62b6

Sekabira, H., Bonabana, J., & Asingwire, N. (2012). Determinants for adoption of information and communications technology (ICT)-based market information services by smallholder farmers and traders in Mayuge District. *Journal of Development and Agricultural Economics, 4(14),* 404-415. DOI: 10.5897/JDAE12.081

Senapati, S., Paikaray, A., Das, B. C., & Swain, P.(2016). Application of remote sensing in agriculture & animal husbandry, ICT programmes in livestock development problems & prospect of ICT in livestock development. *International Journal of Environment, Agriculture and Biotechnology (IJEAB),1(4),* 920-925. DOI: 10.22161/ijeab/1.4.42

Senthilnathan, S. (2019). The usefulness of correlation analysis. Available at SSRN 3416918. DOI:10.2139/ssrn.3416918

Shapiro, K. H. (1983). Efficiency differentials in peasant agriculture and their implications for development policies. *The Journal of Development Studies, 19(2),* 179-190. https://doi.org/10.1080/00220388308421857

Sharif, M. (2004). Opportunities and constraints in the production, marketing and export of citrus in Punjab. *PhD Dissertation, Faculty of Agricultural Economics and Rural Sociology, University of Agriculture Faisalabad, Pakistan.*

Sharif, M. (2011). Structure conduct and performance of the marketing systems Margins and seasonal price variations of selected fruits and vegetables in Baluchistan. NWFP, Northern Areas and Azad Jammu and Kashmir.*Research report, Pakistan Agriculture Research Council, Islamabad.*

Sharif, M., Farooq, U., Malik, W., & Bashir, M. (2005). Citrus Marketing in Punjab: Constraints and Potential for Improvement. *The Pakistan Development Review*, 673-694. DOI: https://doi.org/10.30541/v44i4IIpp.673-694

Sharma, S. (2019). Descriptive Statistics. *Retrieved from* https://www.researchgate.net/publication/333220406_Descriptive_Statistics

Shiferaw, B., Obare, G., & Muricho, G. (2009). Rural institutions and producer organizations in imperfect markets: experiences from producer marketing groups in semi-arid Eastern Kenya. *Journal of SAT Agricultural Research,2(1),37-* .Retrieved from: www.ejournal.icrisat.org/mpiirpaper2.1.htm.

Shlens, J. (2014). A tutorial on principal component analysis. arXiv preprint arXiv:1404.1100.

Shokane, A. L., Makhubele, J., & Blitz, L. V. (2018). Issues around aligning theory, *Research and Practice in Social Work Education (p. 418). AOSIS*. DOI:10.4102/aosis.2018.bk76

Sidhu, D. S., Chand, R., Tyagi, K. C., Chouhan, J. P. S., & Kalra, K. K. (1997). Study of mini dairies of Haryana state. *Indian Journal of Dairy Science, 50(4*), 329-332.

Sikhweni, N. P., & Hassan, R. (2014). Determinants of herd size among small-scale cattle farmers: The case of selected villages at the Mhinga Traditional Authority in Limpopo, South Africa. *Agrekon, 53(4),* 106-122. https:// doi.org/ 10. 1080/03031853.2014.974945

Silva, H. de.,Ratnadiwakara, D. and Zainudeen, A. (2011). Social influence in mobile phone adoption: evidence from the bottom of the pyramid in emerging Asia. *Mobile Telephony, Volume 7, Number 3, 1–18.* http://dx.doi.org/10.2139/ssrn.1564091

Simeonov, V. J., Stratis, C. J., Samara, G. J., Zachariadis, D., Voutsa, A., Anthemidis, M., Sofriniou, T.,& Koumtzis, T. (2003). Assessment of the surface water quality in Northern Greece. *Water Resources, 37(17),* 4119–4124.https://doi.org/10.1016/S0043-1354(03)00398-1

Simon, M. K., & Goes, J. (2011). Developing a theoretical framework. *Seattle, WA: Dissertation Success, LLC.* http://drannejonesuas.learningspaces.alaska.edu/wp-content/uploads/sites/15/2014/02/recipe-for-a-theoretical-framework.pdf

Simtowe, F., Asfaw, S., & Abate, T. (2016). Determinants of agricultural technology adoption under partial population awareness: the case of pigeonpea in Malawi. *Agricultural and Food Economics, 4(1),* 7. DOI:10.1186/s40100-016-0051-z

Singh, K. P., Malik, A., Mohan, D., & Sinha, S. (2004). Multivariate statistical techniques for the evaluation of spatial and temporal variations in water quality of Gomti River, India—a case study. *Water Research, 38(18),* 3980-3992. https://doi.org/10.1016/j.watres.2004.06.011

Siraj, M. (2011). A model for ICT based services for agriculture extension in Pakistan. *Retrieved from http://www.cabi.org date 15-09-2016.*

Sircar, S., & Choi, J. (2009). A study of the impact of information technology on firm performance: a flexible production function approach. *Information Systems Journal, 19(3),* 313-339. https://doi.org/10.1111/j.1365-2575.2007.00274.x

Snyder, H. (2019). Literature review as a research methodology: An overview and guidelines. *Journal of Business Research, 104,* 333-339. https:/ /doi. org /10. 1016/ j.jbusres. 2019.07.039

Somers, S., & Stapleton, L. (2012). Rethinking e-agriculture innovation using a human centred systems lens. *IFAC Proceedings Volumes, 45(10),* 97-102. https:// doi.org/ 10. 3182/20120611-3-IE-4029.00020

Sousa, F., Nicolay, G., & Home, R. (2016). Information technologies as a tool for agricultural extension and farmer-to-farmer exchange: Mobile-phone video use in Mali and Burkina Faso. *International Journal of Education and Development Using Information and Communication Technology, 12(3),* 19-36. https:// files. eric.ed. gov/fulltext/ EJ1124891.pdf

Stake, R. E. (2010). Qualitative research: Studying how things work. *Guilford Press.* https://www.guilford.com/books/Qualitative-Research/Robert-Stake/9781606235454/author

Stanley, J., Clouston, B., & Baker, R. (2006). Understanding land manager constraints to the adoption of changed practices or technological innovations: Literature review. *Charles Sturt University, Bathurst, NSW. https:// cdn. csu. Edu .au/ __data/assets/pdf_file/0009/ 703854/2006report33.pdf*

Stefano, L. A., Hendriks, S. L., Stilwell, C., & Morris, C. (2005). Printed information needs of small-scale organic farmers in KwaZulu-Natal. *Libri, 55(1),* 56-66. DOI:10.1515/LIBR.2005.56

Steinfield, C., & Wyche, S. (2013). Assessing the role of information and communication technologies to enhance food systems in developing countries: A FOCUS on Eastern and Southern Africa. DOI:10.13140/2.1.2794.4966

Stienen, J. (2007). How ICT can make a difference in agricultural livelihoods. https://agris.fao.org/agris-search/search.do?recordID=GB2013201669

Stoltzfus, J. C. (2015). Student's t-test for independent samples. *International Journal of Academic Medicine, 1(1),* 27.

Stryjak, J., & James, H. (2016). Country overview: Pakistan A digital future. *GSMA Head Office. London EC4N 8AF. United Kingdom.* https:// www. gsma. com/ mobilefordevelopment/ resources/ country-overview-pakistan-a-digital-future/

Sturges, R. P., & Neill, R. (1998). The quiet struggle: Information and libraries for the people of Africa. *Burns & Oates.* https://doi.org/10.1093/oxfordjournals.afraf.a008023

Sunding, D., & Zilberman, D. (2001). The agricultural innovation process: research and technology adoption in a changing agricultural sector. *Handbooks in Economics, 18(1A), 207-262.*https://doi.org/10.1016/S1574-0072(01)10007-1

Surry, D. W., & Farquhar, J. D. (1997). Diffusion theory and instructional technology. *Journal of Instructional Science and Technology, 2(1),* 24-36. https:// myweb. fsu. edu/ajeong /eme 5457/ readings/Surry1997_DiffusionTheoryInstrTech.pdf

Sutton, J., & Austin, Z. (2015). Qualitative research: Data collection, analysis, and management. The Canadian Journal of Hspital Pharmacy, 68(3), 226. DOI: 10.4212/cjhp.v68i3.1456

Swanson, B. E., & Rajalahti, R. (2010). Strengthening agricultural extension and advisory systems: procedures for assessing, transforming, and evaluating extension systems. *Agriculture and Rural Development, World Bank.* http://hdl.handle.net/10986/23993

Syiem, R., & Raj, S. (2015). Access and usage of ICT for agriculture and rural development by the tribal farmers in Meghalaya state of north-east India. *Agrárinformatika/Journal of Agricultural Informatics, 6(3)*, 24-41. DOI:10.17700/jai.2015.6.3.190

Tabachnick, B. G., Fidell, L. S., & Ullman, J. B. (2007). *Using multivariate statistics (Vol. 5, pp. 481-498). Boston, MA: Pearson.* https :// www. pearsonhighered. com/assets/ preface/0/1/3/4/0134790545.pdf

Tadesse, B. (2000). *Differential adoption of agricultural technologies: implications for the choice between growth and equity* (No. 5). Working Paper. https:// scholarworks. wmich. edu/africancenter_icad_archive/40/

Talukder, M. (2012). Factors affecting the adoption of technological innovation by individual employees: An Australian study. *Procedia-Social and Behavioral Sciences, 40*, 52-57. https://doi.org/10.1016/j.sbspro.2012.03.160

Tashakkori, A., & Teddlie, C. (Eds.). (2010). Sage handbook of mixed methods in social & behavioral research. *Sage*. https://dx.doi.org/10.4135/9781506335193

Tata, J. S., & McNamara, P. E. (2018). Impact of ICT on agricultural extension services delivery: evidence from the catholic relief services SMART skills and farm book project in Kenya. *The Journal of Agricultural Education and Extension, 24(1)*, 89-110. DOI:10.1080/1389224X.2017.1387160

Teddlie, C., & Tashakkori, A. (2003). Handbook of mixed methods in social & behavioral research. *Thousand Oaks, Calif: Sage Publications*. https:// methods. sagepub. com/ book/ sage-handbook-of-mixed-methods-social-behavioral-research-2e

Teddlie, C., & Tashakkori, A. (2009). Foundations of mixed methods research: Integrating quantitative and qualitative approaches in the social and behavioral sciences. *Sage.* https://www.amazon.com/Foundations-Mixed-Methods-Research-Quantitative/dp/0761930124

Tegegne, M. Y. (2014). ICT for good governance and agricultural development in Ethiopia; Local evidences from Southern Ethiopia. *SNNPR Survey. School of Governance and Development Studies, Hawassa University, Hawassa, Ethiopia.* DOI: 10.14662/IJPSD2015.001

Tekin, A. B. (2013). Current Status and Future Projections of ICT Use in Turkey. http://proceedings.cigr.org/uploads/2013/0377.pdf

Thapa, D., & Sæbø, Ø. (2014). Exploring the link between ICT and development in the context of developing countries: A literature review. *The Electronic Journal of Information Systems in Developing Countries, 64(1), 1-15.* DOI:10.1002/j.1681-4835.2014.tb00454.x

Thompson, B. (2004). Exploratory and confirmatory factor analysis: Understanding concepts and applications. *Washington, DC, 10694*. DOI:10.1037/10694-000

Thong, J. Y. L., Venkatesh, V., Xu, X., Hong, S. J., & Tam, K. Y. (2011). Consumer acceptance of personal information and communication technology service. *IEEE Transactions on Engineering Management, 58(4)*, 613-625. DOI: 10.1109/TEM.2010.2058851

Tirkaso, W. T., & Hess, S. (2015). The role of ICT expenditure for cash crop production and income generation in Southern Ethiopia. *The Electronic Journal of Information Systems in Developing Countries, 71(1),* 1-14. DOI:10.1002/j.1681-4835.2015.tb00511.x

Tirkaso, W., & Hess, S. (2018). Does commercialisation drive technical efficiency improvements in Ethiopian subsistence agriculture? *African Journal of Agricultural and Resource Economics, 13*, 44-57. DOI: 10.22004/ag.econ.273136

Tomarken, A. J., & Serlin, R. C. (1986). Comparison of ANOVA alternatives under variance heterogeneity and specific noncentrality structures. *Psychological Bulletin, 99(1)*, 90. DOI:10.1037/0033-2909.99.1.90

Trochim, W. M., & Donnelly, J. P. (2001). Research methods knowledge base (Vol. 2). *Cincinnati, OH: Atomic Dog Publishing.*

Uehara, H. (2016). Application of information and communication technology to agriculture and animal husbandry. *Feature Articles: NTT Group Activities in the Agricultural Field, 14(6).* https:// www. researchgate. net/ publication/ 305430763_ Application_ of_information_and_communication_technology_to_agriculture_and_animal_husbandry

University of Arizona Military Reach. (2009). Understanding t-tests. *The Arizona Center for Research and Outreach (AZ REACH), USA.* http:// gabrielschlomer. weebly. com/ uploads/ 2/8/8/5/28853963/understanding_t_test_0.pdf

Urgesa, B. (2014). A Study on smallholder farmers' use of Information and Communication Technologies (ICT) to get access to agricultural and market information. *Unpublished Doctoral Dissertation, Addis Ababa University.* http:// 213.55.95.56/ bitstream/ handle/ 123456789/3694/Bayissa%20Urgesa%20Gurmu.pdf?sequence=1&isAllowed=y

Usman, N., & Said, I. (2012). An Assessment of the determinants of ICT acceptance among the construction realm in Nigeria. *International Journal of Academic Research, 4(2).* https://www.academia.edu/download/37120544/determinant_201216A-15_1_.pdf

Van ark, B., Timmer, M. & Ypma, G. 2003. IT in the European Union: Driving productivity divergence? *University of Groningen.*https://ideas.repec.org/p/gro/rugggd/200363.html

Vangala, R. N. K., Hiremath, B. og Banerjee, A. (2014). A theoretical framework for knowledge management in indian agricultural organizations. Í *Proceedings of the 2014 International Conference on Information and Communication Technology for Competitive Strategies. (pp. 1-7).* DOI:10.1145/2677855.2677861

Venkatasubramanian, V., & Mahalakshmi, P. (2012). Innovative institutional approaches for Agricultural Knowledge System management in India. DOI:10.1787/9789264167445-13-en

Venkatesh, V., Thong, J. Y., & Xu, X. (2016). Unified theory of acceptance and use of technology: A synthesis and the road ahead. *Journal of the Association for Information Systems, 17(5),* 328-376. DOI:10.17705/1jais.00428

Viatte, G. (2001). Adopting technologies for sustainable farming systems: An oecd perspective. Í *Adoption of Technologies for Sustainable Farming Systems Wageningen Workshop Proceedings(p.14).* https:// www. oecd. org/ greengrowth/ sustainable-agriculture/2739771.pdf

Wainwright, D. W., & Waring, T. S. (2007). The application and adaptation of a diffusion of innovation framework for information systems research in NHS general medical practice. *Journal of Information Technology, 22(1),* 44-58. https:// doi.org/ 10.1057/palgrave.jit.2000093

Walliman, N. (2017). Research methods: The basics. *Routledge.* ISBN 9781138693999

Walsham, G. (2017). ICT4D research: reflections on history and future agenda. *Information Technology for Development, 23(1),* 18-41. https:// doi. org/10. 1080/02681102. 2016.1246406

Waqar, M., Gu, R., & Nie, F. (2018). Mapping ICT Use along the citrus (Kinnow) value chain in Sargodha District, Pakistan. *Sustainability, 10(12),* 4743. DOI:10.3390/su10124743

Waverman, L., Meschi, M., & Fuss, M. (2005). The impact of telecoms on economic growth in developing countries. *The Vodafone policy paper series, 2(03),* 10-24. https://www.assignmentpoint.com/wp-content /uploads /2012/04/L_ Waverman_ Telecoms _Growth_in_Dev_Countries.pdf

Weerakkody, V., Janssen, M., & Dwivedi, Y. K. (2009). *Handbook of research on ICT-enabled transformational government: A global perspective. Hershey, NY: Information Science Reference.*https://www.amazon.com/Handbook-Research-ICT-Enabled-Transformational-Government/dp/1605663905

Wei, L. H., Osman, M. A., Idrus, R., Sabudin, M., & Shiang-Yen, T. (2012). Factors influencing a new information and communication technology adoption in Malaysia's agriculture community: applying the sustainable livelihoods approach. International *Journal of eBusiness and eGovernment Studies, 4(2),* 51-60. https://dergipark.org.tr/en/pub/ijebeg/issue/26199/275850

Wiggins, S. (2014). Rural non-farm economy: current understandings, policy options, and future possibilities. *New Directions for Smallholder Agriculture. Oxford University Press, Oxford*, 1-46.

Wijekoon, R., & Rizwan, M. F. M. (2011). Cyber Extension: An ICT initiative for strengthening agricultural extension in Sri Lanka. *Success Stories on ICT/ICM in AR4D in Asia and the Pacific Region, 23.* https:// www. academia. edu/ download/ 51816419/ Success_Stories_on_ICTICM_in_AR4D_in_AP_Region_2011.pdf#page=36

Wilcox, R. R., Granger, D. A., & Clark, F. (2013). Modern robust statistical methods: Basics with illustrations using psychobiological data. *Universal Journal of Psychology, 1(2),* 21-31. DOI:10.13189/ujp.2013.010201

Williams, E. E., & Agbo, M. I. S. (2013). Evaluation of the use of ICT in agricultural technology delivery to farmers in Ebonyi State, Nigeria. *Evaluation, 3(10*). https://www.academia.edu/download/32182008/Evaluation_of_the_Use_of_Ict_in_Agricultural_Technology_Delivery_to_Farmers_in_Ebonyi_State__Nigeria..pdf

Winkelmann, R. (2008). Econometric analysis of count data. *Springer Science & Business Media*. https://link.springer.com/chapter/10.1007/978-3-540-78389-3_3

Wold, S., Esbensen, K., & Geladi, P. (1987). Principal component analysis. *Chemometrics and Intelligent Laboratory Systems, 2(1-3),* 37-52. https:// doi. org/ 10.1016/0169-7439(87) 80084-9

World Bank. (2008). World Development Report. *Washington, DC: World Bank.*

World Bank. (2011). ICT in agriculture: Connecting smallholders to knowledge, networks, and institutions. Report Number 64605. *The World Bank, Washington DC.* https://doi.org/10.1596/12613

Yaseen, M., Shiwei, X., Wen, Y., & Hassan, S. (2015). Policy challenges to agricultural extension system in Pakistan: a review. *International Journal of Agricultural Applied Sciences, 7(2).*https://www.researchgate.net/publication/304217310_Policy_Challenges_to_Agricultural_Extension_System_in_Pakistan_A_Review

Yim, K. H., Nahm, F. S., Han, K. A., & Park, S. Y. (2010). Analysis of statistical methods and errors in the articles published in the Korean Journal of Pain. *The Korean Journal of Pain, 23(1),* 35. DOI:10.3344/kjp.2010.23.1.35

Yirga, C., Shapiro, B. I., & Demeke, M. (1996). Factors influencing adoption of new wheat technologies in Wolmera and Addis Alem areas of Ethiopia. *Ethiopian Journal of Agricultural Economics (Ethiopia).* https://agris.fao.org/agris-search/ search. do?recordID=ET9700049

Yong, A. G., & Pearce, S. (2013). A beginner's guide to factor analysis: Focusing on exploratory factor analysis. *Tutorials in Quantitative Methods for Psychology, 9(2),* 79-94.DOI:10.20982/tqmp.09.2.p079

Yvonne Feilzer, M. (2010). Doing mixed methods research pragmatically: Implications for the rediscovery of pragmatism as a research paradigm. *Journal of Mixed Methods Research, 4(1), 6-16.* DOI:10.1177/1558689809349691

Zahoor, A., and Arocha, M. (2014). (TAP) Kinnow (Citrus) - Value Chain Competitiveness Assessment. Retrieved from *http://pdf.usaid.gov/pdf_docs/PA00KN2T.pdf*

Zaremohzzabieh, Z., Samah, B., Omar, S., Bolong, J., & Shaffril, H. (2014). A systematic review of qualitative research on the role of ICT in sustainable livelihood. *The Social Sciences, 9(6),* 386-401. DOI:10.3923/sscience.2014.386.401

Zarmai, J. U., Okwu, O. J., Dawang, C. N., & Nankat, J. D. (2014). A review of information needs of rice farmers: a panacea for food security and poverty alleviation. *Journal of Economics and Sustainable Development, 5(12),* 9-15. http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.1017.8620&rep=rep1&type=pdf

Zaverdinos-Kockott, A. (2004). An information needs assessment in Oribi village, Pietermaritzburg. *Innovation, 29(1),* 13-23.

Zewge, A., & Dittrich, Y. (2017). Systematic mapping study of information technology for development in agriculture (the case of developing countries). *The Electronic Journal* *of Information Systems in Developing Countries, 82(1),* 1-25. DOI:10.1002/j.1681-4835.2017.tb00602.x

Zhang, T., Shen, S., Cheng, C., Song, C., & Ye, S. (2018). Long-range correlation analysis of soil temperature and moisture on A'rou hillsides, Babao river basin. *Journal of Geophysical Research: Atmospheres*, *123(22)*, 12-606. DOI:10.1029/2018JD029094

Zhang, Y., & Yu, L. (2009). Information for social and economic participation: A review of related research on the information needs and acquisition of rural Chinese. *The International Information & Library Review*, *41(2),* 63-70. https://doi.org/10.1016/j.iilr.2009.03.001

Zhao, Y., Zhang, R., & Klein, K. K. (2009). Perceived information needs and availability: results of a survey of small dairy farmers in inner Mongolia. *Information Research*, *14(3).*

Zia, A., & Khan, A. (2012). Media coverage for the development of agriculture sector: An analytical study of television channels in Pakistan. *Journal of Agriculture Research, 50(4*), 555-564. https:// apply. jar. punjab. gov. pk/ upload/ 1374745826_97_548__555 paper10.pdf

Zimmerman, D. W. (2004). A note on preliminary tests of equality of variances. *British Journal of Mathematical and Statistical Psychology*, *57(1),* 173-181. https:// doi.org/ 10. 1348/ 000711004849222

Appendices

Apendix-1: Ethics Approval Letter

UNIVERSITY OF CANBERRA

24 October 2017

APPROVED - Project number 17-231

Mr Nadeem Akmal
Faculty of Education, Science, Technology and Maths
University of Canberra
Canberra ACT 2601

Dear Nadeem,

The Human Research Ethics Committee has considered your application to conduct research with human subjects for the project titled: ***"Investigation of the role and impact of Information Communication Technologies (ICTs) in livelihood improvement of small and large citrus farming households in Pakistan"***

Approval is granted until 31 December 2019

The following general conditions apply to your approval.

These requirements are determined by University policy and the ***National Statement on Ethical Conduct in Human Research*** (National Health and Medical Research Council, 2007).

Monitoring:	You must, in conjunction with your supervisor, assist the Committee to monitor the conduct of approved research by completing project review forms, and in the case of extended research, at least annually during the approval period.
Reporting Adverse Events	You must, in conjunction with your supervisor, report any unexpected adverse events or complications that occur anytime during the conduct of the research study or during the follow up period after the research. Please refer these matters promptly to the HREC. Failure to do so may result in the withdrawal of the Ethics approval.
Discontinuation of research:	You must, in conjunction with your supervisor, inform the Committee, giving reasons, if the research is not conducted or is discontinued before the expected date of completion.
Extension of approval:	If your project will not be complete by the expiry date stated above, you must apply in writing for extension of approval. Application should be made before current approval expires; should specify a new completion date; should include reasons for your request.
Retention and storage of data:	University policy states that all research data must be stored securely, on University premises, for a minimum of five years. You must ensure that all records are transferred to the University when the project is complete.
Contact details and notification of changes:	All email contact should use the UC email address. You should advise the Committee of any change of address during or soon after the approval period including, if appropriate, email address(es).

Yours sincerely
Human Research Ethics Committee

Maryanne Simpson
Research Ethics & Integrity
Research Services
T (02) 6206 3916
E maryanne.simpson@canberra.edu.au

T +61 (0)2 6201 5111
W www.canberra.edu.au

University of Canberra
Locked Bag 1
ACT 2601 Australia

Apendix-2: Survey Questionnaire

Role and Impact of Information Communication Technologies (ICT) in Livelihood Improvement of Citrus Farmers

Survey/Interview identification and site classification

Date of interview		Village	
Tehsil		District	

Respondent information

Name of the Respondent		Contact # of the Respondent	
Education of the Respondent (Years)		Age of the respondent (Years)	
Farming experience of the Respondent (Years)		Involvement in farming (1=full time 2=part time)	
Membership of any village organizations? 1. Yes 2. No		Any position in the village organizations? 1. Yes 2. No	
Level of active interaction with other farmers in farming activities? 1. No interaction 2. Low 3. Medium 4.High		Level of active interaction with other farmers in social activities of the village? 1. No interaction 2. Low 3. Medium 4.High	
How many times do you provide guarantees for other farmers for purchasing inputs and money lending? (#)		Does respondent has active interaction in input/output markets? 1. No interaction 2. Low 3. Medium 4.High	
Respondent Relation to H.H. Head[a]		Education of HH Head (years)	
Household head status in community			

(a) 1=Self 2= Brother, 3=Son, 4=Uncle, 5= Father, 6=Other (specify)

Family Composition and Education level

Type of farm family (1=Joint, 2=Nuclear)				
Total family size* (#)				
	Male<18 years	Female<18 years	Male>18 years	Female>18 years
Family members (#)				
Primary education level of family members (#)				
Middle education level of family members (#)				
Secondary education level of family members (#)				
Intermediate education level of family members (#)				
Graduate education level of family members (#)				
Post graduate education level of family members (#)				

Household Assets

Does your household own its house? (1. Yes 2.No)	
What is the area of your house including boundary walls? Marla (160 Marla=1 acre)	
What is the price of land in the village? (Rs/Marla)	
How many cemented (paccy) rooms do you have in the home? (#)	
How many mud (kachy) rooms do you have in home? (#)	
What is the average construction cost for one cemented(pacca) room at village level (Rs)	
What is the average construction cost for one mud (kacha) room at village level (Rs)	
Electricity availability? 1.Yes 2.No	
What fuel sources do you use? 1. Fuel wood 2 Electricity 3 Natural Gas. 4. LPG 5.Biogas 6.	

Farm and Household Assets

Farm Assets				Household Assets			
Items	**#**	**Items**	**#**	**Items**	**#**	**Items**	**#**
Tractor		Trolley		TV		Motor Bike	
Thresher		Spray pump		Sewing Machine		Car/Pickup	
Cultivator		Diesel Engine		Refrigerator		Washing Machine	
Disk Plough		Tube well		Radio		Other____	
Drill		Other---------		CD player		Other____	

Employment Status of Family Members and Permanent Hired Farm Labor

	Male		Female	
How many are working on the farm full time? (#)				
How many are working on the farm part time? (#)				
How many are working off farm? (#)*				
Total income from off farm work (Rs./Month)				
Retired from government service? (#)				
Pension (Rs./Month)				
Permanent **Hired Farm Laborers** #_______		Wages of permanent hired farm laborers, including all in-kind benefits		

*Include working abroad

SECTION: FARMING SYSTEM AND LAND RESOURCES

Farm size and tenancy status (Acres)

	Own land			Share		Lease		Total Operational Land
	Total	un-cultivable	cultivable	In	Out	In	Out	
	A	b	c	d	e	f	g	H
Area (Acres)								
Share percent?								
Lease rate? (Rs/acre/year)								
Land type? *codes**								
Main source of irrigation? *codes:***								
Power source for tube well? *codes:****								
**1 = sandy, 2 = sandy loam, 3 =loam, 4 = clay 5=Chamb 6=Saline/Kalarathi 7=Rohi/pacci*								
***1=canal; 2=tubewell; 3=canal+tubewell; 4=other (specify)*								
****1=electricity; 2=Peter Engine; 3=Tractor; 4=Other (Specify)* -----								
Canal water availability. *1. Scarce 2. Sufficient*								

Note: Total operational land = Total owned cultivated land + Share in + Lease in – Share out – Lease out*

Cropping Pattern

Sr.No	Crops Rabi 2016-17	Area(Acres)	Production (Maunds)	Price/Unit	Production Cost(Rs/Acre)	Crops Kharif -2017	Area(Acres)	Production (Maunds)	Price/Unit	Production Cost(Rs/Acre)
1	Citrus					Citrus				
2	Wheat					Cotton				
3	Canola/Sarson					Maize				
4	Sugarcane					Sugarcane				
5	Fodder(Berseem)					Fodder				
6	Other-----------					Other------				
7	Other-----------					Other------				
8	Fallow					Fallow				

Livestock

Livestock Inventory			
Animals	**(No)**	**Animals**	**(No)**
Milking Buffalo		Heifers	
Milking Cow		Young stock	
Dry Buffalo		Sheep/ Goat	
Dry Cow		Other	
Other information related to Livestock			
Income from sale of animals last year (Rs)		Income from other livestock byproducts (Rs/Year)	
Expenditures on purchase of animals last year (Rs)		Expenditures in purchasing cotton seed cake, wanda etc. (Rs/Month)	
Average milk production around the year (liters/Day)		Expenditures for animals treatment (Rs/Year)	
Average milk sale around the year (liters/Day)		Any other	
Average milk price around the year (Rs/Liter)			

Adoption, Knowledge and Use of ICT

Sr. No.	**ICT Gadgets**	**Are you aware of this device** ***1. Yes 2. No***	**Total Nos. of ICT in the family (#)**	**Do you use personally?** ***1. Yes 2. No***	**Period of using the device? (*Years*)**	**Prime purpose of using this device***	**Secondary purpose of using this device***	**Level of skill of using these ICT ****	**Average time spent (*hrs/week*)**	**Average time spent for Agri. (*hrs/week*)**	**Average time spent for citrus (*hrs/week*)**	**Total cost (*Rs/month*)**
1	Normal Mobile phone											
2	Smart phone using internet											
3	Radio											
4	TV											
5	Telephone Fixed line											
6	Computer											
7	Internet on Computer											
8	Data Storage & Analysis											
9	Satellite											
10	Sensor Networks											

*1=Social interaction 2=Agriculture (prices, crop/livestock management, weather updates, etc.) 3=Other business 4=Entertainment 5=Other (specify) ------- [*more than one choice applies here*]

**1=No skill 2=beginner, 3=competent, 4=expert

Some other information related to Mobile, Computer and Internet use

1.	Do you use social media on your phone? E.g. Facebook, WhatsApp, viber, etc. [1=Yes, 2=No]	
2.	If Yes, which apps do you use? 1, Face book 2. Whatsapp 3.Viber 4. Imo 5. Skype 6. Other------	
3.	How much do you use social media for agriculture purposes? [1= not at all 2=A little 3=some what 4= a lot]	
4.	Do you use social media using internet on computer? E.g. Facebook, WhatsApp, viber, etc. your computer? [1=Yes, 2=No]	
5.	If Yes, which apps do you use? 1, Face book 2. Whatsapp 3.Viber 4. Imo 5. Skype 6. Other------	
6.	How much do you use social media for agriculture purposes? [1= not at all 2=a little 3=some what 4 = a lot]	
7.	Do you use internet on smart phone for searching websites? E.g. you tube, weather, agriculture websites etc. [1=Yes, 2=No]	
8.	How often do you use website searching for agriculture purposes? [1= not at all 2=A little 3=some what 4= a lot)	
9.	Please name websites used for agriculture 1.----------------- 2.----------------- 3.-----------------	
10.	Do you use internet on computer for searching websites? E.g. you tube, weather, agriculture websites etc. [1=Yes, 2=No]	
11.	How much do you use website searching for agriculture purposes? [1= not at all 2=A little 3=some what 4= a lot)	
12.	Please name websites used for agriculture 1.----------------- 2.----------------- 3.-----------------	
13.	Rate your children's skill level using smart phone (if they use?) [1=beginner, 2=competent, 3=expert 4 =NA]	
14.	Rate your children's skill level using computer (if they use?) [1=beginner, 2=competent, 3=expert4 =NA]	
15.	Do you get help from children in use of ICT? [1=Yes, 2=No]	
16.	If yes, 1. Operating ICT 2. Acquiring agricultural information specifically 3. Both	
	Financial Transactions using ICT	
17	Have you ever used a mobile phone or internet banking for financial services? *1.Yes; 2. No*	
18	If Yes 1. Phone banking 2. Internet banking 3.Both	
19	Do you have mobile money account? (Please encircle the code): *1.Yes; 2. No*	
20	If yes, what type of services do you obtain? (Indicate as many as applicable). *1. Money transfer for non-agricultural activities 2. Money transfer for agricultural purposes 3. Utility bill payment, 4. Balance top up service, 5. Educational Payment, 6. Online Shopping, 7. any other*------------	
21	If internet banking, what type of services do you obtain? (Indicate as many as applicable*1. Money transfer for non-agricultural activities 2. Money transfer for agricultural purposes 3. Utility bill payment, 4. any other*------------	

Information Related to Citrus using ICT

	ICT ERA							Before ICT ERA(5 years before)				
Information	Frequency of getting information*	What is the main source of information? **	What is the communication Sources? ***	What is the method/kind of information using ICT? ****	How do you rate its effectiveness? *****	If fellow farmer is the main source, What is his main source of information? **	If fellow farmer is the main source, What is the communication Sources?	Frequency of information*	What was the main sources of information **	What was the communication Sources? ** *	What was the methods/kind of information using ICT?	How do you rate its effectiveness? *****
New varieties(types)/ Nurseries of good/high repute												
Citrus pruning, hoeing and weed control												
Water and other resource saving technologies												
Rainfall, temperature updates												
Fog incidence												
Diagnosing citrus diseases, insects/ pests and the control/ loss minimizing measures												
Insecticides/pesticides purchase (price and quality)												
Fertilizer application (price, quality and use)												
Information on pre-harvest contract prices of citrus orchards												
Info. on minimizing post-harvest losses/handling												
Citrus wholesale prices in markets												
Labor arrangements												
Other-------												
International Trade Aspects												

General trade in citrus fruits												
Daily price updates in international markets												
Other-------												

[*] 0=No need/Never 1=Daily; 2=twice in a week; 3=Once in a week; 4= Fortnightly; 5=Monthly 6=Bi monthly 7= Quarterly 8=1-2 times in a season; 9=Yearly

***(1) Input/output dealer, (2) Agriculture Extension, (3) Fellow Farmer, (4) Farmer Organization, (5) Research department (6) Contractor/ Beopari, (7)Arhti/commission Agent, (8) Agricultural college/University (9)Private seed/pesticide companies--------(10)Private agricultural consultancy firms--------(11) Met Department, (12)Websites (13)Pre-harvest contractors(90) Other (Please Specify-----------)*

**** (1) Personal visit (2) Mobile (3) Radio (4) Tv (5) Computer (6) Internet using mobile (7) Internet using computer (8) Telephone (9) Free call Telephone Agri. Service (10) Newspapers/Agricultural Magazines (11) Fellow farmer using ICT (12) Other-----------*

***** Kind of information: (1) Verbal information sharing (2) Verbal+ practical orientation(3) SMS (in English (5) SMS (in Urdu), (6) Voice Message (in Urdu), (7) personal call (in Urdu), (8) Usb,CDs (9) website visits (10)Social Media(11)advertisements at radio(12)advertisements at Tv (13)Agricultural programs at TV(14) Agricultural programs at radio (15) Others (specify)*
***** 1=Not effective 2= to some extent 3= effective 4= Very effective
*******) Reasons for not using☹1)high price/costly,(2)not useful information,(3)not received on time,(4)poor quality,(5)service not available any more,(6)Cannot understand the content,(7)Don't trust the information,(90)Others(Specify)*

Information Related to Field Crops (e.g. wheat, rice, Sugarcane, etc.) using ICT

	ICT ERA							Before ICT ERA(5 years before)				
Information	Frequency of getting information*	What is the main source of information? **	What is the communication Sources? ***	What is the method/kind of information using ICT? ****	How do you rate its effectiveness? ****	If fellow farmer is the main source, What is his main source of information? **	If fellow farmer is the main source, What is the communication Sources? ***	Frequency of information*	What was the main sources of information? **	What was the communication Sources? ** *	What was the methods/kind of information using ICT? ****	How do you rate its effectiveness? *****
New crop varieties												
Seed quality and price												
land preparation methods												
Improved weed control methods												
Water and other resource saving technologies												
Fertilizer prices, quality and application												
Rainfall & Temperature updates												
Diagnosing diseases /insects/pests and their control/loss minimizing measures												
Other inputs prices and quality (e.g. chemicals) in local and other cities of Pakistan												
Information on minimizing post-harvest losses on crops												
Wholesale prices of different markets												
Labor arrangements												
Other												

International Trade Aspects												
Status of Pakistan’s in various crops												
Daily price updates in international markets												
Other												

[*] 0=No need/Never 1=Daily; 2=twice in a week; 3=Once in a week; 4= Fortnightly; 5=Monthly 6=Bi monthly 7= Quarterly 8=1-2 times in a season; 9=Yearly

***(1) Input/output dealer, (2) Agriculture Extension, (3) Fellow Farmer, (4) Farmer Organization, (5) Research department (6) Contractor/ Beopari, (7)Arhti/commission Agent, (8) Agricultural college/University (9)Private seed/pesticide companies--------(10)Private agricultural consultancy firms--------(11) Met Department, (12)Websites (13)Pre-harvest contractors(90) Other (Please Specify-----------)*

**** (1) Personal visit (2) Mobile (3) Radio (4) Tv (5) Computer (6) Internet using mobile (7) Internet using computer (8) Telephone (9) Free call Telephone agri. Service (10) Newspapers/Agricultural Magazines (11) Fellow farmer using ICT (12) Other-----------*

***** Kind of information: (1) Verbal information sharing (2) Verbal+ practical orientation (3) SMS (in English (5) SMS (in Urdu), (6) Voice Message (in Urdu), (7) personal call (in Urdu), (8) Usb,CDs (9) website visits (10)Social Media(11)advertisements at radio(12)advertisements at Tv (13)Agricultural programs at TV(14) Agricultural programs at radio (15) Others (specify)*

***** 1=Not effective 2= to some extent 3= effective 4= Very effective

*******) Reasons for not using☹1)high price/costly,(2)not useful information,(3)not received on time,(4)poor quality,(5)service not available any more,(6)Cannot understand the content,(7)Don’t trust the information,(90)Others(Specify)*

Information Related to Livestock using ICT

	ICT ERA							Before ICT ERA(5 years before)				
Information	Frequency of getting information*	What is the main source of information? **	What is the communication Sources? ***	What is the method/kind of information using ICT? ****	How do you rate its effectiveness? *****	If fellow farmer is the main source, What is his main source of information? **	If fellow farmer is the main source, What is the communication Sources? ***	Frequency of information*	What was the main sources of information **	What was the communication Sources? ** *	What was the methods/kind of information using ICT? ****	How do you rate its effectiveness? *****
Information about improved fodder varieties												
Information about methods of preparing more nutritious animal feeds or balance ration												
Prices of oilseed cakes (cotton, mustard) ,*wanda* in wholesale and retail markets												
Prices of dry stalk (wheat straw etc.)												
Prices of *rabi* and kharif fodders in standing fields												
Milk prices offered and fetched by milkmen												
Milk prices at milk collection centers of various dairy industries in your area												
Information about milk specifications demanded at various milk collection enter												
Information about commercial dairy farming												

Prevailing prices of large ruminants in livestock markets/ beoparies												
Prevailing prices of small ruminants in livestock markets/beoparies												
Contacting veterinary doctor for treating the sick animals												
Contacting veterinary pharmacy for the veterinary medicines												
Labor arrangement												
Other												

* 0=No need/Never 1=Daily; 2=twice in a week; 3=Once in a week; 4= Fortnightly; 5=Monthly 6=Bi monthly 7= Quarterly 8=1-2 times in a season; 9=Yearly

***(1) Input/output dealer, (2) Agriculture Extension, (3) Fellow Farmer, (4) Farmer Organization, (5) Research department (6) Contractor/ Beopari, (7)Arhti/commission Agent, (8) Agricultural college/University (9)Private seed/pesticide companies--------(10)Private agricultural consultancy firms--------(11) Met Department, (12)Websites (13)Pre-harvest contractors(90) Other (Please Specify-----------)*

**** (1) Personal visit (2) Mobile (3) Radio (4) Tv (5) Computer (6) Internet using mobile (7) Internet using computer (8) Telephone (9) Free call Telephone Agri. Service (10) Newspapers/Agricultural Magazines (11) Fellow farmer using ICT (12) Other-----------*

***** Kind of information: (1) Verbal information sharing (2) Verbal+ practical orientation(3) SMS (in English (5) SMS (in Urdu), (6) Voice Message (in Urdu), (7) personal call (in Urdu), (8) Usb,CDs (9) website visits (10)Social Media(11)advertisements at radio(12)advertisements at Tv (13)Agricultural programs at TV(14) Agricultural programs at radio (15) Others (specify)*

***** 1=Not effective 2= to some extent 3= effective 4= Very effective

*******) Reasons for not using☹1)high price/costly,(2)not useful information,(3)not received on time,(4)poor quality,(5)service not available any more,(6)Cannot understand the content,(7)Don't trust the information,(90)Others(Specify)*

Time and Cost in Attaining Information for Agriculture

Sr.No	Activity	Time	Cost (PKR)
1	Time per mobile call (Minutes)		
2	Time personal visiting fellow farmer (Hrs/visit)		
3	Time visiting input dealer, agri. Extension etc. (Hrs/visit)		
4	Traveling Expenditure currently (ICT Era) (Rs/Month)		
5	Traveling Expenditure five years earlier (Before ICT Era) (Rs/Month)		
6	Other		

Innovative Practices Introduced/Adopted by ICT Devices and Software

Have you introduced/adopted any of the following innovative methods in your farm during the last two years?		1. Yes 2. No	Name of innovation/Innovative practice	Knowledge source*	**Communication Source** **	Information communication Method***
1	New/good quality citrus variety/types					
2	New methods other than traditional methods for citrus management (hoeing, pruning, nutrient management etc.?					
3	Did you adopt any new plant protection technology/practices for citrus?					
4	Improved irrigation practices (e.g., installation of efficient irrigation system/method) for citrus?					
5	New methods other than traditional methods for citrus harvest post-harvest management?					
6	Did you introduced any marketing strategy for citrus?					
7	New crop variety/seed?					
8	New methods other than traditional methods for crops management?					
9	New nutrients management/application technology (combination of doses) for crops?					
10	Any new plant protection technology/practices for crops?					
11	Improvement in irrigation practices (e.g., efficient irrigation method) for crops?					

12	Any resource conservation related innovative technology for citrus and other crops?					
13	Any new equipment for any of the farm operations (e.g., cultivation, planting, fertilising, spraying or harvesting)?					
14	Have you tried any improved varieties of cereal crops, fruit or vegetables?					
15	Livestock management and marketing related innovative technology?					
16	Other					

**(1) Input/output dealer, (2) Agriculture Extension, (3) Fellow Farmer, (4) Farmer Organization, (5) Research department (6) Contractor/ Beopari, (7)Arhti/commission Agent, (8) Agricultural college/University (9)Private seed/pesticide companies--------(10)Private agricultural consultancy firms--------(11) Met Department, (12)Websites (13)Pre-harvest contractors(90) Other (Please Specify-----------)*

*** (1) Personal visit (2) Mobile (3) Radio (4) Tv (5) Computer (6) Internet using mobile (7) Internet using computer (8) Telephone (9) Free call Telephone Agri. Service (10) Newspapers/Agricultural Magazines (11) Fellow farmer using ICT (12) Other-----------*

**** Kind of information: (1) Verbal information sharing (2) Verbal+ practical orientation(3) SMS (in English), (4) Voice message (in English), (5) Personal Call (in English), (6) SMS (in Urdu), (7) Voice Message (in Urdu), (8) personal call (in Urdu), (9) Usb,CDs (10) website visits (11)Social Media(12)advertisements at radio(13)advertisements at Tv (14)Agricultural programs at TV(15) Agricultural programs at radio (16) Others (specify)*

Attitude/Perception Measurement

Sr.No	Statements	Score*	Which ICT mainly?
1	ICTs increase adoption of innovative technologies/new farming practices		
2	ICTs improve market access for produce		
3	ICTs increase farmers income with better market price information and negotiation		
4	ICTs increase access to financial sources		
5	ICTs improve farm management practices due to easy access to agricultural departments		
6	ICTs improve social interaction between farmers which contributes to efficiency		
7	ICTs reduce dependency on agriculture extension services		
8	ICT based extension services assist the farmer in planning and decision making aspects in agriculture		
9	Easy and cheaper access to accurate and timely information		
10	Farmers can get low prices and quality of inputs using ICT.		
11	Phone-in-live with scientists gives first-hand information about queries.		
12	ICTs based extension services provide new opportunity to build a skilled and Knowledge community.		
13	Weather forecasting through ICT assists farmers in timely decisions.		
14	ICTs provide possible solutions to the present agricultural situation.		
15	Cheaper and Better Storage and Retrieval of information		
16	Other		

	Negative Statements		
17	ICTs cannot meet location specific needs of the farmers		
18	Illiteracy will not deter farmers in availing ICT services.		
19	Existing infrastructure of ICT is not enough to meet the needs of the farming Community.		
20	ICT is a valuable tool, but it will never influence farmers' own decision making.		
21	Only resourceful farmers can get the benefit of the ICT		

***Scale Undecided=1 Strongly Disagree =2 Disagree =3 To Some Extent Agree=4 Agree = 5 Strongly Agree =6**

On a scale of 1 -4* how would you rank the impact of the following limiting factors on your use of ICT?

Sr.No	Limiting Factors	Scale	Which ICT?-Remarks
1	Lack of ICT knowledge		
2	Lack of access to ICT		
3	High cost of ICT services		
4	No interest in ICT usage		
5	Difficulties in ICT use, specifically mobile and Internet etc.		
6	No trust in content delivered through ICT		
7	Lack of ICT need		
8	Language problem		

* 1= No impact 2= some impact 3= Moderate impact 4 = Great impact

On a scale of 1-5* what is your level of priority for information, information source regarding different crops, livestock production practices and usefulness of ICT?

Sr.No		Priority*	Knowledge Source**	Preferable ICT***	Information Kind****
1	Arranging service providers in backward linking sectors (tractor, transport, labour etc.)				
2	Arranging service providers in forward linking sectors (processors, traders, market intermediaries, transport, labour etc.)				
	Seeking information for crops varieties and certified seed				
3	Seeking information/solutions for problems faced in production process(all management practices)				
4	In timely planning the overall production process(purchasing and application of inputs)				

5	Seeking information/solutions for problems faced in marketing process (prices, markets, packaging etc.)				
6	Weather information (rainfall, temperature, fog etc.,)				
7	Seeking information related to livestock production/ management practices)				
9	Seeking information for livestock inputs purchase and use (cotton seed, wanda etc.)				
10	Seeking information in marketing of live animals and the milk				
10	Seeking information/facilities for animal's treatment.				
11	Other				
12	Other				

***Scale (**1=not at all, 2=a little, 3=somewhat, 4 =very important, 5=critically important)

***(1) Input/output dealer, (2) Agriculture Extension, (3) Fellow Farmer, (4) Farmer Organization, (5) Research department (6) Contractor/ Beopari, (7)Arhti/commission Agent, (8) Agricultural college/University (9)Private seed/pesticide companies--------(10)Private agricultural consultancy firms--------(11) Met Department, (12)Websites (13)Pre-harvest contractors(90) Other (Please Specify-----------)*

**** (1) Personal visit (2) Mobile (3) Radio (4) Tv (5) Computer (6) Internet using mobile (7) Internet using computer (8) Telephone (9) Free call Telephone Agri. Service (10) Newspapers/Agricultural Magazines (11) Fellow farmer using ICT (12) Other-----------*

***** Kind of information: (1) Verbal information sharing (2) Verbal+ practical orientation(3) SMS (in English), (4) Voice message (in English), (5) Personal Call (in English), (6) SMS (in Urdu), (7) Voice Message (in Urdu), (8) personal call (in Urdu), (9) Usb,CDs (10) website visits (11)Social Media(12)advertisements at radio(13)advertisements at Tv (14)Agricultural programs at TV(15) Agricultural programs at radio (16) Others (specify)*

Perceived Usefulness and Ease in Use of Various ICT and internet services (Encircle the relevant rank)

Items	Usefulness of ICT*					Relative Ease of Use Ranking**				
Common Communication Technologies										
Normal Mobile phone	1	2	3	4	5	1	2	3	4	5
Smart phone using internet	1	2	3	4	5	1	2	3	4	5
Radio	1	2	3	4	5	1	2	3	4	5
TV	1	2	3	4	5	1	2	3	4	5
Telephone Fixed line	1	2	3	4	5	1	2	3	4	5
Computer	1	2	3	4	5	1	2	3	4	5
Internet on Computer	1	2	3	4	5	1	2	3	4	5
Common Internet Services										
Social Media (Face book)	1	2	3	4	5	1	2	3	4	5
Social Media (WhatsApp, Viber, skype etc.)	1	2	3	4	5	1	2	3	4	5
Websites (you tube, google)	1	2	3	4	5	1	2	3	4	5
Websites (other agriculture related websites)	1	2	3	4	5	1	2	3	4	5
	1	2	3	4	5	1	2	3	4	5

* *1=Extremely useful; 2=Very useful; 3=Useful; 4=Sometimes useful sometimes not; 5=Not useful at all.*
***1=Extremely easy; 2=Very easy; 3=Easy; 4=Not easy, but can operate; 5=Not easy at all*

Can you think of any negative impacts of ICT use in Agriculture? 1. Yes 2. No If Yes;

1.--

2.--

3.--

What are your suggestions to improve the ICT effectiveness in Agriculture?

1.--

2.--

3.--

Citrus Management and Cost of Production/year

Management Practices	Unit	Quantityy	Price/unit
Cultivator	No.		
Pruning	No.		
Hoeing /Weeding (encircle): 1=manual 2=chemical 3=Mechanical 4= None			
Cost of Hoeing/weeding PKR/acre			
Other (earthing etc .) Specify	No.		
Other (Specify)			
Sprays (Insecticide, fungicide, pesticides,etc)	No.		
Source of orchard irrigation (1=canal 2=Tubewell 3= both			
Irrigation Method (Flood, furrow, drip, sprinkler, other specify)			
Total number of irrigation	No.		
Number of irrigation primary source	No.		
Time required for each irrigation hours/acre)	hrs		
Number of irrigations with secondary source	No.		
Time required for each irrigation hours/acre)	hrs		
Number of conductive irrigations	No.		
Time required for each irrigation hours/acre)	hrs		
Fertilizer use			
DAP	Bag/acre.		
Urea	Bag/acre.		
NP	Bag/acre.		
SSP	Bag/acre.		
SOP	Bag/acre.		
MOP	Bag/acre.		
Zinc	Kgs/acre		
Others 1(Sp)	Kgs /acre.		

Others2 (sp)	Kgs/acre.		
Others 3(sp)	Kgs/acre.		
Fertilizer application Method (broadcast, drill, fertigation, other Specify)			
Fertilizer application costs	PKR/acre		
FYM applied to area (acres)			
FYM Qty. in Trollies (no/acre)			
FYM price Rs./trolly			
Method of orchard selling 1= pre-harvest contract 2= self-marketing 3= Both 4= others			
Number of acres/plants contracted out			
Price PKR/unit			
If self-marketing units of marketing			
Harvesting/picking cost/unit including labor in case of self-marketing			
Yield /acre 1= maunds 2= Kgs 3= bags/Palli 4= Crates 5=other in case of self marketting			
In case of crates need to specify the crate weight in KGs			
Price PKR/unit			
Packing material costs PKR/unit in case of self-marketing			
Loading and unloading PKR/unit in case of self-marketing			
Farm to market transportation/unit in case of self-marketing			
Commission charges % in case of self-marketing			
Other marketing Costs PKR/unit in case of self-marketing			

Apendix-3: Focus Group Discussion – Questions

Question: What are the contribution and prospects of ICT for your business?
-Normal Mobile
-Smartphone
-Internet
-Computer
-TV
-Radio
-Other
Question: What are the prospects of ICT for the farming community?
-Normal Mobile
-Smartphone
-Internet
-Computer
-TV
-Radio
-Other

Question: What is the level of use ICT among the farming community?
-Normal Mobile
-Smartphone
-Internet
-Computer
-TV
-Radio
-Other

Question: How effective are these ICT in the interaction of farmers with specific stakeholders?

Question: How are ICT contributing/benefiting both farmers and specific stakeholders in developing business relationship?

Question: What are the factors limiting the effectiveness of ICT specifically for farmers?

Question: Do you have suggestions for how ICT could be more effective for the farming community?

For youth discussions:

Question: What is the level of ICT use?
-Normal Mobile
-Smartphone
-Internet
-TV
-Radio

Question: What is their expertise in ICT use?

Question: What are main purposes of their ICT use?

Question: How can they assist their elders in agriculture using ICT?

Question: How do they think the effectiveness of ICT in Agriculture could be enhanced?