The role of knowledge co-production in climate smart agriculture in Pakistan

by

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Author’s Declaration

“I hereby declare that I am the sole author of this thesis. This is a true copy of the thesis, including any required final revisions, as accepted by my examiners. I understand that my thesis may be made electronically available to the public.”

Abstract

To address the challeges of climate change in Pakistan, new ways of practicing agriculture and mobilizing agricultural research are required. Climate smart agriculture (CSA) is one proposed solution with implications for food security and agricultural sustainability in the context of changing climate conditions. Climate smart agriculture is defined as any practice that sustainably increases agricultural productivity, fosters resilience while reducing greenhouse gas emissions, and enhances achievement of national food security and development goals. In Pakistan, however, the emergence, application and appropriatness of CSA is largely unexamined, and particularly with reference to how agricultural communities, extension agencies and researchers may co-produce innovative agricultural solutions based on different understandings, perspectives and knowledge about agricultural and food systems.

The purpose of this research is to critically assess the role of knowledge (e.g., scientific, local, policy) in the development of climate smart agricultural practices for conditions of water scarcity in the Sindh province of Pakistan. Three objectives guide my research: (1) to characterize the present-day knowledge system and the role of different stakeholders in the study regions as they relate to agriculture and water sector interactions and the development of climate-smart agriculture; (2) to identify key social, cultural, political and economic drivers (e.g., the 'landlord system or patron-client arrangements) that affect how different types and sources of knowledge influence the emergence and implementation of climate-smart agriculture; and (3) to assess if and how different actors and organizations in the water-agriculture sectors can engage in the collaborative production of knowledge to enhance the governance of climate smart agriculture. A qualitative and inductive case study of Sindh Province was used to assess these objectives, critically assess CSA, and to elicit the voices of those most affected and involved in

CSA efforts. Data collection included i) semi structured interviews (n = 70, including 45 farmers and 25 other stakeholders i.e., government), ii) focus group discussions (n = 6, including two in each study district), and iii) a review of content of relevant documents and reports.

Ideally, forms of knowledge co-prodcution for CSA in Pakistan will foster the gathering of relavent information from across disciplinary and epistemic communities, promote shared learning based on diverse experiences, and help to increase legitimacy and relavence of the knowledge generated by different stakeholders in the context of agricultural challenges. In this regard, three key findings emerge from this research. First, CSA is incomplete without the inclusion of both scientific and customary knowledge. Integrated policy support at national and provincial levels is necessary to ensure the occurance of this integration. Second, there are multiple drivers of change impacting the process of knowledge co-production for CSA in Sindh (i.e., natural disasters, socio-economic shifts, political/power dynamics, and water management drivers). These drivers both catalyze and undermine knowledge efforts in the context of CSA. Third, a well governed knowledge co-production process is needed to engage all stakeholders, including agriculture extension services in Sindh. Agriculture extension services serve a central knowledge transmission function and can promote practical know-how to climate-proof and encourage sustainable agriculture in Sindh. Overall, this thesis contributes to an emerging literature on knowledge co-produciton for CSA in Pakistan, highlights the need to consider the multiple drivers of change impacting CSA processes, and emphasizes knowledge co-production as an essential mechanism through which to link the relevant scientific as well as customary knowledge required for climate smart agriculture.

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Dedication

I dedicate this thesis to my parents, siblings and my husband. I hope that this achievement will complete the dream that they had for me and supported me in all those years of my education.

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Chapter 1 - Introduction

1.1 Problem Context

In developing countries, agriculture is the key economic sector and a major source of employment (Lipper et al. 2014), yet 20% of the population is still food insecure (Wheeler and von Braun 2013). Global demand for food and agriculture production is increasing due to growing populations. It is projected that the global demand for food will need to expand agriculture production by 60% by 2050 (Alexandratos and Bruinsma 2012; Lipper et al. 2014). The agriculture sector, on the other hand, is facing multiple challenges and climate change is one of them.

According to the Intergovernmental Panel on Climate Change (IPCC), climate change is affecting crop production in various regions of the world (Masson-Delmotte 2018). Negative effects of climate change are more common than positive effects and negatives effects are more likely to increase in developing countries because they are more vulnerable to climate change (Masson-Delmotte 2018). Climate change is limiting agriculture production in many ways including increased frequency and intensity of extreme events (e.g., floods, droughts), unpredictably heavy rainfall, and increasing temperatures. Besides the impact on the agriculture sector, climate change is also impacting the water sector through extreme heat and droughts. It is predicted that by the end of the century, water scarcity and drought will further increase in already dry regions of the globe (Masson-Delmotte 2018).

Climate-smart agriculture (CSA) is one proposed solution to food security and agricultural sustainability. Climate-smart agriculture includes any practice that improves productivity or the efficient use of scarce resources (i.e. water), reduces exposure, sensitivity or vulnerability to climate variability or change (i.e., water harvesting mulching, drought-tolerant crops, index insurance, communal actions), and enhances farmers' ability to cope with weather extremes or impacts of climate change (Neufeldt et al. 2013). The concept of climate-smart agriculture (CSA) was defined at the First Global Conference on Agriculture, Food Security and Climate Change at the Hague, as agriculture that *"sustainably increases productivity, enhances resilience, reduces/removes greenhouse gas emissions, and enhances achievement of national food security and development goals"* (FAO 2013: ix). This definition was introduced to encourage and establish the global agenda for investment in agricultural research and innovation, joining the agriculture, development and climate change communities under a common brand (Neufeldt et al. 2013).

For complex issues including climate change, however, policy responses to climate change such as 'climate smart agriculture' are usually made at the national and global level, and can neglect the involvement of actors at a local scale (Harvey et al. 2017). A more inclusive approach is needed, across sectors (i.e., water, agriculture sector) and stakeholders including policymakers, researchers and social groups at a local level, to deal with the emerging issues of climate change (De Souza et al. 2015) and other complexities. Yet while doing so we face another challenge which is to organize the collective responses and knowledge of all the different parties and stakeholders involved in this process. For example, weak knowledge systems further hamper the implementation of CSA. Specifically, there is a lack of systematic gathering of information and generation of CSA knowledge at all scales and is discouraged or neglected in the developing countries by the relevant authorities and donors. Wide range of stakeholders makes it challenging to collect and foster the knowledge (local, scientific and policy) available in the form of insights, perspectives, and diverse experiences. Governments and multiple stakeholders tend to keep all the knowledge and hold all the decision-making power without understanding the need of knowledge dissemination and their role as a knowledge broker (Pielke 2007; Kasperson and Berberian 2011). Governments and other decision-making authorities are required to encourage such a knowledge system which is open to consult and use different types of knowledge in legitimate decision-making (Taylor and de Löe 2012). Where "knowledge system" means accumulation of knowledge collected through different sources (Lee 1994), or it's a process where knowledge is collected, used, shared or reorganized between two parties, individuals and organizations.

Given these circumstances, a critical assessment and better understanding are needed for potential CSA interventions and approaches to minimize the impact of climate change. New approaches and ways of doing research are needed (Cochrane and Adam 2017) and bringing the research into action. This research will highlight the gap and need for effective knowledge governance to better understand the complex nature of issues at multiple levels and for the effective implementation of CSA at the local level.

1.2 Purpose Statement and Objectives

The purpose of my research is to critically assess the role of knowledge (e.g., scientific, local, policy, formal, informal) in the development of climate-smart agricultural practices and/or technology for conditions of water scarcity in the Sindh province of Pakistan. Three subsequent objectives guide my research:

1) To characterize the present-day knowledge system and the role of different stakeholders in the study regions as they relate to agriculture and water sector interactions and the development of climate-smart agriculture;

2) To identify key social, cultural, political and economic drivers (e.g., the landlord system or patron-client arrangements) that affect how different types and sources of knowledge influence the emergence and implementation of climate-smart agriculture;

3) To assess if and how different actors and organizations in the water-agriculture sectors can engage in the collaborative production of knowledge to enhance the governance of climate-smart agriculture.

My first objective examines the present-day knowledge system within the agriculture and water sector interactions and how it suports the potential emergence of climate-smart agriculture. In this regard, I also examine the role of different stakeholders in generating and sustainaing curent knowledge types and sources for CSA. I seek to understand how different types of knowledge (i.e. scientific, local and policy knowledge) have been used to understand different dimensions of agriculture and water sector interactions, and how this knowledge can be used to develop climate-smart agriculture systems in the case study area.

My second objective identifies and assesses the factors or 'drivers' that influence different types and sources of knowledge, and the subsequent implications for the introduction, development and implementation of climate-smart agriculture. These drivers include social, cultural, political and economic, or environmental drivers, including for example, the land system (i.e., tenure), policies associated with government institutions, and culture practices (e.g., the role of women) associated with local communities in the study area. This objective helps me to understand what kind of knowledge or whose knowledge prevails and how efforts to develop climate smart agriculture at a local level are influenced by extra-local socio-economic and institutional factors in the study area.

My third objective identifies how different actors and organizations in both agriculture and water sectors may be involved in the collaborative production of knowledge and how they may negage to enhance knowledge governance for CSA. This objective helps me to identify the role of different actors and organizations in producing new knowledge to achieve a common goal (i.e. climate-smart agriculture). In the context of this research, numerous actors are involved in this process, including government institutions, community-level associations, universities, and other research institutions.

1.3 Research Context

1.3.1 Issues faced by the agriculture sector of Sindh

My research takes place in Pakistan, and in Sindh Province, specifically. The agriculture sector in Sindh is important for safeguarding food security and reducing poverty in the country. Unfortunately, despite the importance of the agricultural sector in Sindh, it is experiencing major challenges, including high population growth, water scarcity, inefficient conventional practices of agricultural management, and limited technological innovations, urban expansion into agricultural lands, and uneven land holding patterns. Decision makers in Sindh province are seeking to develop the agricultural sector to foster food security for its population, yet it remains very difficult to improve agriculture production in the three districts which are the focus of my research (Dadu, Badin, and Mirpurkhas).

Several studies indicate that in the last three decades (1990 to 2018) (Chandio and Anwar 2009; Abid et al. 2016; World Bank 2017a; Abbas et al. 2018), major crop production in Pakistan has been negatively impacted by uneven rainfall pattern, floods, droughts, and rising average temperatures. Pakistan has a unique topography and natural irrigation system with the world's second highest peak (8000 meters) in the North, descending to the sea in the southern part of Sindh Province. Yet, such topography also comes with the challenges like floods due to heavy rainfall, melting glaciers and deforestation. Every year floods damage the central plains of Punjab, Khyber Pakhtunkhwa and Sindh, where the majority of food grains are produced to fulfill the food requirements of the country. Agriculture production is always a second priority in such disasters due to the significant destruction to homes and buildings, livestock, and infrastructure.

In Sindh, climate change issues (i.e. rising temperatures, changes in precipitation and reduction in irrigation supplies, and seasonal variability, impacts on agricultural practices) are intensified by a poor system of knowledge and information sharing at different scales (USAID

2009). Relevant and timely information (i.e., weather prediction, rain forecast, flood alerts etc.) do not reach local farmers. There are inefficient agriculture extension services at the local level, that are unable to guide local farmers to handle impacts of climate change. In addition, public extension services mostly benefit educated farmers or are influenced by different political concerns (i.e. profit driven, resource-rich farmers) (USAID 2009). Poor extension service support, lack of knowledge and inadequate research and limited sharing of research in Sindh to address the issues of climate change and water scarcity are the main reasons for low agriculture productivity (World Bank 2017b). A history of extension programs in Pakistan is provided in Appendix 4.

Water is a fundamental source for the agriculture sector in Sindh-Pakistan, and water insecurity threatens the health of communities and the sustainability of livelihoods in local communities. As a result of climate change, water scarcity is increasingly experienced in this region (Smit and Skinner 2002; Schilling et al. 2013; Abid et al. 2015). According to the Global Climate Change Vulnerability Index (CCVI), Pakistan ranked as the 16th most vulnerable country over 2010–11 (Khan and Fee 2014). Most frequently occurring climate-related events in Pakistan include floods (e.g., in 2010, 2011, 2012 and 2014) and the severe drought from 1999 to 2003 (Abid et al. 2016). The main reasons for water scarcity in the country include poor water management systems among different provinces (mainly between Punjab and Sindh), poor irrigation strategies, and other climate change related factors.

Another challenge faced by the agriculture sector in Sindh is its deep-rooted power structure that can be linked with "Feudalism" and traced to the Hindu dynastic rule in the sub-continent (Perveen 2014). The feudal system continues now but in different forms, such as with the "Masandars and Jagidars and Zamindars/landlords" even after the decline of the Mughal empire in the sub-continent. Indeed, the agriculture sector in Sindh is influenced by a strong landlord system where landlords and influential farmers have a strong hold on what type of knowledge is being shared with the local communities, and what kind of knowledge should be disseminated for policymaking at a national scale. Particularly, the small landholders are often deprived of access to knowledge and institutional services and are biased towards landlords or influential farmers (Abid et al. 2015).

Box 1.1: Feudal system in Pakistan: After the Mughal empire, during the early 1700s, Jagidars and landlords received *de facto* possession of agriculture lands in Sindh (Ian 1988). Peasants and local farmers were not allowed to own private agriculture lands, or to take part in decision making to improve and increase agriculture production. Jagirdars and landlords were only involved in accumulating wealth. In the 19th century, the British colonial administration supported the landlord system as an essential collaborator to hold control of the masses (Lubetski 1998). Many privileges were given to those jagidars and landlords who supported them and were loyal to them (Samarrai 1973; Perveen 2014).

1.3.2 Status of climate-smart agriculture in Pakistan

Climate smart agrculture has emerged in Pakistan and Sindh more specifically to address the ongoing challenges of low agricultural productivity and increasing threats of climate change.

In this research, climate-smart agriculture refers to efforts in Sindh to foster the investment in practical know-how for sustainable and productive agriculture and to strengthen the existing institutional arrangements to reduce the impact of climate change. The concept of CSA is still very new in Pakistan and the rate of adoption of CSA practices and technologies will be significantly influenced by several factors, such as economic benefits, socio-economic characteristics, operational land holdings, groundwater quality and scarcity, type of ownership, credit access and extension services (Abid et al. 2016; Ali and Erenstein 2017; Zulfiqar et al. 2017; Khatri-Chhetri et al. 2017; Hussain et al. 2017; Imran et al. 2018).

Moreover, the implementation of CSA is a challenge in Pakistan because of the weak formal knowledge system in the agriculture sector of Sindh. There are many related issues (i.e., socio-economic, governance and power structure issues) that impact the knowledge system of the agricultural sector in Sindh, and without a thorough understanding of these issues, implementation of CSA will be difficult. For example, the agricultural extension services are the main source of agricultural information dissemination among farming communities in Sindh Province, and mainly based on in-person visiting methods (Mengal et al. 2014). However, the capacity of the agricultural extension service is limited due to its poor governance system (see Chapter 4) and lack of knowledge to complement existing technical advice related to specific crops or current common agricultural practices (Mengal et al. 2014). Similarly, there are several other issues in Sindh that impact the implementation of CSA at the local level. Therefore, there is an urgent need to recognize the existence of multiple challenges, and to understand the role and importance of knowledge systems that determine the development and implementation of CSA (Abid et al. 2016). In the following sections, I briefly explain the relevant approaches and concepts I am using to consider the issue of knowledge co-production for climate smart agriculture. These approaches and concepts will be discussed in detail in the literature review (chapter 3).

1.3.3 Role of knowledge co-production in CSA

Knowledge co-production is relevant here to identify critical aspects of understanding and solving global challenges like climate and environmental change. Knowledge co-production provides one pathway to identify problems and solutions through research which is transdisciplinary and multiscale (Lemos and Morehouse 2005), by collecting and sharing of relevant knowledge from across disciplinary and epistemic communities and by promoting shared learning based on experiences (Moser 2016; Campbell and Vanderhoven 2016). Over the last few decades, knowledge co-production has received significant attention in the field of climate change adaptation and sustainable development to address the gap between research, policy and practice (Dilling and Lemos 2011; Abid et al. 2015). A knowledge system essentially should be able to co-produce knowledge through a process that encourages a plurality of knowledge sources and types to identify and resolve problems (Armitage et al. 2011).

This thesis aims to use knowledge co-production to understand the challenges in climate proofing agriculture, and strengthening the existing institutional structure by bringing diverse types and sources of knowledge into action.

1.3.4 Drivers of change in the knowledge system of Sindh

There are several related complex challenges facing the agricultural sector in Badin, Dadu, and Mirpurkhas through a set of multiple drivers of change. Drivers of change in Badin, Dadu, and Mirpurkhas that can directly or indirectly impact the knowledge system and implementation of CSA. These drivers are categorized in this research as climate change, socio-economic change, water governance processes, and power/political structures. Drivers are defined and explained through the framework provided by the 2005 Millennium Ecosystem Assessment (MEA) as any natural or anthropogenic factor that directly or indirectly causes a change in the 'environment' (MEA 2005). The MEA conceptual framework highlights that any change in the indirect drivers like population, culture, or socio-economic structure, can lead to changes in the direct drivers like change in local land use and cover, technology adaptation and use (MEA 2005). According to the framework these drivers are closely linked with each other and impact the ecological system directly or indirectly.

1.3.5 Knowledge governance for CSA

The findings of the research and the approaches discussed above are collectively analyzed with reference to a "three-layered conceptual framework" of knowledge governance (see van Kerkhoff and Pilbeam 2017). This framework guides this research and aims to highlight the overlapping and interconnectivity of CSA, knowledge system of CSA and different set of drivers impacting the knowledge system of CSA through three different layers (i.e., civic epistemology, knowledge systems, and interventions). This framework will thus help to address the research objectives and questions of how to improve the overall knowledge governance of CSA in the presence of multiple drivers of change in the agriculture sector, and consider the role of multiple stakeholders and their knowledge.

1.4 Organisation of the thesis

The thesis is organized into seven chapters, followed by a list of references and Appendices. My first three chapters provide the theoretical and methodological orientation to the thesis and offer a conceptual and practical background to the discussions. Chapters 4 and 5 combine theoretical concepts with research findings. All the three objectives of the research are covered in three separate chapters (4, 5 and 6), but there is also some overlap between the chapters. Chapter 6 combines the material from all other chapters to evaluate the research outcomes and their relevance for academic, policy and applied for work. The following explains some specific details on what each chapter contains.

Chapter 1 provides the background, problem context for the research, conceptual orientation to the analysis, research purpose and objectives of the research.

Chapter 2 provides the literature review to explain the literature areas used to describe the research and contribution of the research in the literature.

Chapter 3 explains the methodological approaches that have guided the research process and outlines the specific field research methods used orientation and introduction to the study area including each study districts.

Chapter 4 covers the first objective of the research to explores the question of present-day knowledge system and the role of different stakeholders in the study regions as they relate to agriculture and water sector interactions and development of climate-smart agriculture.

Chapter 5 identifies and develops an understanding of different set of drivers impacting the knowledge system of climate-smart agriculture in the case study areas, covering the second objective of the research that is to "Identify key social, cultural, political and economic drivers e.g., the 'landlord system (patron-client arrangements)' that affect how different types and sources of knowledge influence the emergence and implementation of climate-smart agriculture".

Chapter 6 deals with the third objective of the research, which is "to assess if and how different actors and organizations in the water-agriculture sectors can engage in the collaborative production of knowledge to enhance governance of climate-smart agriculture". It explains the institutional arrangement and process that can support a new institutional balance to govern the co-production of CSA knowledge through three-layered conceptual frameworks of knowledge governance.

Chapter 7 concludes this thesis by revisiting the research objectives and presents key findings and conclusions with attention to their relevance to theory and practice, including policy.

Chapter 2 - Case study context and research design

2.1 Introduction

In this chapter I outline the study area context and research design used. In the study area context, I explain the overall geographic, socio-economic, cultural and political aspects of Sindh, and emphasize in particular the three districts (i.e., Badin, Dadu, and Mirpurkhas) selected for this research. I then outline the research design I used to undertake this study which primarily adopts a qualitative, case study based approach. I further explain the methods of data collection used, including semi-structured interviews, focus group discussions and review of previous records to collect the information/data needed to address my research objectives.

2.2 Case study

Sindhu in might surpasses all the streams that flow.
His roar is lifted up to heaven above the earth;
He puts forth endless vigour with a flash of light.
Even as cows with milk rush to their calves,
So other rivers roar into the Sindhu.
As a warrior-king leads other warriors,
So does Sindhu lead other rivers.

— Rigveda

2.2.1 Agriculture in Indus Valley Civilisation (Mohenjo Daro)

The name of the present-day Sindh region is derived from 'Sindhu' in Sanskrit, which means ocean or a vast collection of water. When Aryans first arrived in the region, they named the present-day Indus River as 'Sindhu' and the area now comprised of Pakistan, Kashmir, and east Afghanistan as 'Sapta Sindhu', which means land of seven rivers. Nowadays, the name "Sindh" specifically refers to the lower Indus Basin. As the name suggests, water has great importance in this area, and without which Sindh would have been a barren desert.

In 1936, Sindh achieved the status of a separate province after partition. Today Sindh is the second largest province of Pakistan and its largest city Karachi is the financial capital of Pakistan, which also has the biggest seaport. However, agriculture remains a crucial economic and cultural feature of Sindh province.

The history of agriculture farming in Sindh dates back as far as the time of early Indus Valley civilizations (Mohenjo Daro, see Figure 2.1). Farming settlements emerged around 6300-3200 BC in Sindh and Baluchistan (Petrie et al. 2016). This is the time when agriculture was introduced as a technology to produce one's own food. At that time, agriculture was rudimentary and rain-fed. By 2600 B.P., however, farming settlements transformed into a number of larger towns that eventually emerged into the Indus Valley civilization (Mohenjo Daro) based on rain-fed and irrigated agriculture. Between 2300 – 1750 BC, the Indus Valley civilization was at its peak (Gupta 2004: Srivastava 2008). The excavation of (Mohenjo Daro) during the period 1970 to 1980, around the present-day city Larkana, many ruins of agriculture villages were discovered with the approximate size of 300 hectares which shows the extensive agriculture farming in practice in era of Indus valley civilization.

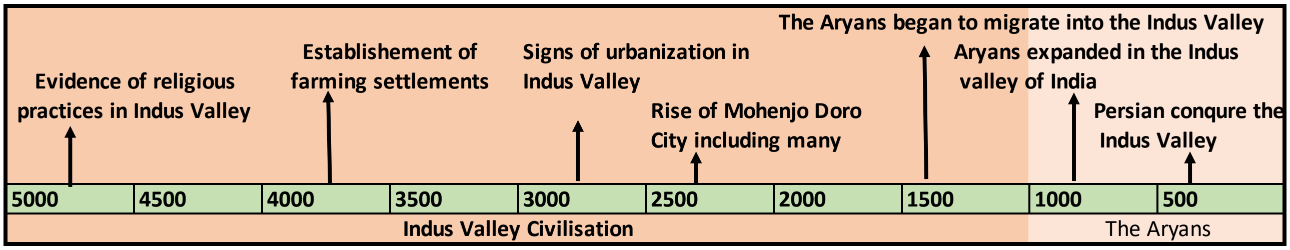
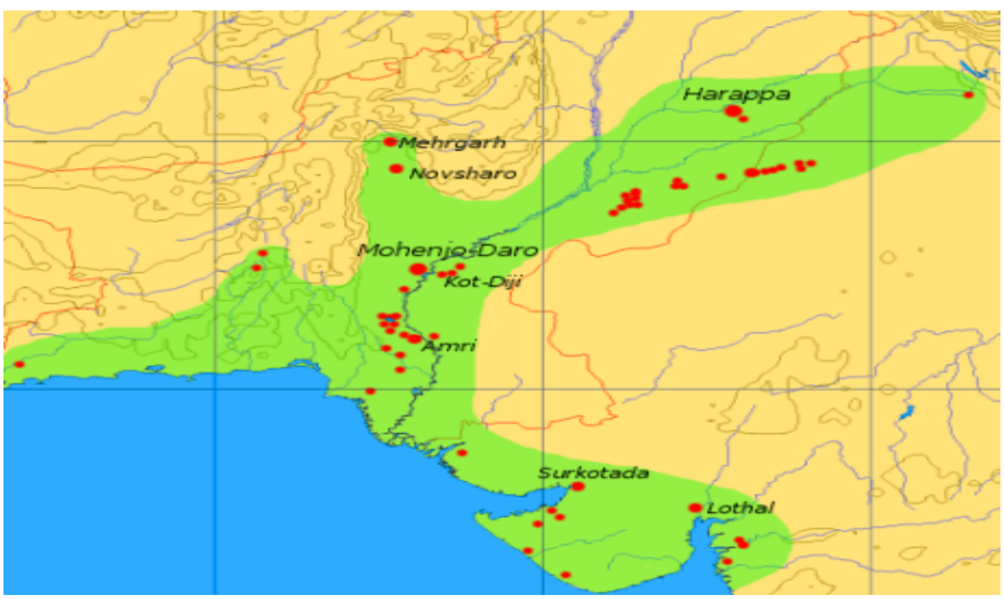


Figure 2.1: Timeline of Indus Valley Civilization (Created by Sajida Sultana)

Historians explain that the Indus Valley agricultural economy was based on the cultivation of barley, peas, and wheat and cotton (Gupta 2004; Weber, Barela & Lehman 2010; Lovell 2015). Copper beats discovered from the area also bought the traces of the oldest cotton thread till date, and which highlights that the Indus valley civilization was aware of how to produce fiber out of cotton threads. During this time, people also started domesticating cattle and goats (Lovell 2015). During excavation of Indus valley (Mohenjo Daro), by different foreign researchers, it was also noted the structure in the forms of ceramic lining cells which were used for the storage of cereal crops (Jarrige and Meadow 1980). Towards the end of the Indus Valley Civilization, Aryans gradually settled the area and adopted agriculture over the course of several centuries (Violatti, 2013). Map 2.1 shows the emergence of Indus valley civilization (in red) in Pakistan and India around Indus River.



Map 2.1: Indus Valley Civilization (Source: Dbachmann 2012)

2.2.2 The current status of agriculture in Pakistan and Sindh Province

The agricultural sector of Pakistan is a backbone of the economy. More than half of the population of Pakistan is directly or indirectly associated with the agricultural sector, and there is a recognition that agriculture is vital for industrial growth since industrial activities heavily depend upon the on-time availability of agriculture commodities (North 1959; Raza, Ali & Mehboob 2012; GoP 2018a). In Pakistan, the agriculture sector contributes around 24% of the Gross Domestic Product (GDP) and employs almost half of the labor force (GoP 2018a). The agriculture sector is also the largest source of foreign exchange earnings (GoP 2018a).

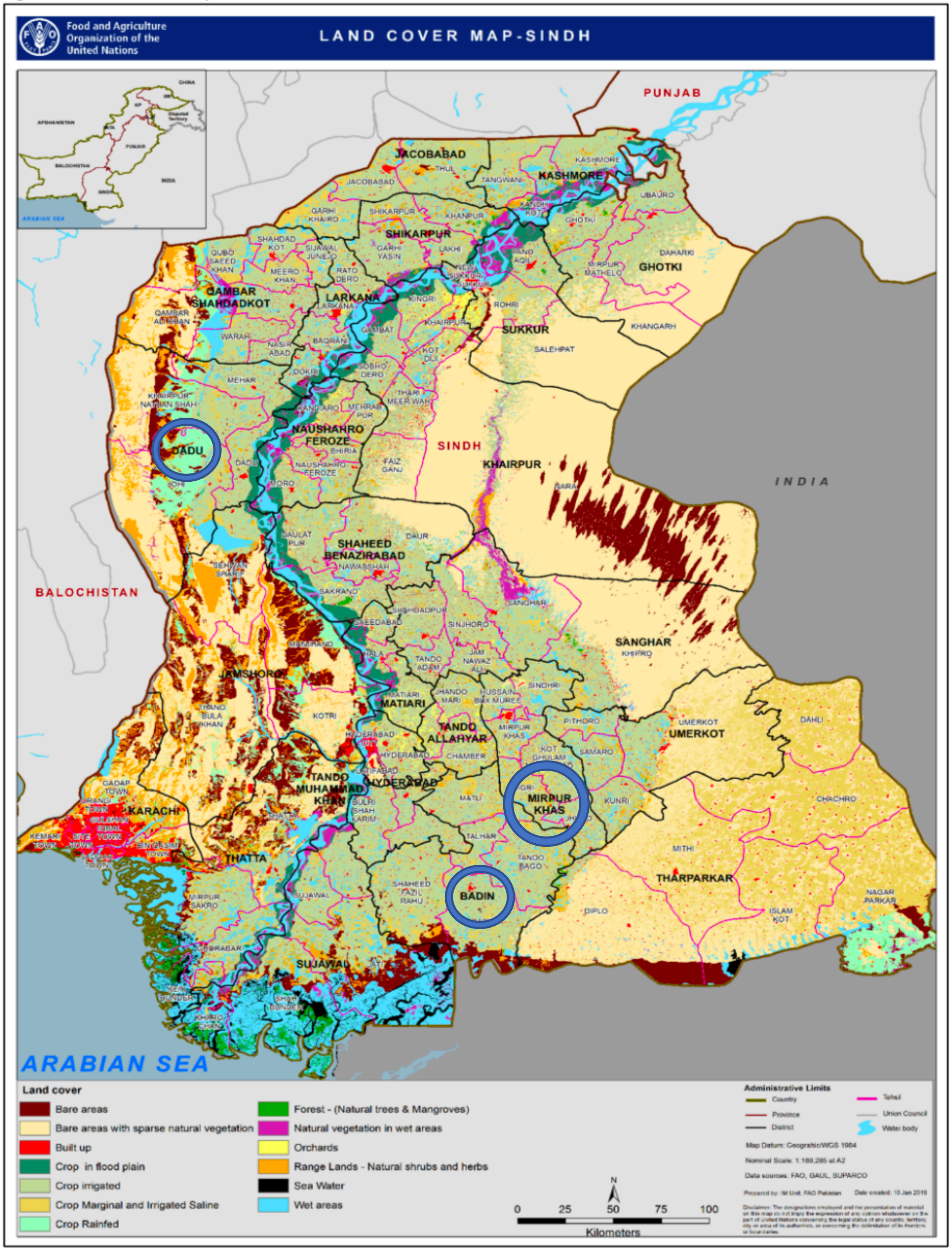
The agriculture sector is the major source of livelihood in the two of the three districts that are the focus of my research (i.e., Mirpurkhas and Dadu), and the second largest source of livelihood in the third district (i.e., Badin). Agriculture in Sindh is central to economic growth and food security. Sindh contributes approximately around 30% of the agriculture economy in GDP of Pakistan. Major crops grown in Sindh include cotton, wheat, rice, sugarcane and mangoes. In addition, Sindh also contributes 48% of the fish export of Pakistan (Raza, Ali & Mehboob 2012). The dairy and meat processing industry is also based in Sindh. The Indus River has changed its course and grew over thousands of years, increasing the cultivable lands around it. The total cultivable area of Sindh is 5.88 million hectares, out of which the total cropped area is 3.10 million hectares.

Approximately, 50% of the harvested area is used for the cultivation of major field crops (e.g. cotton, wheat, rice, sugar cane, and maize) (World Bank 2017). Field crops are the crops other than fruits and vegetables that are grown for agriculture purposes such as cotton, mainly used for fiber, dried grass and foliage used as animal feed (Ham Shehri 2013). Compared to the total agricultural production in Pakistan as a whole, Sindh produces 35% of the rice, 28% of sugarcane, 12% of wheat, and 20% of the cotton (Ham Shehri, 2013). Sindh also produces 88% of all the chilies grown in Pakistan, 73% of all bananas, and 34% of the mangoes (Ham Shehri 2013).

There are two seasons of cultivation in Pakistan and Sindh, known as i) “Kharif” for summer crops (e.g. rice, sugarcane, cotton, maize, pulses), grown between the months of April and June, and ii) “Rabi” for winter crops (e.g. wheat, lentil, tobacco, rapeseed, barley, and mustard), grown between October and December (Ham Shehri 2013; World Bank 2017).

2.3 Research context

This section outlines the geographic, socio-economic, cultural and political context of the three case study districts (i.e., Dadu, Mirpurkhas and Badin in the Sindh province of Pakistan). These three districts are of great value to Sindh as Badin, Dadu and Mirpurkhas are one of the biggest districts with an approximate population of 1.8M in Badin and 1.5M in Dadu and Mirpurkhas respectively. Map 2.2 shows the location of the three study districts in Sindh.



Map 2.2: Land cover map of Sindh showing three study districts (Source: Sindh Drought Need Assessment Report 2019)

2.3.1 District selection criteria

The Province of Sindh is located in the south-eastern part of Pakistan (between Lat 23-35 and Lat 28- 30 N). The geographical area of Sindh is 14 million hectares (PDMA 2012) of 5.08 million hectares are currently used for agriculture (GoP, BoS, 2011a). The remaining area is not available for cultivation and is mostly situated in the northern hills of Khirthar Range, Thar Desert and Achharo Thar and the riverine area.

Sindh is not only the second largest province of the country, but also plays a pivotal role in the national economic and development agenda. Administratively divided into 29 districts, Sindh is flanked by 350 kilometres of coast of the Arabian Sea in the south, where it supports the Indus Delta with its 17 creeks. Sindh is facing a number of environmental issues related to land and water management. Agricultural production is highly affected by limited water availability and crop production is concentrated in those areas only where irrigation facilities are available (GoS-SAP 2018). Overuse of water at the head of canals, distributaries and watercourses, combined with heavy soils, saline groundwater and poor drainage are causing salinity and waterlogging (GoS-SAP 2018). In addition, installation of tube-wells is affecting flood flows and ground water overuse.

Pakistan, and Sindh especially, have experienced very unexpected climate events in the recent past (World Bank 2017). The unprecedented floods in 2010, the unusual heavy spell of rains in 2011, and heat waves in Karachi underline the reality of climate change. Indeed, the three study area districts including Badin, Mirpurkhas, and Dadu have one thing in common - all of them were badly affected in the floods of 2010 and again by heavy rains in 2011 (PDMA 2012). Similarly, several towns and villages of Dadu district were under water (See chapter 5, section 5.2a).

The initial selection criteria for inclusion of the three study sites was based on different agriculture zones in Sindh. These districts are from three different agriculture zones based on their major crops (Koondhar et al. 2018). For example, Badin comes under mixed cropping zone where different crops are cultivated (i.e., wheat, rice, cotton etc.), Dadu is categorized under Rice-wheat zone, and Mirpurkhas is categorized under cotton-wheat zone.

Ultimately, three more criteria were used to identify the three districts and the study villages, including differences in experience of local communities with climate change due to their geographic location, differences in socio-economic background and hence livelihood and vulnerability to climate change, and differences in understanding about potential climate smart agriculture practices and technologies.

First, there is some variation in experiences with climate change in each of these three sites. Badin district represents the coastal area which has been experiencing a cycle of natural disasters including cyclones and acute water shortage (Shah 2016). In Badin, agriculture lands have faced sea intrusion and heavy flooding causing salinity and water logging. Agriculture lands near the coastal area of Badin also suffer from human-made disasters (destruction of LBOD construction project) (DDMA 2008). In contrast, Mirpurkhas district has fertile, high yielding lands with comparatively better access to irrigation water but also edges into the Thar desert in the South. Mirpurkhas was also impacted by the floods in 2010 and 2011 and is also suffering from salinity and poor quality of soil (PDMA 2012). In Dadu, major damage to the agriculture lands is due to extreme heat that not only burns the crops but also results in water shortage. Dadu district is in the middle of Sindh, closer to the Indus river and has a different experience with climate patterns (i.e., extreme heat conditions, drought, etc). For instance, a big portion of Dadu district is called "Kachho" and "Kohistan" which are arid hilly areas (see Map 2.2).

Second, criteria for inclusion are also related to differences in socio-economic characteristics. For example, Badin is a considered as one of the poorer districts, where people are deprived of basic necessities of life (i.e., poor health, education, and water shortage issues are very common) (Shah 2016). It furthermore has a scattered population which could be a hindrance for any development activities (PDMA 2012), farmer communities have migrated or changed their source of livelihood to fishing (Shah 2016). Mirpurkhas is considered a rich agricultural district where people have access to basic facilities of health, education and drinking water. Dadu is also one of the poorer districts, where a majority of the population has suffered a lot due to recurring floods and drought (PDMA 2012). Women are socially deprived despite basic facilities of health, education and social exposure, and despite of their major contributions in the agriculture sector.

The third criteria involve the awareness and understanding of climate smart agricultural practices and technologies. The rate of CSA adoption and replication is different in all three districts. People in Badin have different needs in the agricultural sector mainly because of its geographic location (i.e. coastal district). CSA is a very new concept in Badin. Understanding and implementation of existing CSA is dependent on water availability (World Bank 2017). In Mirpurkhas, many CSA practices and technologies are already implemented. CSA is not a new concept in Mirpurkhas (World Bank 2017). In Dadu, people are mostly unaware of CSA technologies and practices. Understating and implementation of existing CSA is dependent on water availability, and relief from disasters (PDMA 2012). Table 2.1 below indicate the selection criteria for the three districts. Further detail about each district and study villages is given below.

Table 2.1: Selection criteria for the three study districts

District	**Selection criteria**				
	Agriculture Zone	**Land Cover**	**Climate change impact**	**Socio-economic condition**	**CSA Status**
Badin	Mixed cropping	Crop irrigated/ Coastal area	Floods/Cyclones/Sea intrusion. Highly effected	Extremely Poor. Scattered population.	Very new
Dadu	Rice-Wheat	Rain fed/ Hilly area/	Rain floods/Drought. Highly effected	Poor. Lack of basic facilities.	Very new
Mirpurkhas	Cotton-Wheat	Crop Irrigated	Floods. Moderately effected	Agriculture Rich district	In practice

a) District Badin

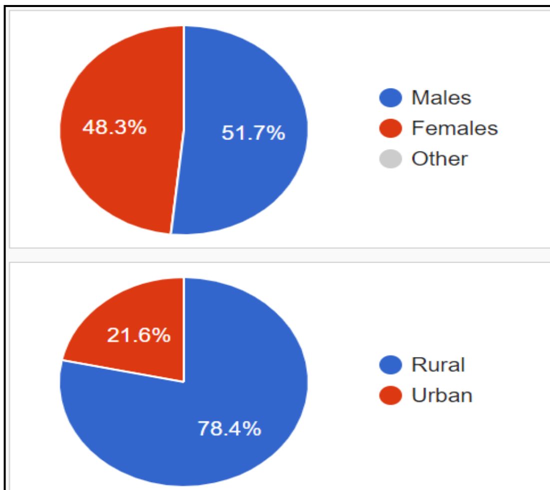
Badin district is the last coastal district of Sindh. Badin is situated between 24°-5` to 25°-25` north latitude and 68 21’ to 69 20’ east longitude and is bounded on the north by the Tando Allahyar District, northwest by the Hyderabad district, east by Mirpurkhas and Tharparkar district, south by Kutch district of India, and west by Sujawal and Tando Muhammad Khan district (GoS 2012). The total population of the district is 1,804,516 according to 2017 census (see table 2.2), out of which 51.7% are male and 48.3% are female. The majority of the population of this district lives in rural areas (see figure 2.2 below).

This district is mostly swampy, although fertile and it is suitable for growing rice. Badin has a scattered population with the average distance among the villages around 10 to 15 km (PDMA 2012). The average number of households in Badin districts is not more than 100 per village (Shah 2016). The village of Soomar Mallah was selected for this research and is the last coastal village of Badin district. Soomar Mallah has a total of 125 households (Shah 2016), out of which half of them are directly related to agriculture and others are mostly fishermen, but also practice agriculture. Badin has multiple ethnic groups and communities including Mallah, Khaskheli, Bhati, Sholani, and Jat (IUCN 2006).

Table 2.2: Population of Badin (Census 1998 and 2017)

Name	Status	Population Census 1972-09-16	Population Census 1981-03-01	Population Census 1998-03-01	Population Census 2017-03-15
Badin	District	...	...	1,106,272	1,804,516
Area: 6,470 km² – Density: 278.9/km² [2017] – Change: +2.60%/year [1998 → 2017]					
Badin District: district in Sindh, Pakistan					

Source: Pakistan Bureau of Statistics (2017)



Gender (C 2017)	
Males	932,488
Females	871,979
Transgender	49

Urbanization (C 2017)	
Rural	1,414,138
Urban	390,378

Figure 2.2: Population of Badin (Gender wise) Census (Source: Pakistan Bureau of Statistics (2017)

The agriculture sector is the major source of livelihood and food stocks for the majority of the population in Badin district. Three major crops are cultivated during the year including wheat, rice, and cotton (IUCN 2006). Wheat and rice are cash crops but they are also used for food consumption. The agriculture sector in Badin is always under threat due to multiple factors like frequent floods, cyclones, sea intrusion and strong hazards like left bank outfall drain (LBOD) canal (DDMA 2008). The faulty design of LBOD, diverted the natural path of Indus delta towards the villages during flood days, which caused severe damage to agriculture lands, houses, livestock and many lives (DDMA 2008; PDMA 2012). Cotton is usually harvested during July-August, which is also the peak time for floods, heavy rains, and storms. Cotton was the most affected crop during the heavy rains and floods in 2011, 2013, and 2015. Other crops like rice and wheat were also badly affected, leaving farmers with economically poor conditions (PDMA 2012). Most usually have no cash to invest in other crops and are under heavy debts. Even if they get the loan, land of Badin is continuously degrading due to sea intrusion and soil erosion. Rice is cultivated during the dry months of July and August but the harvesting of rice is usually done from October to December, which causes a delay in sowing the wheat crop (IUCN 2006; Shah 2016). This delay in harvesting and sowing is affecting the yield of both crops (PDMA 2012).

Within the agriculture sector of Badin, mostly women work in the field, keep the livestock and also take care of their families. Men are mostly involved in fishing and spend most of their time in the sea (i.e., 15 days or longer), whereas women are not involved in fishing (IUCN 2006). Although women work more than men and are equal contributors to the livelihood activities, decision making and financial matters in agriculture are solely handled by men (World Bank 2017). The decision about cropping and day to day agricultural activities are done by the landlords and sharecroppers usually follow their landlords (World Bank 2017). For example, it is usually landlords who decides which crop will be cultivated every year and if landlords decide to stop the harvesting of any crop, farmers will have to follow their decision (Shah 2016). The educational profile of farmers of Badin is very low (DDMA 2008), where almost 50% of the farmers have no formal education (Buriro et al. 2013). Keeping the livestock usually depends upon the profitability of the agriculture lands. Farmers in Badin believe that the current system of sharecropping is not favorable to farmers but only to the landlords as farmers / sharecroppers are usually indebted (Shah 2016).

One of the biggest features of district Badin is a shortage of water. Being a ‘tail end’ district (in terms of water and irrigation) and also close to the intruding sea, Badin has witnessed climate-related gradual economic downfall. Thus, in 2006, according to a study of the World Bank, it was found that 86 percent of Badin’s population was below the poverty line. Adrastic reduction trend in livestock holdings has also been witnessed because of a shortage of water and a shortage of fodder. Hence, Badin is in a vicious cycle of poverty.

With a population of 450, the interview village “Haji Soomar Mallah” is situated 25 KMs South of Badin city. The livelihood of 70% of the villagers depend on agriculture and livestock, 25% are daily wage earners including fishing, and 5% of the population are employed in the government and private jobs. The quality of life here is very low because of frequent natural disasters including heavy rains, floods, cyclones, and water shortage. The health-related issues are an additional burden on almost every household. One of the key stresses found among the villagers was their food security and loss of livelihood. The villagers trace the cycles of natural disasters right from 1955 heavy rains and floods down to the two most powerful cyclones in 1964 and 1999. Other disasters include the earthquake in 2001 and floods caused by the LBOD overtopping.

b) District Mirpurkhas

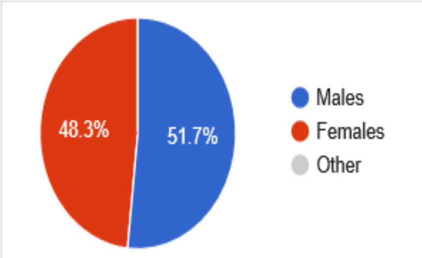
Mirpurkhas is located in the southeastern side of Sindh and 65 kilometers east of Hyderabad, with a total area of 140,914 square kilometers. Karachi City is 220 kilometers of away from Mirpurkhas district. District Mirpur Khas lies in 68o 59’ 3” to 69o 16’ 53” east longitudes and 24o 48’ 33” to 25o 48’ 7” north latitudes (USAID 2014). This district is surrounded by district Umerkot on the east, district Sanghar on the north, district Tando Allahyar on the west, district Badin on the south-west, and district Tharparkar & Badin on the south (USAID 2014).

There are a total of six tehsils in Mirpurkhas district (Mirpurkhas, Digri, Kot Ghulam Muhammad, Sindhri, Hussain Bux Mari and Jhudo) (USAID 2014). The total population of Mirpurkhas district is 1,505,876 with almost an equal percentage of male and female (See table below 2.3). The urban population of Mirpurkhas district is 70% and 30% of the population is living in rural areas (See figure 2.3). Approximately 67% of the population are Muslims and the remaining are mostly Hindu (GoS-PBS 2017).

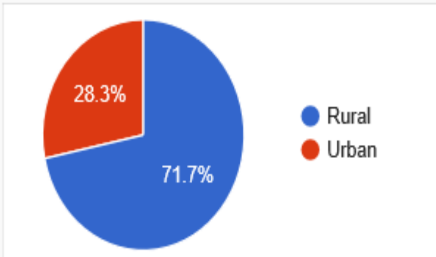
Table 2.3: Population of MirpurKhas (Census 1998 and 2017)

Name	Population Census 1972-09-16	Population Census 1981-03-01	Population Census 1998-03-01	Population Census 2017-03-15
Mirpur Khas	...	...	1,006,329	1,505,876
Area: 3,319 km² – Density: 453.7/km² [2017] – Change: +2.14%/year [1998 → 2017] Mirpur Khas District: district of Pakistan				

Source: Pakistan Bureau of Statistics (2017).



Gender (C 2017)	
Males	778,172
Females	727,650
Transgender	54



Urbanization (C 2017)	
Rural	1,080,124
Urban	425,752

Figure 2.3: Population of Mirpur Khas (Gender & Urban-rural wise) Census (Source: Pakistan Bureau of Statistics 2017)

Mirpurkhas (also called a mango district) is a non-riverine district, and therefore, there is no threat of floods on account of breaches in bunds of rivers. However, district Mirpurkhas is vulnerable to heavy rainfalls (DDMA 2016). In 2011 rains, 3,178 villages/settlements 49 of 51 union councils were affected including 61 casualties and 230 injuries, and in the 2012 rains, 550 acres of crop area were affected, while 1 death and 2 injuries were reported (DDMA 2016).

The agriculture sector is the main source of livelihood in Mirpurkhas district and contributes significantly in the agriculture sector of Sindh because of its suitable climate for agriculture production. Maize, rice, sugarcane, cotton and bajra are the main Kharif crops and wheat, barley, Gram and barseen are the main Rabi crops of Mirpurkhas. In addition to these, fruit orchards are widespread in 67% of the mouzas (PBS-SMS 2008). This district is famous all over Pakistan for its mangoes. There are three different divisions of the population dependent on agriculture sector (i.e., Landlords, small farmers, and *Haris*). Haris are the landless tenants of landlords and are mostly Hindus. Most of the haris depend on their landlords for their basic needs including food and livestock. They depend on their share in the cropping system which also keeps them indebted to their landlords and money lenders. Haris usually have a limited income of Rs. 2000 to 2500 per month, which is not enough to cover the monthly expenses of a big family (SDPI 2009). Haris lack basic facilities of life including health and education and live in mud houses with limited access to clean water, unhygienic living conditions, and poor nutritional food (Arif et al 2010). Contamination of water is high due to poor hygiene and sanitation system; therefore, people rely on ponds and canals for drinking water (Arif et al. 2010). Some haris also work as daily wage labor in the upper region of Sindh province

On the other hand, landlords and small farmers have their own lands and have access to basic facilities (GoS-SDS 2008; USAID 2014). They are mostly educated, aware and have access to cities, clean water, and food. They cultivate the land according to market trends with the help of advanced technologies for agriculture (tractors, machines, fertilizers and good quality seeds (GoS-SDS 2008). Some of the female farmers also own land, therefore, they equally participate in decision making and daily agricultural activities.

'Daulat Pur Minor' spread over 10.5 Kilometers has the farmers' organization (FO-Daulat Pur minor) active in study villages of Makhan Samo, Tehsil Shujabad of district Mirpurkhas. The FO-Daulat Pur minor works in the premises of West Canal of Nara Canal, benefiting the population of approximately 2,200 households and 4359 ha of land (Mangrio et al. 2014). It has a total workforce of 135 members including seven main body members. Total funds collection by the FO exceeds 150,000, which has reduced over time and is insufficient according to FO representatives.

It is important to note here that system of FOs was a pilot project which was widely introduced in the Mirpurkhas (including the study village), and there is no system of FOs established by the government in the case study villages of Badin and Dadu.

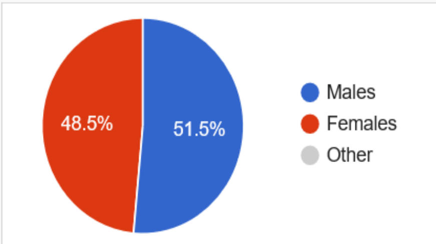
c) District Dadu

Dadu district is located on the western bank of Indus River, with district Larkana on the east, district Kamber Shahdadkot on the north, Kirther range of Baluchistan on the west and district Jamshoro on the south. The total population of Dadu district according to the 2017 census is 1,550,266 which includes 797,857 males and 752,385 females and 24 transgenders (see figure 2.4 and table 2.4). The rural population of Dadu is 1,167,097 while the urban population is 383,169. District Dadu is subdivided into four talukas (i.e., Dadu, Johi, Mehar and Khairpur Nathan Shah). There are total 52 union councils consisting of 336 Mouzas (Revenue villages), out of which, 286 are rural, 3 are urban, 21 are partly urban, 7 are forest mouzas and 19 are unpopulated (GoS 2008).

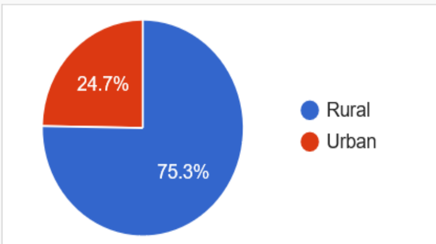
Table 2.4: Population of DADU Census 1998 and 2017)

Name	Population Census 1972-09-16	Population Census 1981-03-01	Population Census 1998-03-01	Population Census 2017-03-15
Dadu	556,669	705,669	1,106,717	1,550,266
Area: 8,034 km² – Density: 193.0/km² [2017] – Change: +1.79%/year [1998 → 2017]				
Dadu District: district in Sindh, Pakistan				

Source: Pakistan Bureau of Statistics (2017)



Gender (C 2017)	
Males	797,857
Females	752,385
Transgender	24



Urbanization (C 2017)	
Rural	1,167,097
Urban	383,169

Figure 2.4: Population of Dadu (Gender & Urban-Rural wise) Census (Source: Pakistan Bureau of Statistics 2017)

District Dadu includes Manchar lake which is one of the biggest fishing grounds and sources of water for agriculture land (AlHassan system 2015). The district is mainly irrigated by the Sukkar barrage and a small portion by Kotri barrage. In addition to these barrages, there are two canals i.e., Rice canal and Dadu canal, that are used for agriculture purposes (See Appendix 3). About 70% of agriculture land is irrigated by these canals and the remaining 30% of agriculture land is also irrigated by tube wells and spillover of river Indus (GoP-PBS 2008). There are two main crop seasons in Dadu like other districts; Kharif (starts in April-May and ends in October-November), and Rabi (starts in November-December and ends in April-May) (Alhasan system 2015). However, crop seasons are highly affected by changing weather conditions, cropping pattern and water availability, soil condition and extreme weather (PDMA 2012).

The agriculture sector is the main source of employment for the majority (85%) of the population in the district population like other districts of Sindh (GoP-PBS 2008). Other than agriculture, people are also involved in labor work and personal business (GoP-PBS 2008). The literacy rate in Dadu is 62%, out of which, 76% are male (Alif Ailaan and SDPI 2016). Social indicators of the district show that the poverty rate is high in this district, health and education facilities are low, and people have limited access to nearby cities due to poor infrastructure (PBS-GoP 2008; Alhasan system 2015). Poverty is relatively high in non-agriculture households, followed by livestock households and small farmers (SDPI 2009).

District Dadu has a long history of floods and extreme heat events (SADR 2009; NDMA 2012; Alhasan system 2015). Some of the heavy floods that hit the district include 2010, 2011 and 2012. The 2010 flood affected the 40 union councils of the districts and approximately 1,200 villages (Memon et al. 2015). Union council is the subdivision of districts and each union council has number of villages in it. Around one million people were affected during these floods (Shah 2012). In 2011, 50 union councils and 1500 villages were affected. Out of 164,297 acres of sown land, 97,248 acres (59%) was damaged (PDMA 2012). Due to floods and extreme heat, agriculture productivity is declining and making the district food insecure (PDMA 2012). Poor quality soil, excessive use of fertilizers has also impacted the agriculture productivity.

2.4 Research design and methodology

Qualitative research aims to collect data in the field where a problem of interest exists (in my case the challenge of knowledge mobilization and transfer related to CSA) by directly talking to people experiencing and/or working through the issue, and observing their behavior in the context of that particular issue (Creswell 2014). Qualitative research approaches are used in different fields like public health, education, industry, public policy, community studies, social studies, etc. (Yin 2009). Qualitative research helps to unpack the complex set of factors surrounding a phenomenon or topic or theme of interest and present the broad, varied perspectives or meanings that participants hold (Creswell 2014). Therefore, a qualitative approach is well suited to my research as it also requires different perspectives and meanings that different stakeholders hold in relation to existing knowledge systems surrounding the promotion and implementation of climate-smart agriculture. In many cases, qualitative research is used because quantitative data and statistical knowledge alone cannot explain some issues associated with gender, individual differences, caste, economic and social values (Creswell 2012). Qualitative data analysis is also helpful where the focus is on collecting knowledge about ecosystem changes caused by single or multiple factors such as destruction of habitat or loss of population (Wilson 2007). To study the expected impact of CSA interventions, qualitative data analysis is used to assess agriculture productivity, resilience and mitigation (Albert et al. 2012; Campbell et al. 2016). In my case study, I am trying to understand the role of knowledge systems in climate smart agriculture as a problem of interest and examine multiple drivers of change and multiple knowledge stakeholders are impacting the knowledge system and implementation of CSA.

My research mainly adopts a qualitative approach as I examine the human perceptions and the historic changes associated with climate-smart agriculture. A qualitative approach helps me to focus in-depth on the perceptions of people, the negative impacts of climate change related events on their lives, and their experience with CSA as a possible solution, and in a context (Sindh, Pakistan) where research on this topic is limited.

2.4.1 Qualitative Case Study Approach

Yin (2013) explains that a qualitative case study approach is useful in three situations: 1) when basic research questions relate to the “why” and “how” of the challenge or issue at hand; 2) where the researcher attempts to understand the complex events in certain behaviour (Bonoma 1985; Yin 1994) and has limited control over behavior; and 3) when the focus of study is related to the present emerging situation or in the real-world context. My research aims to examine the role of knowledge co-production in climate-smart agriculture, how the existence of multiple stakeholders and drivers of change impact the knowledge system of climate-smart agriculture, and the role of institutional arrangements and governance systems in the promotion of climate-smart agriculture in the study villages of three main districts (i.e., Dadu, Badin and Mirpurkhas). All of those conditions explained by Yin (2003) exist and justify my use of a qualitative case study approach.

A case study research methodology has a number of benefits and has made considerable contributions to address a range of social science questions (Yin 2009). However, there are some limitations of the case study approach (Yin 2009) and it is important to be aware of those limitations. For example, some people assume a case study is only appropriate for the exploratory phase of research and is a very preliminary research method (Daughtery 2009). They also believe that it provides little basis for scientific generalization as it takes too long and results are difficult to generalize (Daughtery 2009), which means research emphasizes detail which may divert the attention from the main issues at hand. Yin (2013) explains that a case study can be more exploratory and each research methodology can be used for all the three purposes – exploratory, descriptive and explanatory. Yin (2013) highlighted the following concerns:

1) Conducting the research thoroughly: This implies that systematic and comprehensive research is very important to gather data on all aspects of the issue. I addressed this concern by using multiple data collection techniques within the case study method (e.g., semi-structured interviews; focus groups, observations).

2) How to arrive at the general conclusion where desired: Another challenge associated with case study research is that results cannot be easily generalized. However, in my research, I am not attempting to generalize because findings in each district village have specific relevance to the case study context and can contribute in a different way for the governance of CSA. I am hopeful that while my research cannot be easily generalized, the findings from three districts are useful in drawing comparisons with other agriculture villages that are undergoing similar changes.

3) Managing the level of effort: Case studies are time demanding and require attention to detail. It is important to properly manage time in the field to obtain results using a case study method. I was able to address this challenge by spending four months in the field which allowed me to dedicate enough time not only to complete the case studies but also to implement other data collection methods. Spending time in the field was also important to observe changes (i.e., CSA policy and related reforms) and to understand people's behavior, cultures and traditions in relation to the three districts.

4) Understanding the comparative advantage of case study research: For example, my research has a historical component in it. Case study research is helpful to collect historical explanation of the changes that happened in the three districts and link that information to the current processes of change.

2.4.2 Data collection

Data collection in my research involved a mixed method approach to address the objectives of the research. There was no one source of data collection which could have covered all the required information for the research, and therefore, I decided to use several data collection methods to achieve the desired results. Table 2.5 outlines different data collection methods in relation to each objective related sub-questions.

Table 2.5: Guided sub-questions for each objective

Objectives	Sub-Questions	Data collection methods
Characterize the present-day knowledge systems in the study regions as they relate to agriculture and water sector interactions and development of climate-smart agriculture.	• What is the basic knowledge system in that study area in agriculture and water sector (if any)? • What are the different types and sources of CSA knowledge available in the study area? • Who are the different stakeholders involved in the knowledge system of CSA? How has the existing knowledge system impacted / supported the development of climate-smart agriculture?	• Government documents • Previous studies if any • Oral record (discussion with elders in the community) • Reports from international agencies like UN, NGOs, and local research institutions
Identify key social, cultural, political and economic drivers e.g., the 'landlord system (patron-client arrangements)' that hinder how different types and sources of knowledge influence the emergence and implementation of climate-smart agriculture	• What drivers influenced knowledge systems in the context of water-agriculture sector interactions? • What is the impact of different drivers on the knowledge system of CSA? • How has the knowledge system of CSA emerged over time in the three districts? • How do local communities understand knowledge co-production?	• Government documents • Previous studies if any • Semi-structured interviews • Focus group discussions
To assess if and how different actors and organizations in the water-agriculture sectors can engage in the collaborative production of knowledge to enhance governance of climate-smart agriculture”	• What is the role of co-production of knowledge in the context of CSA? • What is the existing institutional arrangement to support co-production of knowledge for CSA in emergence and implementation? • What is the role of knowledge co-production to enhance the knowledge governance of climate-smart agriculture?	• Semi-structured interviews within the community, NGOs, government officials etc. • Focus group discussions i.e. women. • Pictures of agriculture lands, farmers, CSA technologies etc.

I have used the following data collection methods: i) focus group discussions; ii) semi-structured interviews; iii) review of literature and documentation, and iv) informal discussions and observations. Each one of these methods is discussed in detail below.

A) Semi structured interviews

Interview techniques are used to understand the feelings, thoughts, perceptions, intentions, perceptions, and significance of historical events, which the researcher cannot observe (Patton 2002). Qualitative interviews allow researchers to articulate constructed realities held by individuals and assumes that the perspective of others is meaningful. Interviewing permits the researcher to interact with people who are knowledgeable and are the source of important information about the research case and to describe and uncover the interpretations of participants.

For my research, interviewing was used to understand the historical as well as current perspective of knowledge system in water-agriculture sector interactions and development of climate-smart agriculture in the case study areas (objective 1). Interviews are used to examine the present-day knowledge system and different drivers influencing the knowledge system and how they facilitate or constrain implementation of climate-smart agriculture (objective 2). Interviews were also helpful to understand how the collaborative production of knowledge between the water-agriculture sector at different scales can help to implement climate-smart agriculture through an effective governance system in the case study area (objective 3).

Semi-structured interviews provide a systematic approach to interviewing individuals in case study areas and allowing their perspectives and experience to emerge (Patton 2002). Semi-structured interviews were based on a pre-determined set of questions (See Appendix 1). These questions were flexible enough to also allow asking some critical questions that cannot be asked directly. The purpose of selecting a semi-structured interview technique is that it does not necessarily follow the interview guide, which means that depending on the requirement and discussion, a number of questions can be modified to ensure relevance.

In total, 70 semi-structured interviews were conducted with local farmers, officials from NGOs, INGOs, UN and government departments and research institutions, all of whom have a good knowledge and understanding of the research subject and have been working in the research study sites for a long period of time (i.e., 40 to 50 years). Out of the 70 semi-structured interviews, 45 interviews involved local farmers in the villages in Badin, Dadu, and Mirpurkhas (15 per village). As a guide, sub-questions (See table 2.5) were used to develop a detailed questionnaire. Semi-structured interviews involved local farmers to understand their perspectives about the historical and present-day knowledge system in relation to CSA. The semi-structured questionnaire (See Appendix 1) helped me investigate local farmer's actual experience with climate and their knowledge and responses to climatic conditions that might influence their farm-level decisions.

Age groups were identified based on their number of years of experience in agriculture to understand different views about CSA technologies and practices. Interviewing different age groups of local farmers also helped to understand their perception and first-hand experience (if any) in climate-smart agriculture practices and technologies. This segregation also helped to understand the customary knowledge and practices of sustainable agriculture.

Women community representatives and ethnic group members were interviewed who have been directly affected by the impacts of climate change and resulting changes in agricultural practices. In the agriculture sector of Pakistan, almost 72 percent of women work in the farms contributing agriculture-related activities (FAO 2015). Women and minority groups were also interviewed to understand how information is being shared with them and how they are involved in any decision-making process related to the farming practices and implementation of CSA. I also inquired about their understanding of the concept of climate-smart agriculture and how they learned from different CSA practices and technologies.

Other groups of people selected for semi-structured interviews were government officials, scientists from major universities and research institutions of Sindh, and officials from NGOs, INGOs, and the UN. These groups were interviewed to examine different perspectives and their role in climate-smart agriculture, their involvement in related research, decision-making, and policy making. These groups further guided me to explore how local, expert and scientific knowledge is being used and shared at different scales and between different authorities. They also helped me to identify different aspects of climate-smart agriculture based on their knowledge - for example, in terms of how government officials interact with the NGOs and UN agencies like the FAO working in the case study area on the different development projects in water and agriculture sector, or in terms of what kind of knowledge they possess about the local communities and their agricultural practices. Similarly, semi-structured interviews also helped me identify previous research related to water and agriculture sector particularly related to CSA practices and technologies.

Snowball sampling was used where each community participant was asked to identify additional potential participants. For example, for semi-structured interviews, I started with interviewing different professors from Sindh Agriculture University, Tandojam (SAUT) who later helped me to identify other relevant government officials and local community leaders. SAUT is the major research institution in Sindh founded in 1977, working in agriculture education and research. They also helped me to in selecting the villages based on their knowledge and expertise to ensure that I receive maximum and relevant information about climate-smart agriculture.

B) Focus group discussions

Focus group discussions are helpful in gathering information by interviewing a small group of people through a shared discussion about relevant features of interest (Berg 2004). Focus group discussion is helpful to understand the different socio-cultural characteristics (norms, traditions, social setup etc.) and different groups of people with similar interests within the society (i.e., agriculture and fish farming etc.). I have used focus group discussions to identify key insights or concepts and the relation of communities with their agriculture lands, local needs, community resources, adaptation strategies, and their consequences.

In total, I held six focus group discussions in the villages of Badin, Dadu, and Mirpurkhas (two per village). Groups were organized on the basis of different gender (i.e. separate male and female groups) from farming communities so that women were more comfortable to discuss their issues. Focus groups were organized keeping in view the local traditions. Other themes to disaggregate groups were agriculture and non-agriculture communities and minority groups. Each group had five to six members and was facilitated by myself. The duration of each focus group was approximately one hour.

These groups were asked a pre-determined set of questions (Appendix 2). Focus group discussions were based on the sub-questions (See table 2.5) to cover all three objectives of the research. Groups were selected based on knowledge and experiences surrounding the research topic (i.e. climate-smart agriculture and knowledge system) in the case study areas. Knowledge of CSA was accessed through individual discussions with village experts, who further helped to identify group members. Groups were formed or recruited based on guidance provided by the community partner and government officials and researchers in the water and agriculture sector, elders, and the local IP that have a role in water-agriculture governance. For example, in the process of group selection, experts from FAO and Agriculture University Tandojam were also involved.

There were a number of challenges while conducting the focus group discussions but I was successful in overcoming these challenges. For example, one challenge was the language barrier I faced as the local and provincial language is “Sindhi”. I hired translators (i.e., both male and female) who accompanied me in conducting interviews with different groups where there was a language barrier. Another main challenge was that participants of the focus group discussions were farmers and some of them were daily wage earners, and it was difficult to bring them all together at the same time. The month of May, June, and July are the hottest months Pakistan, which was another big challenge for me to conduct interviews and focus groups in far places like Badin and Dadu. It was around 45 to 50 degree centigrade with sand storms when I was conducting focus group discussions in Dadu and Badin. I was making sure that I have enough drinking water and food to keep myself hydrated and active.

C) Review of previous record and currents government documents

Another important source of data collection in my research was to review existing official and unofficial records (articles, published and unpublished reports etc.), including government reports and peer-reviewed research. As my research is mainly focused on the history and present-day knowledge system in both agriculture and water sector, reviewing the previous record, government documents and any previous study provided additional empirical foundations. The review of these materials helped me to understand the existing knowledge system in the water-agriculture sector (objective 1,2). In addition to the overall knowledge system, I examined current policy documents (e.g., Framework for implementation of climate change policy, CSA draft policy, agriculture policy, seed policy, etc.) and practice guidelines of agriculture extension services after consultation with Ministry of climate change Pakistan and agriculture extension wing, agricultural supply and price department, Sindh. Reviewing different policies and related documents helped me to examine the existing practices in agriculture and water sector in the light of impacts of climate change and drivers that influenced the knowledge system of CSA (objective 2).

Previous case studies and research documents also helped to identify some key issues and important information highlighted in them related to knowledge governance in agriculture and water sectors in Sindh, and governing issues in the agriculture and water sectors for the implementation of climate-smart agriculture (objective 3). This information was important to improve the processes of knowledge co-production between the water-agriculture sector at multiple scales in the future. The literature review included previous studies undertaken on the Indus delta, and documentation was collected mostly through the University of Sindh library, government, and non-government websites. Historic documents mostly were collected from government offices such as the extension service department, SAUT, Irrigation department, Farmer organizations (FOs), World Bank (WB), FAO, and the UNDP GEF Small Grants Program.

D) Participant observation

I also carried out participant observation to collect some additional information about my research topic. Participant observation usually took place during research activities (i.e. interviews) and during community gathering (i.e., annual festivals at community levels). I recorded observations as field notes in my notebook and used the information to compare it with the data collected through interviews and document review. Participant observation helped me to collect information about existing practices, culture, norms, practices, knowledge, and stakeholders involved in the case study areas (objective 1), about the role of institutions/drivers facilitating and constraining local communities to adapt climate-smart agriculture (i.e., training services, farmer schools, manuals and agriculture magazines provided to farmers etc.) (objective 2). Observation also helped me to understand the different power dynamics (hidden or identifiable) within the community groups, government departments, and research institutions at different scales.

Besides the observation and informal discussions, I also organized a consultative workshop with FAO, UNDP GEF Small Grants Program and other stakeholders where farmers, officials from irrigation department, extension services department and community organizations participated. This workshop helped me to gather information from different stakeholders under one roof and to understand the several issues faced by the different stakeholders in the agriculture sector. Other supplementary means of data collection included field notes, and mapping with groups flips charts used during focus group discussions. Table 2.6, below provides a summary of data collection methods.

Table 2.6: Summary detail of data collection methods, participants, and the process

Method	Participants	Data Collection methods	Total numbers	Objectives
Semi-Structured Interviews	• Key informants (village unions, water and agriculture management authorities, farmers organizations, UN, NGOs etc.) • Farmers and other agriculture dependent groups 70 participants	• Identified semi-structured conversation topics • Prepared guided questions to stick to the topic • See Appendix 1 for interview questions	Dadu: 15 MPK: 15 Badin: 15	1, 2,3
Focus group discussions	• Farmers and other agriculture dependent groups • Agriculture service extension officers • Officials from UN, NGOs and other CSOs 6 groups 5-7 per group	• Groups selected after the approval of concerned authorities • Each group was debriefed and provided with the consent form to sign. • Groups were determined to keep in view the diversity in a population. See Appendix 2 for interview questions	Dadu: 2 (1 male: 1 female group) MPK: 2 (1 male and 1 female group) Badin: (1 male and 1 female group)	1, 2, 3
Review of previous and current record	• Government officials from water and agriculture sector, extension services, agriculture university NGOs, FAO, World Bank etc.	• Previous studies were done on the similar topic. Researchers, universities, UN, NGOs etc., were contacted for such document. Government record was used to review the previous and existing policies and rules	40 to 50 documents	1, 2
Informal discussions & observations	• Farmers • Officials from UN, NGOs and other CSOs	• Informal gatherings during field visits and interview sessions • Consultative workshop conducted by FAO and other local partners • Local festivals. Annual Sawalo Faqeer festival attended to understand local community celebrations		1,2,3

2.5 Ethical consideration

2.5.1 Informed consent

An invitation statement (translated) was used to introduce the project and invite participants with the understanding that agreement to continue implies informed consent. All the semi-structured interviews, focus group discussions, participatory data collection and analysis techniques were done at the place where participants were working and living (agriculture communities). Verbal consent was taken from all the interviewees to use their names in the thesis especially for the female participants of semi-structured interviews and focus group discussions. All the interviews were recorded after taking consent from the participants. For further detail, a copy of research ethics is attached (Appendix 6).

2.5.2 Confidentiality:

Confidentiality and privacy were ensured while collecting and documenting the information from the participants. The participants in the individual interviews are recorded with alias names to ensure their confidentiality, or where interviewees didn't want to disclose their name. Focused groups were more informal and participants who agreed to participate knew that they are sharing their knowledge and understandings about the particular problem. In focus groups, participants were not anonymous to each other but outcomes of those groups (maps, etc.) were kept confidential and will not reveal individual identities. The recorded interviews (both semi-structured and focus groups) were kept in safe local and access was limited to myself and my supervisors. I sought prior permission to use a direct quote and names where necessary in my thesis. Names are not disclosed to ensure anonymity of interviewees who didn't want to disclose the names.

2.5.3 Field preparation and travel plan

A thorough travel plan was prepared with the help of the field manager and implementing partner agency (UNDP-GEF SGP). Once the plan was prepared, I shared it with my supervisors and Waterloo-International staff to ensure that everything in my travel plan is up to the mark and meet all the international safety standards.

2.6 Data analysis

I gathered all the information collected through interviews, focus groups and literature in a separate folder according to the theme of each chapter (i.e. introduction, climate smart agriculture practices, drivers of change, stakeholder's knowledge etc.) and at the end linked CSA practices with drivers of change and stakeholder's knowledge. After downloading all the recorded interviews from the field, I revisited all the recorded interviews and extracted the information from transcripts.

I used thematic coding and narrative analysis to understand people's interpretation based on their experience and how they explain it (Holstein & Gubrium 2012). Thematic coding involved following steps to analyze the interview data: 1) transcribe and summarize the interviews; 2) code the themes, events, examples, names, places, and dates; 3) sort similar themes, events, and examples, etc., into one group and then summarize the content of each group; 4) sort the themes, events, and examples and compare the excerpts of different sub-groups; 5) integrate description from various interviews to create a complete picture; 6) at the end different themes are combined to generate your own theory or test the existing theory (Rubin and Rubin 2012: p 190). I carefully used all the steps to understand and analyze what people said and how they said it based on their individual and group experiences and knowledge.

To explain my research, I used a story telling method as recommended by (Pratt 2009) who argued that we should "think about telling a story" that provides descriptive during the development phase of the study and at the end of the study. Sharing a descriptive story that captured my thoughts (i.e., about living conditions, social and economic factors associated with the knowledge and implementation of CSA.) in addition to collected primary data, helped me to establish a clear ground of communication and analysis. I also ensured to limit personal bias, review errors by building an understanding to incorporate valid suggestions and reflecting multiple views.

Results from my semi-structured interviews and focus group discussions helped me to identify the relationship among local conditions, scientific research, decision-making process and institutional policymaking related to CSA. These interviews also helped me to examine how researchers, government and other stakeholders and their knowledge interact with the socio-economic and power/political structures associated with climate-smart agriculture in the case study areas. Information collected through semi-structured interviews and focus group discussions fed into a three-layer conceptual framework of knowledge governance: civic epistemology, knowledge systems, and interventions (see chapter 6, section 6.3).

2.7 Challenges and limitations

In this section, I have also identified some of the key challenges and limitations I faced during my research and how I took different measures to mediate them. First, my research was conducted as a part of a larger project with multiple objectives and outcomes. There were more four researchers involved (two from Canada and two from Pakistan) to conduct the qualitative research (for which I was responsible) and the detailed survey regarding the status of CSA in Sindh. The challenge was to conduct my research smoothly in the study areas according to the identified timeline. There were some expected delays in coordinating with the project team in Canada and in Sindh- Pakistan. To overcome this challenge, I tried to engage with the project team and my supervisors as frequently as possible to gather required information and collect funds to conduct my research.

Second, I was working with local communities in the case study areas characterized by cultural and linguistic complexities. It was difficult to understand some practices, informal rules, and traditions within the community. To overcome this challenge, I ensured that I understand local traditions and informal rules and conducted my research under the guidance of a professor and director of extension services from Sindh Agriculture University Tandojam, Mr. Ismail Kumbhar and Mr. Masood Lohar, National Program Manager, UNDP-GEF SGP Pakistan. The language barrier was overcome by one female and one male translator, who accompanied me during interviews and field visits. Ethics guidelines were also followed to ensure the positive, productive and smooth interaction with the local communities. Some of the interviews were conducted during the month of Ramadan (the holy month of fasting). During this month, arranging interviews was difficult. It also took several hours daily to visit the impacted communities because of the remote location and dirt tracks. Due to security reasons, I was not allowed to stay in remote locations a few times, which made it very hectic for me to travel on a daily basis. Another challenge was the hot weather. The temperature was around 30 to 40 degree when I was conducting semi-structured interviews.

Third, a common challenge associated with almost all research is the reliability of a study. To ensure the reliability of the process of data/information collected, I recorded the interview and the relevant detail (i.e., date, time, people accompanying me during the interview etc.) detail clearly at each step of my research. All the research activities were recorded and documented with a date. Moreover, by drawing on different sources of evidence (e.g., from interviews, focus groups, the literature), I triangulated my findings and interpretations. Triangulation is a process used to "*substantiate an interpretation or to clarify its different meanings*" (Stake 1995: 173). Multiple data collection methods (i.e. semi-structured interviews, focus group discussions and reviewing the record) thus ensured my efforts to enhance reliability.

Lastly, I have used semi-structured interviews to understand the linkages and processes of knowledge sharing among the different stakeholders (highlighted in Chapter 4, section 4.4). There are constraints in regards to this because my total number of interviews (while appropriate for my ability to address my research objectives) does not cover all potential participants. Moreover, I have not sought to reduce my analysis to a specific measure (e.g., quantitatively). To overcome this challenge, I validated key findings (e.g., those reflected in Figure 4.2) with the stakeholders through a participatory workshop at the end of my data collection process. In this context, I shared the findings with research participants to further understand the linkages and knowledge sharing processes, and specifically in terms of their qualitative categorization (i.e., how weak, very weak or strong are the links among different stakeholders) (see Figure 4.2.

Chapter 3 - Literature Review

3.1 Introduction

This chapter critically reviews the different bodies of scholarship used in this research and elaborates on the scholarly context necessary to address the research questions and objectives guiding my research. For this research, I draw on five main bodies of scholarship: (1) climate smart agriculture (CSA) (Section 3.2); (2) knowledge systems, which explains what knowledge is and what are the different types of knowledge (Section 3.3), (3) Knowledge systems for "agriculture production", which explains how the knowledge system for CSA can be used as a tool or process to facilitate and improve agriculture production (through soil management, seed and crop management, and water governance) and what are the challenges associated with it in the water-agriculture sector (Section 3.4); (4) knowledge co-production and role of knowledge co-production in CSA, outlines how knowledge co-production can facilitate the implementation of CSA through a collaborative process of gathering knowledge from different sources (i.e. farming communities, scientists, and policymakers) (Section 3.5), and (5) Knowledge governance, which establishes the relevance of knowledge governance to manage the knowledge system, the role of different stakeholders and institutions (Section 3.6). The chapter also analyzes the knowledge-decision-making and implementation process, its legitimacy and institutional arrangements to support knowledge governance to manage the complexities associated with the implementation of CSA in the case study areas.

3.2 Climate smart agriculture (CSA)

This section explains the core definition of CSA and its role in enhancing agriculture productivity. There is growing body of literature explaining the management practices and approaches to reduce vulnerability, enhance the adaptive capacity and mitigation potential of agriculture systems to climate change (Smith et al. 2007; McCarthy et al. 2011; Wollenberg et al. 2012b; FAO 2010, 2013). These approaches include: i) scientific solutions to address climate related-risk and environmental stresses (i.e., development new varieties of seeds that are heat and drought tolerant, pesticide control, organic inputs etc.), developing early warning systems, establishing crop insurance systems, increasing carbon stock in the soil etc.; and ii) farm management practices such as soil moisture techniques and water conservation practices, multi croping, limited or zero tilage practices and discouraging deforestation and reducing agricultural emissions. (Howden et al. 2007; Smith et al. 2007; Wollenberg et al. 2012b; Harvey et al. 2014). These approaches enhance the resilience of agricultural systems towards climate change, and diversify livelihoods for the farmers (Harvey et al. 2014). CSA is a combination of these approaches that ensures adapting to changing climate, reducing GHG emissions, and ensuring the food security around the globe (FAO 2013).

The concept of climate-smart agriculture (CSA) was presented and defined at the First Global Conference on Agriculture, Food Security and Climate Change at the Hague, as agriculture that "*sustainably increases productivity, enhances resilience, reduces/removes greenhouse gas emissions, and enhances achievement of national food security and development goals*" (FAO 2016: ix). According to this defnition, there are three main pillars of CSA; i) increase productivity, ii) enhance resilience and iii) reduce GHG emission. This definition was introduced to encourage and set the global agenda for investment in agricultural research and innovation, joining the agriculture, development and climate change communities under a common framing (Neufeldt et al. 2013).

CSA was also recognised by and evidenced in many international conferences and initiatives such as policy conferences on Agriculture, Food Security, and Climate Change in Vietnam (2012), the Commission on Sustainable Agriculture and Climate Change (Beddington et al. 2011), and new global initiatives on Climate Smart Agriculture (World Bank 2011; Vermeulen et al. 2012). The overall aim of CSA is to enhance the efforts from local to global levels to achieve food and nutrition security for all people at all times and integrating necessary adaptations (Lipper et al. 2014).

CSA practices and technologies include integrated crop, livestock, aquaculture and agroforestry systems; improved pest, water, and nutrient management; landscape approaches; improved grassland and forestry management; practices such as reduced tillage and use of diverse varieties and breeds; integrating trees into agricultural systems; restoring degraded lands; improving the efficiency of water and nitrogen fertilizer use; manure management, including the use of anaerobic bio-digesters; and enhancing soil quality can improve agriculture productivity by regulating carbon, oxygen and plant nutrient cycles (McIntyre 2009). All these practices also help to enhance resilience against drought and flooding and reducing the carbon sequestration (Lipper et al. 2014; FAO 2016a; World Bank 2017b).

Many CSA practices and technologies are already well known and are categorized as conservation agriculture (Harvey 2013), with different labels such as agroforesty, sustainable agriculture, sustainable land management, ecoagriculture management practices, etc. (McNeely & Scherr 2003; Hobbs 2007; FAO 2010; Garrity et al. 2010). The literature explains the major strength of CSA, which is the "triple win" effect (Neufeldt et al. 2013; Lipper et al. 2014; FAO 2016b), of increasing the agriculture productivity, reducing the GHG emissions and enhancing resilience, and therefore, addressing both mitigation and adaptation for climate change (FAO 2013; 2016b). Finally, CSA is a powerful approach associated with the climate change-agriculture nexus and it has been applied to diverse aspects of agriculture including food systems, food supply chain (Neufeldt et al. 2013), agriculture practices at plot, farm and landscape scale (Harvey et al. 2013). It also involves benefiting small farmers, vulnerable communities of developing countries, and in the capacity building of agriculture institutions or agriculture finance institutions (FAO 2013).

However, various concerns about CSA approaches have been raised (Suppan and Sharma 2011; Stabinsky 2014; Caron and Treyer 2016; Karlsson et al. 2017), including misconceptions about CSA technologies and practices, undermining the livelihoods of small scale farmers, ignoring the negative effects on biodiversity, discouraging traditional crop varieties, and undermining crop genetic diversity. For example, there are apprenhensions related to the unclear direction of what "triple win" means and who interprets the term and how it is applied. Although, the aim of CSA is to achieve all three pillars (explained above) it doesn't imply that every practice must generate a "triple win" effect (Lipper et al. 2014), as it very much depends upon the local conditions, existing practices and consideration of multiple factors involved in the implementation of CSA. Therefore, CSA has its own limitations. Harvey et al. (2013) suggest that CSA must offer wider options (i.e., management practices). To address the complex challenges and successfully implement CSA in Sindh, an additional focus is needed on the collaborative efforts to strengthen the knowledge systems between stakeholders that support the appropriate CSA technologies and practices that suit local conditions.

CSA has also failed to consider the impact of broader social, political and cultural dynamics (i.e. loss of cultural heritage, increased social inequity and long-term ecosystem instability) involved in agriculture sector (McCarthy et al. 2012). For example in Sindh there are multiple drivers (social, economic, political driver etc.) associated with agriculture sector that may determine the success or failure of CSA. Another concern highlighted in the literature is the chance that trade-offs may occur, while implementing the adavanced practices and technologies for both climate change mitigation and adaptation (Rosenzweig & Tubiello 2007; Verchot et al. 2007; Smith & Olesen 2010; Harvey et al. 2013). For exmaple, to increase agriculture productivity to meet the demand for food security, chemical fertlizers are used to maintain or increase the crop yield, but this may result in unavoidable GHG emissions (Kandji et al. 2006). In LMIC countries like Pakistan, with extreme water shortage, food security is another main challenge, but use of heavy chemical fertilizers to increase agricultural productivity may cause further damage to the soil and crops as well as increasing the GHG emissions. Similarly, an increase in the carbon stock in the soil, fast growing tree monoculture and cultivation of biofuel crops are recommended which may increase the risk of water shortage for the lands in the downstream areas (Huettner 2012). In Sindh, where water scarcity is the biggest issue, especially in the downstream district, such solution may not be helpful. To minimise and avoid such tradeoffs, collaborative and integrated approaches are needed (i.e., co-production of CSA knowledge) to learn about different possible solutions/options (Scherr et al. 2012; Sayer et al. 2013). These solutions may include CSA practices in agriculture like uses of composts or minimum tilage to retain soil moisture and carbon stock (Delgado et al. 2011; Harvery et al. 2013).

In the case study areas, CSA is studied through its role in agriculture production - a core unit of analysis for this research (see section 3.4), particularly focusing on CSA practices and technologies related to soil management, water use, and seed and crop management to enhance a) agriculture production, b) increase adaptive capacity and c) without compromising GHG emissions. A list of CSA technologies and practices for 'soil management', 'water use' and 'seed and crop management are' are summarized in Table 3.1. Most of these interventions overlap. For example, interventions related to the sustainable use of water are also relevant to the interventions for seed management (i.e., drought resistant seeds).

Table 3.1: List of CSA technolgies and practices in the case study areas

CSA techniques and practices
Soil moisture retaining techniques like soil mining is used to retain the moisture in the soil for a longer period of time. In soil mining, organic matter absorbs nutrients and moisture through water and then slowly release it into the soil (Dawn 2002).
Zero or no tilling techniques: In zero tilling, crop residues are left on the soil and distributed evenly without turning or disturbing the soil. Crop rotation is fundamental to zero till as it provides adequate biomass for mulch cover. It also helps to control pests, diseases, and weeds

and improves the physical condition of the soil. Zero-till helps to reduce soil erosion by 90%. In Sindh zero till is effective for the planting of wheat after rice to use rice residual soil moisture for wheat germination (FAO 2018).
Land laser leveling techniques: Land leveling is effectively used to avoid over- or under-irrigation due to the micro-ground surface undulations thus facilitates on-farm water control and management (Aslam and Prathapar 2001)
Management of nitrogen and nitrogen fertilizers: These contribute to high crop yields. The recycling of nitrogen through manures and nitrogen-fixing plants is the organic technique used to enhance soil quality. Proper timing and management are very important for this technique. In the case of nitrogen fertilizers, excessive use is harmful to the environment and habitats.
Green Manuring: The growing of legumes and other plants to fix nitrogen and absorbing the nutrients into the soil for the following crop. Commonly used green manures are Sesbania and the fern Azolla, which contains nitrogen-fixing, blue-green algae in rice fields (ZTBL 2018). Similarly, green manuring between the fallow period of the rice-wheat crops is very productive.
Drip irrigation and sprinkler techniques: Drip Irrigation Systems delivers water and agrochemicals directly to the root zones of plants according to their requirements. This method helps as compared to conventional methods to save 70% of water. Sprinkler system is the method of applying water in the form of artificial rain. Water is distributed under pressure through pipes (such as uPVC or PE) as a jet or sprays into the air over the land to be irrigated without the prior need of land leveling (required in the case of traditional irrigation methods). Sprinkler irrigation is used extensively all over the world. It helps to provide moisture to the crop and in the application of pesticides, weedicides, and fertilizers.
Storage ponds and Submersible pumps: These are used to optimize the use of water by creating storage ponds in the areas (i.e. Badin and Dadu) where water is scarce (World Bank 2017).
Furrow irrigation methods: Every Furrow Irrigation (EFI) is the efficient conventional method of surface irrigation which is being widely used for row crops with the proper combination of spacing, length, and slop of furrows and duration of water application. Alternate Furrow Irrigation (AFI) method significantly enhanced root growth in arid areas, resulting in high crop yield with 50% less use of water. AFI involves manipulation of soil water to make the crop's inherent response to drought conditions improve their water use efficiency (Memon et al. 2017)
Lining of watercourses: In these techniques, the lining is prepared by using the soil sealant/emulsions under varied local conditions. Some researchers suggest the use of fiberglass type plastic material with semi-circular or U-shaped, pre-cast fabricated RCC Trapezoidal or Parabolic in place of brick mortar and concrete could be used for watercourse lining for dry and hot weather conditions (Soomro et al. 2018). this technique is used to reduce the water seepages due to improper maintenance, illegal cuts.
Alternate wet and drying technique for rice paddy: the technique where water is only applied to the rice field when required based on the plant and soil moisture requirement. i.e. when the water table goes 15 cm below the surface (Alam et al. 2009)
Intercropping and multi-cropping: Intercropping means the growing of more than one crop in rows where the minor crops are planted between the rows of major crop. For instance, the crops like canola, mustard, garlic, tobacco, watermelon, muskmelon, etc. can be successfully intercropped with sugarcane crop. The crops in intercropping may have a different sowing and harvesting time. Although, it is known that intercropping is used for soil conservation purpose

but during research many farmers indicated that they use it for soil conservation as well as water saving technique. Multi or mixed cropping is the growing of two or more crops that require same soil condition, water use, sowing and harvesting time. Mixed cropping is especially important for fodder crops where it can provide enormous quantities of feedstuff for supporting sustainable livestock production (ZTBL 2018).
Use of good quality, approved and certified seed varieties and proper preservation of seeds. Seeds that are drought, heat, and flood tolerant, unlike conventional seeds. This also includes the use of the right quantity/rate of seeds for different crops.
Crop rotation techniques: In Sindh, Rice-wheat system in Dadu and Rice-sugarcane system in Badin is in practice. Pulses are preferred as they enrich the nitrogen content of soil for the coming wheat crop.
Adjusting and maintaining crop calendar: The Crop Calendar is a tool that provides timely information about seeds to promote local crop production. It contains information on planting, sowing and harvesting periods of locally adapted crops. It also provides information on the sowing rates of seed and planting material and the main agricultural practices. It can also help in emergency planning of the rehabilitation of farming systems after disasters (FAO 2010)
Mulch technology: It is the CSA technique through which soil surface around the plant is covered to create congenial conditions for crop growth. This technique helps to maintain soil moisture keeping the temperature moderate. It also helps to reduce salinity and weed resulting in high and good quality crop
Integrated Pest Management (IPM): is a strategy which promotes climate-smart practices in Sindh. For example, it promotes the use of bio-fertilizers, bio-pesticides, bio-powered fertilizers, and weed control practices to reduce GHG emissions and solid waste pollution in Sindh. In general, the IPM approach is used by universities, extension services, FOs and NGOs

Source: adapted from World Bank (2017).

3.3 Knowledge systems

An emphasis on 'knowledge' has become an integral dimension of any effort to understand linked social and ecological systems. North (1990), for example, highlights the three fundamentals for economic development which include institutions, organizations and knowledge. Within a social-ecological system, there is an essential link related to people's local knowledge to understand how humans interact with the environment (Berkes 2009). The Millennium Ecosystem Assessment also emphasizes the knowledge available from different sources (Hahn et al. 2006) through social networks to handle constantly changing ecosystems and changing dynamics of people depending on those ecosystems (i.e. increasing population, migration, change in livelihood needs). However, collecting knowledge is not enough and does not imply a sustainable ecosystem. Knowledge is only effective if shared and distributed at different levels through a collaborative process aimed at generating positive outcomes.

A knowledge system is defined as the process of social learning through which knowledge is accumulated from all different sources to deal with the dynamics of the ecosystem (Lee 1993). Lee (1994), explains a "knowledge system" itself as "accumulation of knowledge collected through different sources" or it's a process where knowledge is collected, used, shared or reorganized between two parties, individuals and organizations. Knowledge systems and associated institutions act as a memory or reservoir for social-ecological system dynamics, change and their adaptation process (Berkes and Folke 2002). According to Cash et al. (2003), an effective knowledge system should be able to facilitate bringing knowledge into action through a mechanism to facilitate communication, translation, and mediation. Knowledge systems help to deal with uncertainties and increase the capacity to deal with future change (Berkes and Folke 2002). According to Olsson and Folke (2001), the nature of knowledge and institutional arrangements to produce and share knowledge is important for understanding social-ecological system dynamics and plays an important role in creating strong social networks. To understand these dynamics, uncertainties and trends of ecosystems, it is important to analyze the knowledge distributed at different levels (i.e. local, regional and national agencies) and groups of people (i.e. local communities and scientists) (Berkes 2009).

Agriculture communities in many developing countries are experiencing dramatic changes in their requirements for and access to information, knowledge, and know-how related to agriculture production (i.e., cropping systems, soil protection, seed storage, etc.) (World Bank 2007). In an effort to enhance agricultural productivity, changing research focus toward improved genetic materials (Convey2007), changing management practices for different crops (Hazell 2009), changing landscape of agricultural production (Tilman et al. 2002; Rosegrant and Cline 2003), increasing food demand and environmental concerns (McCullough and Mastan 2016), knowledge systems are also required to evolve to continue providing relevant support (McCullough and Matson 2016).

In this research, existing knowledge systems are analyzed to understand the dynamics, uncertainties, and complexities of agriculture productivity, which is further extended to understand the knowledge system for CSA in the case study areas of Sindh, Pakistan. Before further explaining the role of knowledge systems in CSA, it is important to understand the different forms of knowledge in the literature that can be associated with agriculture production and CSA.

3.3.1 Different types of knowledge

This section summarizes the different forms of knowledge and different terminologies used to explain various types of knowledge. This section further highlights different systems to preserve knowledge and arrangements to produce new knowledge.

Berkes et al. (2008), in their book "Navigating social-ecological systems", highlight the importance of building resilience for complexity and change in social-ecological system (SES). In this book, Berkes et al. (2008) emphasised a need to understand the ecological systems through **local/customary knowledge** and through people who live close to their resources and use them. Local knowledge is also known as customary, indigenous, primitive or savage, recognizing that these later terms are negative and inappropriate (Agrawal 1995). The purpose of using local knowledge is to expand the information about change in social-ecological systems and use the information to improve resource management (Berkes et al. 2008). Customary knowledge reflects the understanding of local individuals (farmers) and the communities in which they are a part, based on their experience, oral traditions, spiritual beliefs, and practices that they have learned from their family members over generations (Warren and Rajasekaran 1993). A brief summary of different knowledge types is provided below:

a) **Indigenous knowledge** is usually held by the local communities and is unique to the culture or society (Berkes et al. 2008). For many rural communities, indigenous knowledge is very important and most of their local level decisions are based on it (Soropa et al. 2015). Indigenous knowledge also has a value for the culture of rural communities in which it evolves. Warren (1991: 1) explains indigenous knowledge as an "*important natural resource that can facilitate the development process in cost-effective, participatory, and sustainable ways"*. It is unique to a given culture or society.

b) **Traditional knowledge or traditional ecological knowledge** (TEK) is defined as *"a cumulative body of knowledge, practice and belief, evolving by adaptive processes and handed down through generations by cultural transmission"* (Berkes 1999: 8). Unavailability of traditional knowledge impedes the implementation of generic guidelines and principles available to manage the natural resources.

c) **Scientific knowledge** is also known as 'modern', 'civilized' and western knowledge (Agarwal 1995). Western knowledge is a more analytical and abstract depiction of the world, disconnected from the lives of people (Agrawal 1995), and claims to be superior on the basis of its universal validity (Banuri and Apfell-Marglin 1993). Western knowledge is also characterized as a knowledge with a high prestige (Agrawal 1995). Warren (1989), describes scientific knowledge as more centralized and connected with the state's decision and policy making processes. Scientific knowledge is also explained as "*explicit knowledge that has been derived from applying more formal methods that aim to increase rigor in relation to different positions on validity and reliability. This includes natural science and social science research*" (Raymond et al. 2010: 1769). Other authors explain scientific knowledge as knowledge which focuses on an agreed set of principles or process of study, reliability, validity and is based on scientific evidence (Gunderson et al. 1995; Turnbull 1997; Fazey et al. 2004; Pullin and Knight 2001). Dietz et al. (2003) explains that scientific knowledge and understanding of social-ecological systems are very uncertain because of their inherent unpredictability and constantly evolving nature.

   Raymond et al. (2010) highlight the overlap between different types of knowledge by explaining that local knowledge can be either informal or expert, similarly both scientific and informal knowledge can be explicit, where explicit knowledge is written and codified (Fazey et al. 2006).

d) **Policy knowledge** might be defined as "*information and ideas useful in framing, deepening our understanding of, and/or enriching our conceptualization of policy problems"* (Dumas and Anderson 2014: 8). Policy knowledge is usually developed from the analysis of experiential data from one or more than one studies and is also taken as an explanation of a specific research design (Dumas and Anderson 2014). Policy knowledge that involves many actors (i.e., decision makers, policy makers, communities etc.), is normally used to discuss several policy problems (Bacchi 1999). Policy knowledge may include input from policy makers, education practitioners, non-profit organizations, practitioners, and communities (Dumas and Anderson 2014). James and Jorhensen (2009) explains that the result of policy knowledge must reach the appropriate audience which may include producers of policy knowledge, affected target population, and decision makers. Policy knowledge can help to solve a wide range of policy problems including agriculture policy, education policy, foreign policy, unemployment, etc. (James and Jorgensen 2009).

However, my emphasis here is primarily on two different forms of knowledge to understand the specific dynamics and uncertainties associated with the implementation of CSA in the agriculture sector of Sindh: i) customary knowledge which is typically held by individuals with a long association with their agriculture land. This knowledge is often informal, inherited and based on farmer's own perception and lifestyle; and ii) scientific knowledge which is held by researchers and government, NGOs and policy makers etc.

3.3.2 Customary knowledge in CSA

Customary knowledge is usually generated through observation of a local society and is generally mixed with scientific and practical knowledge (Berkes et al. 2008). For successful implementation of CSA, customary knowledge (i.e., beliefs, cultures, traditions and practices) are important to consider to expand the understanding of natural resources (i.e., agriculture land) and the connection of the local communities with these resources. In this research, customary knowledge is analyzed to understand the knowledge system of local communities based on their beliefs, norms, traditions, and practices in agriculture and their understanding of CSA practices specifically. Customary knowledge helped me to understand the existing/inherited knowledge of CSA (if any) they adapted from their families and forefathers.

3.3.3 Scientific knowledge in CSA

Scientific knowledge in this research is used to explain the different forms of knowledge available in the Sindh with different stakeholders for climate-smart agriculture and how they use or share the knowledge they possess. This knowledge is often formalized through text, reports, policy document etc., and is based in some manner on the application of the scientific research method. For example, in the case study areas, CSA is introduced after scientific research and consultation of different individuals from government, donors, policy makers and decision makers at the national level. Scientific knowledge helped me to understand the basis of new CSA technologies and practices introduced in the case study areas by researchers and other stakeholders.

3.4 Knowledge system for agriculture production

To narrow the focus of the knowledge system around the agriculture sector in my research area, "agriculture production" is used as a core unit of analysis. Specifically, my research mainly focuses on the knowledge system that revolves around enhancing agricultural productivity. Knowledge systems for agricultural productivity are further categorized into three sub-unit of analysis - knowledge about: i) soil management; ii) water use; and iii) seed and crop management (see figure 3.1 below).

Food security is a key global issue and increased productivity and equity of distribution in the agricultural sector plays a vital role in addressing food security issues for the projected 8 to 10 billion people (Tilman et al. 2002). However, whether this can be achieved through sustainable agricultural approaches (high yield, low impact) (Conway 1997) and agricultural practices with less harmful effects on the environment is less clear (Tilman et al. 2002; FAO 2016b; World Bank 2017b). There are numbers of environmental impacts associated with agriculture (i.e. agricultural nutrients polluting the aquatic habitats and groundwater; pesticides impacting the human and animal health). Therefore, the major challenge faced by the agriculture sector are the trade-offs among conflicting economic and environmental goals. Considering water as a fundamental part of the agriculture sector, FAO (2016b) suggests that agricultural productivity should not be measured in terms of land but also through water productivity. Hence, crop water productivity can be improved through production per unit of land through improved and environmentally friendly soil and seed quality, water management, pest control and use of fertilizers.

To enhance agricultural productivity, availability of knowledge in a timely fashion is important for decision making (Mtega and Ngoepe 2018; Kirchhoff, Lemos & Dessai 2013). Stakeholders in the agriculture sector must be actively involve and connected to each other to share and effectively utilize their knowledge (McCullough and Matson 2016). These stakeholders including farmers, agriculture researchers, extensions service providers, and policy makers, all of whom are responsible to enhance the access and usage of the knowledge in the agricultural sector, and in combination help to form the agriculture knowledge system (Isinika 2007; Lwoga, Ngulube & Stilwell 2010). Previous research mostly addresses the importance of knowledge systems as a main function to manage the boundaries between scientific knowledge and decision making, but less attention has been paid to understand changes in knowledge systems over time due to emerging challenges (i.e., climate change) (Guston 1999; NRC 2006; Kirchhoff, Lemos & Dessai 2013). Figure 3.1 highlights the links among agriculture production, knowledge systems and the three contexts in which knowledge systems can contribute to agriculture productivity: efficient soil management, water use, and seed and crop management.

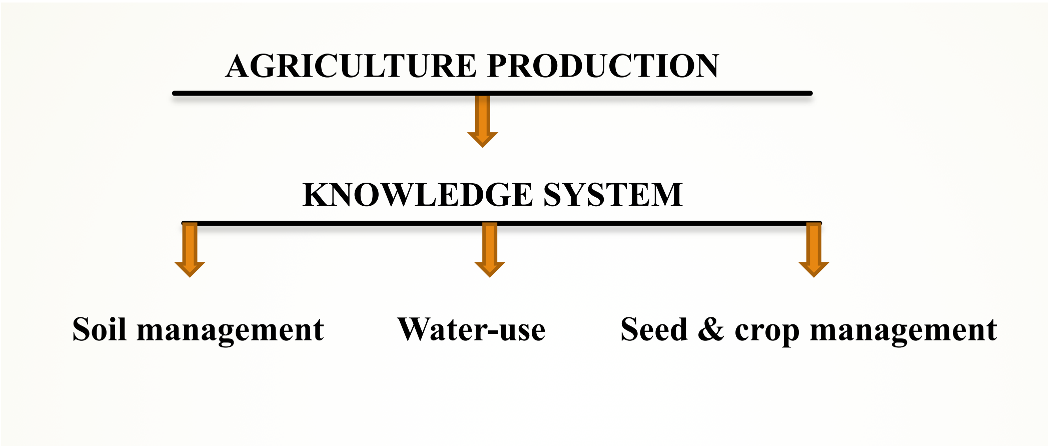


Figure 3.1: Core and sub-unit of analysis for agriculture production (Created by Sajida Sultana)

3.4.1 Soil management

In this research, soil management is one of a sub-unit of analysis for agriculture production. Before investigating the role of CSA in soil management, it is important to understand what soil quality and management means. Improving the soil productive capacity is a key to high crop production. Doran and Zeiss (2000) note that soil quality is the capacity of the soil to sustain biological productivity, promote environmental quality and maintain plant and animal health. Soil quality is also defined by SSSA (2008) as the ability of the soil to supply nutrients essential to plant growth and to produce crops. Soil management practices that sustain its quantity and quality (i.e., biological, chemical, and physical) can enhance soil productivity (Doran and Parkin 1994). On one hand, soil quality directly correlates with the farmer's fertilization practices and their ways of soil management (Omari et al. 2017). On the other hand, soil quality assessment is usually done through scientific methods with a set of different indicators which tend to dominate the local knowledge of farmers about soil management (Omari et al. 2018). In countries like Pakistan, the yield gap indicates that effective soil management could have significantly increased yields with the appropriate use of CSA and other agriculture technologies. In some countries, including Pakistan, agriculture is also heavily influenced by the use of fertilizers for high-yield outcomes, but at the same time, use of fertilizers (i.e. nitrogen fertilizers) increases the emissions of greenhouse gas (i.e. nitrous oxide).

The need for effective collaboration between scientists, farmers, extension services and policymakers to design policies (i.e., CSA policy) that integrate all forms and sources of knowledge about soil management and productivity is established (Winklerprins 1999; Niemeijer and Mazzucato 2003; Desbiez et al. 2004; Dawoe et al. 2012; Omari et al. 2018). However, it is important to understand how farmer practices and local knowledge as well as scientific advancement affect the soil health, fertilization management and ultimately the crop yield (Omari et al. 2018). In-depth knowledge of farmers about soil processes and understanding the impact of climatic and non-climatic variables on soil degradation has significant implications for soil management (Lal 2001). A participatory research approach is needed for the development of technologies to improve soil management under CSA. This research centers and analyze the different form of CSA knowledge from different sources associated with soil management and soil productivity in three study districts of Sindh, Pakistan.

3.4.2 Water-use efficiency

Agriculture around the globe heavily depends on water use, and this is why agriculture is always at the core of discussions about linked water and food security issues. The agriculture sector accounts for 70% of all water withdrawals globally and this percentage is even higher for "consumptive water use" (World Bank 2017b). Consumptive water use means "*The part of water withdrawn from its source for use in a specific sector (e.g. for agricultural, industrial or municipal purposes) that will not become available for reuse because of evaporation, transpiration, incorporation into products, drainage directly to the sea or evaporation areas, or removal in other ways from freshwater resources. It is opposed to non-consumptive water use*"

(FAO 2016b: web). Irrigated agriculture lands are on average 20% of the total cultivated land which contributes 40% of the total food produced globally (World Bank 2017b). With the expected increase in population over 10 billion by 2050, the need for food and fiber will increase significantly which means agricultural production will need to expand 70% by 2050 (World Bank 2017b). Therefore, it is important to look at the policy interventions at all levels related to water use and water management in the agriculture sector. In many developing countries, public and private institutions involved in agriculture and the water sector, basin authorities, farmer organizations, and water users generally lack the authority and capacities to perform their functions effectively. At the same time, they face a number of challenges in the implementation of large-scale schemes due to lack of accountability, political involvement, and capital-intensive large-scale schemes. For example, at the local level, farmer organizations are usually facing highly distorted incentive in terms of water pricing and agriculture support policies (World Bank 2017b). There is a lack of knowledge at the local level regarding the vulnerability of agriculture in terms of water availability.

Irrigated lands constituted a substantial portion of increased yield obtained after the introduction of green revolution technologies. However, the global rate of increased irrigated land is declining. Moreover, water is scarce in many parts of the world and it is believed that China, India, Pakistan, middle east countries and countries of northern Africa are currently or will have inadequate water to maintain per capita food productivity from irrigated lands. Salt accumulation and water-logging is another problem that reduces yield in developing countries (Rietz and Haynes 2003).

Therefore, water-use efficiency is one of the key factors in agriculture production and ultimately, CSA. CSA techniques and processes such as drip and pivot irrigation can help to improve water-use efficiency, and hence maintain or increase agricultural yield. In developing countries, other solutions under CSA like increasing the water-holding capacity in the soil can be enhanced through the use of manure and reducing tillage and by increasing soil organic matters. Crops with high water-use efficiency as compare to others and greater drought tolerance can be introduced and cultivated to increase the yield with limited use of water (Knight and Knight 2001: Stringer et al. 2009). In this research water use/water governance is analyzed to access what type of knowledge is important to produce and share with local communities and other stakeholders to ensure improve water governance and water use in the agriculture sector.

3.4.3 Seed and crop management

Agricultural productivity also very much depends upon the control of weeds, crop diseases, and pathogens that are supressed through heavy application of chemical inputs. Farmers use these chemical insecticides for higher gains to protect the crops from pests and diseases (Lekei, Ngowi & London 2014). For example, the lifetime of maize hybrids in the US is doubled to four years as compared to 30 years ago (Tilman et al. 2002), but pests become resistant to these chemicals very quickly. To overcome this, more chemicals and a mix of different chemicals (Oben-Ofori et al. 2002) are used which cause a resurgence of pests, damage to the crop beneficial insects and the environment in general (Dutcher 2007). There is also a complex interaction between the cultivated crops and their pests and diseases (Berger et al. 2017). Plant pathogens and crop feeding insects are an essential part of agroecosystem as they have coevolved with the crops over a millennium (McCann et al. 2013).

Unfortunately, there is a substantial knowledge gap between the scientific research and knowledge to protect seeds and crops through chemicals, and understanding of farmers in this regard. Despite the number of training opportunities in recent decades, farmers in developing countries are still unfamiliar with current approaches to control pests and diseases like integrated pest management (IPM) (Ofuoku, Egho &Enujeke 2009). There are several factors which should be considered (i.e. socio-economic and demographic) (Machekano, Mvumi & Nyamukondiwa 2017) for the successful implementation of different policies like CSA and management programs like (IPM). For example, it is important to understand farmers' experience and knowledge in the identification, management, and information about pests and diseases as it varies with the level of education, gender and family status (Caulkins and Hyatt 1999, Abang et al. 2013). Similarly, the success of the CSA practices like integrated pest management depends upon the motivation, right skills and knowledge and participation of the farmers at the community level (Borkhani et al. 2013). As farmers are the final decision makers for the adoption of any technology (Allahyari et al. 2017), it is also important to understand the local agro-production systems and context-specific folk knowledge to guide the farmers about different techniques to control pest and diseases (Ashraf, Raza & Younis 2012; Allahyari et al. 2017).

3.5 Knowledge co-production

This section highlights the basic definition of knowledge co-production, benefits of knowledge co-production and its importance in handling the complexities of multiple stakeholders and drivers that are involved in the knowledge system and implementation of CSA (with reference to the three areas of concern noted above: soil, water and seed/crop management).

Co-production research first appeared in the work of Elinor and Vicent Ostrom (1977a), who introduced the idea of "consumers as co-producers of public services". This led to the development of institutional analysis and its application on the management of common pool resources (Ostrom and Ostrom 1977b). Their research involved public service delivery where government agencies and other stakeholders were involved in collective action for community security, education, health, welfare and environmental protection (Miller and Wyborn 2018).

However, there is a persistant confusion on what exactly co-production means and how to apply co-production in practice (Van der Hel 2016; Turney 2014; Van Kerkhoff and Lebel 2015). As explained by Miller and Wyborn (2018), confusion exists because of the fact that co-production research initially developed in three different field of study: i) public administartion (Ostrom and Ostrom 1977a); ii) science and technology studies (Latour 1990; Jasanoff 1996); and sustainability science (Kates et al. 2001; Kofinas 2002; Cash et al. 2003). In public administration, knowledge co-production was used initially in the Charter of the American Society of Public Administration, that read "To develop approaches to public service education based on the concept of the learner as a co-producer of knowledge" (Adams et al. 1988). In science and technology studies, Jasanoff (1996: p 397) used the language of co-production as "A full-blown political analysis of science and technology…" that "…seeks to illuminate the 'co-production' of scientific and social order—that is, the production of mutually supporting forms of knowledge and forms of life". A working paper on sustainability science also used the language of co-production in the following way: "…*sustainability science must be created through the processes of co-production in which scholars and stakeholders interact to define important questions, relevant evidence, and convincing forms of argument*" (Kates et al., 2000: 2).

Co-production has since been defined and used by many different research communities with different interpretations and definitions (Miller and Wyborn 2018). Ehrmann and Stinson (1999) defined knowledge co-production as an "…interaction process between experts, bureaucrats and stakeholders aimed at exchanging, combining and harmonizing elements like facts, interpretations, assumptions and causal relations from these different knowledge domains". Dale and Armitage (2011) explain knowledge co-production as a "multifaceted process of gathering, sharing, integrating, interpretation and application". Armitage et al. (2011) defines knowledge co-production as "*the collaborative process of bringing a plurality of knowledge sources and types together to address a defined problem and build an integrated or systems-oriented understanding of that problem*".

Many authors believe that both expert and lay knowledge should be used in the production of new knowledge (Yearley 2000; Rinaudo and Garin 2005; Petts and Brooks 2006) where experts, policymakers and citizens are all knowledge providers (Backstrand 2003). Knowledge co-production scholarship is now being widely used in environmental governance (Jasanoff 2004; Frantzeskaki and Kabisch 2016), sustainability (Jasonoff 2010; Hilgartner, Miller & Hagendijk 2015; Van Der Hel 2016) and climate change (Bremer and Meisch 2017). Co-production is being used to crically evalutate organizations and using the co-produced knowledge in global affairs (i.e., climate change, global sustainability etc.) (Beck et al. 2017). It provides a comprehensive framework (Beck et al. 2017), and guidelines to design and implement the global research into action (Future Earth 2014).

In this research, knowledge co-production is further explored in the context of climate smart agriculture, impacted with multiple drivers of change, and stakeholders at different levels (i.e., local, provincial and national) with a variety of knowledge types. The use of knowledge co-production for CSA emerges from Ostrom's idea of citizens producing knowledge for public services (Ostrom et al. 1978), which emphasize that citizens produce knowledge in collaboration with policy experts and decision makers to ensure that co-produced knowledge is used for public services (i.e., education, health or in the case of this research, CSA). Indeed, successful implementation of CSA also demands co-production of knowledge well beyound scientific knowledge: "*in a world put at risk by the unintended consequences of scientific progress, participatory procedures involving scientists, stake-holders, advocates, active citizens, and users of knowledge are critically needed*" (Kates et al. 2001: 641). Therefore, knowledge co-production in CSA can help to combine all different forms of knowledge (i.e., customary and scientific etc.) collected from different sources (i.e., government agencies, NGOs, farmers, researchers etc.) to identify the problems and generate solutions through discussions and negotiations (Berkes et al. 2008).

In CSA, knowledge co-production process may not be very smooth and are likely to be impacted by several other challenges and drivers of change. To reduce such impacts, different stakeholders may have different standpoint (i.e. water and agriculture sector), and therefore, it requires inclusive and coordinated efforts to share the knowledge and information they have and find a collective solution (Bremer and Meisch 2017). Knowledge co-production can facilitate negotiation between different parties through sharing knowledge, addressing their concerns and finding common ground (Ehrmann and Stinson 1999). Knowledge co-production can be seen not just as a product but also as an outcome of joint effort (Edelenbos et al. 2011). In the case of agriculture and CSA, there are different forms of knowledge (i.e., customary and scientific knowledge) based on agriculture practices, experinces, dynamic environments and research which require collaboration and a sharing platform for different stakeholders. This literature helps to identify how a process of knowledge co-production can facilitate combining different forms of knowledge to produce new knowledge, and so that it can help to address multiple issues keeping in view the needs of multiple stakeholders (Bremer and Meisch 2017).

However, co-production of knowledge has its own limitations. Some of these key limitations are highlighted below:

i) Processes of knowledge co-production may cause conflict (Taylor 2003), or there maybe unclear division of role and responsibilities between the parties involved in the process of co-production (Mayo and Moore 2002). In Sindh, there is a clear lack of communication and coordination gap between different sectors (i.e., water and agriculture) and also at different levels (i.e., national, provincial and local level) (see Chapters 4 and 5)

ii) Knowledge co-production may also involve under estimating the role of third parties or powerful actors influencing the outcomes of knowledge co-production process (Ilcan and Basok 2004). Miller and Wyborn (2018) highlight that co-production may complicate the inevitable power differences and political conflict in and among scientists, communities, and others stakeholders with an interest in local or global outcomes. They also explain that any attempt to reconfigure the relationship between these groups and between knowledge and action may cause further confusion instead of solving the problem.

iii) According to Cook el at. (2013), in knowledge co-production processes, exchange of knowledge between diverse knowledge systems can be challenging due to the lack of mutual understanding between the parties. According to Cook et al. (2013) conflict may arise between the parties as their views and interpretation of credible, salient, and legitimate knowledge may differ from each other.

iv) Another important challenge, that may occur due to large number of stakeholders and different levels of governance (i.e., national, provincial and local), is the lack of dialogue, cooperation and the incompatibility of databases or decision-making tools used by regulating authorities (Bovaird 2007: van Wyk et al. 2008). In Sindh (see Chapters 4-6), all these factors are very much relevant due to diverse knowledge systems across a large number of stakeholders in different sectors and within the different levels of government.

To overcome these challenges and limitation in the case study areas and to support the implementation of CSA, it is important to consider how the knowledge co-production process is deisgned, what practices are adapted and how the producers and their roles are defined (Miller and Wyborn 2018). Both internal (Kates et al. 2001; Hackett et al. 2017) and external arrangements (Guston 2001; Jasanoff 2009) along with governance processes that can accommodate and support diverse knowledge system (Miller and Wyborn 2018) are needed to ensure effective knowledge co-production processes. With regard to CSA in the case study areas, internal arrangements means alignning relavent government authorities (i.e., research instituions, agriculture sector, and farmer organziations at local level) with rules and regulations within the agriculture sector, whereas external arrangements are related to the policy making, funding and roles regulatory agencies and funders, and addressing the multiple drivers of change that impact the process of co-production.

Second, it is also important that all the key stakeholders (i.e., government departments, farmers, NGOs, research institutions and private sector) participate in the policy process (i.e., CSA policy) to develop shared policy objectives (Roux et al. 2008), to stimulate dialogues and cooperation, and build trust and consensus for future actions. It is also important to have greater influence on the structure and direction of knowledge system to support co-production process. Power challenges can be addressed by understanding the stresses, tensions and finding synergies between different disciplines and parties involved in the process of co-production (Miller and Wayborn 2018). It is also helpful to clarify who is 'counted' as a relevant stakeholder in the process of co-production and how social and political inequalities and conflict can be resolved (Miller and Wyborn 2018).

Third, to overcome the issue of compatible CSA database and decision-making tools to bring all the stakeholders together, several knowledge co-production workshops and trainings are often needed which help to build the capacity of stakeholders for managing and introducing CSA technologies at local level (Nel et al. 2016). Ultimately, the goal of knowledge co-production is not to mix different forms of knowledges for decision making, but it is to create a knowledge governance system that not only supports the co-production of knowledge but which also encourages use of knowledge to address the multiple drivers of change and the complexities of existing knowledge systems and problem contexts (i.e., agricultural productivity)

3.5.1 Knowledge co-production - power nexus

Before examining the knowledge - power nexus, it is important to understand what 'power' means in the context of this research. Power is defined by Lukes (2005: 37) as "*A exercises power over B when A affects B in a manner contrary to B's interests*". Lukes (2005), further analyzed power through three different, over-lapping dimensions: i) instrumental; ii) structural; and iii) discursive. These three dimensions of power are explained below:

i) Instrumental power

Instrumental power "*depends on possession of resources that are useful in shaping policy outcomes in competition with others. This type of power is characterized by overt competition for influence and measurable use of resources in that competition*" (Brisbois and de Loe 2015: 3).

Instrumental power is definite, visible and has cause–effect relationships (Fuchs 2007), and therefore, people are aware of the decisions by the authorities. For example, institutions and government at national and provincial levels have an instrumental power to make decisions on behalf of the people.

ii) Structural power

Lukes (2005) explains structural power as the ability to shape policy agendas, and therefore, refers to this as agenda-setting power. It may exist within social structure (class), where even in the absence of visible force, dominant views shape decisions, and limit the ability of marginalized stakeholders to put forward issues and solutions that best reflect their interests (Flyvbjerg 1998). This power can be hidden or visible (Lukes 2005). Structural power can influence what can be discussed and what cannot be discussed in the agenda setting process. Lukes (2005), explains that power is not just about decision making, it is also influencing the decision-making process and reducing the choices to be made. For example, it can be illustrated by the influential group in the society to ignore the rights of weak groups (i.e., their right to know about the new upcoming policies).

iii) Discursive power

Discursive power is related to the exercise of power on others to get them to do what they don't want to do, or by influencing, shaping or determining their wants. Discursive power controls their thoughts and desires until they comply (Lukes 2005). Discursive power is subtle and cannot be easily identified (Fuchs 2007; Falkner 2008). Gaventa (1982: 15) explains it as "*the means through which power influences, shapes or determines conceptions of necessities, possibilities and strategies of challenge in situation of conflict*". In other words, it controls and manipulates minds of the people. For example, powerful actors in society or government influence people's thinking to the point that they agree to something to which they may actually disagree, or want something that may be harmful for them.

All of these power dimensions also influence the knowledge system and there is a strong linkage between power and knowledge. In this research, these three dimensions of power (i.e., instrumental, structural, and discursive) are elaborated in the context of knowledge for CSA and how power influences the knowledge system for CSA in the case study areas (see chapter 5, section 5.4).

The knowledge/power nexus is captured by Foucault (1998) who argued that power is dependent on knowledge and makes use of knowledge, while power reproduces and shapes the knowledge according to the intentions and desires of certain groups. Sometimes power creates and shapes the boundaries that enable and constrain action, knowledge of the people and their relative capacity to know how to shape these boundaries (Hayward 1998). Long debatable interfaces like scientific versus indigenous knowledge,and theoretical versus practical knowledge, have actually resulted from fundamental power relations among different social agents (Ojha et al. 2008). Power and knowledge systems shape one another (Assche et al. 2011) and sometimes power defines which knowledge will privileged. This influences which policies are opposed, ignored, reinterpreted, repackaged and sometimes selectively enforced (Hill and Hupe 2002: Foucault 2003b; Van Dijk and Beunen 2009).

Policies for issues like climate change and CSA (that are dynamic and complex in nature) are usually made at a global and national scale which limits the sharing of knowledge at local levels. For example, in the agriculture sector, governments maintain much of the technical knowledge and hold all the decision-making power on behalf of local farmers and thus excercising their instrumental power.

Ward (1995) explains that farmer's knowledge about farm practices is influenced by the advisors of chemical industries exercising their structural and discursive power. Even though farmers understand that the information provided by these advisors is biased in favour of over use of the chemicals, they still rely on these advisors and perceived them to be on their side because they are frequently visiting, friendly, provide free advice (Tsouvalis, Seymour & Watkins 2000). Most of the time advisors, brokers and powerful instituions make decisions or act on behalf of farmers in different agricultural activities (i.e., selection of chemical fertilizers, seeds etc.) so and so that they also start influencing the knowledge given to these farmers about new technologies and innovations (Morgan and Murdoch 2000). Agriculture knowledge becomes a property of influencial groups and instituions, where specialised knowledge overcomes the local knowledge and understanding of farmers.

In this research, the knowledge-power nexus is important to study in regards to both water and agriculture sectors in Sindh where there are strong influences from landlords. Here, landlords and influential farmers have a strong hold on what type of knowledge is being shared with the local communities and what kind of knowledge should be disseminated for policymaking at a national scale. In particular, the small landholders are often deprived of access to knowledge and institutional services and are biased towards landlords or influential farmers (Abid et al. 2015).

As a result, the dynamic and complex agriculture resources impacted by multiple drivers of change, necessitates the understanding of knowledge-power nexus. According to Armitage (2008: 24), "*the interplay of power, the positioning of various actors within nested hierarchies and the role of context all exert a powerful influence on the knowledge used to understand environmental change*". To ensure that knowledge is being shared with all the related stakeholders, government must encourage and create the opportunities to facilitate the dissemination of knowledge at different levels and act as a knowledge brokers (Pielke 2007; Kasperson and Berberian 2011). Governments and other decision-making authorities who have the power to influence the knowledge system should encourage open and effective consultations, and which drawn upon different types of knowledge in legitimate decision-making (Taylor and de Löe 2012). I have used knowledge co-production-power nexus in CSA (objective 2) to understand: i) under the current power structures at a different scale, what are the different kinds of knowledge that prevails at the local level; and ii) how does power affect the knowledge system and decision making at the local level for CSA.

Knowledge of CSA cannot be disseminated and implemented unless we address the power dynamics or at least understand them. CSA is often portrayed as a force to transform the agriculture sector, but it is evident that CSA cannot fundamentally shift power that blocks the promotion and implementation of pro-poor CSA technologies and practices (Karlsson et al.

2018). Instead, it may lead to new challenges, risks, and complications in the presence of dominant market forces and may entrench already unequal power structure.

3.5.2 Role of knowledge co-production in Climate-smart agriculture

CSA includes any practice that improves productivity or the efficient use of scarce resources (i.e. water), reduces exposure, sensitivity or vulnerability to climate variability or change (for example, water harvesting, terracing, mulching, drought-tolerant crops, index insurance, communal actions) and enhance farmers' ability to cope with weather extremes or impacts of climate change (Neufeldt et al. 2013). To do this, there is a need for a systematic gathering of information and data to generate knowledge at all scales for improved decision-making. Knowledge co-production process can help to collect the information and data through different sources, which can be collaboratively filtered, analyzed, interpreted and transformed into useful information. In this way involvement of stakeholders at all scales can help to identify scientifically credible and legitimate interpretations of long-term safe operating spaces in the context of a changing climate and growing environmental and societal changes (Neufeldt et al. 2013).

The ultimate goal of my research is to understand how knowledge co-productions can facilitate the development and implementation of climate-smart agricultural practices. Therefore, it is important to understand the literature that links knowledge co-production with climate change (i.e., natural disasters) and other drivers (socio-economic and political drivers, etc.), impacting the knowledge system of CSA.

To achieve the desired goal of establishing a robust knowledge co-production process in CSA, it is important to consider what methods are being used to gather the knowledge and later how this knowledge is used or implemented through policies. For example, to promote CSA knowledge flow between stakeholders, government agencies, researchers and other decision-making authorities, a number of methods and ways to assess and evaluate climate-related views, values, expectations, and knowledge of stakeholders are possible (e.g., interviews, surveys, focus groups, workshops community meetings) (Dilling and Lemos 2011; Furman, Jensen & Murray 2012). However, interactions through these methods is usually limited (Cohen 2010). For example, it is difficult to capture if people really understand what CSA is, are they pleased with introduced CSA practices and technolgies, and are they willing to adapt such technolgies?

In an effective knowledge co-production process, there is a need to build proper mechanisms to engage stakeholders for repeated knowledge sharing, learning, negotiations, and dialogues (Collins and Ison 2009; Bartels et al. 2013). Non-scientific stakeholders should not be treated as passive recipients of knowledge and information, but they should be actively and regularly involved in the negotiation process (Weber and Stern 2011). Bartels et al. (2013) also suggest that the mechanism and modes of sharing information should also be considered important. For example, sometimes scientific facts and information do not consider experiential components related to emotions, cultural values, and personal experiences (Marx et al. 2007). In the case of Sindh Pakistan, the current literature about climate change and agriculture mainly explains the biophysical and economic relationship between climate change and agriculture across different regions and districts (Hussain and Mudasser 2007; Hanif et al. 2010; Ahmed and

Schmitz 2011), but there is a little focus on the role of knowledge systems to support adaptation processes at a local scale to mitigate the impacts of climate change on agriculture farming (Abid et al. 2016).

In this research, knowledge co-production is useful to elaborate the complexities in the form of multiple drivers (i.e., climate change, socio-economic, political and power dynamics and water management) impacting the knowledge system of CSA in the agricultural sector of Sindh (objective 1 and 2). Knowledge co-production also helps in analyzing the role of different stakeholders in the knowledge system of CSA in the case study areas, and how to find develop common ground and shared solutions to address different concerns (objective 2 and 3) related to knowledge governance.

3.6 Knowledge governance

Knowledge governance as a concept helps to identify how researchers, government actors, and other stakeholders (e.g., farmers) understand the cultural, social, economic and political conditions that shape the relationship between science, decision-making process and institutional policymaking. Knowledge governance is defined as *"the formal and informal rules and conventions that shape the way we conduct or engage in knowledge processes, such as creating new knowledge, sharing or protecting knowledge, accessing it and applying or using it"* (van Kerkhoff and Pilbeam 2017: 29). Knowledge governance provides the broader setting in which to consider how it may be possible to bring together different stakeholders and local communities to discuss and co-produce the knowledge that addresses a wide range of issues. Frantzeskaki and Kabisch (2016) explain that knowledge governance can help to improve the mutual learning relationship and trust building between different stakeholders through the rigorous collaboration and co-creation between researchers and policy officers.

Olsson, Jonsson & Nyberg (2008) and Holling (2017) suggested that approaches like learning-by-doing and other learning-based approaches are important to deal with the complexities and uncertainties of the future. The literature also highlights the need for joint action by government agencies, public-private-civil society partnerships (Berkes 2009) and combining social learning with collaborative management for adaptive governance (Olsson et al. 2004; Folke et al. 2005; Carlsson and Berkes 2005; Armitage et al. 2007; Biermann et al. 2009). This requires a focus on networks connecting people, ideas and knowledge (Innes and Booher 2010). However, knowledge generation through "learning-by-doing", social learning, and learning through netwroks, are facing even greater challenges when it comes to sharing of power or co-management of complex resources (Olsson, Folke & Berkes 2004; Armitage, Marschke & Plummer 2008; Berkes 2009).

Scholars believe that co-production of knowledge is itself a process that not only involves the construction of knowledge but simultaneously the construction of the governance systems that use that knowledge (St Clair 2006; Bovaird 2007; Roux et al. 2008; and Muñoz- Erickson 2014). Wilson (2002) and Dietz et al. (2003) highlighted that effective governance of complex ecosystems (i.e. agriculture system), requires information about the state of the environment and human actions as well also information and understanding about uncertainty (e.g., of environmental change) and values people hold about human-nature relationships. For example, policies like CSA will always be incomplete without understanding the social values, cultures and norms that influnce the decisions of local communities in regard to adapting CSA technologies and practices.

The important role of knowledge co-production in adaptive governance also emphasizes the importance of diversity of knowledge (Berkes 2009; Armitage et al. 2011; Robinson and Berkes 2011; Watson 2015; Wayborn et al. 2016). Studies suggest using different models of engagement and interactive research to address environmental problems (Lemos and Morehouse 2005) surrounded with complex and dynamic drivers (i.e., power structure) . Some have used "knowledge co-production operating space" to identify the complex nature of issues and to produce new knowledge through participatory research and knowledge consolidation with multiple stakeholders (Leith et al. 2014; Pereira et al. 2015; Vincent et al. 2018). These efforts help to improve the legitimacy of co-produced knowledge through inclusiveness. Berkes and Tuner (2004) highlighted the need for a flexible multi-level governance system in which ecological knowledge is tested and revised in an ongoing process of trial and error (Folke et al. 2002). Transformation and uncertainty in CSA requires, a governance system with a continuous process of learning through knowledge testing creates resilience towards sustainability (Berkes and Tuner 2004; Mitchell et al. 2014).

There are several challenges to fostering knowledge governance. Some of these challenges are discussed in the literature. One of the most common challenges highlighted is the significant differences across multiple stakeholders and local communities involved in the governance of resources and knowledge co-production. These differences usually involve how knowledge is included in the policies and how power is excercised on and within these communities through these policies (Cash et al. 2003: Beck and Forsyth 2015). Knowledge governance for CSA in Sindh can face very similar problems due to differences in among group stakeholders at local, provincial and national levels. Therefore, understanding such differences, their engagement and negotiation is central for sustainability challenges (i.e., successful and sustainable implementation of CSA in agriculture sector of Sindh) and to achieve effective knowledge governance of CSA (Miller and Wyborn 2018).

Another main challenge associated with the concept of knowledge governance is the equal and transparent connections between different knowledge systems (Tengo, Malmer & Raymond 2017). CSA in Sindh may also require synergies which will allow empowerment of communities to become a part of knowledge co-production system and to level the power dynamics (Tengo et al. 2014). There is a need of true intercultural dialogues, which brings credibility and legitamacy for the stakeholders involved in the process of knowledge co-production and governance (Cash et al. 2006; Rist et al. 2016).

Contemporary ways of knowledge governance (i.e., governance system to facilitate collaboration between different stakeholders) may not be very helpful to introduce and implement CSA in a complex agriculture system like in Sindh (World Bank 2017) where outcomes are difficult to predict (Bovaird 2007). In Sindh, CSA is a new concept but local communities are aware of some CSA techniques, which they have learnt from their ancestors (World Bank 2017). There is a need of new approaches, tools and methods for co-production of knowledge, mobilization and sharing of co-produced knowledge, and utilization of co-produced knowledge for analysis and insights (Tengo et al. 2014). In other words, effective knowledge governance for CSA in Sindh requires not just a collaboration between stakeholders but also between forms of knowledges for CSA (i.e., customary and scientific knowledge). Similarly within the scientific, we can further explore natural and social science, qualitative and quantitative approaches within and across disciplines (Mackinson 2001; Berkes and Berkes 2009; Sutherland et al. 2013).

For an effective knowledge governance, it is important to consider that sometimes our sole source of knowledge may exist within the local communities and users (Bovaird 2007). For example in case of Sindh, it very much depends upon the local understanding of the climate change and local conditions for sustaining local livelihood (Mijatovice et al. 2013) and adapting new CSA technolgies and practices. Local communities across the globe face number of challenges (i.e. impacts of climate change) and learn to develop their own knowledge to cope the local conditions and evironmental change. It is important to establish a knowledge governance mechanism to recognise and strengthen such knowledge which is maintained, adapted and transmitted orally and in practice (Berkes 2008; Nakashima et al. 2012).

Figure 3.2 provides a general conceptual framework for my research and draws attention to several key features of knowledge co-production and governance I use to understand the emergence and implementation of CSA in my study sites. This framework emphasizes how formal and informal rules, institutional arrangements and organizational practices (layer one), structure the knowledge system (layer two) and influence the relationship between knowledge, decision making and interventions (layer three).

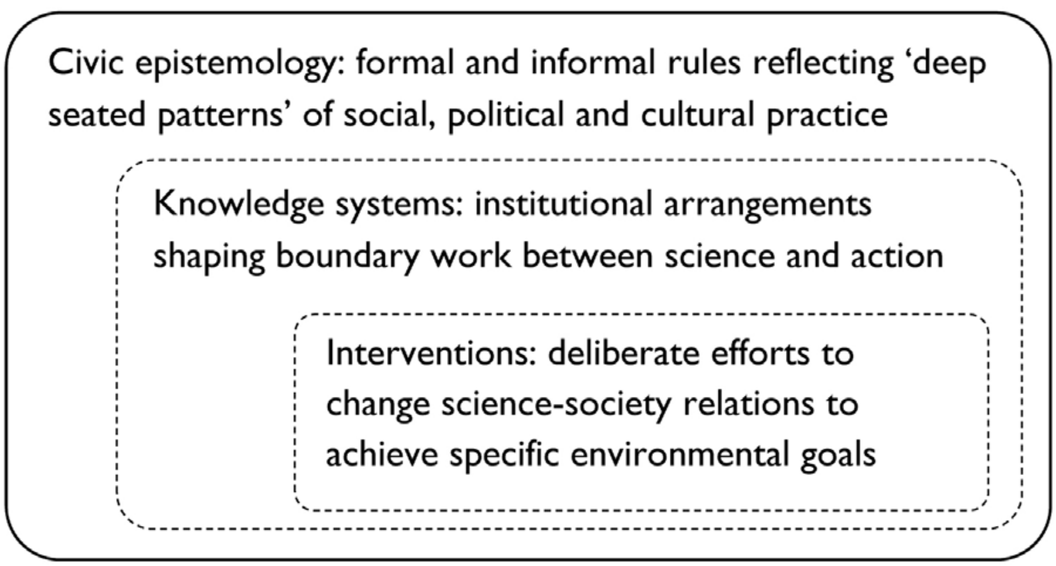


Figure 3.2: A three-layer conceptual framework of knowledge governance (Source: Adapted from van Kerkhoff and Pilbeam 2017)

For the purposes of my research, this framework is used to guide my assessment of how existing knowledge governance arrangements for CSA are effective and lead to desirable outcomes (e.g., improved agricultural productivity, greater understanding of agricultural production needs in light of climate change and water scarcity and other challenges at local level). Using this framework and knowledge governance literature in my research, I elaborated the existing formal and informal rules, stakeholder's involvement promotes the knowledge for CSA (chapter 4 and 5), the multiple drivers of change affecting the knowledge system of CSA (chapter 5), the institutional arrangements for existing knowledge system of CSA (chapter 6), and highlighted the missing links and gaps that can structure knowledge co-production process for CSA (chapter 6). This framework also helped to improve the knowledge-to-action process for CSA through a defined set of institutional rules emerging from scientific and customary rules (chapter 4) that reflect challenges of multiple drivers (i.e., socio-economic, political/power, climate change and water management) (discussed in chapter 5).

For example, layer one is "Civic epistemology" which implies a social process in form of a public and collective action. This involves scientific and political communities who construct, review, validate, and deliberate, to produce knowledge to be translated into action (knowledge for CSA in my research), thus constituting the epistemic foundations of public life (Miller 2008). I used layer one to explain formal and informal rules which highlight the social, cultural and customary practices and knowledge related to CSA influenced. Layer two focus on the institutional arrangements (chapter 6) that formalize and facilitate the role of scientific and customary knowledge (discussed in chapter 4) in decision-making for CSA. Finally layer three focuses on the impacts of deliberate interventions, actions (van Kerkhoff and Pilbeam 2017). It explains the understanding of local communalities and their actions about CSA technologies and practices and how they bring their new co-produced knowledge of CSA into action through day to day practices in agriculture farming.

Chapter 4 - Knowledge system of CSA technologies and practices in agriculture and role of different stakeholders in the study region

4.1 Introduction

This chapter addresses the first objective of my research, which is "*to characterize the present-day knowledge systems in the study regions as they relate to the agriculture sector, with specific reference to the development of climate-smart agriculture*". The need and importance of the knowledge system in the development of climate smart agriculture is discussed in the introduction section. To explain the role of different knowledge systems in the agricultural sector in the three study districts in Sindh, I have divided the chapter into three main parts.

The first part of this chapter examines the agriculture production of Sindh as a core unit of analysis, and with reference to three main components: i) soil management; ii) water use in agriculture; and iii) seed and crop management. Here, I explain the existing knowledge (scientific or customary) about different forms of climate smart agriculture (CSA) technologies and practices in the agricultural production sector (with soil management, water use in agriculture and seed & crop management).

The second part of this chapter assesses the science-driven CSA knowledge systems of Sindh agriculture that exists within different government and non-government and research institutions involved in the agriculture sector. I consider what type of scientific knowledge these actors have about climate smart agriculture (CSA) practices with regard to soil, water use, seed, and crop management, and how they use and distribute that knowledge to different stakeholders, including farmers (large and small-scale).

In the third part of this chapter, I elaborate on the farmer's customary knowledge systems of farmers in Sindh, and its potential role in CSA. In particular, I consider how farmers preserve and share their knowledge acquired from ancestors, culture, customs, old traditions and practices. This part of the chapter also considers the role of that knowledge in Sindh farmers' daily agricultural practices. Here, I examine the use of farmer's customary knowledge in adapting climate smart technologies and practices to conditions in Sindh, and if their farmer's customary knowledge complements the implementation of sustainable and climate smart agricultural practices.

In the final section of the chapter, I consider the strength of interaction among different stakeholders and their knowledge sharing based on the outcomes of the interviews, focus group discussion, review of previous reports and articles and general observation during the field research.

4.2 Agricultural productivity in Sindh

My research focuses on the knowledge system of agricultural productivity in Sindh through three main components or sub-unit of analysis (i.e., soil management, water use and seed and crop management) (see Chapter 2). To do this, this section explains the agricultural productivity in Sindh in general and later will further elaborate the role of each sub-units (i.e., soil, water, and seed) in agricultural productivity in Sindh and the importance of different forms of CSA knowledge associated with each of them.

Table 4.1: Production of different crops in Sindh

Crop	Percentage
Major crops	
Rice	35
Sugarcane	28
Wheat	12
Cotton	20
Other crops	
Chilies	88
Banana	73
Mangoes	34

Source: World Bank (2017)

The agriculture sector of Sindh is facing a number of challenges from the last three decades, including high population growth, water scarcity, conventional unsustainable agricultural practices and management, limited use of advanced technological innovations and farming techniques, urbanizations, and uneven land holding pattern (Waqas et al. 2017; World Bank 2017; Imran et al. 2018). Table 4.1 indicates the percentage of production of different crops in Sindh. Several studies also indicate that in the last three decades (1990 to 2018), major crop production in Sindh has been reduced due to water scarcity, soil degradation and poor seed varieties and these issues are further aggravated severely by an uneven rainfall pattern, floods, droughts and rising temperature and increasing population (Abid et al. 2015; Abid, Schneider and Scheffran 2016; World Bank 2017; FAO 2017). The country's water scarcity issue is aggravated due to the outdated and old water management system of canals established during British rule that causes disputes between different provinces (mainly between Punjab and Sindh). Poor irrigation patterns and other climate change factors are further discussed in the next chapter.

Within the agricultural productivity of Sindh Pakistan, the sub-units of analysis are further explained in relation to CSA practices in the study area. Figure 4.2 explains the CSA technologies and practices under each sub-unit. These CSA technologies and practices are explained in the literature chapter (section 4.2) in detail.

AGRICULTURE PRODUCTION IN SINDH

TYPE OF KNOWLEDGE

Soil Management	Water Use	Seed and Crop Management
Soil moisture retaining techniques	Drip irrigation and sprinklers techniques	Use of approved & certified seed varieties / preservation methods
Zero or no tilling techniques	Storage ponds and submersible pumps	Crop rotation techniques
Land laser leveling techniques	Furrow irrigation methods	Adjusting and maintaining crop calendars
Management of nitrogen and nitrogen fertilizers	Lining of watercourses	Mulch technology
Green Manuring	Alternate wet drying technique for rice paddy	Integrated pest management (IPM)
Intercropping	Intercropping and multi-cropping	

Figure 4.2: Agriculture Production in Sindh (Source: Created by Sajida Sultana)

4.2.1 Soil management in Sindh

Soil salinization is the major cause of low agricultural productivity in Sindh. There are number of challenges related to the soil management in Sindh including the case study areas. This section explores the role of knowledge of CSA technologies to improve the soil management in the case study areas. Salinity was produced during the process of soil formation well before the establishment the canal system in Pakistan (Rafiq 1975; Mian and Ali 1980) affecting the agricultural productivity. "*Since 1972, we have notice number of variations in the physical and chemical composition of the soil in different parts of Sindh (including the study areas), contributing towards the continuous degradation of the soil*" (Professor 1, Soil Management department, Sindh Agriculture University Tandojam (SAUT) Sindh, 5 March). Before the 1980s, salinity produced due to the irrigation was very limited and only contributed a negligible portion of the affected area (Mian and Ali 1980). Currently, most of the area is salinized because of the poor quality of irrigation water in addition to saline groundwater (Qureshi et al. 2008). Around 70% of tube wells used in Indus basin provide sodic and saline water causing 2.3 Mha of land saline and sodic (Qureshi and Barrett-Lennard 1998; PCST 2003; Aslam 2016). Table 4.2 shows that out of the total cultivated area of 5.65 Mha, 3.04 Mha is affected by salinity in Sindh. Total revenue loss per year due to low crop yield resulted from salinity in Pakistan is US$ 230 million with 28000 to 40,000 ha of land (Aslam and Prathapar 2006; Qureshi et al. 2008; Aslam 2016)

Table 4.2: Salinity effected area (Province-wise)

Status	Pakistan	Punjab	Sindh	KP	Baluchistan
Cultivated area (Mha)	21.87	12.27	5.65	2.11	1.84
Salt-affected area (Mha)	4.5	1.234	3.04	0.11	0.12

Source: Aslam (2016)

Aside from salinity, ineffective and overuse of fertilizers (Hamid et al. 2006) and several climatic factors also played an important role in soil health of the study districts. For example, soil erosion due to heavy flooding and heavy rains caused a depletion of soil nutrient in Indus plains resulting in low agriculture productivity (Iqbal and Ahmed 2005; Ali 2013). Similarly, a respondent (Research Officer, Agriculture Research Institute, Sindh Agriculture University Tandojam (SAUT) Sindh, 19 March) explained that season variation has also had an impact upon the soil health a lot. "*In 2010-2011, frost appeared suddenly in Mirpurkhas and its surrounding districts after several decades and there was no forecast about it, which damaged wheat crops*"

Soil health in all study districts is mostly affected by the use of chemical fertilizers (Professor 2, Soil Management department, Sindh Agriculture University Tandojam (SAUT) Sindh, Hyderabad, 5 March). Several CSA techniques (i.e., soils moisture-retaining techniques, zero tilling and green manuring) were introduced to overcome the problem of soil salinity and poor soil fertility in the case study areas but the farmers' knowledge varies in all the three study districts. "*We are promoting the knowledge of CSA practices that are less harmful and help to improve the soil health. For example, we encourage the use of alternate fertilizers like organic manures and biofertilizers produced through animals and plants*" (Professor 2, Soil Management department, Sindh Agriculture University Tandojam (SAUT) Sindh, Hyderabad, 5 March). Some of these have been successfully used in Pakistan and have shown 20% increase in the crop yield through the use of land leveling techniques (Ali and Erenstein 2017) and 12 to 15 % increase through zero tillage (Gill et al. 2002; Ahmed et al. 2012; Aslam 2016). Farmers in Mirpurkhas who have used land laser leveling techniques clearly indicated that it requires less quantity of seed as compared to the conventional methods. During focus group discussions (Mirpurkhas, 19 April), some farmers indicated that they have adapted the zero tilling techniques for a rice-wheat system and it is very successful. Focus group discussion (Mirpurkhas 19 April) and World Bank (2017), also indicated that in zero tilling technique, wheat, for example, is planted right after the harvesting of rice without tilling the land and disturbing the soil. In this CSA technique, shallow passages are made in the soil for seed germination to ensure less damage to the soil. According to a respondent (Professor 1, Soil Management department, Sindh Agriculture University Tandojam (SAUT) Sindh, 5 March), this technique helps to increase the soil productivity by maximizing the carbon storage. One of the respondents, (former employee, Sindh Irrigation Development Authority, Mirpurkhas, 4 May), explained that farmers do not have the credible knowledge of CSA technologies. But some have customary knowledge about multi-cropping and intense cropping methods which they think are tested, credible and reliable. He added that the farmers know about multi-cropping and intensive cropping methods but they are unaware of the stresses these methods can cause on the soil and the soil nutrients if not used with proper knowledge. Therefore, knowledge about CSA practices with proper training and regular monitoring is very important.

Soil ripping, which is also called minimal tilling is also adopted by the sugarcane producers in Badin province (World Bank 2017). A 90 year old farmer (Kumal, female farmer, Dadu, 24 May), indicated that knowledge of the CSA practices like green manuring and zero tilling is not new. She explained that she learnt these techniques from her forefathers but now people are destroying their lands and soil with heavy machines and extensive use of fertilizers. A female social worker explained that most of the female farmers still believe in organic farming and they have good knowledge about soil fertility and productivity but due to the changing climate pattern, they require new knowledge and understanding of CSA technologies and practices (female Social Organiser, Dadu, 24 May). For example, use of good quality fertilizers are encouraged in CSA practices to rehabilitate and recover the soil she added. She also explained that female farmers of Dadu were trained for several years about the use of right type of CSA techniques and practices (i.e., use of good quality fertilizer and green manuring).

Similarly, male farmers are trained about the land leveling and moisture retaining techniques beside good use of seed variety. A 65 years old respondent farmer, (Lalji, farmer, Mirpurkhas 07 May), explained that extensive use of fertilizers and machines have destroyed the soil and its natural recovery mechanism. Extended use of poor-quality fertilizers damages the soil nutrients. He also explained that the change in weather conditions also effected the soil quality. *"There used to be a cold weather, morning dew on the lands, and plenty of water to keep the soil naturally moisture. Sometimes, we use to protect our lands from frost and dew. But now due to less water availability, hot weather and changing weather patterns, farmers need to understand new CSA technologies and different methods of managing and maintaining soil nutrients"* (Lalji, farmer, Mirpurkhas 07 May). He explained that soil ripping or soil mining is a helpful technique to retain soil moisture.

Three farmers, (Ghulam, Natha and Hanif, male farmers, Badin, 15 April) also highlighted the changing soil conditions over the time in Badin and how their knowledge of soil and soil requirements changed according to that. They explained that mostly people were engaged in natural ways of managing their soil i.e., people used to provide enough time to the soil to recover after one crop and use to prepare the soil with organic fertilizers for the next crop. But now people only focus on high productivity in a short period of time and use large quantities of fertilizers which has a negative impact on the soil quality. They also explained that sea intrusion has greatly affected the soil quality of Badin coastal areas and that CSA technology is needed here to rehabilitate the vast agriculture land. Most of the CSA practices and technologies will fail in Badin coastal areas because of extreme water shortage and completely destroyed land.

As explained by (Professor 1, Soil Management department, Sindh Agriculture University Tandojam (SAUT) Sindh, Hyderabad, 5 March), SAUT has identified different regions of Sindh through eight different classifications. These classifications determine the productivity and quality of the soil. He explained that this exercise of classifying the soil will also help determine the right CSA technology according to the requirements and local soil conditions in different areas. Lands under the top category have no limitations for multiple cropping, crop rotation, and intensification since it has a rich soil. But lands under class 7 or 8, are usually considered as a land with poor soil which requires large quantities of fertilizers, water and care in general to give high productivity. Lands in Dadu and Badin fall under category 7 & 8 and are considered as costly lands for agriculture production. During an interview (Professor 1, Soil Management department, Sindh Agriculture University Tandojam (SAUT) Sindh, Hyderabad, 5 March), he explained the importance of guiding farmers about the correct implementation of CSA technologies for these technologies to be useful.

To improve the soil fertility and productivity in Sindh, FAO in collaboration with other partners such as the Ministry of National Food Security and Research, Pakistan Agriculture Research Council (PARC), USAID, and the US Department of Agriculture (USDA) have launched Soil Fertility Atlases for Sindh on 17th July 2017 (FAO 2017). A respondent (Former employee, Sindh Irrigation Development Authority, Mirpurkhas, 4 May), explained that the purpose of these Atlases is to record comprehensive details of soil type and their current fertility status and provide complete knowledge of soil management to the local farmers. He explained that CSA is at its very early stage in Sindh and such initiatives are important for the CSA profiling of different districts including the study districts. This will also help to provide the credible and authentic knowledge of CSA practices to the farmers of different districts based on research. He further elaborated that farmers will be trained through farmer field schools and extension field staff according to the comprehensive soil fertility management strategies about the fertilizer type, amount, timings and use of modern technology. This training would be an encouraging step towards CSA. Atlases use the data from provincial and federal departments and agencies including agricultural statistics and field-based assessment. A number of workshops and consultations were conducted with local farmers and growers of major crops like wheat, rice, cotton, maize, and sugarcane in various districts in Sindh. However, Atlases are not yet available to the public and relevant provincial departments.

Most of the farmers especially in the case study area are unaware of the new CSA technologies and have very little access to the knowledge about CSA technologies (Jehangir et al. 2007). Table 4.3, indicates the type and level of knowledge among farmers in the different study districts. It shows that in Mirpurkhas, farmers have a high level of knowledge about the new or climate smart techniques for soil management. Whereas, farmers in Dadu have a mostly moderate level of knowledge about all different techniques. Farmers of Badin have a very little knowledge about the CSA techniques and practices for soil management because most people have migrated to the other cities or villages and some have left the agriculture as a main profession because of the poor soil condition and massive level of environmental destruction (i.e., water shortage, floods, cyclones and degradation of land because of sea intrusion). More than 70% of the responses indicate that they used to practice agriculture farming where wheat and rice were their main crops two to three decades ago, but due to extreme water shortage, they have completely lost the productivity of their agriculture lands. These responses include both small and large-scale farmers (See box 4.1).

Box 4.1: Large-scale vs Small-scale farmers

Large-scale farmers are defined in this research as farmers having more than hundred acres of land. Small-scale farmers are those who have less than ten acres of land.

Knowledge about soil moisture methods under CSA is also limited because of the overall weak knowledge system for CSA. As explained by a respondent (Javed, Field Officer, Red Crescent, Badin 15 April), working in agriculture sector for the last 20 years, knowledge sharing and management about the CSA technology is not a priority for most of the donors, the government and the progressive farmers. He explained that the farmers who are well aware of CSA technology and have reliable knowledge (gained from their ancestors or trained by government/NGOs) have migrated to nearby rich agriculture districts or tehsils (subdivision of districts) like Mitrari or Mirpurkhas. According to a Program Manager, Land Tenure FAO Badin's priority issues are basic necessities (shelter, food, and source of livelihood). Very few agricultural lands have been rehabilitated and the soil has been treated through various techniques and frequent availability of water for a short period of time. However, these practices are not a permanent solution for those lands as explained by the farmers. Continuous sea intrusion and salinity is damaging the rehabilitated lands too.

Table 4.3: Type and level of knowledge about soil management in the study area (N = 45)

CSA techniques and practices	Badin (n=15)	Dadu (n=15)	Mirpurkhas (n=15)
Soil moisture retaining techniques	Level of knowledge about soil moisture retaining technique in Badin is low. Most of the people who know about these techniques have already migrated or changed their profession to fishing. Few people have got training about these techniques but because the soil is completely saline and unfit for agriculture none of them have ever used this knowledge.	Level of knowledge about soil moisture retaining technique in Dadu is moderate. Out of 15 semi-structured interviews, nine people have expressed their understanding about the knowledge and six people explained how they used this technique in the agricultural practices. Source of this knowledge comes from their ancestors, NGOs and private extension services	Level of knowledge in Mirpurkhas is about soil moisture retaining technique is very good. Out of 15 almost everyone was aware of these techniques and have been using them to mitigate the dry weather conditions. Their source of knowledge about these techniques is university researchers, NGO and private extension services
Zero or no tilling techniques	Zero tilling is a known to 12 farmers out of 15 but due to the poor soil quality and drought condition, people are not practicing it. Farmers have gained the knowledge and training about zero till technique mostly from their fellow farmers and ancestors. Half of the farmers were aware of it.	Zero tilling technique is also common in Dadu and is in practice only if water is available. Most of the time farmers face drought condition and hence do not follow such practices. Almost 80% of the farmers gained this knowledge from their ancestors and training from NGOs	Farmers of Mirpurkhas have a good level of knowledge about such techniques and have been regularly practicing. 13 farmers expressed that they learnt about this technique and got benefited from it.
Land laser leveling techniques	Knowledge about land laser technique is very low in Badin. Obvious reason about their less knowledge about such techniques is that farmers are not practicing farming very often. They are facing extreme drought conditions. People to have the knowledge about are willing to practice but there is no water and soil condition is very bad.	It is noticed that almost all the farmers are aware of this technique but farmers are out of practice or were unable to use this technique due to extreme drought conditions and frequent floods	13 Farmers have a good knowledge about these techniques and use it where required. They have learnt this technique from fellow farmers, FOs and NGOs.

Management of nitrogen and nitrogen fertilizers	Level of knowledge about the right use of fertilizer is low. In general farmers know that extensive use of fertilizers is bad but they are desperate to get some production from destroyed lands hence farmers are trying different forms of fertilizers. Only six out of 15 indicated that are aware of it.	Level of knowledge about the use of nitrogen fertilizers is moderate. Out of 15, approximately half of them believe that use of fertilizers at all is harmful for the crops and old methods to use organic fertilizers are better. Whereas others believe that it gives higher productivity and that's what we need to meet the demand. They are not really worried about the future damage. Nine out of 15 farmers indicated their knowledge about it.	In Mirpurkhas, all the farmers indicated their knowledge about the right use of fertilizers but due to dominant fertilizer industries, farmers are still using all different kinds of fertilizers to get higher productivity in the short period of time. Some farmers also believe that good quality fertilizers are important to mitigate the changing climatic conditions if mixed with the organic fertilizers
Green Manuring	Although majority of the farmers are facing water scarcity and have completely saline land due to sea intrusion, still most of the people believe on the benefits of green manuring for the soil health. Farmers of Badin have a good knowledge about the green manuring and its benefits but the current condition of land cannot be fixed with these measures. They need frequent and sufficient flow of water for their lands. All farmers were aware of it.	Level of knowledge about the green manuring in Dadu is also high. People are aware of the benefits and use of green manuring on their lands. Some of them still use green manuring for agriculture and they learnt this practice from their ancestors. Fourteen out of 15 farmers were aware of it and practiced it.	There is a very good knowledge of use of green manuring and many farmers are using this knowledge and practice to protect the soil health. Farmers have learnt this from their ancestors and NGOs. Almost all the farmers were aware of it.

Source: Semi structured interviews and focus groups discussions in Badin, Dadu and Mirpurkhas

4.2.2 Water-use in Sindh

Water shortage is a rising concern in Pakistan and a major constraint to agricultural productivity (GoP 2010). This section explains how water shortage in the study area has posed serious challenges for agriculture productivity. This section also examines the role of knowledge in promoting different CSA technologies and practices towards the sustainable use of water in agriculture in the case study areas.

Water use in agriculture sector in Pakistan is 69%, whereas it is 23% for industrial water-use and 8% for domestic use (Khoso et al. 2015). According to GoP (2010), Pakistan is becoming a water-stressed country with less than 1000 m^3/capita of available water per year. The water shortage is expected to increase from 28 million-acre feet (MAF) in 2015 to 41 MAF in 2025. Ninety-four per cent of the total agriculture area in Pakistan is covered through irrigation systems relying on rivers, dams, canals and barrages (World Bank 2017). However, availability of water in agriculture sector is affected by irregular monsoons patterns, low water storage capacity, on-going cross boarder water disputes with India and unequal water distribution between different provinces and within provinces (Arif et al. 2010). Inter-provincial water disputes are not new in Pakistan. Punjab and Sindh have faced water disputes on the distribution of water as per entitlements and sharing of shortages since the independence (Ali et al. 2018).

Table 4.4: Current crop-wise water-use efficiency in agriculture sector of Pakistan

Crops	Kg/m^3	Standard kg/m^3	Comparison
Wheat	0.76	1.0	24% less than the world average
Rice	0.45	1.0	55% less than the Asian average
Other cereal crops	0.13	0.39 India 0.82 % China	

Source: Watto and Mugera (2016)

In Pakistan, agricultural productivity very much depends upon regular and reliable water supply and impartial water distribution (Hussain et al. 2003). Major crops in Pakistan (i.e., Wheat and Rice) are not getting enough water needed to produce a good quality and quantity. Table 4.4, explains the crop-wise water use efficiency in Pakistan compared with different benchmarks. In Pakistan saline-sodic tube well water is affecting the agricultural productivity (Rashid et al. 1997; Ghafoor et al. 1998; Aslam 2016), as explained in the previous section. Poor irrigation management, water use efficiency in the agriculture sector and quality of irrigated water affects the productivity of major crops. CSA provides a wide range of techniques and practices that help to minimize the use of water (e.g. drip irrigation and sprinkler techniques, alternate wet drying technique for rice paddies etc.), and improve the quality of water and soil which can increase agriculture productivity. It is important to highlight here that different CSA techniques and practices may overlap between the different sub-units of agriculture production (i.e., soil management, water use and seed and crop management) because of their multiple benefits. For example, heat tolerant seeds varieties are used not only in the areas where there is drought but also can be used in water surplus areas to save water. Similarly, drip irrigation is not only used to save water but it is also helpful to avoid excessive use of water in irrigation which may cause damage to the seeds and crops.

Sindh accounts for 16% of the total cropped area of Pakistan and its national agriculture share is 23% which is the second highest share after Punjab province. In the last few decades, the agriculture sector in Sindh has decreased mainly due to the water shortage (GoS-SAP 2018). In addition to the above challenges Sindh has a very old and complex system of canal irrigation in place which requires proper management and monitoring to avoid water wastage and inequitable water distribution (See Appendix 3). Only 15-17% of the provincial budget is allocated for the maintenance of irrigation infrastructure which is not enough and causes huge water losses (Lashari and Mahesar 2012). An estimated 55 to 66% is subject to seepage losses and 30 to 40% application losses are recorded every year, due to which 50% of the cultivable command area does not receive water (Lashari and Mahesar 2012). Success of any form of CSA technologies and practices in Sindh agriculture depends upon the proper supply of water and improved system of irrigation. Table 4.5, shows the crops and the cultivated area depending on different sources of water which is mostly the irrigation.

Table 4.5: Cultivation of crops through different water sources in Sindh

Unit / Title	Orchards	Crop cultivation under irrigation	Crop cultivation in river flood plains	Rain-fed crops
Million of Hectares	0.13	4.02	0.40	0.35
% of total area of Sindh	0.9%	28.5%	2.8%	2.5%

Source: Sindh Agriculture policy (SAP) 2018-2030

The water shortage necessitates the need to promote water conservation, water storage development and efficient use of water in agriculture sector through new CSA technologies and practices. Agricultural productivity can be improved through promoting CSA for an efficient and sustainable water management practices (i.e., drip irrigation, sprinkler technology, watercourse improvement, and bed furrow irrigation) in Sindh (Lashari and Mahesar 2012).

CSA technologies and practices and the knowledge of those among farmers vary in the different case study areas based on the climatic conditions and issues in those areas. For example, in upper Sindh (covers the study area district Mirpurkhas) the prominent reason behind salinity and waterlogging is poor land and irrigation management resulting in high water table (Khoondar et al. 2016). In the upper part of the Sindh (Mirpurkhas), 70% of the farmers are less concerned about water quantity as they still get enough water during the rainy season as well as through water distribution from the nearby canal. In upper Sindh, people are mostly concerned about other issues related to agricultural production (i.e., advanced irrigation methods, fertilizer use, and soil management). Knowledge of the CSA techniques and practices in upper Sindh are mostly related to improvement of irrigation methods (i.e., sprinkler and drip irrigation technologies, storage ponds, and salinity resistant seed varieties and multi-cropping (Multi-cropping is highlighted as a CSA technique by some farmers of Mirpurkhas). A respondent (FO Kaho Minor, Mirpurkhas 16 April), explained that "*We have enough water for everyone but the problem is misuse of water distribution…The main issue is the water quality. Ten to 15 years ago* *there was both a good quality of underground and groundwater but things are changing now. Practices like heavy fertilizers and tree cutting are effecting the water quality and surface drainage system*". He added that knowledge of the CSA practices like less use of fertilizers, laser leveling, storage ponds and zero tilling is very common for a while and people find these very helpful in their agricultural practices.

Lower Sindh (covers the study area district Badin and Dadu), which is also mixed and the cotton-wheat zone is affected by soil erosion and salinity due to poor quality of groundwater (Khoondar 2016). Lower or extreme south Sindh which is also the last land area and coastal area of Pakistan is unfit for groundwater and relies mostly on canal irrigation water. Interview results from the lower Sindh (Badin) show that 90% of the respondents discussed the change in agriculture pattern due to water shortage and extreme weather condition (i.e., drought conditions). Their main concern is about poor water quality and no irrigation water for agriculture lands. Therefore, the knowledge about CSA techniques and practices are mostly related to heat and drought tolerant seed varieties and crops cultivation methods to ensure less water use i.e., Alternate Wet Drying in case of rice paddy.

According to an elderly female farmer, "*30 to 40 years ago, we used to have three different varieties of rice in the coastal areas, but due to repeated floods and cyclones we don't have even a single good variety of rice now. People shifted from rice and cotton to fishing*" (Amma Hawa, female farmer, Badin 28 April). She explained "*as far as I can see, lands are all white due to salinity, dry and barren*". Another 45 year old female respondent (Magi, female farmer, Badin, 28 April), explained that *"Earlier there were green lush lands of wheat and rice field around our village and drinking water was also available in wetlands close by and ponds but now we have to walk for 600 to 700 feet in search of water"*. She explained any new CSA technology that can provide them enough water for their survival would be good but people are not open to learn about other CSA practices. The water scarcity issues in Badin and to some extent in Dadu are chronic and long-term due to climatic changes like uneven rain pattern, prolonged droughts and drying of lakes over the time and the shortage has aggravated to an alarming situation in the last three to four decades due to downstream water distribution issues. Whereas water scarcity issues in Mirpurkhas and other districts of upper Sindh only emerged in the recent 10 to 15 years (due to climate change and reduced water flow). A respondent (Professor 5, Extension Services, Sindh Agriculture University Tandojam (SAUT) Sindh, Hyderabad, 1 May), highlighted that the tail end districts (districts at the end of the water distributary canals) are less productive because they are facing a water scarcity issue during sowing season and receive more than required water (i.e., floods) when it is not needed, therefore resulting in massive land destruction due to floods.

Currently World Bank under the project "Better use of energy in agriculture" promotes CSA technologies that are more suitable to the local conditions of different parts of Sindh including the case study areas. Such projects are also reliable source of knowledge for researchers and decision makers. Under this project, World Bank is supporting two High-Efficiency Irrigation Systems (HEIS) for drip irrigation, storage ponds and submersible pumps to optimize the use of water in the agriculture sector of Sindh for high yield (World Bank 2017). A respondent, (Professor 4, Plant Pathology department, Sindh Agriculture University Tandojam (SAUT) Sindh, Hyderabad, 5 March), highlighted that plant and seed research mainly focuses on the CSA technologies like drought-resistant seeds and crops that required less use of water throughout the cultivation process because of the dry weather in many parts of the study districts. For example, he mentioned that Badin has two major problems, i) no fresh water and ii) the available water is saline which inhabits plant growth.

Although the overall water use efficiency is low in Sindh, it varies in all three districts. Table 4.6, indicates the type and level of knowledge about the water use efficiency in the three study districts. Again, the farmers of Mirpurkhas are more aware of the efficient water use techniques as compared to the other two districts where water scarcity is high. One important reason for a high level of awareness in Mirpurkhas is the presence of Farmer Organizations (FOs established under the pilot project of World Bank). A respondent, (Hanif, farmer / member of Farmer Organization, Mirpurkhas, 7 May), explained that due to the availability of a good amount of water through canals and rains, lands in Mirpurkhas are rich. He mentioned that Mirpurkhas has several other advantages as well. For example, being close to the urban area (i.e., Hyderabad city) is an advantage because Mirpurkhas is getting a lot of attention from the government, NGOs, and donors to introduce CSA technologies. He highlighted that another reason why Mirpurkhas is more progressive in adapting CSA technologies and practices is because of farmer's level of education and availability of reliable and credible knowledge (research based) about CSA technologies and practices. He also highlighted that water use efficiency has improved in the last few years due to the increasing use of drip irrigation and sprinklers by large farmers, whereas others are using techniques like multiple cropping and intercropping. He explained FOs also help to improve watercourse lining for fair distribution of water from head to tail end districts of different canal systems.

Farmers in Dadu are aware of some of the efficient water-use CSA techniques and the main source of knowledge for these CSA techniques and practices is different across NGOs. For example, CSA technologies like lining of the water courses and alternate wet drying are common. A respondent (Muhammad Khan, farmer, Dadu, 24 May), explained that for rice paddies, a separate canal is dedicated by the government for higher production of rice in this area but only the big landlords are getting benefit of it while poor and small farmers hardly get any water for their land. He explained that they have a good understanding and knowledge of CSA technologies like alternate wet drying but there is a need of a proper management system to promote and monitor such technologies. A 70 year old respondent (Zahid, farmer, Dadu, 23 May), also explained that he has practiced some of the CSA techniques and practices like lining of the water courses to reduce water leakages and also furrow or surface irrigation methods as learnt from friends and elders. Other than that, farmers have limited access to the research based modern knowledge. Gatherings like “Kacheri system or Hukka system” where people used to sit together for a cup of tea and smoke (hukka) were opportunities for farmers to discuss different issues and share their knowledge about the agriculture lands and new practices. He explained now this type of social gathering is hardly seen. Like Badin, farmers in Dadu are also struggling with the basic issue of food and poverty and land degradation. Because seasonal variation and change in the rain patterns have destroyed the soil and many crops over the last two decades, farmers are no longer motivated to adapt more water efficient CSA technologies.

In Badin, a CSA technique called alternate wet and drying (AWD) of rice paddies is introduced to closely monitor the soil saturation, where rice fields remain underwater only during the critical growth period (i.e., flowering) instead of constantly being submerged. But these techniques are not adopted yet in many districts of Sindh. Almost every single farmer mentioned that they have not seen a regular flow of water on their lands from the last several decades, therefore some of these new CSA technologies are out of context in Badin. A respondent (Ghulam Hussain, farmer, Badin, 29 April), indicated that "*If our lands have enough water, we can practice CSA technologies but being at the tail end there is an uneven distribution of water and no rain. We need immediate relief first. People are suffering from skin diseases due to poor quality and quantity of water. Under these conditions who wants to learn about CSA*?". Low level of knowledge and implementation of CSA technologies in Badin are mainly because of the water scarcity issues. Water scarcity issue is further discussed in chapter 5, section 5.5. People have forgotten about many CSA related techniques and practices over the time.

Table 4.6: Type and level of CSA knowledge about efficient water use in the study area (n = 45)

CSA Techniques and Practices	Badin n=15	Dadu n=15	Mirpurkhas n=15
Drip irrigation and sprinkler techniques	Knowledge about this practice is very limited and most of the farmers have never used this technique due to water shortage. Also, most of the farmers are poor and cannot afford such techniques	Farmers are aware of this technique and have learnt about it from different sources like NGOs and private extension services but most of them have never used it because of extreme drought conditions.	Knowledge about drip irrigation and sprinklers technique is common is Mirpurkhas. Most of the large farmers have recently started using this technique on their lands but small farmers find it expensive.
Storage ponds and Submersible pumps	Farmers are aware of this technique but have not practiced it yet due to water shortage. People mostly use stored water for other needs i.e., drinking or cleaning purposes. All farmers were aware of it.	Farmers are aware of it and some large farmers practice it during rainy season. They store water to use it later for farming. Almost all farmers were aware of it.	Farmers are aware of it mostly but this practice wasn't very common in the past. Due to predicted water shortage, people have now realized the importance of storage ponds.
Furrow irrigation methods	Very few farmers are aware of it and they have never used it. They have only heard about this technique from private extension services but they have never practiced it. 6 out of 15 farmers indicated that they are aware of this technique and practice it	Very little knowledge about this technique and have not heard of any implementation of this technique during interviews. Five out of 15 interviewees indicated their knowledge about this technique	Good level of knowledge about furrow irrigation technique and is common in many farmers. Fourteen out of 15 farmers highlighted that they aware of this technique
Lining of watercourses	Knowledge of this CSA technique is very customary. Many farmers have learnt it from their ancestors and also understand the benefit of it but due to water shortage this technique is not in practice now a days. All farmers were aware of it.	Farmers have a good knowledge about it and is one of the practices they have learnt from their ancestors but this practice is not very common in Dadu due to water shortage.Thirteen out of 15 farmers were aware of it.	Farmers have a good knowledge about it and is one of the practices they have learnt from their ancestors. Majority of the farmers practice this technique in different ways and have relearnt from the NGOs and FOs.

Alternate wet and drying technique for rice paddy	Knowledge about this technique is common in Badin but only few have adopted due to water shortage. Obvious efforts are being made to expand the knowledge about this technique as Badin is the largest producer of rice. Knowledge about this technique is very recent. Only four out of 15 farmers practiced it.	People have a good knowledge about it but this practice is not very common. Farmers gained the knowledge about this technique very recently. Twelve out 15 farmers were aware of this technique but only few have practiced it.	People are aware of this but only few farmers have practiced it mostly because rice is not a major crop of Mirpurkhas. Almost all of the 15 farmers were aware of this technique.
Intercropping and multi-cropping	Intercropping technique is used both for soil conservation and water saving technique. Farmers have a good knowledge about it but due to water scarcity and sea intrusion farmers do not find it very helpful. Almost all the farmers were aware of this technique.	Good knowledge about intercropping and multi-cropping techniques. But limited use of knowledge due to extreme weather conditions. During the rainy season farmers practice this technique. Almost all the farmers were aware of this technique.	Intercropping technique is used both for soil conservation and water saving technique. Multi-cropping is highlighted as a CSA practice by farmers in Mirpurkhas. Farmers have good knowledge about it and this practice is now becoming very common in Mirpurkhas. Farmers got benefited from such techniques. All 15 farmers were aware of this technique.

Source: Semi structured interviews and focus groups discussions in Badin, Dadu and Mirpurkhas

4.2.3 Seed and crop management in Sindh

Since seed and crop management is another important and fundamental part of agricultural production in Sindh (Afzal and Ahmad 2009), it is important to see how the knowledge about CSA technologies and practices is helping the seed and crop management in the study area to mitigate climate change impacts. This section highlights some of the challenges faced by the farmers in case study area in seed and crop management and their knowledge about CSA technology and practices.

Pakistan is facing a number of issues including no regulation and policy on the different varieties of seed, seed distribution, pricing of fertilizers. For example, Pakistan has only a few public and private seed production institutes that are facing several constraints including financial, infrastructure and human resource (Aslam 2016). These institutions have a limited capacity to invest in CSA technologies required for seed and crop management. According to a respondent (Mr. X, FAO, Hyderabad, 4 April), due to lack of governance system and lack of rules and regulations for seed management in Pakistan, private seed companies dominate the market and distribute the low-quality seeds and do not encourage climate resilient seed varieties (i.e., heat tolerant and drought resistant seed varieties). In addition to that, meeting the demand for food requires more seed, but public and private seed institutions can only meet 40% of the total yearly demand (GoS 2012). Most of the staff in the private seed production institutions are also not properly trained for CSA technologies and do not understand the requirement of different cropping zones and changing climate conditions of Sindh in relation to different climate smart seed varieties. For example, they are not aware of the wheat seed varieties that are more heat tolerant and tolerant of saline soil (Koondhar et al. 2016).

Seed growers should also be encouraged to produce only climate smart certified and approved seeds registered under Sindh Seed Corporation and Wheat Research Institute Sakrand as emphasized by (Mr. X, FAO Hyderabad, 4 April). He explained growers are unaware of most of the CSA technologies and choose cheaper and less productive seed varieties. Sindh Seed Corporation and Wheat Research Institute Sakrand has the authority to approve and certify different seed varieties. In Sindh researchers encourage farmers to use only approved seed varieties because they are more resilient and productive. This mechanism ensures that only useful, productive and safe seed varieties should be sold.

Another challenge is the use of different types of fertilizers. According to (Professor 1, Soil Management department, Sindh Agriculture University Tandojam (SAUT) Sindh, 5 March), "*Nowadays, the soil is not very mature due to over-cropping, heavy feeders, and overuse of chemical fertilizers therefore there is a need of CSA related interventions. Instead of two or three required fertilizers, 16 to 17 different fertilizers are being used at one time only to get high production in a short period of time because people have no knowledge and concept of CSA*." A respondent, (Professor 3, Plant Breeding, Sindh Agriculture University Tandojam (SAUT) Sindh, Hyderabad, 19 March), highlighted that 75% of the farmers use seeds which provide a high yield because they want to sell the remaining production after meeting their own demand. The poor economic situation of Sindh farmers prevents farmers from using climate smart fertilizers beneficial for the seed (Iqbal and Ahmed 2005; GoS 2012). On the other hand, intensive cultivation and overuse and poor quality of fertilizers are damaging the essential soil and plant nutrients, resulting in low productivity (Hussain et al. 2009). Rice, wheat, cotton, and sugarcane in Sindh are also often attacked by the diseases and pests causing low productivity (Khan and Damalas 2015). He further explained that people have no formal and reliable knowledge of CSA techniques to help them prevent the pests and disease attacks on the crops.

In some part of Badin, CSA technologies of drought and heat tolerant seed varieties are introduced and progressive farmers are aware of these climate smart varieties, whereas most of the small farmers are not. During an interview, a respondent (Professor 2, Soil management department, Sindh Agriculture University Tandojam (SAUT) Sindh, Hyderabad, 5 March), explained that university research focuses on the different varieties of seeds. They keep the CSA approach in mind because they understand that CSA is the only way to cope with the changing climatic conditions. For example, recently 30 different varieties of rice seeds were tested in different parts of the Sindh to see how suitable they are in the drought and dry weather conditions. Integrated Pest Management (IPM) is apparently a known management practice in Sindh that comes under CSA, but only where farmers are literate (upper Sindh / Mirpurkhas) and have some knowledge of CSA. Some other CSA practices like bio-pesticides, and weed control practices are now increasingly common in Sindh (particularly for sugar cane) and other parts of the country as a means to reduce GHG emissions and solid waste pollution (World Bank 2017).

A respondent and expert (Research Officer, Sindh Agriculture University Tandojam (SAUT) Sindh, Hyderabad, 19 March) explained that there are different forms of hybrid seeds available in the market, but farmers prefer original seeds because hybrid seeds are more expensive although they give high production. He explained some hybrid seed varieties are very well promoted under CSA and they have done continuous research on different CSA promoted seed varieties. Hybrid seeds are modified through chemicals and bio-fertilizers to make them more productive and resilient under specific circumstances i.e., drought). In general, Pakistan has adopted a balanced use of chemical and bio-fertilizers for the cotton crop only. Considering the growing issues and decline in agriculture productivity, there is a need to invest more in dissemination of related knowledge about seed varieties and advanced CSA technologies and practices like maintaining crop calendars, row spacing, constructing agroforestry wind barriers, earthing-up during cropping of sugarcane, and crop rotations with legumes (wheat and maize) (World Bank 2017). The private and public sector can play an important role in generating and sharing the relevant, reliable and credible knowledge in collaboration with agricultural biotechnology research institutes and private sector seed producing firms, farmers and extension services to enhance and adopt the good practices in seed and crop management. Another important aspect highlighted by (Professor 5, Extension Services, Sindh Agriculture University Tandojam (SAUT) Sindh, Hyderabad, 31 April) was that even after the 18th amendment (devolution of authorities at provincial and district level), where agriculture has become a provincial subject, CSA technologies and interventions related to seed management and control are still handled by the federal government which causes several delays in the approvals and implementations at local level.

Table 4.7, summarises the level and type of knowledge about CSA techniques and practices about the seed and crop management that prevail in the three study districts. Mirpurkhas is well aware of the new seed varieties (heat tolerant seed varieties) and also well aware of the benefits of management practices like IPM. Although, farmers in Mirpurkhas seem motivated and are aware of seed related CSA technologies, the majority of them have still not fully adapted these technologies. According to a Program Head, FAO, provincial government and policymakers are not very aware of the operationalization and implementation of CSA but Mirpurkhas is very progressive in adapting new CSA technologies. A respondent (Hanif, farmer/member Farmer Organization, Mirpurkhas, 17 April) also has the same opinion. "*Farmers are very active in Mirpurkhas due to the establishment of FOs. They are well connected through mobile phones and share their knowledge on a regular basis with other farmers through village meetings and community-based networks. CSA is a new emerging concept; therefore, it will take some time for people to fully understand the benefit and adapt the technologies of CSA*". He explained that farmers receive four months of training on different techniques like land leveling, alternate cropping, tree plantation to protect the crops and seed management.

Farmers of Dadu have learnt new CSA techniques to preserve the six indigenous wheat seed varieties with some modifications to enhance their productivity (i.e., Kahani, Sonalika, Pawan, Yakoriya, Danglo, Forum). According to a respondent (Altaf, Field Coordinator, Basic Development Foundation, Hyderabad, 26 February), one experiment showed that farmers in Dadu enhanced the productivity of their lands from 15-18 acres to 20-21 acres through different CSA techniques and the use of heat tolerant modified seed varieties of wheat. In Badin, as explained by a local farmer (Haji Sumar Mallah, farmer, Badin, 28 April), "*30 to 40 years ago, there were good quality heritage seeds perfect for natural weather conditions for wheat and rice, but now heritage seeds are gone and new seeds are not good quality seeds to tolerate the heat and water shortage*". He explained the farmers are not aware of CSA technologies that can resist and tolerate the dry weather and heat. An experienced farmer (Ghulam, farmer, Badin, 29 April), also explained that heritage seeds were good even in the hot weather conditions because they were organic seeds. They are mostly destroyed by the floods also damaged by the use of excessive use of chemicals. Farmers of Badin have a very little knowledge about new CSA techniques to improve seed and crop management.

Mulch technique, pest control and alternate cropping of vegetable, wheat and pulses are few CSA techniques that farmers of Badin have learnt during the kitchen gardening training on the small piece of land of Mr. Ghulam, a farmer, who volunteered to use his land as demo plot. Other farmers of the same village also benefited from this one-week training. According to (Ghulam, Farmer, Badin, 29 April), farmers were only motivated to adapt these techniques for two cropping seasons and stopped continuing these CSA practices as the funding of the project ended. This pattern is noted in all different kinds of climate smart practices in Badin. He explained such knowledge is not long lasting. Farmers usually learn or adapt certain technology until they receive training, free farming kits (with seed samples and information broachers) and frequent monitoring visits from the NGO or private extension service personnel. Once the project is over, only few farmers retain that knowledge but discontinue the practices.

Table 4.7: Type and level of CSA knowledge about efficient seed & crop management in the study area (n = 45)

CSA Techniques and practices	Badin n=15	Dadu n=15	Mirpurkhas n=15
Use of good quality, approved and certified seed varieties	Farmers in Badin are not really familiar about the good quality seed variety available in the market. They are mostly misguided by the middle man and usually rely on the seed variety provided by the unauthorized seed distributors. Farmers are mostly poor and uneducated to access the right knowledge and learn about the good quality seed varieties. Most of the farmers also believe that good quality seed varieties are expensive and they cannot afford it.	Farmers have a very limited knowledge about the different seed varieties. Farmers are poor and cannot travel to far places. Therefore, they rely on what is available to them. Their source of knowledge about this CSA and about good variety seeds are seed distributors who visit them very frequently. Four out of 15 farmers are aware of seed quality through their ancestors and follow that knowledge for selecting the seed variety.	Most of the farmers are aware of different quality of seed varieties but due to the heavy influence of seed distributors and fertilizer company, they only purchase seed from them. Implementation of this CSA practice is very limited but farmers have a good knowledge about the good quality seed varieties.
Crop rotation techniques	Farmers of Badin have a limited knowledge about such CSA techniques. Farmers are mostly learning about this technique from the NGOs and private extension services but they have not practiced such techniques because of no availability of water and drought condition.	Nine out of 15 farmers are aware of these techniques but only four have not practiced it because of the extreme weather condition and water shortage.	Farmers have a good knowledge about these techniques and some have practiced it and got benefited from this CSA technique. Ten out of 15 farmers were aware of this technique
Adjusting and maintaining crop calendar	Farmers have never heard about it and have never used it for farming because they have a limited knowledge about the changing weather condition.	Only five farmers are aware of this technique and have never used it because of extreme drought condition. Rain patterns are hard to read.	Large farmers are aware of this technique and regularly maintain it. But small farmers have never practiced it. Although they have learnt about the technique from different sources.

Mulch technology	Due to poor soil conditions and the water scarcity issue, farmers have never practiced it but they are aware of the technique and learnt it from their ancestors. Older farmers are aware of this technology and used it in their old times when there was a sufficient water	Some farmers have learnt it and used it in their farming practices. Older farmers have their own knowledge about it but they understand that new CSA techniques are important to learn new ways of maintaining soil moisture	Almost all the farmers are aware of this technique and gained this knowledge from several sources including some from their ancestors
Integrated Pest Management (IPM)	Knowledge about IPM is very limited because of the lack of interest in farming, hence farmers are not very open to learn about new farming techniques in CSA.	Farmers understand the use and benefit of IPM. They have learnt about it from several sources including university trainings and lectures.	Farmers have a good knowledge and understanding about IPM and its benefits.

Source: Semi structured interviews and focus groups discussions in Badin, Dadu and Mirpurkha

4.3 Knowledge system of CSA in Sindh agriculture and role of different stakeholders

As evident from recent studies and assessments on the status of CSA in Pakistan, in the introduction of CSA technologies and practices, it is important to create a general awareness about soil management, efficient use of water in agricultural practices, and soil & seed management and requires a continuous access to information and knowledge through community-based interventions of knowledge networking (World Bank 2017, Mohey-ud-din 2017). There are different stakeholders involved in the agriculture sector of Sindh, that are responsible for the generation, dissemination of knowledge between different stakeholders and local farmers. These include agriculture universities and research institutions, NGOs, private and public extension services, fertilizer companies, farmer organizations, and progressive farmers.

This section will further explore the role of these stakeholders in generating and distributing knowledge about CSA. To do this, I have used the information from previous studies and reports, focus group discussions and semi-structured interviews covering the period of the last three decades. This section explains how several changes in the agriculture sector impacted and changed the knowledge system of CSA over time.

To explain the different forms of knowledge system here, I have divided it into two broad categories: **i)** Scientific knowledge system under the agriculture management model set by the government and other established institutions, **ii)** Farmer's customary knowledge system at the community level.

4.3.1 Scientific knowledge system

The scientific knowledge system is defined in the literature chapter (section 3.3). For the purpose of this research, I have broadly categorized the extension services, government research institutes, UN organizations, universities, NGOs, and media as a part of scientific knowledge system.

i) Role of agriculture extension services

Agriculture extension services in many countries are vital for rural development because of their indispensable role in the agricultural development through sustainable farming, agriculture diversification, advanced technology and integration of small and medium farmers into dynamic markets (Mengal, Mirani & Magsi 2014). Agriculture extension improves the income, livelihood, and capacity of the farmers by providing them with need-based and demand-based training, ultimately contributing to the overall development of the rural population. By building a good working relationship with the farmers, agriculture extension facilitates dispute resolution between the farmers and other stakeholders (Mengal, Mirani and Magsi 2014; Aslam 2016; World Bank 2017). At the same time, agricultural services all around the globe are facing a number of issues and challenges (i.e., increasing demand for food, environmental changes, growing population increasing pressure the agriculture sector)

Agriculture extension also plays a very important role for the dissemination of right and timely knowledge of agronomic techniques and new seed technology (Baig, Al-Subaiee and Straquadine 2009; Khan et al. 2011) for the improved agriculture production (Jalvi 1996; Farooq et al. 2010; Aslam 2016). Many authors have discussed the role of agriculture extension in improving the production and farming techniques through the dissemination of useful knowledge and providing skill and knowledge-based training to the farmers (Siddiqui, Mirani & Bukhari 2012; Picciotto and Anderson 1997). To understand the formal knowledge system of Sindh agriculture sector it is important to review the agriculture management model in Pakistan which is almost similar to the other developing countries (Appendix 4). Agriculture extension services in Sindh introduce the new technology in the agriculture sector, providing relevant information and transferring the relevant knowledge about the type of seeds and fertilizers, different farming techniques and various other aspects of farming. Mostly knowledge transfer is done through training the different groups of farmers in selected villages. According to Sindh government (GoS 2017), type of the knowledge, extension services are responsible is *"........ to advise/educate growers/farmers in modern crop production practices and technologies, so as to increase overall farm production and improves yield per unit area. To achieve the goal, the agriculture extension workers are performing their duties to disseminate the timely seasonal information amongst the growers for cultural practices; proper seed requirement, timely sowing, balanced and efficient use of fertilizer, efficient/judicious use of irrigation water, pesticide use, effective crop management, harvesting, threshing and storage / marketing etc*."

Agricultural extension is one of the key components of the Agriculture Knowledge and Information System (AKIS) – research and education being the other two components (Shahbaz and Ata 2014). After partition 1947, the Government of Pakistan has implemented several extension services models as a part of overall rural development strategies to improve agricultural services in Pakistan (Abbad et al. 2009). These agriculture extension services followed the top-down approach in-lined with the overall national governance system (Baloch and Thapa 2016). This approach to extension continued until 2003.

Table 4.8, explains the detail of the extension services since partition and their roles and responsibilities in rural development of Sindh. Some of these extension services were not completely dedicated to the agriculture services but the overall rural development. Different colours of the table indicate the degree of relevance of some of these bodies to the agriculture sector and the type of knowledge they disseminated through different ways/mediums. Structure, hierarchy wise responsibilities of current extension services are explained in (Appendix 4).

Table 4.8: Extension services in Sindh and their role in promoting the knowledge about soil management, water use and seed & crop management in Sindh

Extension Services	Common Responsibility	Type of knowledge	Medium
The Village Agricultural and Industrial Development Program (V-AID) Period 1952-1961	Provision of services and information dissemination related to crops, livestock, fisheries, education and sanitation sector at door-step. Provision of credit facility to improve agricultural productivity. crop management skills and techniques towards improved production, yield and income. To understand farmers problems and issues and resolving those issues	Scientific knowledge about modern technologies in agriculture including pesticides and inorganic fertilizers. To change the customary practices into use of new technology with the aim to improve production, yield and income to improve overall socio-economic condition. Technical knowledge to improve existing and new farm management techniques	Monthly visits and workshops Trainings Exposure visits to the demo farms
The Basic Democracies System (BDS) Period 1959-1970	To solve the overall rural problems related to agriculture, social welfare, education, infrastructure, health, and economic development. Information dissemination related to crops, livestock and fisheries.	Awareness raising and empowering the rural community to solve problems on their own and to encourage the local leaders and to ensure the maximum involvement of the rural people in the rural development process	Through union councils at union level Monthly visits Workshops Trainings Meetings
Rural Works Program (RWP) Period 1963-1972	To improve their socio- economic conditions and stimulation of the rural economy. To improve agriculture production as well as empower the rural population.	Knowledge about self-awareness and problem solving without getting much help from government. Dissemination of knowledge about rural infrastructure development projects such as irrigation channels, bridges, roads etc.	Through extension service staff. Monthly visits Workshops Trainings
The Integrated Rural Development Program (IRDP) Period	To improve farm service delivery and to increase agricultural output by utilizing modernized methods including farm planning and management, providing physical/ social infrastructure, transport, marketing, and credit facilities	Knowledge about increasing agricultural output through modernized methods including farm planning	Through Markaz (center of the activities of IRDP), a focal point of farm information and knowledge sharing.

1970-1978			
The People's Works Program (PWP) Period 1972-1975	PWP emphasized the effective rural institution establishment and agrarian reform including infrastructure at rural and urban level	Improving the overall knowledge system and service delivery of various institutions involved at district and local level. Maximize crop yield and improving agricultural productivity	Through different rural institutions
Inputs at Farmers' Doorsteps Approach Period 1970 -1978	Maximizing crop yield and improving agricultural productivity. Government also provided agriculture inputs such as improved seed, fertilizer and pesticides at considerable subsidy rate to the farmers through this program	Knowledge to maximized the agriculture production through various sustainable techniques and methods. Knowledge about improved seed varieties and safe fertilizer use for different crops.	Through field visits. Farmer's training programs and community-based workshops.
Training and Visit system (T&V) Period 1980-1994	Aim of this World Bank funded project was to enhance the relationship between research, extension, and farmers. Another aim was technology transfer at community level	Knowledge about new technology to improve agriculture production. Provided a multi-sectoral feed back towards agricultural experts and researchers for further inquiry or solution	Training of extension service staff and frequent visits to the rural communities.
Farmer Field School (FFS) Period 2002-To date	Introduced by Pakistan Agricultural Research Council, government of Pakistan for cotton, fruits and vegetables. Purpose was to promote knowledge which enhances production with minimum use of environment friendly pesticides	Providing knowledge about scientific and technical knowledge about biological control practices under various dynamic ecological conditions. Providing knowledge about integrated pest management (IPM) specifically for cotton.	Group-based learning process, community-based activities, training activities in field and site-specific experiments
Devolution of Power Plan, 2001 Period 2001 – To date	Introduced to change the administrative structure of extension services by introducing private extension services to increase the outreach in the community.	To ensure the top-down as well as bottom up approach. Through collaboration and involvement of NGOs and university research groups and local farmers.	Field based trainings through demo plots and field schools

Directly relevant (green) | Indirectly relevant (blue) | Not at all relevant (yellow)

Source: Shahbaz and Ata (2014)

Despite the extensive network, several interviews with farmers and experts highlighted the limited role of extension services at community/village level. Farmers highlighted that extension officers are not well trained and they cannot address the issues of the farmers. Farmers, university professors, and NGO professional are all of the opinion that extension service officers have a very limited presence and are not making frequent visits to guide the farmers. Some farmers showed mistrust of extension services. For example, (Professor 1, Soil Management department, Sindh Agriculture University Tandojam (SAUT) Sindh, 5 March), highlighted that extension services do not frequently interact with the university and so the university staff not aware of new research (i.e. seed varieties and soil testing results) to guide the farmers properly. A respondent and expert (farmer and President Halal-e-Ahmar, Badin, 28 April), indicated that frequency of visits by extension officers are very limited and farmers are facing lot of difficulties because they have no or very limited guidance and support from extension services. Another respondent, (Sher, farmer, Badin, 29 April), explained that the knowledge and training they received about new CSA practices (i.e., soil softening, molasses for soil and compost use) is from university researchers/field officers or through private extension services. He explained that the farmers rely and trust on the knowledge provided by university researchers and private extension services.

Outcomes of the focus group discussions (Badin 17 April and Dadu 23 May), also highlight the absence of extension service officers at the village level. Participants of focus group discussion (Dadu, 23 May) indicated that NGOs and private extension organizations are more active and frequent source of information in their villages as compare to public extension services. Focus group discussion (Badin, 17 April) also indicated that for water dispute, crop diseases and other seed variety issues they have to go through several government departments which is time consuming and costly for them. A respondent (Professor 5, Extension Services, Sindh Agriculture University Tandojam (SAUT) Sindh, Hyderabad, 31 April), explained that extension officers have low salaries and they do not have proper facilities especially at union council level (i.e., no local office or offices with no basic facilities and no transport facilities to reach to the far end places), due to which they are demotivated and usually absent from the field. He emphasized that keeping in view their tough field work and hot weather conditions, the government should provide basic facilities (i.e., air-conditioned offices, proper transport and training facilities to keep them motivated) to the extension service officers at district, union council, and village level.

ii) Role of research and development (R&D) in Sindh agriculture

Another important system that played a significant role in establishing a scientific knowledge system in the agriculture sector is Research and Development System (R&D). Pakistan had one of the largest Research and Development Systems (R&D) in Asia (Usman, Ahmed & Javed 2017). However, in the last two decades, agriculture R&D expenditure has decreased significantly. Agricultural research spending relative to agricultural GDP in Pakistan is the lowest in the region (Flaherty et al. 2013, Shahbaz and Ata 2014). Table 4.9, explains the expenditures of different countries in South Asia on agriculture research and development. Pakistan has the lowest spending in agriculture R&D.

Table 4.9: South Asia Agriculture Research & Development intensity ratio (for every 100 dollars of agricultural GDP)

Country	$ spent on R&D
India	0.4
Sri Lanka	0.34
Bangladesh	0.34
Nepal	0.27
Pakistan	0.27

Source: Shahbaz and Ata (2014)

Considering the need of CSA in Pakistan, Government of Pakistan has recently taken some initiatives to develop some CSA technologies to address climate change issues (Ahmed 2017). For example, a respondent (National Program Manager, UNDP-GEF SGP, Hyderabad, 15 March), explained that some of the CSA related priority areas for R&D includes high yielding, drought resistant, pest tolerant and heat resistant crop varieties. However, he explained that action is required for the dry, desert and coastal agroecological zones of Pakistan which include Sindh also. Another respondent (Ministry of Climate Change, Islamabad, 24 February), also explained that there is also some advancement related to the technologies for soil and water conservation and ground water recharge to improve crop productivity. He also explained that Pakistan has established Climate Change Act in 2017, which has a strongly focus on mobilizing domestic and international funds to enhance CSA research and knowledge sharing system is one of the themes beside other CSA related interventions.

Research and Development in the agriculture sector in Pakistan is dominated by the public sector. A brief history of agriculture research dates back to 1929 when the Imperial (currently Indian) Council of Agricultural Research was established to promote agriculture research in India. After partition in 1947, Pakistan received a very little portion of research institutes and human capital as most of them were located in India. At the time of partition, Pakistan only had one agriculture college and one agriculture research institution with very few resources.

In 1948, the first Food and Agriculture Committee was established, which was re-formed as Food and Agricultural Council of Pakistan (FACP) in 1951. In 1973, it was again reorganized as Agricultural Research Council (ARC). In the 1950s another ground-breaking step was taken towards establishing teaching and research institutions with the help of United States. These institutions were established in the North West Frontier Province, Punjab, and Sindh, which also set the foundation for current agriculture education and public research system (Mohammed 1983; Nagy 1984; Akbar 1999). Between 1968 to 1973, American agriculture scientists helped Pakistan's ARC team to review and implement new strategies and as a result of that, ARC emerged as an effective and functional institution in Pakistan. In 1981, ARC re-organized as Pakistan Agriculture Research Council (PARC) as a federal institution. In 1982, Pakistan announced a comprehensive agriculture plan (It was sixth Five-Year Plan:1983–88). Following this Plan, PARC, laid the base to strengthen the coordination, research facilities, training facilities in agriculture along with maximizing the productivity. PARC also made efforts to introduce new CSA technology for sustainable agriculture practices and introduced National

Coordinated Research Programs to look into the new reforms (Khan 2006). By 1998, Pakistan's agriculture research system was well established at the national as well as provincial level, but was missing the linkages between these institutions and knowledge sharing mechanism.

Research and Development for the agriculture sector in Pakistan has a clear distinction at the national and provincial levels. National government mostly deals with the long-term research priorities whereas provincial government deals with the short-term research priorities which are mostly adaptive in nature. PARC is the main federal agency involved in the research in agriculture as explained earlier. National agriculture research council (NARC) is another largest R&D institution in terms of research staff and spending. During interview (National Program Manager, UNDP-GEF SGP, Hyderabad, 15 March), explained that another challenging factor for research institutions at the national and provincial levels is to implement CSA technologies at a local level through realistic policies. He explained any research is only useful and effective if implemented through proper policies and reliable knowledge sharing mechanism. At the provincial level, several research institutions are attached to the department of agriculture to facilitate agriculture research and have established several research farms and agro-ecological zones within the province to enhance and promote CSA interventions. In Sindh, the prime research institute is Agricultural Research Institute Tandojam. In addition to that, Sindh Horticulture Research Institute MirpurKhas, Rice Research Institute Dokri, Wheat Research Institute Sakrand, Quaid-e-Awam Agriculture Research Institute Larkana are also research institutions working on CSA technologies in Sindh agriculture sector through a network of agricultural research stations and sub-stations (Shahbaz and Ata 2014). But so far these institutions are not very effective particularly to promote the knowledge about CSA technologies and practices in Sindh (Ahmed 2017).

iii) University of Sindh and Sindh Agriculture University Tandojam

There are only two universities at the provincial level in Sindh that are involved in the agriculture sector. The University of Sindh has its own agriculture research institute whereas Sindh Agriculture university is completely focused on agriculture research and development in Sindh with different specialized departments. The focus of both universities in mainly looking into CSA related research to overcome and reduce the impact of climate change. Different department are providing research funding at graduate and PhD level for CSA related technology and research.

During interviews (Professor, Plant Pathology, Sindh Agriculture University Tandojam (SAUT) Sindh, Hyderabad, 5 March), explained that lot of research on CSA is already happening at the university level to improve soil and seed health considering the changing environmental conditions. He highlighted that the university is also disseminating the outcomes of CSA related research at the local level through several ways that are more practical and affordable for the farmers. For example, there are two to four magazines (i.e., Abadgar, Sindh Zarat, and Agriculture digest) that publish the latest CSA research for the farmers every month. He also explained that the university research institute also collaborates with NGOs to conduct several exhibitions, seminars and training sessions to guide and teach farmers about the new CSA interventions (i.e., different varieties of heat and water-resistant seed, soil protection techniques and other sustainable practices). "*I agree that there is a lot of communication and* *knowledge gap which can be improved but that doesn't mean the university is not making any effort into this regard. Things are happening at a very slow pace*" (Professor Plant Pathology, Sindh Agriculture University Tandojam (SAUT) Sindh, Hyderabad, 5 March).

A respondent who has taught for the past 21 years (Professor 1, Soil Management department, Sindh Agriculture University Tandojam (SAUT) Sindh, 5 March), highlighted that public extension services are not very active in coordination with the university but NGO are very active and are engaged with the university on regular basis. He also stated that there is a very little direct coordination between the university and farmers and the reason for weak coordination is that majority of the farmers are less educated and it is difficult to convince them about the benefit of new CSA technologies. Therefore, it is important that the government invest in local CSA innovations and techniques based on university research. The university research is credible and reliable which can be shared with NGOs workers for further dissemination to the farmers. During an interview, a respondent (Professor 2, Soil Management department, Sindh Agriculture University Tandojam (SAUT) Sindh, Hyderabad, 5 March) also verified that strong collaboration of NGOs with the university. He said that the university provides training to the farmers on CSA practices like soil management through NGOs and community-based organizations (CBOs) as they have a strong presence at the village level. He highlighted that integrated pest management (IPM) and Integrated plant nutrient management (IPNM) are the core CSA components of university research for seed and crop management.

Regarding the role of government extension services, a respondent (Professor 2, Soil Management department, Sindh Agriculture University Tandojam (SAUT) Sindh, Hyderabad, 5 March), explained that university is mainly responsible for the research part of CSA technologies whereas the government is responsible for the implementation part of CSA technologies and ensuring the farmer's training and awareness about CSA through agriculture extension services. He explained that progressive farmers are very much aware of the CSA technologies and sustainable practices, but small farmers are more concerned about productivity, therefore they rely more on chemical fertilizers that give more productivity. He highlighted the need of authentic, reliable and research knowledge to convince farmers to follow effective practices. Professor 3, Plant Breeding, SAUT, explained that in spite of the quantity of research done on CSA in the agriculture sector, most of the research work is published but is not fully utilized. He highlighted that public and private extension services can play an important role in the awareness raising about CSA and the effective implementation of the credible CSA knowledge.

A respondent, (Altaf, Field Coordinator, Basic Development Foundation, Hyderabad, 26 February), also identified very limited sharing of CSA research with the farmers. He gave the example of soil or water testing done by the university several times but the results were not shared with the farmers to explain the quality of water and soil and what measures should be taken to improve the quality of water and soil. Mr. Javed, an NGO worker also explained that in Badin there are three water and soil testing laboratories. Yet, only NGOs and extension service staff have an access and farmers have no access to the labs although these are meant for the general public.

iv) Role of NGOs, UN agencies and Donors in Sindh agriculture

Beside government institutions and departments, there is a long list of NGOs working in the agriculture sector of Sindh. Due to their presence at the community level, NGOs are usually more involved and trusted by the local communities. Considering the rising security concerns in Pakistan, the Economic Coordination Committee (ECC) at the federal government level has recently approved a policy in 2013 so that is mandatory for all the NGOs to disclose their source of funding, mandate, detail of projects, areas of work and geographic location of their projects (Ahmed 2013). List of some of the organizations working towards the sustainable and climate smart agriculture are listed below (see table 4.10). Fifty-six per cent of the farmers from all three districts note a frequent presence of NGO workers for training purposes or sharing the knowledge about new agriculture technologies/climate smart technologies.

A respondent (Ali, Welthungerhilfe Pakistan, Hyderabad, 3 March) mentioned that "I*'ve been working at the community level for the last 21 years. In my personal experience, private extension services are more active than public extension services and they play a major role in providing access to knowledge about sustainable agriculture practices. CSA is a new concept that emerged only in the last five years and even government departments are not aware of this term properly*". Two respondents (Zeb, Human Appeal, Hyderabad, 5 March) and (Wajid, Plan International Pakistan, Hyderabad, 5 March), also highlighted the importance and role of NGOs at a community level and explained that NGOs train the farmers through free training schools (FFS), Women Open Schools (WOS), interactive sessions, demo plots of ½ - 1 ½ acre land and field trips to other districts to promote organic farming. Farmers are also usually provided with the "farmer kits" containing a sample of different seeds and brochures with some basic information about soil, seed and water management at farm level and also information about good hygiene practices. Most of the material is translated in Sindhi language because most of the farmers can understand Sindhi but not Urdu or English (Wajid, Plan International Pakistan, Hyderabad, 5 March).

Some of these NGOs (i.e., Human appeal, Basic development foundation and Sindh rural support program) work in collaboration with the agriculture research department of the University of Sindh and Sindh Agriculture University Tandojam. Collaboration is done usually through MOUs where university shares research findings through training and seminars and NGOs facilitate the implementation of these research-based technologies through their village level network. During interviews, several university professors also highlighted the important role of NGOs in the dissemination of knowledge at the farmers level (as explained the section above).

During all 6 focus group discussions (Badin 17 April, Mirpurkhas 19 April, Dadu 28 May), in three study districts, female farmers identified that they learned about the preservation of seeds and right use of fertilizers and about kitchen gardening and basic hygiene practices like cleaning the house, kitchen, and general knowledge about improving the basic health of children and women. Most of the training is demand based which means that farmers asked for this basic training. During the discussion with one of the NGO worker Mr. A, explained that when they go to the villages to train or to create awareness both male and female farmers about new and climate smart farming practices, the famers always demand additional training related to health and hygiene facilities, kitchen gardening and livestock management etc. According to Ali (Ali, Welthungerhilfe Pakistan, Hyderabad, 3 March; Zeb, Human Appeal, Hyderabad, 5 March), farmers are mostly poor and deprived of basic facilities, so the best way to approach them and share the knowledge about CSA is to address their core issues in a package, where their basic issues are also addressed. A respondent (Mai Sakina, female farmer, Badin 28 April), highlighted that NGOs training is very helpful for the women in village. The training explains efficient water use in agriculture practices, use of compost and kitchen gardening techniques and trains women about good hygiene practices, cleanliness of their house and surroundings, healthy eating practices and taking care of their livestock. Another respondent (Maryam, female farmer, Badin 28 April), also highlighted the need of basic facilities as a female farmer. She highlighted that her mind is mostly occupied with many issues (i.e., working in the farm lands, health and education of kids, taking care of their house and their own health) all the time. She explained if our kids are hungry and sick, our focus is to provide them clean drinking water, food for at least two times and good health facility and only then we can learn about CSA.

A respondent (Ghulam Mustafa, 30 years old farmer, Dadu, 24 May) explained that after the floods of 2010 and 2011, farmers have demanded training with early warning system for floods and rain, training on disaster management and facilities of disease control in humans and livestock after disasters. He explained that Farmer Field Schools by different NGOs use to provide trainings on land leveling, water use and storage beside etc.

Donors and UN agencies play an important role to change the lives of poor communities of Sindh. Some of these work through close collaboration with NGOs and government while some donors prefer to directly implement their projects to ensure transparency and accountability. Overall there is no formal system of knowledge sharing between donors and NGOs but some of the projects have knowledge dissemination as a major component through which they share the project detail with the beneficiaries (i.e., local communities), government and implementing partners (i.e., NGOs). FAO is the biggest UN agency in Pakistan working in agriculture sector followed by the World Bank and Asian Development Bank and USAID. During research, I also interviewed an international consultant of FAO, working on the consultative process to make effective use "Green Climate Fund". She highlighted that coordination and knowledge sharing at different levels is a very basic issue in the agriculture sector of Sindh and particularly for CSA. Therefore, a frequent consultation is very important between FAO, government, NGOs and other stakeholders in the agriculture sector.

Table 4.10: List of NGOs, Donors and un agencies actively working in the study area

Donors and UN agencies	Food and Agriculture Organization (FAO) Pakistan World Banks USAID Asian Development Bank (ADB) World Wide Fund (WWF) for Nature Pakistan
National and International NGOs	Basic development Foundation Human Appeal Trocaire Thar Deep Rural Development Aga Khan Rural Support Program Sindh Rural Support Organization Rural Support Program Network

	Sindh Rural Support Program Integrated Rural Awareness & Development Organizations Plan international Welthungerhilfe Laar Humanitarian & Development Program Office Lower Sindh Rural Development Association Management and Development Foundation

Source: Created Sajida Sultana

v) Role of print and electronic media in Sindh agriculture

Interviews and focused group discussions confirm that after NGOs and FAO in Badin, Mirpurkhas and Dadu, the most frequent source of information and knowledge sharing about CSA comes from neighboring farmers, fertilizer and seed dealers, farmer organizations (FOs). Communities in Mirpurkhas also use radio and TV as a primary source of information and knowledge to learn about new agriculture practices and technologies. The third biggest source of knowledge sharing about CSA is agriculture magazines, newspapers, articles and publications but this would only pertain to regions where people are literate enough to read. Most of the farmers that were interviewed have at least a primary qualification. The least common knowledge sharing sources are public extension services, universities, internet, books, cooperative society and mobile services. Previous studies also indicate that knowledge and adaption of the climate smart technology and practices also very much depends upon the farmers income and well-being and mobility to the different knowledge sources (Challinor et al. 2014; Schneider and Scheffran 2016; Khatri-Chhetri et al. 2016; Khatri-Chhetri et al. 2017; Hussain et al. 2017; Imran et al. 2018;). These factors are discussed in detail in the drivers' chapter.

vi) Farmer Organizations (FOs)

Farmer organizations (FO) are established by the government and funded by World Bank (WB) as a part of reforms to promote decentralization and participatory management system where irrigation and management system from Sindh Irrigation Department were transferred to multi-tier independent institutions. Under these reforms the Sindh Irrigation Department was converted to independent Sindh Irrigation and Drainage Authority (SIDA) under the SIDA Act 1997. The Area Water Board was established as a self-accounted authority to take over and manage the irrigation and drainage system from canal drains operated by SIDA. Sindh Area Water Board will look after Farmers Organizations and Watercourse Associations through a certain set of defined rules. FOs are formed at distributary and minor level. FOs were established to effectively operate and maintain the irrigation and drainage system at farmers level, to improve distributary canals (i.e., watercourse lining, lining, installation of concrete turnout culverts, community structures, cattle crossings and buffalo baths; and, construction of water storage tanks in the rain-fed areas) and to provide other agriculture support services to the farmers and enhance their knowledge about farming (i.e., water smart technology, land leveling, zero tillage, sprinkler and drip systems, IPM and Integrated Plant and Soil Nutrient Management (World Bank 2017).

Farmer organizations were only implemented in few districts of Sindh as a pilot project for ten years started in 1998 and ending in 2018. Out of three study districts, FOs were established in Mirpurkhas, whereas Dadu and Badin are still under the old institutional structure of Sindh irrigation department. Farmers learn about the updates and different techniques about soil management, water use, and seed & crop management from their fellow farmers in different FO meetings. They can raise their concerns in the weekly meetings of FOs. This structure is more interactive and effective because of the extensive spread of FOs network at community and village level (Memon et al. 2012; World Bank 2017). Farmers can discuss their issues and learn about the new techniques while remaining close to home. FOs are also considered helpful because they have customized solution for the majority of the small farmers facing the unique issues in their farms (Memon et al. 2012). Mr. Rasheed, Narra Canal division, SIDA explained that, "*FOs bought lot of confidence and relief to the small farmers. We encourage farmers to participate in FO meetings as much as they can and use it as their plate form to raise their voices*". Mr. Ghulam Mustafa, a 30 years old farmer says that "*FOs not only create awareness about CSA techniques and practices but helped farmers to improve their lives*". He emphasized that there should be FOs for women too since women equally participate in the agriculture farming. He highlighted that the current structure of FOs do not have any female participation. Some farmers also highlighted that FOs also organize exposure visits for the farmers to the other provinces and even to other countries.

Besides the scientific form of knowledge system, there is another form of knowledge through which farmers in the case study area learn about climate smart practices for soil management, water use, and seed & crop management. This other form of knowledge system refers to locally produced or customary knowledge. Next section will explain the farmer's customary knowledge.

4.3.2 Farmer's customary knowledge system in Sindh Agriculture:

Farmer's customary knowledge is further explained in the literature chapter (section 3.3). The farmers were asked questions about their knowledge and understanding of climate smart agriculture, how they learn about different CSA technologies or practices, how they usually share knowledge about new CSA techniques and old practices they use in their day to day farming.

Farmer's customary knowledge is the knowledge of the local people acquired through their experiences, informal experiments and intimate understanding of the environment in a given culture (Warren and Rajasekaran 1993). Most of the customary knowledge explained in this research can relate to CSA practices because most of them are promoting the sustainable agriculture practices. In this research farmer's customary knowledge is further divided into three categories.

i) Inherited knowledge (Family knowledge)

Most of the farmers in the study area still prefer and use their customary knowledge which they believe is climate smart. Farmers have their own ways of monitoring the health of the soil through visual signs which they can easily observe. For example, soil color, texture, tilth, and compaction. Similarly, they note the absence or presence of particular plants that are harmful or useful for the crops. Even though the farmers cannot exactly identify the non-visible signs such as chemical composition and microorganisms the older farmers can easily identify the soil quality through texture. During the detailed interviews of farmers above the age of 70, it is noted that people in the old days use to prefer climate smart agriculture practices that were sustainable and environmental-friendly (i.e., seed storage methods, water storage techniques, land leveling techniques). They have experienced several changes (i.e., extreme weather conditions, changing rain patterns, floods, and droughts) during their whole life and they have learned about modified climate smart – how to protect their soil, seeds and their crops and learnt how to protect lands under less water availability and differing conditions. At the same time, they also agree that old practices are not always helpful.

Young farmers (i.e., Ishram from Mirpurkhas (22 years old), Bhanua from Mirpurkhas (27 years old) and Ghualm Mustafa Khan from Dadu (30 years old) indicated that they learned different climate smart practices and techniques from their ancestors about the identification of different weeds and plants, their benefit and threats to the cultivated crops. At the same time these young farmers are also interested to learn new CSA techniques to manage their crops and lands. According to (Altaf, Field Coordinator, Basic Development Foundation, Hyderabad, 26 February), "*Family knowledge used to be strong before because of strong family ties and involvement of the whole family in the agriculture but now only one or two members of the family are associated with the agriculture farming and other family members are not directly linked with farming (i.e., either working in cities or studying). This is one of the reasons why limited knowledge is being shared*". A respondent (Hanif, farmer / member of Farmer Organization, Mirpurkhas, 7 May), added that young farmers are open to learn new CSA techniques and practices even if they follow the old practices of their forefathers. He is managing his own farm using the knowledge he gained from his father and learning several CSA techniques like lining of water courses, water resistant seed varieties and new land leveling techniques.

Farmers from all three district are in consensus that the old practices are more conducive to CSA and that there is a strong need of climate smart agriculture technology now, more than ever before (See table 11 below). A 65 years old respondent, (Lalji, farmer, Mirpurkhas 07 May), highlighted that farming was relatively simple four decades ago. For example, there was no need to use the chemical fertilizers, water was sufficient, weather conditions were also better for wheat, cotton, and rice, and production was enough to meet the food required of a big family There use to be a combined family system at that time. Now things have changed, weather is unpredictable and there are a lot of fertilizer companies who sell their seeds and fertilizers claiming high yield in the short period of time. On the other hand, farmers also need more production to meet their food requirement and to sell and generate profit. As explained by Hanif, farmer / member of Farmer Organization, Mirpurkhas, now farmers are influenced by the fertilizer companies and are mostly concerned about the high productivity and profit due to changing livelihood needs and other economic factors. According to Altaf, Field Coordinator, Basic Development Foundation, Hyderabad, small farmers are still using the tractors and other heavy machines to save time. "*Now farmers think that old techniques are time-consuming and take a lot of energy and are less rewarding*" (Altaf, Field Coordinator, Basic Development Foundation, Hyderabad, 26 February). Small farmers usually rent the harvesting machines and tractors which is an added burden for them. Economic factors are further discussed in the next chapters.

During the interviews with the female farmers (Mai Jannat: age 60, Mai Raheema: 70 and Amma Hawa: age 45, Badin, 15 April), they explained that life was relatively simple 30 to 40 years ago. They were all in the opinion that increasing population, changing climate and water scarcity are the factors behind the low productivity of the land to some extent but people have worsened the situation by leaving behind their old practices and farming techniques and adopting the new techniques that are less sustainable. For example, excessive use of chemical fertilizer, modified varieties of seeds for early production (FAO 2018). Some farmers perceive that their customary knowledge is more reliable and they believe what they see. For example, they explained that in old times, the use of tractors, harvester machines, and chemicals were not common and the land was healthier but now excessive use of machinery and fertilizers have destroyed the lands.

It is noted that out of 45 farmer interviews, openness to learn the new CSA techniques varied based on their experience. Farmers between the age 20 to 40 were mostly unaware or less aware of their customary practices and they were very open to learn the new CSA techniques and practices. For example, they explained that crop rotation techniques should be adapted due to changing weather pattern and shifting season patterns and authentic knowledge about how much and how many crops can be used in this process. Farmers between the age 40 to 70, had a good knowledge about customary practices and showed less desire to learn new CSA techniques. Farmers between the age of 70 to 85 believe that not all new CSA interventions would help. For example, Hanif, farmer / member of Farmer Organization, Mirpurkhas, explained that multi-cropping or crop rotation may lead to intense cropping and early harvesting may leave no room for the soil to recover and breathe properly. A respondent (68 years old male farmer, Mirpurkhas, 1 March) explained that one crop at a time helps soil to recover properly. Some of the old and experienced farmers were open to learn about the CSA technologies related to water use, as they agree that old water use practices were not very sustainable and research-based knowledge would be more helpful.

ii) Knowledge shared by the friends and neighbours and land owners

In the study areas, some farmers also identified that they have learned climate smart farming techniques from their friends (who are trained by field schools or have learnt through their experience), FOs and neighbours or they just follow what is their landowners wanted them to do. Most of the farmers in Sindh and particularly in the study area also work as farm workers (called "Haaree" in the local language) on the lands of the landlord beside maintaining their own lands of 4 to 5 acres. The type of customary knowledge generated and shared by these group of people includes leaching of soil, crop rotation, building and maintaining bunds, use of compost as a fertilizer, land ploughing, intensive cropping and tree plantation. All these customary techniques help to maintain the ground cover, retain the soil moisture, and protect the land from surface salt.

There were some mixed responses from different focus groups because of different set of issues they are facing but some of the responses were common in all the focus groups. For example, all the focused group discussions (Badin 17 April, Mirpurkhas 19 April, Dadu 23 May), highlighted that old water irrigation practices and the knowledge about water use is not applicable in the present and future times due to water shortage and illegal breakages in the canals which require new but reliable knowledge of CSA technologies and practices from credible sources for sustainable use of water in agriculture lands beside interventions to control illegal breakages.

Similarly, the famers were also in consensus that the existing/customary knowledge and ways of ploughing should be the same for most of the crops because old methods kept the soil healthy. They believe that the old methods of soil mixing are still applicable as some of their fellow farmers benefited from these methods and this knowledge is being promoted as a CSA practices by private extension services. The farmers believe that such techniques are only helpful for small farm holders and that large farmers may still require use of heavy machines with proper knowledge.

Focus group discussions (Mirpurkhas, 19 April) clearly highlighted that farmers have learnt several methods of crop rotation techniques and most of their knowledge about crop related CSA techniques is coming from their neighbour villages and friends. Old farmers explained that they used to have their own leaders to guide them and these farmer leaders used to share their experiences and knowledge. These leaders were informally selected by the villagers, based on their experience, successes, and knowledge about farming. For example, knowledge about different forms of rice or wheat varieties and their properties etc. Similarly, they learnt practices and useful ways to store the seeds. Farmer leaders of old times had good knowledge about seed storage (i.e., how long grains can be stored under different weather conditions, at what temperature and their exact state of ripeness). The most common customary method of grain storage was underground storage and storage in the mud and brick structure.

4.4 Interaction and knowledge sharing between different stakeholders involved in Sindh Agriculture:

Sindh and particularly the three study districts have shown a low agricultural productivity in the last three to four decades as compared to 1960s and 1970s, despite a lot of agriculture research done at the provincial level by private and public research institutes, the implementation of different forms of extension services by the government and the effort done by different NGOs, UN agencies (i.e., FAO) and donors to improve the agriculture sector of Sindh. The very obvious reason that explains the low agriculture productivity is the lack of knowledge sharing.

All the different stakeholders involved in the agriculture sector are disconnected and hold their respective knowledge to themselves instead of making the knowledge available to all the potential users of their knowledge. For example, interviews show that a lot of university research has been done and is currently still being conducted on the new varieties of seeds and new forms of farming techniques but these are only available in the research papers and is never shared with policymakers or with local farmers. Similarly, extension services are responsible to provide information and train farmers about the new technology and practices but they themselves are hardly trained about these technologies and practices. Therefore, there is a very little flow of information between government departments at a provincial level and district level and farmers at a village level.

Based on the initial assessment of semi-structured interviews, focus groups and informal discussions supported by previous reports or research done of the knowledge sharing and awareness about CSA and other sustainable technologies or practices (that by definition may or may not include all the three CSA pillars), I have identified the network web (see Figure 4.2) explaining the strength of interaction and knowledge sharing between different stakeholders involved in Sindh agriculture. This analysis is completely based on the trend of different responses, reading the patterns, self-assessment and knowledge of the agriculture sector in Sindh in general. Limitations of this network web are that it is not supported by the quantitative data to support the strength through numbers of the responses to clearly indicate the strong, weak and very weak level of interaction.

This network web shows the interaction of each stakeholder with the remaining stakeholders in the agriculture sector for sharing their respective knowledge about CSA technologies and practices among each other. This diagram shows that there are many weak and very weak connections between different stakeholders. For example, public extension services have a weak (shown in blue) and very weak (shown in red) connection with almost all the stakeholders except the government departments and NGOs and private extension services. But the most important connection (i.e., with the farmers) is very weak considering that agriculture extension services are the only services with their presence at the union council (village level) structure wise. Similarly, NGOs / private extension services and research institutes are playing a major role in Sindh agriculture. They are well connected with farmers at the village level and universities for training purposes, to bridge the gap between research and implementation. NGOs are also well connected with the public extension services to use their presence and to train them about the new technology. NGOs are also well connected with donors, FAO and UN agencies and the motivation behind this is funding the future projects. FAO and some donors besides the direct implementation also rely on local NGOs to implement their projects at local level. NGOs mostly acquire knowledge from agriculture universities and other research institutions to ensure that the disseminated knowledge is reliable and credible (see section 4.3.1 -iv).

Another important interaction emerging from the research is FOs and their interaction with the other stakeholders. FOs are considered as a successful informal structure introduced by World Bank in few agriculture districts of Sindh as a pilot project for 10 years. The FOs have shown some great results and has gained a lot of confidence from the farmers. But these FOs are very much working on their own. They are facing a number of political issues to be formally recognized. Existing irrigation departments do not want their authority to be shared under the proposed structure of FOs. Therefore, the farmers are getting very little knowledge and information from the agriculture department at the district level although national and provincial government have approved this project of World Bank. FOs in Mirpurkhas are very well connected with the farmers especially small farmers. They are facing some trouble from big farmers and landlords because of the different political and power-related interests (Further detail is discussed in the driver's chapter). FOs are in favor of preserving the customary knowledge and practices as they believe that such knowledge is conducive for innovative technology in farming if it is institutionalized by the government. For example, a respondent (farmer, Mirpurkhas, 11

May) believes that the quality of ground water effects the cotton production and he has noted that over time the quality of ground water has deteriorated reducing the cotton production in his field. Therefore, he suggests new CSA interventions to improve water quality in his district are very important. He also explained that his ancestors taught him that humidity damages cotton crops and new CSA methods like of reducing humidity and vaporization can help reduce pests and disease.

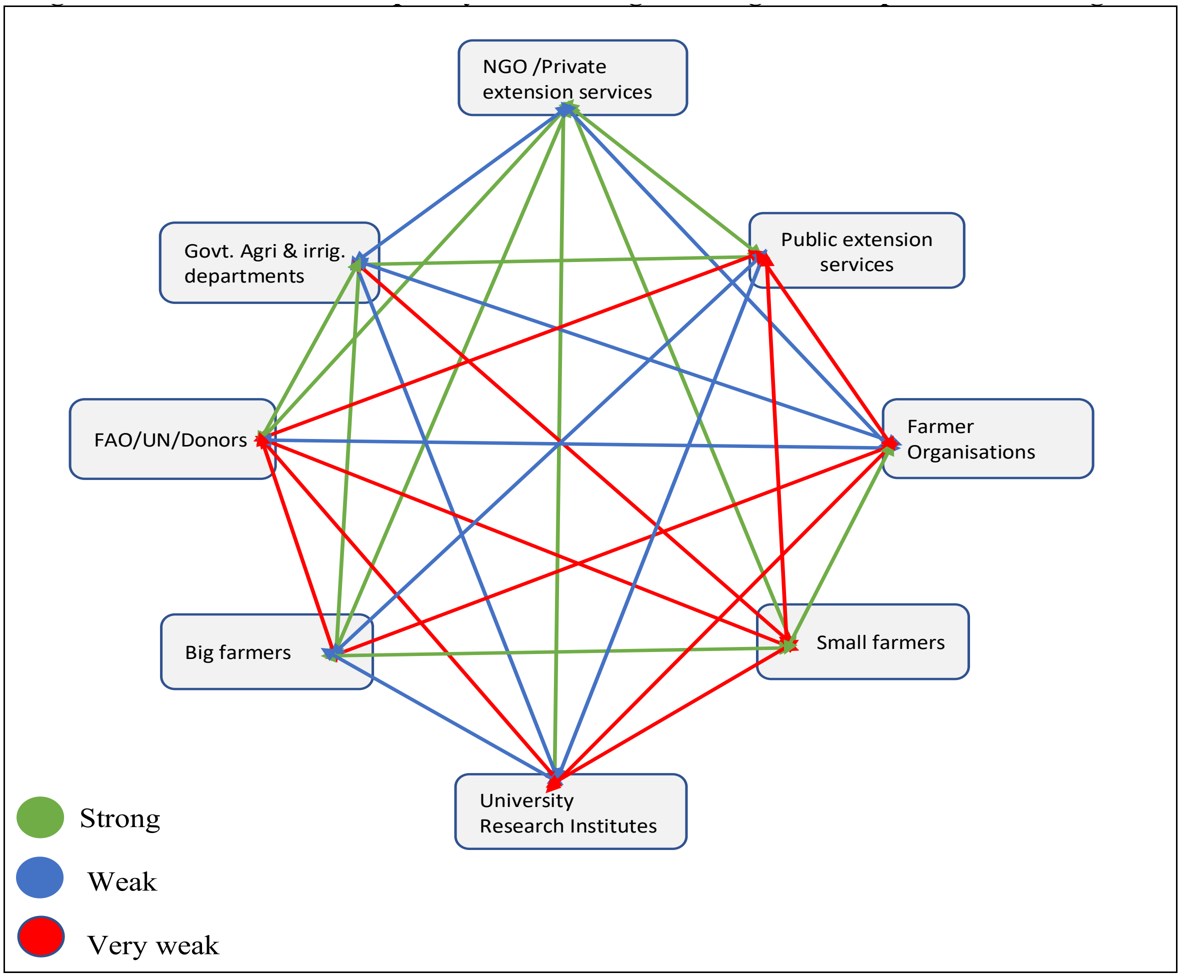


Figure 4.2: Interaction of different stakeholders in agriculture sector for knowledge sharing (Created by Sajida Sultana)

4.5 Conclusion

This section explains some of the key findings of the chapter and also highlights the potential of CSA technology and practices more generally in agriculture sector of Sindh and more specifically in the study areas. The agriculture sector in Sindh has a very low rate of adopting new CSA technologies to mitigate different environmental and climatic change. A general observation is that most of the CSA technologies and interventions are adapted in the agriculture sector of Punjab province of Pakistan (World Bank 2017). Places (in Punjab) where CSA technologies and practices are introduced have shown a positive impact on the production of major crops (i.e., wheat and cotton). Sindh is still behind in terms of adopting new practices and technologies in the agriculture sector. Farmers in Sindh are reluctant to adopt new CSA technologies and still very strictly follow the old agricultural practices and conventional methods of farming (Imran et al. 2018). Farmers lack sufficient awareness of the CSA technologies and even if they have a knowledge, implementation is weak due to several factors (i.e., economy, social and cultural taboos, poor literacy rate). CSA practices also have to be knowledge smart to convince and encourage farmers in Sindh to adopt new CSA technologies (World Bank 2017; Imran et al. 2018). In order to raise the agricultural productivity, it is important to understand the knowledge system around CSA at all levels and recognize the importance of regular coordination between different stakeholder (i.e., agriculture departments, research institutions, and local farmers and donors). Lack of timely training, awareness raising and weak knowledge sharing at the local level is the main cause of low productivity in Sindh (Masood et al. 2012; Aslam 2016).

In the case study areas, findings of the focus groups and semi-structured interviews clearly identify that farmers do not get enough guidance on the new practices and the use of new CSA technology (i.e., zero tilling, laser land leveling, sprinklers, and bed planting). There is a constant need for sharing of knowledge about CSA technology and practices at all levels to improve the quality of agriculture inputs (i.e., soil management, water use, and seed management) (Husain 2012; Aslam 2016). Low agriculture productivity in the case study areas is mainly due to the prevailing knowledge system. For example, the scientific knowledge system in Sindh agriculture sector is weak and fragmented. Different stakeholders have their own knowledge about the soil, seed and water management but all different bodies carrying CSA knowledge are not closely linked and interconnected. NGOs and private extension services are playing an important role in disseminating the knowledge about CSA and bridging the knowledge gap at various levels.

Previous studies in the case study areas and focus group discussions also revealed that poverty and small land holdings are also the main hindrances to acquire the knowledge about modern CSA technology to improve the soil condition (Sattar 2012; Aslam 2016). Farmers' perception about the new CSA technology is that it is costly for their small land holdings (i.e., Three to five acres of land) and they do not feel motivated to learn new CSA techniques. 60% of the farmers in the study area have less than 5 acres of land.

It is also noted that in the case study areas insufficient progress has been seen towards the implementation side of the CSA related research on ground to improve the soil fertility, water utilization and new seed varieties (Husain 2012). There is a clear knowledge gap between the research on CSA technology and local practices. Farmers are unaware of the new CSA technology and their benefits towards sustainable agricultural productivity and consequently the farmers are reluctant to adopt the new technologies. Information and knowledge sharing on CSA at the local level to translate the research into practices is weak and in most cases, the research is done without the consultation of local farmers (World Bank 2017).

Farmers in the case study areas have their own customary knowledge mostly based on their perception, folk knowledge and old ways of managing their farms including soil management, water use, seed management and the use of different chemical fertilizers (Aslam 2016). Most of their agriculture practices under customary knowledge can be considered as CSA because farmers have learned to mitigate climate change impact through their experience over time and through innovation. For example, customary knowledge to store water, or distribute water through multiple channels, methods of no tilling and land leveling already exist but are limited in practices due to other drivers of change (i.e., water shortage, degradation of soil, discontinuation of agriculture practices etc.). In order to disseminate and ensure the implementation of new CSA technologies and practices, it is important to recognise, respect, restore and integrate customary form of knowledge through the participation of local farmers during CSA consultation, policy making and implementation processes.

Chapter 5 - Drivers of change impacting the knowledge system of CSA technology and practices

5.1 Introduction

In the previous chapter I examined the different forms and sources of CSA knowledge in the study area with regard to agriculture production, particularly focusing on soil, seed and crop management, and water. I also assessed the role of different stakeholders in promoting knowledge about CSA technologies and practices. This chapter emphasizes the second objective of my research, which is to "*identify key climate change, socio-economic and political drivers that affect how different types and sources of knowledge influence the emergence and implementation of climate-smart agriculture*". This chapter is divided into three different parts. First, this chapter will define and explain the different drivers (i.e., natural disasters, socio-economic, political and water management) in the case study areas that have impacted the agriculture sector. Second, I assess how these drivers impact knowledge systems for CSA, and specifically in relation to soil, seed and crop management, and water management.

Drivers are defined as any natural or anthropogenic factor that directly or indirectly causes change (MEA 2005). Many drivers cause a two-way effect between humans and nature as a part of a social-ecological system. These drivers can cause multiple changes (i.e., natural resources like agriculture lands, forests, lakes, lagoons etc.) at any level and any scale irrespective of their source, and sometimes one single driver can cause multiple changes (Nayak and Berkes 2014). Drivers are further explained in the literature chapter but this section will access the role of different drivers on the knowledge system of CSA.

Multiple changes are caused by the different drivers (i.e., socio-economic, climate change etc.) in the agriculture sector (i.e., increase and decrease in the agriculture production). New and diverse knowledge is an important indicator of adaptive capacity (Williams, Fenton & Huq 2015). Therefore, understanding changes in the existing knowledge system (i.e., customary, scientific knowledge etc.) of agriculture and CSA is important for effective adaptation and planning at local levels and in terms of policy level (Williams, Fenton & Huq 2015). In the case study area, natural disasters (i.e., floods, drought etc.) are discussed as drivers under climate change. These drivers caused several changes (i.e., destruction of lands and water resources) by severally impacting the agriculture sector in Sindh (i.e., food security issues, low agriculture productivity etc.) and altering the knowledge system of CSA in the agriculture sector (further discussed in the next section 5.2).

In Sindh, for example, the knowledge about yield variability in the quality and quantity of food production impacted due to climate change has changed over time. Similarly, knowledge of different drivers (i.e., floods, drought, rainfall pattern) on the agriculture sector and knowledge to cope with these changes through CSA and other sustainable practices has also evolved. It is important to note that these drivers are interconnected. Degradation of land is caused, for instance, by the driver of climate change and by associated socio-economic drivers (use of chemical fertilizers, intercropping to increase agriculture productivity). Similarly, water shortage is caused by the driver of climate change but at the same time it is caused by poor water governance and political dynamics.

Table 5.1 outlines the impacts of different direct and indirect drivers in the agriculture sector in the case study areas, and the knowledge system for CSA. These drivers are determined based on the thorough analysis of the data collected through focus group discussions, semi structured interviews and published reports. 90% of the responses from interviews and focus groups highlighted these drivers. Notably, drivers highlighted in table 5.1, are directly or indirectly changing the knowledge of agriculture practices that farmers were practicing over the past several decades. These drivers and their impacts on knowledge system of CSA are further explained below.

Table 5.1: Drivers impacting the knowledge system of CSA

Drivers of change	Impact on agriculture sector	Impact on knowledge system of CSA
Direct Drivers: Climate change Natural disasters Socio-economic status Political and power dynamics Water governance	**Direct Impact:** Degradation of agriculture lands Decrease in agriculture production increasing food security issue Loss of heritage seed varieties Over-use of water and fertilizers Use of poor-quality seeds for higher production	**Direct Impact:** Limited access to learn new knowledge of CSA Customary knowledge is ignored CSA knowledge is not localized Limited awareness of CSA techniques & practices Disintegrated knowledge of CSA
Indirect drivers: Demography Customs & traditions Migration Fertilizer and seed industry	**Indirect Impact:** Displacement of communities Malnourishment and poor health Loss of sense of belonging Increased job stress due to unstable source of livelihood Increasing conflicts and street crimes	**Indirect Impact:** No policy for CSA Lack of evidence for CSA knowledge CSA knowledge is not integrated with other policy at national and provincial knowledge

5.2 Climate Change

Climate change brings long term shifts in weather conditions, the possibility of increasing frequency and severity of extreme weather events (O'Brein et al. 2006). Climate change is not only a multifaceted (from drought to flood) but also multidimensional (from local to global) with many short, medium- and long-term aspects, which affects settlement, infrastructure and livelihood systems in the face of increasing uncertainty and frequent disasters (Masika 2002; O'Brien et al. 2006). Many analysts believe that to adapt to the impact of climate change, collective learning is important (Armitage et al. 2011; Huitema et al. 2016; Lemos and Morehouse 2005; Serrao-Neumann et al. 2015) and taking into account diverse knowledge and collective perspective is the key (Olazabal et al. 2018; Bremer and Meisch 2017; Collins and Ison 2009).

Climate change is defined in this research through the different drivers of natural disasters (i.e., floods, season variation, rains and droughts) including extreme events. These drivers of natural disasters acted in two ways: i) limited agriculture production, changed the way people practiced agriculture, and ii) people gained new knowledge about agriculture practices through CSA, which they would have never learned otherwise. For example, in Mirpurkhas, farmers learned about sustainable use of water in agriculture through CSA techniques because, in normal conditions, they never felt the need to save water before (further explained in section 5.5). This section will explain how climate change (i.e., natural disasters and changing weather patterns) as a driver has impacted the agriculture sector and the knowledge about CSA to manage agriculture.

According to the global climate change vulnerability index (CCVI), Pakistan's ranking stood at 29th in the list of most vulnerable countries for 2009–2010, and ranked 16th in 2010–2011 (Khan and Fee 2015). In Pakistan, drivers of natural disasters like floods, droughts, melting of glaciers, earthquakes, heavy rainfalls, and rise in sea level have impacted the agriculture sector in all different ways including loss of multiple varieties of seeds, crops and loss of soil nutrients. Destruction to agriculture crops, livestock, forestry, and fisheries occurred due to monsoon floods in 2010, 2011, and 2014, which also damaged key infrastructure such as animal shelters, tube wells, fertilizers, houses, water channels, seed stocks, and agricultural equipment. Usually these floods occurred before the harvesting season of the main crops including wheat, rice, maize, sugarcane, and vegetables causing an approximate loss of 13.3 million tons in agriculture production due to the yield loss of major crops (Ali et al. 2017). In 2010 floods, 20 million people were affected including extensive damage to infrastructure (USD 4 billion), 2.2 million ha of crops and 450,000 livestock worth USD 500 million, with an estimated total loss of over USD 10 billion (Chapagain and Raizada 2017). Natural disasters have very severely disrupted ecosystems, livelihoods and agriculture production in Mirpurkhas. For example, according to a joint report of the ABD, Government of Pakistan and World Bank (2010), the 2010 floods in Pakistan affected 4.5 million workers, two-thirds of whom were employed in agriculture; more than 70 percent of farmers lost more than half of their expected income.

Moreover, anthropogenic activities such as lack of awareness about unique geo-climatic conditions and lack of knowledge of coping strategies like climate-smart agricultural also contributed to damage in the agriculture sector in the case study areas. One of the reasons behind the lack of knowledge about CSA is that after every disaster the focus is usually to provide immediate relief to the affected population through food and drinking water supply, providing shelter and medicines, and ensuring the safety to communities (see below). A brief history of natural disasters in Sindh is highlighted in table 5.2.

Table 5.2: History of Natural disasters in the study districts

Nature of Disasters	Years
Cyclone A-1 & A-2	1964 and 1999
Floods	1970, 1975, 1979, 1994, 2003, 2006, 2010 & 2011
Earthquake	1958, 1960, 1963, and 2001

Source: Disaster Risk Management Plan, Government of Sindh (2008)

Some of the main natural disasters impacting the agriculture sector in the case study area are explained below.

a) Floods

The floods of 2010 heavily impacted the study area districts (i.e., Mirpurkhas, Dadu and Badin) and these districts have still not recovered from the damages caused to lives, infrastructure, agriculture land and loss of livestock. In 2010 floods, one-fourth of the country's land area was inundated damaging the infrastructure, houses and leaving millions of people food insecure (FAO 2011). The immediate concern after the floods 2010 was the spread of disease, snake bites, and clean drinking water supply (PDMA 2012). Key losses in Sindh during 2010 floods are highlighted in the table 5.3.

Table 5.3: Key losses in Sindh during 2010 floods

Losses	Damage in numbers
Number of Villages affected	11,992
Number of persons affected	7,254,355
Number of People Died	414
Number of houses damaged	876,240
Number of people reported in government relief camps	1,821.479
Standing crops destroyed (cotton, rice sugarcane, pulses and vegetables)	0.88 million hectors
Livestock damage	116,000 dead, 5 million affected
Irrigation structure submerged	20,400 structures

Source: PDMA (2012) and FAO (2011)

According to a respondent, (Former employee, Sindh Irrigation Development Authority, Mirpurkhas, 5 May), during floods, people were concerned about saving their lives, food, and water. They were least concerned about the damage to their stored seeds, crops and their agriculture lands. He explained, in the last two decades floods have not only destroyed land masses but also the irrigation system of many districts in Sindh including Mirpurkhas, Dadu, and Badin. He explained that the irrigation system of Pakistan is one of the oldest and most complex systems in the world and floods have caused major damage to the irrigation system in Sindh. Some people have migrated after floods from Badin and Dadu district to the large cities like Hyderabad and Karachi and never returned. Some families have changed their source of livelihood from agriculture to other livelihood sources like fisheries and daily wage jobs in other cities. The long history of floods (see table 5.1) has not only impacted the agriculture and water sector in general, but it also impacted the understanding and day to day practices of farmers in the agriculture sector. As explained by a former employee, Sindh Irrigation Development Authority, (Mirpurkhas, 5 May) *"In old days selling cow milk was considered as a lowly job but now farmers have no choice, they sell milk to earn a living"*

Farmer's knowledge and understanding of the agriculture practices have either changed or been completely erased. For example, farmers who have migrated have largely forgotten their knowledge and understanding about their agriculture lands, crops and ways of agriculture farming. Similarly, several farmers have noticed and are learning about new diseases and weeds damaging their crops, months after heavy floods, impacting the crop health and agriculture productivity. According to a respondent (Muhammad Ayub, farmer, Badin, 26 April), several rice varieties are damaged after the heavy flooding in the 1970s and 2010. He explained *"Keel and Saghrio were good quality rice and were very famous in Badin four decades ago. Government use to export them. The smell of these rice varieties was really good. No fertilizer was needed at that time to grow these rice varieties but they have disappeared completely"*. He explained, now there are many diseases that we have never seen before and these are harmful to old rice and wheat varieties. In these conditions' farmers have identified the need for new and credible sources of knowledge and understanding of CSA technologies and practices as explained by a local farmer in Badin (Mohammad Khan, farmer, Badin, 27 April).

Sindh is experiencing floods almost every year. Farmers in the study area also believe that in addition to learning the new CSA technologies and practices, their knowledge and understanding about the natural disasters and managing disaster risks is imperative. A respondent (Ghulam Mustafa, 30 years old farmer, Dadu, 24 May) explained that *"After the 2010 floods, agriculture lands remain inundated for almost a month. We left our houses, lands and livestock and we came back after three months. It completely destroyed our lands, livestock, crops and stored seeds.* He also highlighted that *"We are interested to learn about disaster risk management, first aid, and early warning systems as a package with CSA practices and technologies".* So far, few training opportunities are provided by NGOs on Disaster Risk Reduction (DRR) and early warning systems but very few training opportunities were related to rehabilitation of agriculture lands. Also, as explained in Chapter 4, section 4.3.1., farmers of Dadu and Mirpurkhas have noticed that after the floods of 2010, the soil was very fertile and agriculture production was good both in quality and quantity, but remained so only for the next two years. A respondent (Naseem Naz, female landowner, Mirpurkhas, 17 April) narrated that *"After two to three years of flooding, our earnings from agriculture production were very high but after third-year both quantity and quality of agriculture production decreased"*.

A respondent (Rasheed, an expert and a landlord, Hyderabad, 6 May) said that people have forgotten the old practices of farming because they are not applicable in the current scenario. He explained "*Floods have changed everything in agriculture farming. Earlier supply-based model used to exist where government use to introduce whatever they wanted to but now* *we need demand-based model where knowledge of CSA techniques and practices is based on local needs, circumstances, and conditions that are changing every day".*

b) Rainfall pattern and seasonal variation

In Pakistan, three-fourths of the country receives less than 250 mm of rainfall annually and which is not enough when distributed through a comprehensive network of canals and dams. Climate change is determined through long term shortage of rainfall in the semi-arid and arid regions of the country and increasing temperature by 0.5°C in the past 30 years (World Bank 2017). During the monsoon and winter seasons, Sindh faces extreme water shortage because of delayed and fewer rainfalls. For example, in 2017, during the monsoon season (July – September), the country received 22.8% of the rainfall which is 108.8 mm against the normal rainfall of 140.99 mm. During the post-monsoon season, the rainfall was 39% below the normal rainfall of 26.4 mm. Similarly, in 2018, the rainfall was below the average as shown in table 5.4. According to the World Bank reports (2017), due to change in the monsoon pattern, water resources for agriculture sector of Sindh will further decline in the coming years.

Table 5.4: Rainfall recorded during 2017-2018 (in Millimeters)

	Monsoon Rainfall (Jul-Sep) 2017	**Post Monsoon Rainfall (Oct-Dec) 2017**	**Winter Rainfall (Jan-Mar) 2018**
Normal**	140.9	26.4	74.3
Actual	108.8	16.1	32.2
Shortage (-)/excess (+)	- 32.1	-10.3	-42.1
% Shortage (-)/excess (+)	-22.8	- 39.0	-56.7
*: Area Weighted, **: Long Period Average (1961-2010)			

Source: Pakistan Metrological Department Retrieved from http://www.ndmc.pmd.gov.pk/index.htm

In Sindh, during 2011 rains, Dadu, Badin and Mirpurkhas were among 20 severely impacted districts. Table 5.5 indicate the losses during 2011 rains in three study districts.

Table 5.5: Key losses during 2011 rains in Three study districts of Sindh

Study districts	Total People Died	Villages Affected	Persons Affected	Houses Damaged
Dadu	19	1454	325,000	18,594
Mirpurkhas	61	3178	705,151	118,110
Badin	73	6,395	1,021,301	382,562

Source: PDMA (2012)

Shifts / variability in the monsoon course is causing heavy floods (see section 5.1 a). For example, in 2010 floods, monsoon course shifted from East Pakistan (Punjab) to the North West mostly Khyber Pakhtunkhwa (KP). Punjab province has a capacity to absorb more monsoon rains due to its plains, cultivated fields, well-designed canal system, and due to effective coordination between different institutions in Punjab (i.e., Provincial Disaster Management

Authority (PDMA), agriculture department). Whereas, KP province has mountains and slopes aggravating the speed of runoff water with no barriers and easy infiltration causing the floods Southern part (i.e., Sindh) of the country. According to Pakistan Metrology Department, this shift of monsoon pattern from East to North-West is due to climate change, others claim that the intense heat and below average rainfall is the result of La Nina effect during the period 2000-2010 (Lead Pakistan 2017).

Change in monsoon season and increasing temperature is causing a number of challenges to the agriculture production in Sindh Pakistan (World Bank 2017) which is also affecting and changing the related knowledge of different stakeholders. A respondent (Assistant Professor Plant Pathology department, Sindh Agriculture University Tandojam (SAUT) Sindh, Hyderabad, 5 March) confirmed these findings and explained that *"The overall crop growth cycle is impacted due to changing monsoon pattern, shortening the time between sowing and harvesting. Knowledge about CSA practices that can help farmers to understand the changing pattern of monsoon as well as a critical investment in the improved varieties of seed, and improved technology in water infrastructure is needed to tackle the water shortage issue in Sindh agriculture sector"*. He added that the agriculture university and other research institutions are credible and reliable sources of knowledge about CSA practices. He explained agriculture university and other research institutions are diverting their research towards developing their understanding and knowledge of such techniques but the progress is very slow due to limited resources. Another respondent (Rizwan, Social Organiser, Mirpurkhan, 07 May) explained that unprecedented rain during the summer season is causing the floods in the study areas, damaging the standing crops. He explained that unpredicted rain in summer causing huge losses to the farmers as wheat grains, sugarcane, and cotton that is ready to go to the factories and markets. He also explained that due to lack of knowledge about the changing rain pattern coupled with poor irrigation infrastructure, rainwater cannot be restored in the reservoirs, resulting in the discharge of excess water in the sea. Due to which most of the districts in Sindh remains water-stressed for the large part of the year.

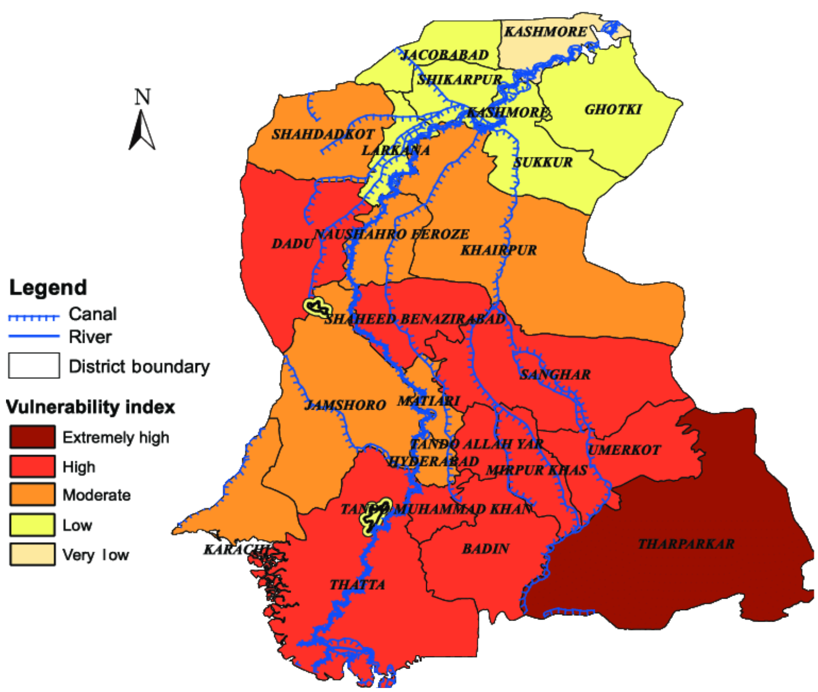
Knowledge of CSA practices and techniques has greatly changed over time due to continuous changing rain pattern. For example, two respondents and experts (Amna and Rizwan, Social Organisers, Area Water Board, Mirpurkhan, 07 May) explained that in Mirpurkhas farmers lost their standing crops due to heavy rains in the last few years. Farmers of Mirpurkhas are interested to learn about CSA practices and techniques (i.e., crop protection and soil maintenance training through demo plots) but most importantly they want to learn about the changing pattern of rain to change their sowing and harvesting time for crops accordingly. There is a clear knowledge gap between the Pakistan Meteorological Department (PMD), irrigation department and agriculture sector. Farmers expect weather forecast for rain and intensity of rain but PMD has a very limited capacity and lack of funds to use new technology to predict weather ahead of time. FAO in its report on Provincial and Regional Assessment- Sindh (2016) has also highlighted the poor coordination for the meteorological system.

Farmers of Mirpurkhas are well organized, therefore with the help of FOs they are learning about maintaining the seasonal calendars for different crops. Farmers highlighted the importance of using seasonal calendars for everyone (Focus group, Mirpurkhas, 17 April). They explained that through regular FAO meetings, different farmers share their knowledge and experience of change in the timeline for cultivation and harvesting. It helps both small and large-scale farmers to understand the changing monsoon pattern and also how to maintain water level for crops with less rainfall. They also highlighted that training about disaster risk reduction (DRR) for farmers is important in which they learn about how to drain the water from deep land areas during heavy rainfalls through motor pumps and spread it to shallow land areas. They explained that their knowledge was limited to normal rainfall pattern and weather conditions but changing rainfall pattern induced them to learn new knowledge and a better understanding of CSA techniques and practices to mitigate the impact of changing rainfall pattern and weather conditions.

Other two study districts (i.e., Badin and Dadu) are experiencing very limited rainfall during the year and therefore knowledge of the farmers is very much limited about changing rainfall pattern. Seasonal calendars are not common in Badin and Dadu. In Dadu, some farmers try to practice rainwater harvesting but this technique does not save enough water to meet their water demand. Their knowledge of CSA is mostly directed towards learning new seed varieties that are drought resistant and require less water use.

c) Droughts

Pakistan often experiences periods of severe droughts, followed by devastating floods contributing to low crop yield and food shortages in recent years (World Bank 2017). According to World Bank (2017) and the Climate Change Vulnerability Index (CCVI), droughts in Asia are expected to increase in winters affecting the yield of cash crops. In Pakistan, droughts are mainly due to rainfall variations in the southwest monsoon (IWMI 2004; Mazhar et al. 2015; Anjum et al. 2016; Lead Pakistan 2017) and unseasonably high temperatures, both influenced by El Niño (IFRC 2019).



Map 5.1: Drought hazard map showing the vulnerability index for each district of Sindh (Source: Adnan 2015)

Sindh has a long history of droughts, including worst droughts in 1871, 1881, 1899, 1931, 1947, 1999, where drought in 1998-2000 was prolonged till 2002. According to an estimate five million people are affected by drought and food production in the affected areas (IFRC 2019). According to the PMD, this situation will continue to deteriorate over the coming four years, in part due to climate change (IFRC 2019). Diagram 5.1, show the drought the vulnerability index for each district of Sindh including the three study districts. According to the map, study district (i.e., Dadu, Badin and Mirpurkhas) have a "high" vulnerability index for drought.

Most of the population in Dadu and Badin are suffering from agriculture drought conditions (see table 5.6) from three decades. Knowledge of the formers to handle the drought conditions changed or altered over time. For example, old farmers of Dadu identified the use of stored water as a supplement to irrigation system but now this is not enough because heat intensity is increasing which evaporates the stored water and water cannot be stored for more than three to four months. (Focus group discussion, Dadu 23 May). Focus group discussions in Dadu and Badin (Badin 17 April and Dadu 23 May) and 90% of the interviews with farmers highlighted the adverse impact of droughts on agriculture productivity and also identified the need for other CSA techniques and practices to cope with drought conditions.

Table 5.6: Definition and types of droughts in Pakistan

Definition:	
A drought is an extended period of months or years when a region notes a deficiency in its water supply. Generally, this occurs when a region receives consistently below average precipitation. It can have a substantial impact on the ecosystem and agriculture of the affected region. Although droughts can persist for several years, even a short, intense drought can cause significant damage and harm the local economy.	
Types of droughts in Pakistan	
Meteorological Drought	Meteorological drought is the amount of dryness and the duration of the dry period. Atmospheric conditions that result in deficiencies of precipitation change from area to area.
Agricultural drought	Agricultural drought mainly effects food production and farming. Agricultural drought and precipitation shortages bring soil water deficits, reduced ground water or reservoir levels, and so on. Deficient topsoil moisture at planting may stop germination, leading to low plant populations.
Hydrological drought	Hydrological drought is associated with the effects of periods of precipitation shortages on water supply. Water in hydrologic storage systems such as reservoirs and rivers are often used for multiple purposes such as flood control, irrigation, recreation, navigation, hydropower, and wildlife habitat. Competition for water in these storage systems escalates during drought and conflicts between water users increase significantly.
Socioeconomic Drought	Socioeconomic drought occurs when the demand for an economic good exceeds supply as a result of a weather-related shortfall in water supply.

Source: National Drought Monitoring Center, Pakistan Metrological Department, Retrieved from http://www.ndmc.pmd.gov.pk/index.html

Farmers during focus group discussion (Badin 17 April) explained that they used to practice old techniques of water harvesting called Sailaba or spate irrigation or rod-kohi system in Badin, which was also common in Dadu and Mirpurkhas. The Sailaba cultivation is done by diversion and spreading of intermittent flows of hill torrents (Akhtar 2004; Sahrif et al. 2019). As water flows down the hill through main channels, the excess water flows out of the main channels and passes through several diversion bunds constructed by farmers to meet their irrigation needs (Sahrif et al. 2019). These diversion bunds allow water to seep slowly into the soil and is good for deep-rooted crops. Sailaba system is good to irrigate around three hectors of land. A respondent (Amma Hawa, an old female farmer, Badin 15 April) explained that this was one of the old CSA practice but now the system of Sailaba has almost disappeared. Upon inquiring, she explained, *"there are two reasons for that: i) new techniques (i.e., tube wells) have taken over the old methods of water harvesting system and, ii) this system works when there is enough water but now there is no water or extreme water shortage to run Sailaba system"*. Another farmer (Abdul, farmer, Mirpurkhas, 28 April) explained that we still have knowledge about Sailaba system but this system is no more applicable and is not in practice due to extensive use of tube wells, and saline water. He also explained that farmers have no knowledge about the actual water requirement of crops and most of them are over-irrigating their agriculture lands. Farmers should be guided with the right and reliable knowledge and technology to pump the groundwater for the sustainable use of water resources he added. Some experts explain that due to reduced rainfall, stream flows available for Sailaba system have completely dried up (Chaudhri et al. 2002).

An expert (Professor, Sindh Agriculture University Tandojam (SAUT) Sindh, Hyderabad, 1 May) responded that most of the farmers in these study districts are small-scale and poor farmers representing the majority and backbone of the agriculture sector. He explained, these farmers have limited knowledge about the new CSA technologies and practices because they cannot afford modern CSA technology (i.e., land laser leveling, sprinkler, and drip irrigation technique). High prices of drought and weather tolerant seed varieties, expensive heavy machines, high-quality fertilizers and lack of support from government is restricting the small-scale farmers to learn, use and adopt CSA practices (World Bank 2017). Also explained in the section 5.3 (socio-economic drivers).

Washing bed is built beside water storage ponds (Photo: Sajida Sultana)

A respondent (Hanif, farmer/member of Farmer Organization, Mirpurkhas, 7 May) explained that knowledge of the farmers is now shifting towards the new affordable CSA techniques of water storage and irrigation in Mirpurkhas. For example, farmers use watercourse lining, water storage ponds, and water storage tanks to save and use the water in a sustainable manner. He explained that *"NGO and government have guided us on how to build water storage tanks and ponds in Mirpurkhas. Normally storage ponds are constructed through muds and storage tanks are contracted through cement. We use them to store the rainwater, which can be used for six months. We have also planted trees to reduce the water flow during floods".* Depending on the size of the pond or a tank and weather conditions these water tanks can be used for several months (FAO/WFP 2002a). The depth of the water storage pond varies up to 4 to 6 meters with the storage capacity of 2000 to 5000 m3 (Bhutta et al. 2005).

Table 5.7 explains the natural disasters as the key drivers of change (i.e., floods, rains, droughts etc.) in the study areas under climate change (column one). Climate change is the main compelling force behind the concept of climate-smart agriculture (CSA), at the same time, under the climate change, drivers of natural disasters are adversely impacting the knowledge and implementation of CSA in the study areas. Table 5.7 summarize the impact of these drivers on the agriculture sector (column two) consequently affecting the knowledge system of CSA (column three). Moving from right (column one) to left (column three), table explains the transition in agriculture sector due to different drivers such as floods, season variation, rain pattern and droughts. These drivers have adversely affected the agriculture lands, farmers and reduced the agriculture productivity in the last three to four decades.

Table 5.7: Impact of drivers of climate change on knowledge system of CSA

MIRPURKHAS		
Climate Change	**Impact on agriculture sector**	**Impact on CSA knowledge**
• El Niño has caused a decrease and irregularity in rainfall, increasing frequency of floods (in the last 10 to 15 years), droughts and intense heat waves and uncertainty with regards to prediction of weather conditions • Drought, flood and a decrease in average rainfalls have severely impacting agriculture sector of Mirpurkhas	• Increasing crop diseases, pest attacks, loss of livestock due to various diseases, and water shortage. The decrease in fodder, wheat and sugarcane production. • Farmers are accumulating livestock and other assets to secure their future. • The decrease in water supply for agriculture lands. Water contamination has increased causing several water-borne diseases. Increasing waterlogging and salinity issues. • Farmers have migration from one tehsil to another in the search of water. Shifting their livestock to the other tehsils where sufficient water is available. Livestock vaccination to prevent diseases. • Farmers are drilling wells and extensively using water pumps and tube wells.	• Farmers are learning about changing weather patterns, rainfall pattern, and early warning systems. • Farmers are planting more trees and plants to protect their lands from floods. They are also learning about draining excess water from their lands and diverting it to the highland areas. • Farmers are learning about storing water in water ponds and tanks. Learning about storing techniques for seeds and fodder for future use. • Most of the farmers are involved in using pesticides to protect crops from damage. Some farmers are learning about organic ways to protect lands, which is still not very common. • Farmers are also learning different measures to enhance soil quality through fertilizers and intercropping techniques.
BADIN		
• Major disasters include cyclones in 1964, 1965, and 1999. Major rainfalls include rainfall in 1973, 1994, Major floods include floods of 1988, 2003 2010 and 2011. Heavy rainfalls of 350 to 450 mm and breaches in the Left Bank Outfall Drain (LBOD) impacted several coastal districts including Badin. • Badin coastal area has also suffered from severe drought from 1996 to 2003 and fourteen cyclones were recorded between 1970 to 2000. Infrequent rainfall pattern in the	• Huge loss of livestock recorded in 1999 cyclone resulted in great economic loss to the poor farming communities of Badin. The aftermath of cyclone and floods has spread a number of diseases in livestock. • The major impact is the reduction of freshwater resources in Badin, that has changed natural resource base, agriculture lands and livelihood patterns of farmers. • Agriculture lands are sunken and remaining are deeply impacted by sea intrusion, waterlogging, and salinity. Farmers now rely on fishing and daily wage labor.	• Farmers have migrated from coastal areas to agriculture-rich district and upper part of Badin district. • Farmer's training packages include disaster risk management (DRR) training, early warning systems, and first aid training. • Diverse and sustainable cropping pattern is being adapted that requires less water and tolerates heat but it is not very common in Badin. • Alternate cropping is encouraged to compensate for the losses of the sugarcane industry. • Study area in Badin is very much behind in learning new CSA techniques and practices due

coastal area of Badin is also impacting the agriculture sector. • Rise in the sea level has raised the level of water in the wells from 50 to 20 feet (IUCN 2016)	• Several old and good quality varieties are rice and wheat are lost after multiple natural disasters. • The use of pesticides has increased for cotton which is further causing water and land contamination. Such practices are impacting the health of farmers and their livestock • Due to water logging and salinity, the soil has lost strength and is less productive.	to the complete destruction of agriculture lands. Farmers still use higher doses of chemical fertilizers to crops for higher economic returns. • Few farmers are learning new techniques and practices of CSA including organic herbicides and insecticides in various crops. The seeds of approved pest-resistant varieties are usually unavailable and treatment of seeds is not very common.
DADU		
• Climate changes in Dadu include, increase in frequency and intensity of heat waves, rainfall, temperature rise, and floods. The district is prone to floods, and droughts. Summers are intensively hot and winters are moderately cold. Heavy rainfalls and floods in 2011 have destroyed a huge land mass of Dadu. Crops, livestock, houses and agriculture lands were completely destroyed.	• All traditional ways of agriculture practices are drastically affected including farmer's quality of life (i.e., access to food, water, and health services). • Change in weather patterns has changed the lifestyle and work pattern of farmers in many ways. For example, intense heat, farmers cannot work for long hours in the field. They start their day early in summers when heat intensity is low and start late in winters when it becomes warmers. Extreme weather conditions have also affected the water quality and human health.	• Farmers are trying to cope with climate change on their own and also through the help of NGOs and private extension services. • Knowledge about CSA practices depends upon the access of extension services which is very limited. Private extension services are very limited too. Knowledge of CSA mostly revolves around technologies and practices that are helpful to cope with extreme heat and drought i.e., heat tolerant and drought resistant seed varieties. Alternate wet drying is becoming known in Dadu but small-scale farmers cannot afford it.

Source: Semi structured interviews and focus groups discussions in Badin, Dadu and Mirpurkhas

5.3 Socio-economic drivers

Socio-economic drivers include the living conditions, education status, health conditions, livelihood sources and social status of the farmers (including minority groups and female farmers). These drivers impact the knowledge and implementation of CSA in diverse ways. For example, poverty, absence of basic services like education, health, good living conditions, availability of clean water and nutritious food are the determining factors behind learning CSA technologies and practices. Poor farmers cannot afford expensive CSA technologies and due to their low education status, they also cannot understand/learn some of these technologies. Change in the social and economic drivers highlighted above, may persuade or discourage farmers to learn about CSA practices. This section will examine how different economic and social conditions have impacted the knowledge system of agriculture over time.

The majority of the farmers in the study areas are deprived of basic necessities, uneducated, live in mud and straw houses with poor hygiene conditions, have no access to clean water and have no main source of livelihood other than agriculture. The purchasing power of most of the farmers is low because of limited income from agriculture production and fertility which is highly affected due to limited access to basic amenities for farming activities, such as irrigation water, good quality seeds, and good quality fertilizers. Due to decreases in agriculture production, and limited purchasing power, food consumption has also declined. Reduction in food consumption has impacted the health of farming communities across the study areas, particularly in Badin and Dadu. According to a female farmer (Amma Hawa, Badin 15 April) *"In our childhood we used to eat three times a day and meat, desi ghee and milk was necessary part of the diet, but now we have restricted food to twice a day and consume pulses and vegetables only when they are available".* During interviews in Badin, I observed that women are malnourished and kids are also facing a number of skin and stomach diseases. Over time, the availability of good food, meat, milk, and other important nutrients have largely disappeared from the family diet causing poor health and malnutrition, particularly in children and mothers (Ahmed et al. 2019). Poor health has also affected the efficiency of female farmers on agriculture lands (Ahmad et al. 2004). In addition, farmers of Badin and Dadu do not have money to access good doctors in the cities. With limited access to food and poor health conditions, farmers of Dadu and Badin are less motivated to learn CSA technologies and practices. Their priority is to provide the basic necessities of food and health to their families.

To provide the basic necessities of health and to feed their large families, farmers are more inclined towards learning only those agriculture practices that can give them higher production and profit margins. Knowledge of the farmers is directed towards the higher-input and resource intensive farming system, which is causing further water scarcity, soil depletion and high level of greenhouse gas emissions. This shows the two-way impact of an economic driver. During a focus group discussion, (Badin 17 April and Dadu 23 May), farmers admitted the harmful effects of high-input farming. They also explained that the only source of knowledge for them are seed distributors selling poor quality seeds which give low-quality productivity. During several interviews (in Badin and Dadu) farmers expressed the desire that they are keen to learn such climate-smart technology which can protect their soil from further damage and at the same time give higher productivity. An old farmer (Kandero, farmer, Badin, 28 April) explained that knowledge of agriculture practices very much depends upon the economic condition of a family. He said, *"People have no food and shelter, in this condition how can we expect them to learn new CSA technologies and practices".* He added people are demotivated due to water shortage and salinity issue.

Knowledge of CSA is limited in Badin because the majority of the farmers have changed their source of livelihood or adapted other professions in addition to agriculture. Some farmers have started labor work in the surrounding districts (upper Sindh) on daily wages. Seasonal migration is becoming very common in the study areas. Seasonal migration is when farmers temporarily migrate to upper Sindh during harvesting season where they receive higher wages as compare to their native places. Some farmers permanently migrate to agriculture rich districts or cities for labour work other than agriculture (i.e., construction, factory work etc.). Due to seasonal and permanent migration, farmers are not able to concentrate on their land rehabilitation and to learn new CSA technologies and practices.

An experienced farmer (Fazal Chand, farmer, Hyderabad, 19 April) explained that now farmers have multiple sources of income because agriculture income is not enough for a big family. He explained, that their ancestors were farmers and they only had agriculture as a source of income. Income was more than enough for food, clothes, and other necessities. However, male farmers have migrated to the bigger cities in Dadu and Badin, whereas female farmers handle and take care of their lands, household, and kids. A respondent (Sakina, a female farmer, Dadu, 15 May) explained that she is taking care of her four acres of land, besides managing her house and taking care of her children. She explained that *"My husband works as a daily wage laborer in the city because agriculture income is not enough, it hardly meets our own food consumption requirement"*. An old female farmer (Mai Raheema, 70 years old female farmer, Badin 15 April) explained that there used to be enough water, lush green wheat and rice fields but now everything is changed. Now, there are largely barren lands that have been destroyed due to salinity and water shortages. She explained, how income from agriculture lands was previously enough for the whole family but now there is a need to catch fish to meet food requirements of a large family. Also, she explained *"…we used to have a good knowledge of farming as it was our family profession but now we have barren lands and we are not practicing agriculture neither have [we] adopted any CSA technology and practices. If we have enough water, good soil, and a good source of knowledge, we can learn and start farming happily again"*. It shows that farmers customary knowledge is still intact but due to changing socio-economic conditions, farmers knowledge has to be revived with and co-evolve with a changing knowledge system of CSA technologies and practices. At the same it is important to keep in mind the usefulness of knowledge of CSA technologies and practices in the presence of challenges like water scarcity.


Female Hindu Haris (farmers) of Mirpurkhas (Photo: Sajida Sultana)

A respondent (Professor, Sindh Agriculture University Tandojam (SAUT) Sindh, Hyderabad, 1 May) explained that due to food insecurity and poor economic condition, farmers are forced to adopt unsustainable agriculture practices. They use heavy fertilizers and unsustainable techniques which often leads to further soil depletion, water scarcity and less production at the end. Due to poor agriculture production, farmers are facing acute poverty, increasing frustration, crime and other social issues. He added that due to the lower levels of agriculture production, farmers take desperate measures (theft of livestock, water, grains etc. to meet their both ends) that compromise their respect in the community, dignity and their livelihood. They become less acceptable in the community, he explained.

Women's levels of education, knowledge, economic conditions, social status, and control over resources is an important driver in the adoption of CSA technologies and practices. Many studies show that women's social and economic empowerment, their education and income level is the major factor for healthy communities and future generation (Pallas et al. 2013; WHO 2014; Cunningham et al. 2015). Unfortunately, in low-income countries, women are mostly low-skilled, less paid and are usually trapped in casual and insecure employment (Kilic, Palacios-Lopez, and Goldstein 2014). According to a recent FAO (2018) report, the ratio of female-share in the agriculture sector in Pakistan increased from 12% in 1980 to 30% in 2010.

Economic empowerment, levels of education and social status of female farmers also affect the knowledge of CSA practices and its implementation. As per the local culture of Sindh, a share of female members of the family in the inherited lands is usually not transferred to them. Instead, they receive the cash equivalent to their share. It is also considered a disgrace to divide the family land. In the case of Mirpurkhas, it was noted that female farmers are very prosperous. Middle-class female farmers in Mirpurkhas have their own lands and they contribute in everything including the main decisions for buying seeds, use of fertilizers or any new practices under CSA. Female farmers of Mirpurkhas, in general, understand the CSA technologies and practices. They have also received a lot of training on embroidery, kitchen gardening and training to manage their livestock well. According to a female respondent (Naseem Naz, female landowner, Mirpurkhas, 17 April) *"We are educated and encourage our daughters to go to school and college. We are also well aware of our lands and how to take care of them. We have received several trainings on embroidery, kitchen gardening and are open to learn about new CSA practices too".* In contrast, female farmers in Badin and Dadu are illiterate and they have less knowledge about CSA technologies and practices. Even if they receive training, the implementation of CSA practices is still limited. Female farmers of Badin and Dadu are less confident and do not have much independence despite their major contribution to agricultural activities. They are mostly involved in functions like cutting crops, taking care of their livestock, and taking care of their families. These are usually not involved in the management activities or decision making mainly due to the male dominant culture.

Almost all the experts (85%) who were interviewed in Dadu and Badin are of the opinion that there is a positive relationship between education and knowledge of CSA technologies and practices. Education is always a crucial socio-economic driver as it affected the risk aversion behaviour of many farmers in Sindh (Imran et al. 2017) and their attitude to learn new knowledge about CSA technologies and practices. Educated farmers are more adaptive towards climate change and avoid risk due to their understanding and knowledge towards CSA technologies and practices. However, research findings also indicate that experience of the farmers is also correlated with knowledge of CSA practices and technologies. For example, experienced farmers of Badin and Dadu want to gain the knowledge of CSA technologies and practices and understand the need of CSA in the changing climate conditions. Experienced farmers are more receptive towards the new CSA technologies and practices because of their customary knowledge about the impact of prevailing environment and weather conditions on agriculture sector.

Left: Female farmers in Mirpurkhas, Right: Female farmers in Badin (Photo: Sajida Sultana)

The female farmers of Badin and Dadu have numerous skills and talents, but they rarely receive an opportunity to market their skills. For example, during focus group discussions, I observed handicraft and embroidered work done by several female farmers, but they have no outlet to market their product. According to an expert (National Program Manager, UNDP GEF-

SGP, Hyderabad, 10 May) although women's contribution to the agriculture sector are more than men, in general women are not empowered in Badin and Dadu, they have limited access to health care, they are not educated, and they have limited opportunity to meet with other female farmers because the population is mostly scattered. Therefore, he explained, the level of knowledge about CSA practices is low. He added that the only knowledge they have about agriculture is what they received from their forefathers, female social workers and private service extension staff. But such percentages of females receiving training or knowledge about CSA practices is very limited.

According to a female farmer (Chagli, a female farmer, Badin 28 April) *"We have never been to school and our daughters will also never go to school because they will get married between the age of 13 or 16".* She explained that this is because of the culture and tradition in their family. She added that women take care of their home and their families and also work on agriculture lands. Due to their limited exposure to the different sources of information, lack of awareness and illiteracy, most of the female farmers are not aware of CSA technologies and practices. Those who have been trained by NGO workers, private extension staff and other community farmers have some know-how of CSA technologies and practices but implementation of CSA is very limited (explained further in chapter 4 section 4.3).

Left: Handcraft prepared by a female farmer, Right: Cooking on a mud stove in a kitchen built with mud (Photo Sajida Sultana)

Table 5.8 below, highlights the key socio-economic drivers of change in the study area (i.e., level of education, livelihood sources, social status, living conditions, migration and health facilities. These drivers greatly impact the willingness and attitude of the farmers to learn new CSA technologies and practices. Drivers in each district are explained in column one, their impact on agriculture sector is explained in column two, and how these drivers are transitioning the knowledge of CSA in the study areas is explained in column three.

Table 5.8. Impact of socio-economic drivers on the knowledge system of CSA

Socio-economic drivers	Impact on agriculture sector	Impact of CSA knowledge
MIRPURKHAS		
• Socio-economic drivers include social value, social interactions and setup. Divided farmer families due to migration and other reasons (i.e., education or business in other cities) • Economic condition of the farmers including source of livelihood. Affordability of the farmers to purchase certain seed varieties, fertilizers and other agriculture needs. • Level of education, awareness and exposure to the cities •	• The decrease in fodder has increased the cost of fodder due to disturbed supply and demand. • Farmers have lost the value of their lands over time due to less productivity. Agriculture production is not enough to meet family expenses. • To meet the food demand, intensive and multiple cropping has become common which is impacting the soil quality. • Because of the reduction in income, family members have adopted other sources of livelihood. They have migrated to big cities for daily wage work, business and other jobs, which has reduced family and social bonding. Farmers are encouraging their children to, adapt to other professions.	• Farmers are mostly well aware and educated, therefore they are open about learning new CSA techniques. Learning and adapting new ways of agriculture farming, through land laser leveling techniques to recover the damaged land after floods and droughts. • Farmers are learning about new seed varieties including heat and drought tolerant, and water-resistant seeds from their neighbors, friends, and FOs. • Farmers have sold or reduced their livestock due to financial crises and animal diseases. Now, most of the farmers have limited livestock. • Some female farmers are being trained for tailoring, embroidery and handcrafts work beside learning the CSA technologies and practices.
BADIN		
• Social value, social interactions and influence of other farming communities. • Economic condition of the farmers including source of livelihood (i.e., fishing as another major source of livelihood) • Affordability of the farmers to purchase certain seed varieties, fertilizers and other agriculture needs • Scattered farming communities causing disconnect with the other farming communities • Lack of health facility and poor hygiene practices	• Many farmers have lost their lands and livestock in multiple disasters which have impacted their overall economic condition. • Most of the farmers are sharecroppers and work on the lands of the landlord. Therefore, they are not involved in decision making. Landlords mostly live in the cities. If they feel they are facing loses in agriculture, they order farmers to stop harvesting. • Male farmers have mostly adapted fishing and agriculture farming is only occasional depending on the water availability.	• Farmers are receiving multiple trainings by the NGOs and other private extension services but their basic needs (i.e., food, shelter, health etc.) are the priority for them. Therefore, they are less motivated to receive CSA related training unless they are packaged with basic facilities of water, food, health, and hygiene. • Several farmers are benefited through demo plots training and kitchen gardening. • Female farmers are now getting some healthcare and they are trained about the hygiene practices along with CSA practices.

• Illiteracy, limited awareness and lack of exposure to the cities, technologies and good agriculture practices	• Agriculture communities are mostly scattered and have limited access to available resources or resource outfall. • Farmers are mostly uneducated and poor. Female farmers are neglected as social norms in the district restrict women's' interaction with male trainers and extension service officers. Women and children are facing a number of health issues. There is a lot of social unrest in the district. Street crimes are increasing due to desperation and hopelessness. • Small-scale farmers do not have enough cash to invest in crops and overall agriculture cycle is disturbed. Some farmers are trapped in a debt cycle.	There are limited opportunities for women to market their handicraft and embroidery work which they have learned from their ancestors. • Knowledge of CSA is limited as men are getting involved in fishing and spend most of their time in the sea, whereas female farmers look after agriculture as they cannot stay in the sea for a long time. • Coastal communities of Badin purchase water in jerrycans at a heavy price which make them economically more vulnerable. With no water, they have practiced very few CSA technologies and practices.
	DADU	
• Almost similar to Badin. Social value, social interactions and influence of other farming communities. • Economic condition of the farmers including source of livelihood. • Affordability of the farmers to purchase certain seed varieties, fertilizers and other agriculture needs. • Scattered farming communities causing disconnect with the other farming communities • Lack of health facility and poor hygiene practices, Illiteracy, limited awareness and lack of exposure to the cities, technologies and good agriculture practices	• The economic condition of farmers is greatly affected due to the decrease in agriculture production. Many male farmers have migrated to agriculture rich districts, increasing the workload of female farmers. Some have adapted alternate source of livelihood • Women are mostly bound to do household activities. older women are involved in agricultural activities only. Men do not allow women to go out and work with males on agriculture lands. • Farmers have to borrow loan from banks and landowners to buy good quality seeds, tractors and water services.	• Female farmers are not very much aware of CSA practices and techniques because they are not allowed to go out. Female extension services are very limited. • Level of education is slightly better; therefore, farmers are interested to learn about CSA practices but if basic facilities are available to them

Source: Semi structured interviews and focus groups discussions in Badin, Dadu and Mirpurkhas

5.4 Political / Power dynamics influencing knowledge system of CSA in Sindh

Power structures play an important role in disseminating and sharing different forms of knowledge in the agriculture sector. One main reason for the limited knowledge of CSA technologies and practices is the deep-rooted power dynamics in Sindh. This section will explain how CSA knowledge is impacted by the political forces and other powerful groups in the society (i.e., influential farmers and landlords).

> **Box 5.1: Deep rooted power dynamics** in agriculture system of Sindh is linked with the system of Jagidars and Zamindars originated during Mughal empire and promoted in the 19th century during British rules. The British power supported Jagidars and Zamindars system as an essential collaborator to hold control on the masses in the subcontinent (18). Jagirdars and Zamindars (also called landlords) got the de facto possession of agriculture lands in Sindh (16) and use to accumulate wealth as much as they could from peasants and local farmers (Perveen and Dasti 2014). Local farmers were not allowed to own private agriculture lands, or to take part in decision making to improve and increase agriculture production (Perveen and Dasti 2014) (further explained in introduction chapter).

One of the reasons behind limited knowledge of CSA technologies and practices in the case study area is power dynamics. It is insufficient to introduce and implement new technologies, when there are certain social dimensions (powerful actors) that block access to those technologies for marginalised groups (Karlsson et al. 2018). In the case study area there are different power dynamics involving multiple stakeholders that influence the knowledge system of CSA, some of which are obvious to identify (i.e., politicians, influential landlords etc.) and others that are less obvious (fertilizer companies, sugar mills etc.) For example, in the case study areas, local farmers have usually limited access to information due to lack of education and their dependence on their landlords. Keeping in view the different power dynamics, the CSA knowledge system in the case study area is analyzed through structural, discursive and instrumental power to discuss how politics and power dynamics decide and steer research and knowledge of CSA. Power is defined by Lukes (2005: p 37) as "*A exercises power over B when A affects B in a manner contrary to B's interests*". Lukes (2005), further analyzed power through three different over lapping dimensions i) instrumental, ii) structural, and iii) discursive (further explained in the literature chapter (section 3.5). These dimensions are explained and linked with the knowledge of CSA in the table 5.9 below).

Table 5.9: Power dynamics in the knowledge system of CSA

Dimensions of power	Parties involve in exercising power	Influence on the knowledge system of CSA
Instrumental power Possession of resources that can shape policy outcomes. Characterised by overt competition for influence and measurable use of resources in that competition Definite, visible, cause–effect relationships (Fuchs 2007)	National, provincial and district government, Donors, Agriculture research institutions, FOs,	• Absence of CSA policy/ guidelines at national and provincial level is limiting the knowledge of CSA. • Delegation of limited authority to provincial level limiting the knowledge and scope of CSA • Scientific knowledge is not shared with the stakeholders • Customary knowledge is ignored
Structural power The ability to shape policy agendas (Lukes 2005). Exist within the social structure, where dominant views shape decisions, even absent the visible use of force, and can constrain the ability of marginalized stakeholders to bring forward issues and solutions that best reflect their interests (Flyvbjerg 1998). Can be hidden or visible (Lukes 2005)	Provincial government, Irrigation and agriculture department, fertilizer companies, Donors such as WB, FAO, INGOs and other UN agencies, power within the social groups	• No collaboration between irrigation and agriculture departments for CSA knowledge sharing. • Disseminating the clear CSA knowledge is not the priority for fertilizer companies as they are working for profit. • Limited efforts to promote CSA knowledge at local level by related donors. FAO is now developing plan to promote CSA.
Discursive power Discursive power, related to exercise power on others to do what they don't want to do or by influencing, shaping or determining his very wants. It controls their thoughts and desires until they reach their compliance (Lukes 2005). Subtle and cannot be easily identified (Fuchs 2007; Falkner 2008)	Landlords, Sugar mills and other industries, fertilizer companies, private and public extension services	• Fertilizer companies and private extension services are promoting their fertilizers and seeds for profitability. • Farmers are misguided with new technologies and poor-quality seeds • Sugar mills and middlemen are controlling the prices of agriculture products • CSA technologies introduced by big fertilizer companies.

Source: Semi structured interviews and focus groups discussions in Badin, Dadu and Mirpurkhas

Discursive power in the case study is exercised on the knowledge system of CSA, when certain technology or practice is introduced in a way that it is within the social norms and is politically legitimate (Fuchs 2007; Konefal, Mascarenhas & Hatanaka 2005). For example, in the case study areas, fertilizer companies and private extension services try to exercise discursive power by influencing the farmer's perception and thereby promote their own interest and preferences based on sole aim of profitability. The fertilizer industry has a prominent and a strong hold on the knowledge system of agriculture in the three case study areas, especially in Badin and Dadu. A respondent (Akram, Farmer and president Halal-e-Ahmer, Badin, 28 April) explained that in Badin and Dadu district, people are relying on the information provided by the private extension service agents from fertilizer industries. For example, he explained that fertilizer companies take advantage of the limited exposure and ignorance of uneducated farmers and sell them poor quality seeds by showing and convincing the farmers for one-time high productivity of seeds, seeds that either destroy or reduce their productivity in the next season. On the contrary, in Mirpurkhas, the middle-class female respondent explained (Amma Sara, old female farmer, Mirpurkhas, 7 May) *"we are not influenced by fertilizer companies because we know what is good for our lands and we learn about new practices to improve our agriculture production and save water and other resources".* Almost all the middle-class farmers who own their lands, had the same response. This response shows moreover that the farmers are not only facing the ack of education and desperation due to poverty, but also that private-sector actors are spreading incomplete information or disinformation which creates further hardships for vulnerable individuals and communities.

Similarly, the irrigation department in the case study areas also exercise structural power by emphasizing their role as a custodian of water distribution for agriculture, where they decide and set their own standards and rules for water distribution to different districts in Sindh. In Mirpurkhas, landlords also influence the water distribution for the agriculture sector and they have strong connections with local irrigation authorities exercising the structural power. Another important aspect highlighted in the focused group discussion is that most of the landlords and influential large-scale farmers have their lands in the most productive zones of upper Sindh (i.e., Mirpurkhas, Jamshoro, Tando Allah Yar and upper area of Badin district). Therefore, most of the resources (water availability), CSA technologies and research focus in these areas and knowledge is also limited to only agriculture rich zones (Focus group discussion, FOs, Mirpurkhas, 17 April). Coastal areas (i.e., lower Badin and less productive zones (i.e., Dadu) of Sindh are usually neglected or not the priority).

Knowledge of CSA is also impacted when landlords and influential farmers exercise discursive power by deciding what kind of knowledge will prevail based on their vested interest and agenda (i.e., mostly financial gain). For example, some of the fertilizer companies are owned or have major shares of influential landlords. Therefore, they promote low quality seeds and fertilizers to uneducated and ignorant farmers for their profit share but use high quality seeds and fertilizers for their own lands. Similarly, some landlords who are actively involved in politics who try to keep poor farmers and communities ignorant to maintain their political influence in the surrounding villages and communities. More knowledge and awareness mean less control and influence on the communities, and therefore, limited knowledge of new CSA technologies and practices prevails.

It is also noted that sometimes knowledge holders do not understand the value and worth of their knowledge of climate-smart practices and hence they do not recognize the need to share it with others (Olazabal et al. 2018). A respondent, (Ghulam Ghos, District Government, Mirpurkhas, 7 May) explained that farmers who have knowledge of CSA do not share their knowledge to maintain their influence (as explained above) or due to limited community involvement or due to limited time and resources and farmers who need the knowledge of CSA are illiterate and cannot access that knowledge.

Within Mirpurkhas district, women working on the lands of land owners in Mirpurkhas are poor and mostly belong to minority groups (i.e., Hindu). Their source of knowledge about CSA practices and technologies is their land owners. This shows that instrumental power exists in Mirpurkhas between the landlords and Hari communities (farmers/tenants working on the lands of landlord), which is also affecting the knowledge of CSA technologies and practices. Most Haris in Mirpurkhas are under continuous debt of their landlords and money lenders. They are usually living in continuous bondage and unjust cropping system. Most of these haris are very poor and cannot even afford three meals a day because of lack of livelihood opportunities and limited and irregular income from their landlords. Haris follow their landlords when it comes to learning new technologies and practices in agriculture. They have a limited say in decision making and future planning for agricultural activities as they don't have their own land.

According to a local farmer (Meena, female farmer, Mirpurkhas, 17 April*) "we only follow what our landowners tell us. We can suggest our land owners but we cannot practice or learn anything new without the permission of our land owners because its land. They know better what is good for them."* Another respondent (Magi, female farmer, Mirpurkhas, 7 May) explained that her grandparents used to work with the same landowners and now her entire family is following the tradition. She added *"We are in good relationship with our landlords as they provide us food, grains, clothes, livestock. We also receive a lot of economic benefit from them. For example, for any marriage, our landlords pay all the expenses of the marriage ceremony and also give a girl's dowry. They provide us with a loan whenever we need it and also take care of our health expenses"*. 90% of the farmers of minority groups in Mirpurkhas are in the same opinion and explained during interviews that they are satisfied with their landowners as long as their landowners take care of their basic needs and help them in their hour of need. But at the same time, they admitted that they have no say in the decision making or day to day agricultural activates. Which shows that their knowledge of CSA technologies and practices depends upon the landowner's knowledge and willingness to adapt CSA technologies and practices.

Land reforms also contribute and play an important role in spreading knowledge about CSA practices and technologies and can be seen through the lens of structural power. Land reforms refer to any kind of changes in the law and regulations for the transfer of ownership of agricultural lands evenly in the whole state which is backed by the government (Kinsey 1999). Land reforms are in very poor shape in Pakistan, due to which any farmer-based subsidies and incentives provided by the government do not reach to the small-scale farmers and only enjoyed by the big landlords, rich and politically influenced farmers (Haq 2012; Ahmad et al. 2013; Noonari et al. 2015; Khan, Nakano & Kurosaki 2019). Landlords and politically strong farmers receive the benefits of the new CSA technologies and subsidies in the water sector which increased their yield significantly whereas small-scale and poor farmers are bearing losses from their agriculture lands (Ahmad et al. 2013). According to a respondent (Ali, Welthungerhilfe Pakistan, Hyderabad, 3 March) majority of the affected farmers are small growers and shared croppers who have no control over the decision making or in learning new CSA practices. He highlighted that large-scale farmers and landlords are the actual decision makers but they are not severely affected by water scarcity or other farming issues as they have multiple sources of income. Therefore, they are not very keen to promote or talk about new CSA technologies and practices.

In 2010, the Government of Pakistan passed the 18th amendment (Article 140A) to the constitution, by devolving legislative power from federal to provincial government. All the ministries, including Ministry of Environment, delegated powers over environmental issues to the provincial government. Agriculture policies and local level implementation also became provincial subjects to ensure that priorities emerge from the district level authorities and are reflected in provincial policies (World Bank 2017). But this significant change in the institutional and governance structure in the country came with a number of challenges including the exercise of structural power. For example, the limited capacity of provincial governments in policy development and implementation, fragmented coordination and lack of shared learning at different levels of the government (i.e., national, provincial and local level) (World Bank 2017). A respondent (Altaf, Field Coordinator, Basic Development Foundation, Hyderabad, 26 February) explained that actual authority is still with federal government even after 18th amendment because provincial government is not fully equipped and have no proper system of governance. A respondent (landlord and retired Sindh government official, Mirpurkhas, 6 May) explained that after the 18th amendment there is a lot of confusion regarding delegation of authorities. He added that the 18th amendment was a disaster and political tension between different government departments hampered the implementation of the 18th amendment in the countries in almost all the sectors.

Almost all the interviews at provincial and district level indicated that although National Climate Change Policy (NCCP) aims to address climate change impact through CSA in Pakistan but it is unable to deliver result due to the limited capacity of provincial government. Within the 18th amendment, structural power is exercised by national government to a greater extent, where powers are delegated to the provincial level, funding is still being handled at the federal level which is also causing a lot of delays in implementation at the local level as explained by the representative of the government at the local level (Mr. X, District Government Mirpurkhas, 7 March).

According to (Amir Mandro, an agriculture expert, Hyderabad, 09 May), knowledge sharing at the national and provincial level is weak, due to which CSA is still facing a lot of challenges for implementation. He explained CSA is a new subject in Pakistan and the concept of CSA has not been formalized clearly for agriculture policies, strategy documents and action plans in Sindh. Some development in Punjab province can be seen in this regard. For example, the establishment of the Agricultural Model Inter-comparison and Improvement Project (AgMIP) in Pakistan. Purpose of the project is to promote CSA and developed climate change scenarios for the region, modeled climate impacts on key crops, and determine the resulting economic impacts of climate change on the agricultural sector in Pakistan. This project is the collaboration of Pakistan's Agro-climatology Lab at the University of Agriculture in Faisalabad and UK AID. Sindh is very much behind to start any such mega project.

As explained (Abdullah Jatt and Farooq Jafferi, farmers and community leaders, Hyderabad, 28 February) there is a lot of coded knowledge that is explained in scientific and policy terms of CSA with different stakeholders and they use this knowledge to market their own interest and decision making. They explained that simple and illiterate farmers cannot understand the coded form of knowledge used in different policies, reports and other documents. It should be translated into a simple and common language which farmers and other beneficiaries can understand (Farooq Jafferi, literate farmer and community leader, Hyderabad, 28 February). He explained that good stories and active knowledge sharing between Punjab and Sindh is limited and the government has to take an active role in it.

Table 5.10, explains the summary of drivers of political and power structure (i.e., landlords, political influence of the landlords and fertilizer companies, and power structure in irrigation and agriculture department at district level) in the study area and its impact on agriculture sector and the knowledge system of CSA. Table shows that the power structure and political set up is almost similar in all three study areas at provincial level and at district level except little change in Mirpurkhas due to establishment of FOs at local level and minority groups working as "Haaris" with landlords. It is also noted that there is some overlap within the power structure. For example, knowledge system of CSA is facing instrumental and structural power exercised through the different policies including CSA policy and at the same time it is facing discursive power exercised by landlords, sugar mills and fertilizer companies.

Table 5.10: Impact of political & power dynamics on the knowledge system of CSA

Political & power dynamics in agriculture sector of Sindh	Impact on agriculture sector	Impact on CSA knowledge
MIRPURKHAS		
• Deep rooted power dynamics prevail throughout Sindh province due to which small farmers, poor communities and minorities remain under privilege • Politically strong landlords have more access and affordability for the agriculture inputs (water, good quality seeds and fertilizers, crop management, information about new technologies etc.) • Landlords have strong influence on decision and policy making at district level and on local farmers and Haris. • Fertilizer companies are dominating the seed industry and private extension services.	• Due to water shortage, canal head villages are better off in receiving water for their lands and livestock but villages at canal tail end are deprived and have to wait for the remaining water and usually do not get water during sowing season. This is causing damage to crops and land as well. • Irrigation department and big landlords mostly impact the policy and decision making in the agriculture sector. Whereas agriculture department (including extension services) is weak and less influential. • Good quality seeds are very expensive and are out of reach for small farmers and far districts. Due to lack of seed policy there is no check on the quality of seeds being distributed to districts • "Haris" are not involved in decision making and are usually dependent on their landlords even for their basic necessities.	• FOs are working hard to provide equal water supply to all villages on the canals according to their needs. • Farmers are well aware of new CSA techniques and have adopted several techniques under the guidance of FOs and NGO workers and social organizers. • Establishment of FOs is the major achievement in Mirpurkhas and farmers are very happy with the current structure. Farmers are learning about several CSA technologies and practices through FOs. • Haris learn about new CSA practices and technologies only if allowed by their landlords
BADIN		
• Deep rooted power dynamics prevail throughout Sindh province due to which small farmers, poor communities remain under privilege • Politically strong landlords have more access and affordability for the agriculture inputs (water, good quality seeds and fertilizers, crop management, information about new technologies etc.)	• Lack of interest by political leaders in the district and negligence is further aggravating the issues in the coastal villages of Badin. Public sector services usually follow a top-down approach which is unsuccessful in Badin and hardly reach to the local farmers. • Agriculture department is weak in Badin and Dadu due to limited budget. Irrigation	• NGOs are the main source for CSA related knowledge and raising awareness about the excessive use of fertilizers and poor-quality fertilizers and seeds in the market. • NGOs have distributed some sample seeds (i.e., heat tolerant) and fertilizers ensuring the availability of good quality seeds and fertilizers to the coastal communities of Badin. But still, most of the farmers are

• Landlords have strong influence on decision and policy making at district level and on local farmers. • Fertilizer companies are controlling the seed and fertilizer industry. • Both districts are surrounded by sugar mills that belong to politically influential people. • Extension department is male dominated	department is also relatively weak in Badin and Dadu as compare to Mirpurkhas • Public extension services are heavily dominated by men in Badin and Dadu and female extension service officers are hardly visiting. Therefore, female farmers are ignorant of new agricultural practices • Fertilizer company exploit the local farmers by selling poor quality fertilizers. Expensive hybrid seed are not giving good results to the farmers and shared croppers. Therefore, farmers are always at loss whereas landowners get the maximum profit. • 6 sugar mills belong to powerful politicians are dominating the Badin district and are contaminating the water resources and agriculture lands.	unaware of new seed varieties and sustainable agriculture practices. • Coastal communities of Badin and poor districts like Dadu are not at the priority list of government. Many villages on the coastal line including the study village are not even listed with the Union Councils. Government is more interested in expanding fishing in the coastal areas. Therefore, the knowledge of CSA is limited. • Extension services are very limited in Badin and Dadu and there is no female extension officer to guide female farmers. Therefore, female farmers are ignorant of new CSA technologies and practices • CSA knowledge and implementation depends upon the willingness of landlords. • Sole motivation of fertilizer companies is to earn profit by any mean therefore discourage the knowledge and implementation of CSA.

Source: Semi structured interviews and focus groups discussions in Badin, Dadu and Mirpurkha

5.5 Water governance

Another important driver of change in the knowledge of CSA in the study areas is related to water governance. Water governance (see Box 5.2) in this section will cover water distribution and management in Sindh which is also impacting the study districts. Agriculture in the Indus Basin is very much dependent on the two main sources of water, monsoon rains and melting of glacial ice and snowmelt covering the distance of 3000 km from the Himalaya at over 8000 meters to Indian Ocean (Parry et al. 2017; Yu et al. 2013). This water is distributed to different provinces and parts of the country with approximately 18 million hectares through a complex irrigation system with 60,000 km of canals. Pakistan has transitioned to a water stressed country from a water affluent country. According to Government of Pakistan (2017), per capita, water availability is reduced from 5000 cubic meters in 1947 to 1000 cubic meters and is expected to further reduce to 800 cubic meters per capita by the year 2025. Despite the spread out and wide system of canals, there is insufficient water to meet the agriculture needs in lower Sindh. Climate change (discussed in the section 5.2) is reducing the availability of water. As well, insufficient water is related to an uneven distribution of water in interior Sindh between the 'head' and 'tail' canal districts, between industrial and agriculture sectors, and between large and small farmers. Another reason is the outdated and dysfunctional system of irrigation due to reoccurring natural disasters (i.e., floods and heavy rains, further explained in the section 5.2).

Box 5.2: Definition of Water Governance: Water governance has been defined as ". . .the range of political, social, economic and administrative systems that are in place to develop and manage water resources, and the delivery of water services, at different levels of society" (Rogers & Hall, 2003). Water governance also refers to "the range of political, social, economic and administrative systems that are in place to develop and manage water resources, and the delivery of water services, at different levels of society" (Global Water Partnership 2002).

Water Scarcity has become a major issue for the farmers in Badin and Dadu. Their living conditions, life patterns, socio-economic conditions, and agriculture practices are greatly impacted by the water availability. Due to water scarcity, many farmers have abandoned their agriculture lands and moved to the other districts, some have changed their source of livelihood from agriculture to fishing, and some are adapting new agricultural practices by learning new CSA technologies and practices that require less water use (further explained in chapter 4 section 4.2.2). The CSA profiling report of World Bank (2017) explains that water scarcity issue is the biggest challenge for the implementation of CSA technologies and practices. Almost 80% of the interviews and results of six focus group discussions also indicate the same and clearly highlight that knowledge and implementation of CSA technologies and practices depends on water availability. With no water, salinity and sea intrusion and extremely hot weather, CSA technologies and practices cannot be easily implemented. According to a respondent (Mr. X, Sindh Agriculture Development Authority, Mirpurkhas, 6 May), Mirpurkhas is better in terms of knowing and adapting the CSA technologies and practices because the water crises in Mirpurkhas are not as bad as Badin and Dadu. Therefore, CSA knowledge in Badin and Dadu mostly involve techniques focusing on less water use (i.e., sprinklers techniques, drought-tolerant seeds, and water efficient seed qualities. As explained earlier (section: 5.1 subsection:

Drought), CSA needs are different in Badin and Dadu. Farmers are mostly concerned about water shortage and water conserving technologies and practices in the agriculture sector, whereas farmers of Mirpurkhas are mostly concerned about CSA techniques to improve their production and use of advanced technologies of CSA.

According to a respondent (Former employee, Sindh Irrigation Development Authority, Mirpurkhas, 5 May) knowledge of water conserving CSA technologies and practices is very important for both upper (i.e., Mirpurkhas) and lower Sindh (i.e., Badin and Dadu) to stop further damage to the agriculture lands in lower Sindh. Two respondents (Abdullah Jatt and Farooq Jafferi, literate farmers and community leaders, Hyderabad, 28 February) explained that to support the transition from conventional agriculture practices to CSA, there is a need of serious and strong collaboration for CSA knowledge sharing between irrigation and agriculture departments, farmers and other key stakeholders. According to Awan et al. (2017) and Jabran et al. (2017) efforts are needed to enhance the awareness and knowledge about water for water use through proper administration and protection of accessible water assets, water gathering and reuse of wastewater enhanced administration and protection of accessible water assets, water gathering and reusing of wastewater, particularly in the dry and semi dry zones (i.e., Badin and Dadu district).

Knowledge and implementation of CSA practices for better crop production are very much dependent on both quality and quantity of water supply in all three study districts (i.e., Badin, Dadu, Mirpurkhas). Crop production is mainly concentrated in the area where the irrigation system provides enough water supply. For example, Mirpurkhas has a well-spread irrigation system and water supply is frequent as compared to the other two districts. Similarly, upper Badin has also a good irrigation system but water supply reduces as we further go down to South of Badin towards the coastal area. It is also noted that farmers at the head of the canals, distributaries, and watercourses, over-use the water for their crops. Their knowledge about the overuse of water is limited as a result overuse of water on wheat and cotton rice rotation, with heavy use of fertilizers on cotton is damaging the soil and water quality. One common point raised in all the focus group discussions (Badin, Dadu and Mirpurkhas) was about CSA technologies that promote sustainable use of water are needed in Mirpurkhas and other head districts with plenty of water so that tail end district and villages also get sufficient water for their crops. Two different focus group discussions (FOs, Mirpurkhas, 17 April; Farmers, Badin, 15 April) highlighted the problem of misuse of water through heavy groundwater pumping which is depleting the water table and causing the sea water intrusion and saline ground water.

Two respondents (Amna and Rizwan, Social Organisers, Area Water Board, Mirpurkhan, 07 May) explained that *"a few years ago when we started training the farmers in the study village, farmers response was not very positive and they were reluctant to learn new knowledge of CSA techniques for water conservation. Landlords and large-scale farmers perceived that we have plenty of water for our lands and we do not need CSA trainings for water conservation. It took us some time to convince and motivate farmers that these trainings are still needed"*. He explained, *"they were also reluctant to allow their Haris (small-scale farmers working on their lands) to receive training from social organizers but later they were willing to introduce their haaris to social organizers to receive trainings"*. CSA techniques like de-silting, reservoirs for water storage and other related CSA techniques were introduced to the farmers recently.

Focus group discussions (FOs, Mirpurkhas, 17 April; Farmers, Badin, 15 April) also highlighted another fact that poor effluent disposal from the nearby sugar mills is damaging the groundwater quality in Badin and Mirpurkhas. Sugar mills have no proper mechanism of dealing with their effluent as required by the Environmental Impact Assessment (EIA). Such groundwater contamination and untreated industrial waste are polluting canals, rivers, and wetlands in the area, causing damage to the agriculture lands and human health (i.e., several skin and stomach related diseases). According to another respondent (Mr. X, Ministry of Climate Change, Islamabad, 29 January) knowledge of CSA technology and implementation of CSA for efficient use of resources is only possible if different stakeholders are engaged in the discussion including industrialists, government and farmers. But often such dialogues are avoided by industrialists and big landlords because of their own interests in the local industries and factories. According to an expert (National Program Manager, UNDP-GEF SGP, 10 March), many industries have done their Environment Impact Assessments (EIAs) but due to the poor accountability mechanism and strong political influence, they avoid following the recommendations of EIA in its true sense. He added that knowledge and implementation of CSA is restricted due to poor governance system at the provincial and district level.

Table 5.11: Public expenditure for Agriculture Development

Years	Total ADP PKR Billions	ADP allocation PKR billions		ADP allocation (% of total)	
		Agriculture	Irrigation	Agriculture	Irrigation
2012-2013	161	11.6	8.6	7.2	5.3
2013-2014	165	10.8	16.4	6.5	9.9
2014-2015	143	10.6	12.9	7.4	9.0
2015-2016	142	11.9	27.2	8.3	14.9
2016-2017	200	14.9	21.2	7.1	10.6
2017-2018	244	15.3	48.9	6.2	20.0

Source: Sindh Agriculture Policy 2018-2030

According to Government of Sindh, public development expenditure on agriculture has increased following the 18th amendment to improve agricultural productivity with the main focus on CSA, but actual expenditures are very much below the allocated amount. This means that CSA related research is also very limited. The reason behind low expenditures is the delay in the release of funds, financial and procurement issues, limited policies and lack of coordination between the different department of Sindh government. Irrigation department of Sindh got their funds allocation mostly for the canal lining and their expenditure increased to 20% in the budget for 2017/2018 (see table 5.11).

Table 5.12 highlights the key drivers of water governance including water scarcity, water distribution, water contamination and overuse of water in canal head districts and for industrial sector (column one). These drivers are impacting the agriculture sector (column two) in general and are also the determining factor for the knowledge and implementation of CSA technologies and practices in the study areas (column three). Drivers under water governance impact each other and consequently impact agriculture production in the study areas. For example, water scarcity is affecting the distribution of water between different district and different water users at provincial and district level. Similarly, water contamination by sugar mills in the surrounding areas is impacting the water availability for irrigation purposes.

Table: 5.12: Impact of water governance on the knowledge system of CSA

Water governance	Impact on agriculture	Impact on CSA knowledge
MIRPURKHAS		
• Water scarcity is increasing every year increasing number of challenges for people • Water distribution between industrial and agriculture sector is uneven. • Water contamination is becoming a serious issue effecting the water quality in the district • Water excessive use of water for agriculture in canal head districts and for industrial purposes is very high	• Water scarcity is not an old issue in Mirpurkhas. It only emerged in the last 10 to 15 years with an overall decrease in water distribution. • Irrigation and canal system are very old and is further damaged due to natural disasters. Repair of water infrastructure is very slow which is causing water contamination and leakages. • Misuse of water is increasing with illegal breaches in water courses and excessive use of water pumps. Water contamination is also increasing due to heavy use of fertilizers • Some farmers are still not realizing the need for water conservation because they have plenty of water.	• Farmers were initially reluctant but now they are recognizing and understanding the need for sustainable use of water on their agriculture lands. • Farmers are receiving trainings to save water through the building and correcting water lining. Farmers are involved in the construction of water lining, water ponds, and tanks for water storage. • Even though Mirpurkhas has sufficient water, farmers are now trying to adopt water conservation techniques like drip irrigation and water sprinklers techniques
BADIN		
• Water availability is decreasing drastically for basic needs i.e., drinking, sanitation, agriculture production etc. • Overall water distribution is limited, which is further aggravated due to leakages and breaches in the irrigation system. Water courses are also damaged due to heavy regular flooding every year • Water contamination is becoming a serious issue effecting the water quality in the district. Heavy use of fertilizers and factory effluents are contaminating the available water	• Farmers heavily rely on Rainfalls and freshwater resources. But there is an acute water shortage in the coastal area of Badin. People have limited access to drinking water. People cover a long distance in search of water for their daily use. Shortage of freshwater downstream from kotri Barrage has left people with no drinking water and water for agriculture needs. • April and May are dry months in Badin and canals get no water until the monsoon season after which cultivation of rice starts in July and August. Harvesting time is in October and November which is late for	• Water scarcity is an on-going issue in Badin which has not been taken care of yet due to which knowledge and implementation of new CSA practices and technologies is also limited. • Being the last coastal village in Badin, water distribution here is not a priority for the government. • Government is paying more attention to introduce CSA technologies in Mirpurkhas and towards other agriculture-rich districts. • Cost of fixing infrastructure and introducing CSA technologies in the coastal areas is very high due to difficult access, acute water

	wheat cultivation. This delayed pattern is affecting the farmer's income.	shortage, sea intrusion and completed degraded land.
DADU		
• Water availability is decreasing drastically for basic needs i.e., drinking, sanitation, agriculture production etc. • Overall water distribution is limited, which is further aggravated due to leakages and breaches in the irrigation system. Water courses are also damaged due to heavy regular flooding every year • Water contamination is becoming a serious issue effecting the water quality in the district. Heavy use of fertilizers and factory effluents are contaminating the available water.	• Several crops damage every year due to scarcity of water. Due to extremely hot weather, water on agriculture lands evaporates very quickly • Due to no rain water storage facilities and absence of small dams, running water destroy the standing crops and stored seeds every year. • Contaminated water is being used for irrigating the agriculture lands. • Farmers are facing serious health concerns due to contaminated water.	• Rainwater harvesting is becoming popular through different ways. • Knowledge of flood water storage tanks and ponds is common but resources and facilities are not available. • Less use of fertilizers is being encouraged and only good quality fertilizer is being suggested

Source: Semi structured interviews and focus groups discussions in Badin, Dadu and Mirpurkhas

5.6 Summary

Understanding the different drivers of change is important to study the knowledge system in the agriculture sector that has evolved over time. This chapter highlighted the several drivers of change (i.e., climate change, socio-economic driver etc.) impacting the knowledge of CSA techniques and practices in three different districts. These drivers have caused several changes, including changes in the landscapes, livelihoods, lifestyle and practices in agriculture farming. Some of these drivers are natural and others are human-derived drivers of change. Notably, reduced water availability due to climate change and uneven distribution of water are the main drivers that are impacting all others drivers of change. To cope with the changes farmers and agriculture stakeholders have adopted and introduced new ways of farming and agriculture practices, some of which are sustainable while others contributed towards further damage to the agriculture production over time. The impact of these drivers in three study districts is different and hence the knowledge system also varies in each district (i.e., Mirpurkhas, Badin and Dadu).

Impacts of different drivers on the knowledge system of CSA in Mirpurkhas is different as compared to the other two districts. Mirpurkhas is more organized and progressive and is less impacted by climate change. Therefore, farmers of Mirpurkhas are more open and quicker to adapt the knowledge of CSA techniques and practices. As an agriculture-rich district, the focus of research towards introducing and adapting CSA technologies and practices is also high. Even though Mirpurkhas is advanced in learning new CSA technologies and practices but small-scale farmers (mostly Hindu communities) working on the lands of landlords are very poor and have limited knowledge of CSA technologies and practices because of their limited exposure and low level of education.

Badin being the last coastal district of Sindh, and Dadu being severely affected by natural disasters, face a number of challenges (i.e., lack of political will, poverty, extreme water shortage and the high cost of introducing advanced technologies and practices due to very remote location) to produce new knowledge and implement CSA technologies and practices. Farmers of both Badin Dadu district are very poor and mostly illiterate, water shortage is at its extreme and agriculture is very much limited. Farmers of Badin have limited hope because of complete destruction of hundreds of acres of lands due to salinity, sea intrusion and water scarcity. Farmers are motivated to learn about CSA techniques and practices to cope with the extreme climatic conditions but there are very few resources available. Dadu is also a poor district of Sindh, where lands were mostly destroyed due to extreme weather conditions, heat intensity other climate change drivers (i.e., heavy flooding, changing weather patterns). Farmers are motivated to learn new practice and technologies of CSA but they are also preparing themselves for future disasters.

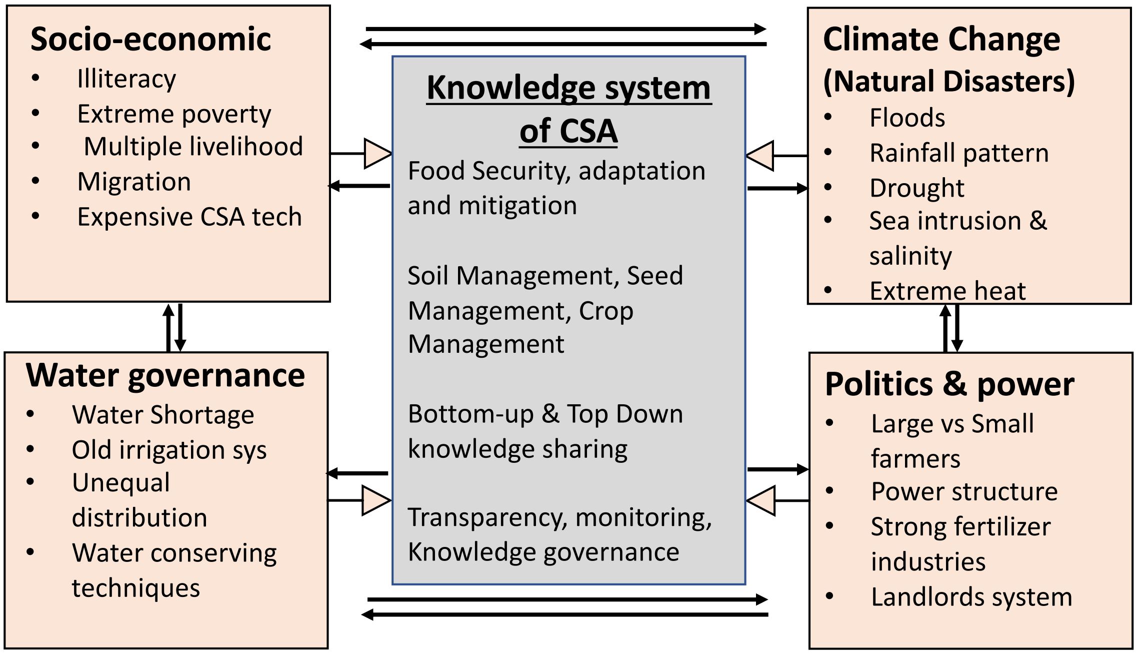


Figure 5.1: Impact of different drivers of change on the knowledge system of CSA (Created by Sajida Sultana)

Figure 5.1, explains the direct and indirect impacts of different set of drivers (i.e., climate change, political and power dynamics and socio-economic drivers) on the knowledge system of CSA. For example, the impact of climate change on the agriculture sector of study areas is influencing farmers and other stakeholders to gain new knowledge and adapt new technologies and practices of CSA. Figure 5.1 also highlights the two-sided impact of different drivers on each other and on the knowledge system of CSA. Farmers and stakeholders learn new CSA technologies and practices to cope with the climate change and as a result this knowledge impacts the drivers by contributing towards sustainable agriculture and reducing the impact of climate change.

Chapter 6 - Knowledge co-production and knowledge governance for climate smart agriculture

6.1 Introduction

Chapter four highlighted the role of different stakeholders in understanding and influencing the knowledge system of CSA. In that chapter, I examined the different forms of knowledge (e.g., scientific and customary knowledge) that exist with different stakeholders (e.g, government, farmers, NGOs) as related to seed and crop management, soil management and water use for agriculture production. In chapter four I also explained how these stakeholders share their knowledge with other stakeholders to promote and implement technologies and practices of CSA.

However, the different forms of knowledge about CSA shared among stakeholders is also influenced by the various drivers of change those stakeholders experience (i.e., climate change, social, economic and political drivers). In chapter five, I assessed how different drivers impact the knowledge systems associated with CSA presently and over the past several decades. These drivers have both positive and negative impacts on the knowledge system of CSA, and the drivers also interact to influence how knowledge is produced, shared and acted upon.

In this chapter I address the third objective of my research, which is *"to assess if and how different actors and organizations in the water-agriculture sectors can engage in the collaborative production of knowledge to enhance governance of climate-smart agriculture"*. Specifically, I focus on the technical, social and political opportunities and barriers to knowledge co-production, and the implications for governance (e.g., legitimacy, accountability) for CSA. To facilitate my presentation of findings and analysis, I apply an existing framework on knowledge co-production and governance (see van Kerkhoff and Pilbeam 2017), which draws attention to three linked knowledge domains: 1) knowledge practices and interventions; 2) institutions and institutional arrangements to bring knowledge into action; and 3) the epistemological context in which knowledge co-production is linked to governance for CSA (see in literature review chapter - section 3.6).

6.2 Complex knowledge systems of CSA in Sindh

Climate-smart agriculture (CSA) as defined by the FAO means: i) sustainably increasing agricultural productivity and incomes (food security), ii) adapting and building resilience to climate change (adaptation); and (iii) reducing and/or removing greenhouse gas emissions (mitigation), where possible (FAO 2010). In the case study areas, with the current existing complex network of stakeholders and dynamic set of drivers, it is very challenging to introduce and implement CSA in its true sense unless all the drivers and complexity of stakeholders involved are taken into consideration and thoroughly analyzed.

Diagram 6.1, indicates the complexities of an existing knowledge system for CSA in the case study area. The grey area indicates the knowledge system of CSA for agriculture production (i.e., includes seed, crop, soil management, and water use). It also indicates the network of multiple stakeholders involved in the knowledge system of CSA and how different stakeholders are linked with each other to share their knowledge about CSA for agriculture production. Diagram 6.1 also indicates four different sets of drivers impacting the knowledge system of CSA in case study areas. These drivers are climate change, socio-economics, politics, and water management. These drivers are impacting the CSA in different ways which are discussed in detail in chapter 5. It is also important to note that these drivers have a two-way impact on each other, as well as on the knowledge system of CSA.

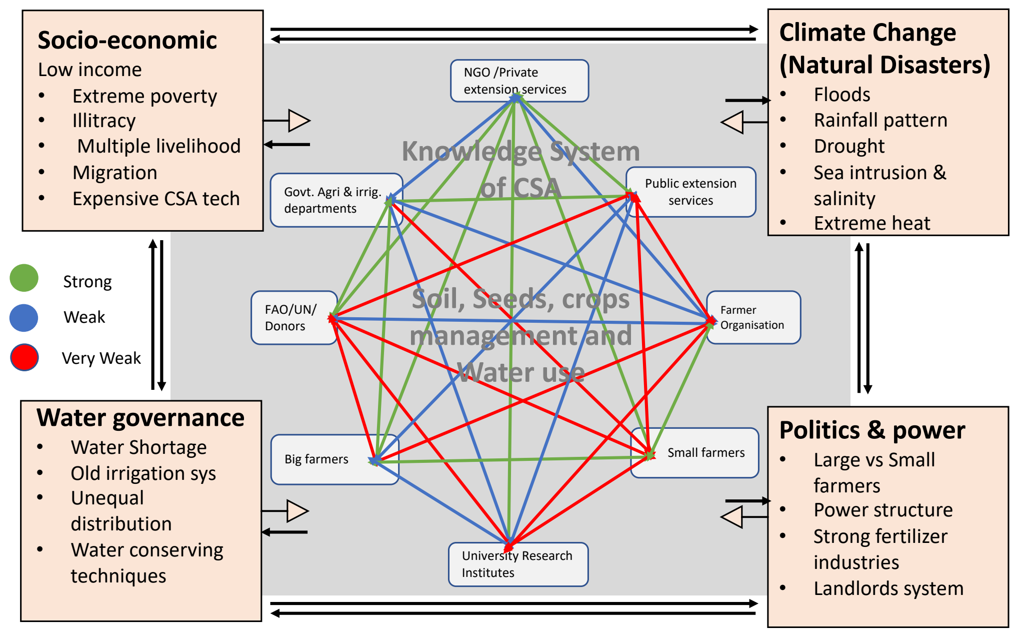


Figure 6.1: Knowledge system of CSA linked with multiple stakeholders & drivers in the case study area (Created by: Sajida Sultana)

Stakeholders highlighted in the diagram, are directly or indirectly promoting CSA technologies and practices and are involved in generating the different form of knowledge about CSA. For example, research institutions are engaged in developing knowledge based on scientific experiments on different varieties of seeds and their resistance towards extreme weather conditions. Similarly, research institutions are also experimenting to understand the different crop diseases and how they can be controlled. There is a lot of localized research going on in the case study areas based on the local soil conditions and weather patterns in all three districts. FOs, NGOs, donors, and government departments have their own system of sharing the knowledge of CSA with other stakeholders and farmers (see Chapter 4). NGOs and FOs have their own community farmer schools, where they teach and train the farmers about new CSA technologies and practices. As a part of the training process, they also encourage farmers to share their experiences and knowledge with the other farmers and trainers to promote customary knowledge. Sometimes, these customary techniques are combined with new technologies to meet the changing environment, climate and local conditions.

Some of these stakeholders, like NGOs, are strongly engaged with each other to promote and implement CSA, whereas my research shows that others have very weak linkages to share and promote the CSA knowledge (see Chapter 4). For example, public extension services have very weak linkages with the farmers and they have limited knowledge of CSA practices and technologies that are designed for local needs and weather conditions. NGOs have a strong presence at the local level and farmers are mostly trained by NGOs or other private extension services about CSA practices and technologies. Linkages and CSA knowledge sharing are further explained in chapter 4, section 4.4. But it is important to note that all the stakeholders are working independently without any support of the government.

My research shows that there are issues of coordination with different stakeholders. For example, farmers are displeased with the water management and distribution by the irrigation department. Large landlords and progressive farmers have easy access to the officials of the irrigation department, extension services, and other agriculture laboratories but poor and small - scale farmers cannot access these stakeholders easily. Moreover, poor farmers have limited access to the justice system (i.e., court, lawyers) in case of local conflict and water disputes. Most of the time, poor farmers give up on these local disputes because they cannot afford to hire lawyers and other associated costs to settle the disputes.

In the case study areas, CSA is not just about a strategy to handle climate change, increasing agricultural productivity and reducing GHG emissions but it is also about taking into consideration all the different drivers (Karlsson et al. 2017) that are influencing the knowledge system of the agriculture sector in Sindh. For example, most of the farmers in the case study areas are poor and don't have access to basic facilities like clean drinking water, healthy food and access to large cities. People are mostly illiterate in Badin and Dadu which is adding another layer of difficulty for them to understand new technologies. Under such conditions, climate-smart agriculture is not helpful if it is unable to change to the basic living condition of the farmers.

What then, are the prospects for co-production of CSA among farmers, governments and civil society organizations? In the case study areas, knowledge co-production can be catalyzed by governance processes to address the dynamic social, cultural and economic drivers. Specifically, knowledge governance depends on how different stakeholders (i.e., farmers, government extension services, NGOs, researchers, and scientists) are engaged to promote and create authentic, reliable and effective knowledge about CSA technology and practices at the right time.

6.3 Moving towards knowledge governance of CSA in Sindh Province

Knowledge governance relates to the process where researchers, government, and other stakeholders interact with each other and with the different drivers (i.e., cultural, social, economic and political) that shape the relationship between science, customs, decision-making process and institutional policymaking. Knowledge governance is defined as "*the formal and informal rules and conventions that shape the way we conduct or engage in knowledge processes, such as creating new knowledge, sharing or protecting knowledge, accessing it and applying or using it*" (van Kerkhoff and Pilbeam 2017: 29).

In the complex and disconnected knowledge system of the study areas, it is evident that knowledge for CSA should be co-produced with multiple stakeholders (Lipper et al. 2014). It is also important to note that for the successful implementation of CSA, knowledge co-production can set the stage for better and strong knowledge governance system for legitimate, transparent and useable CSA knowledge. Knowledge co-production is defined as the interactive process among experts, bureaucrats, and stakeholders aimed at exchanging, combining and harmonizing elements like facts, interpretations, assumptions and causal relations from these different knowledge domains (Ehrmann and Stinson 1999). Knowledge co-production is explained as a multifaceted process by Dale and Armitage (2011), where knowledge is gathered, shared, integrated, interpreted and applied in any specific context (i.e., CSA in this research) (see Chapter 2)

Figure 6.2 highlight the linkages among knowledge governance and knowledge co-production. Specifically, the framework draws attention to three linked knowledge layers: 1) knowledge practices and interventions; 2) institutions and institutional arrangements to bring knowledge into action; and 3) the epistemological context in which knowledge co-production is linked to governance for CSA. The first layer (inner layer) explains the most technical aspect of interventions that relate to the efforts to change science-society relations to achieve the specific environmental goals, which in the case study areas is an implementation of CSA technologies and practices to mitigate climate change impact. The second layer emphasizes the institutional arrangements to bring knowledge into action. In this research, this layer draws attention to the institutional arrangement of knowledge co-production for CSA and role of multiple stakeholders within these institutional arrangements. Finally, the third layer is "civic epistemology" which gives a broader view of formal and informal rules reflecting the deep-seated pattern of social, political and cultural practices.

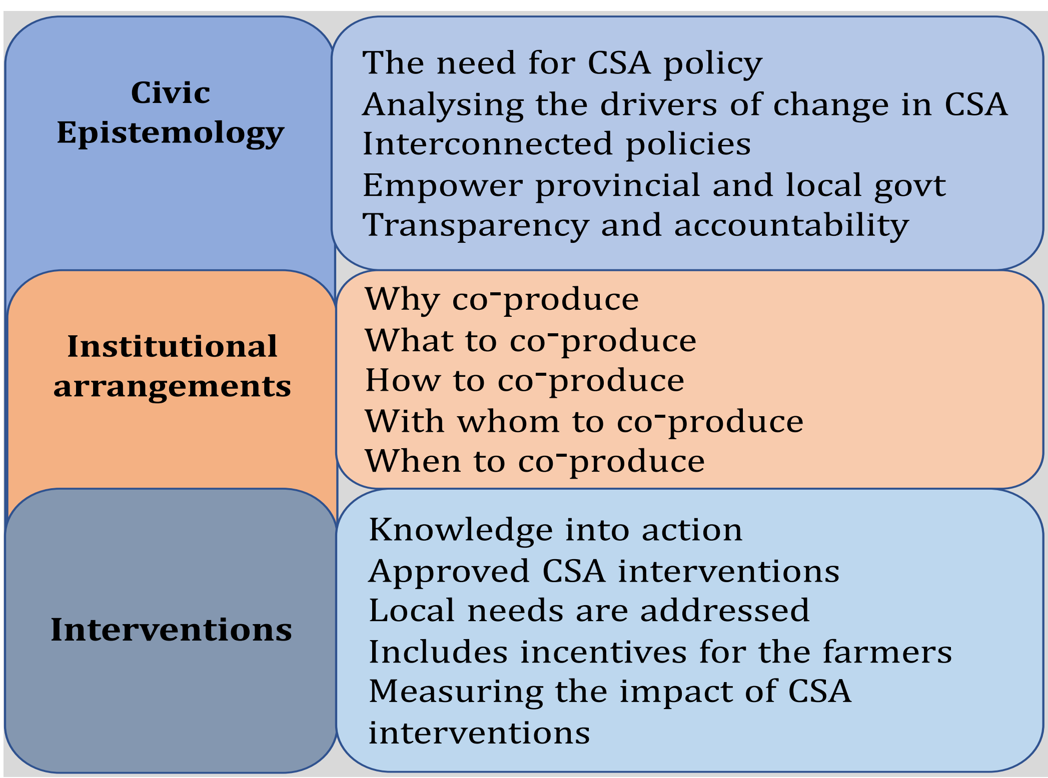


Figure 6.2: Key dimensions of knowledge governance for CSA (Adapted from van Kerkhoff and Pilbeam (2017)

In the following section, I systematically analyze each domain to determine the essentials of knowledge governance arrangements and their effectiveness to achieve the desired result of implementing CSA at the local level to improve agriculture production (i.e., through three sub-unit of analysis: seed and crop, soil and water management). Specifically, I analyze the 'knowledge into action' process for CSA and whether or not an existing set of institutional rules and organizational set-up is effective to promote CSA technologies and practices under the different drivers of change (i.e., social, cultural and political etc.).

6.3.1 Practice and intervention for CSA in the case study areas of Sindh

To analyze knowledge governance for CSA in the case study areas, I will start with the first layer (see Figure 6.2) to consider the technical and practical knowledge of CSA at the local level (i.e., knowledge about CSA interventions in seed, crop and soils management, and water use). Technical aspects of CSA in the case study areas will be explained through agriculture production as a unit of analysis and sub-units of analysis (see chapter 4, section 4.2).

"Intervention" refers to how the knowledge of different stakeholders impacts the implementation of CSA in the three study districts. This layer will then be used to explain the impact of decision making at different levels (i.e., local, national and international) based on the scientific and customary knowledge of CSA, and how this knowledge is converted into action (i.e., improving the agriculture production through seed and crop, soil, and water use) at farm level. "Intervention" describes the goal-oriented actions that directly shape science policy relationship and guides us on how to successfully share a lesson from good practices around to meet specific environmental goals. (Ibarra et al. 2018). In Sindh, the goal-oriented actions are set to implement new technologies and practices of CSA at a farm level. But there are many gaps to meet these goals due to lack of knowledge, different level of understanding about new and existing technologies and practices of CSA. "Intervention" is further discussed through three sub-units of analysis below:

a) Seed and crop management

For seed and crop management, there is an urgent need for a seed policy at a national or provincial level. Due to the absence of seed policy and a weak governance system, fertilizer companies, private extension services, and individuals are selling different seed varieties to the local farmers who have no access to the market. Most of the farmers in all three case study districts have limited or no knowledge about alternative seed varieties. Having a seed policy and effective implementation of such a policy will ensure that only approved seed varieties are being introduced at the local level.

Another important aspect to be considered under "intervention" is the access, source, and authenticity of the information. It is important to ensure that farmers are fully aware of seed varieties and their qualities in the market. Currently, the only source of information for them is the entity who is selling the seeds, and with the primary objective of economic benefit. This requires access to knowledge about different aspects of seed and crop management. For example, farmers need a detailed understanding and knowledge about the different types of seeds, how these seeds can provide higher yields, and at the same time produce good quality crops. Farmers also require knowledge about different weather conditions under which different seeds can be used and how to apply good quality fertilizer. This insight was articulated on many occasions through semi-structured interviews and during informal discussion with farmers, and summarized by Sindh (Professor 5, Extension Services, Sindh Agriculture University Tandojam (SAUT), Hyderabad, 31 April 2018) who noted that farmers have a good understanding about seeds varieties but they require new and up to date informtion about changing soil conditions and about advanced fertilizers that can improve their soil conditions and seed productivity. Curently, knowledge of these issues is largely scattered and poorly integrated. It is also important that farmers have access to diverse and credible sources of information (i.e., local agriculture departments, research institutions, extension services, etc.) whenever they need it.

Research also indicates that older farmers have a very detailed customary knowledge about seed and crop management which they also pass to their next generation. They have their own knowledge and ways of understanding the old seed varieties and their use. Unfortunately, such practices have been shown to be largely ignored in the case study areas and are replaced by the new practices and authorities who consider that customary knowledge outdated for the present circumstances. As highlighted by an older farmer (Lalji, Mirpurkhas 07 May), *"Young farmers are learning new techniques through field schools but old practices not a part of these trainings. He added that trainers should have knowledge about old pratices that can be effectively combined with new practices, otherwise the young farmers are receiving incomplete knowledge"*. Research shows that farmers are more comfortable to learn new CSA practices that are linked or have some relevance to their customary knowledge. A 70 years old female farmer (Mai Raheema, Badin, 15 April) stated that *"Farmers are open to learn new CSA practices and they relate some of these with their customary knowledge which help them to understand the new techniques well (for example old seed storage techniques combined with chemicals that are helpful to preseve seed from humidity and different diseases)"*. In the case study areas, customary knowledge has a deep connection with farmer's culture and traditions which they don't want to disconnect with. There is a need to encourage and enhance the customary knowledge and practices at the local level and farmers should be encouraged to disseminate their customary knowledge to other farmers. As explained by (Ghulam Mustafa, 30 year old farmer, Dadu, 24 May) "*Farmer field schools must include experinced farmers who have thorough understanding of customary practices. They have authentic and relevant knowledge about the local conditions*" (see chapter 4 – section 4.3.2) about old varieties or heritage seeds in their farming practices.

There are a number of good efforts at the local level to promote effective CSA knowledge about seeds, including seed preservation, identification of high yield seed varieties, proper use of seeds and crop management. Field workers from different NGOs, private extension services and experienced farmers are playing a major role in the study areas to promote such efforts individually (see chapter 4 - section 4.3.1). There is a need to bring those efforts and knowledge together to share it in a more coherent and systematic way on a wider scale. As noted by Professor 1, Soil Management department, Sindh Agriculture University Tandojam (SAUT) (Tandojam, 5 March), *"NGO and extension services have a good community reach and they can help in spreading the right and pertinent knowledge of CSA at community level"*. The local agriculture university has also taken a lot of initiatives to divert their research towards CSA to improve seed varieties that suit local conditions and requirements like drought and extremely dry weather. These efforts necessitate the translation and proper utilization of scientific research knowledge at the local level by connecting with the already existing networks of NGOs and private service extensions.

b) Soil management

Knowledge of and implementation of CSA technologies and practices for soil management (i.e., land leveling, use of organic fertilizer, soil moisturizing techniques) are very limited in Badin and Dadu as compared to Mirpurkhas. Soil conditions in all three districts are quite different, and therefore, it requires different understandings and knowledge of CSA technologies and practices in all three districts. As explained in chapter 4, section 4.2.1, farmers in Badin and Dadu highlighted the need of CSA knowledge to recover the land in both districts which at one point was very fertile. As stated by a Professor 1, Soil Management department, Sindh Agriculture University Tandojam (SAUT) (Sindh, 5 March), extremely saline land in Badin due to sea intrusion may require different approaches and knowledge of CSA technology and practices to overcome the issue, then approaches and knowledge used to treat the saline land in Dadu due to floods and extreme droughts. Similarly soil conditions in Mirpurkhas may require altogether a completely different approach and CSA knowledge. In addition, farmers in each district need a thorough understanding and knowledge of these multiple factors effecting the soil fertility as stated by Professor 3, Plant Breeding, Sindh Agriculture University Tandojam (SAUT) Sindh, (Hyderabad, 19 March).

Research institutions, local experts and local government authorities need improved collaboration to understand this diversity before introducing any CSA technology in case study areas. Appropriate knowledge must be provided to the farmers based on their diverse soil conditions, which is only possible if NGO field workers and extension service officers are aware of such diversity and specific soil conditions. This requires a mechanism and effort of NGO field workers and extention service officers to consult with local authorities and research instituions to learn about local soil conditions and may be properly get trained before disseminating the knowledge about CSA technologies and practices to the farmers. One example of such effort in Sindh is the launch of “The Soil Fertility Atlas for Sindh” which provides a comprehensive account of the soil types and their current fertility status, native best management practices, fertilizer use trends at the farm-gate level, and management strategies for normal and constrained soils for resource based improvement (FAO 2017). Challenge ahead is how this project which is singed between the FAO, the Ministry of National Food Security and Research, Pakistan Agriculture Research Council (PARC), USAID, and the US Department of Agriculture (USDA), is implemented successfully at the local level and whether such efforts are integrated or not into CSA policies.

CSA technologies (i.e., land leveling, laser techniques etc.) may also be available at an afforable price to all the farmers. One respondent (Farmer and president Halal-e-Ahmer, Badin, 28 April) highlighted that currently, small-scale and poor farmers cannot afford most CSA technologies, and as a result, many farmers have either changed their source of livelihood from farming to fishing in Badin or migrated to other fertile districts (i.e., Mirpurkhas, Upper Badin, Jamshoro). Local governments can also play an important role in facilitating farmers and providing them access to the modern technology (i.e., land leveling mechaines, tractors etc.) on subsidised rates on afforable terms. In addition, government, NGOs and researchers should also promote afforable CSA practices by promoting customary knowledge of agriculture that has climate smart attributes.

Local government need to invest in CSA technologies and practices to recover the saline soil in the study areas specially coastal areas that are highly neglected (i.e., Badin). If the farmers in Badin and Dadu have enough water and resources through the support of local government authorities, they are willing to learn CSA practices and technologies to recover the land. As stated by Professor 2, Soil Management department, Sindh Agriculture University Tandojam (SAUT) Sindh, (Hyderabad, 5 March) in Mirpurkhas, the soil is still intact and can sustain the use of multiple fertilizers and CSA interventions like intercropping. However, farmers must be encouraged to learn about CSA practices prior to further damage being done to the soil.

c) Water use

Water use for agriculture production is more complicated than any other factor in all three districts, and it is becoming a major issue. Dadu and Badin are in extreme water crises and Mirpurkhas is also now facing water shortage. Badin and Dadu being at the tail end, receive a very limited quantity of water for a limited time, therefore, agriculture lands are and production is heavily impacted by water scarcity.

There is an urgent need to ensure the frequent and sufficient distribution of water by the irrigation authorities with special attention to 'tail end' districts. CSA technologies and practices that are relevant to water conservation and sustainable use of water in agriculture may be introduced. For example, as stated by Abdul Raheem (farmer, Mirpurkhas, 28 April) most of the farmers still have knowledge about the Sailaba system but it is not in practice anymore. Research shows that the Sailaba system is able to irrigate around three hectares of land and is very much affordable, and therefore, such systems are required to be reintroduced among farmers in Mirpurkhas, Badin and Dadu.

Research also indicates that water conflicts and disputes are common at the local level in Badin and Dadu, but there are relatively fewer disputes or disputes are of a different nature in Mirpurkhas. The reasons for less local disputes in Mirpurkhas is the presence of FOs (see chapter 4 - section 4.2.2), which ensures that local disputes are resolved and water distribution is fair between small-scale and large-scale farmers. A similar mechanism of FOs should be established in Badin or Dadu, where farmers can raise their voice and their concerns are heard. Fair distribution of water between small-scale and large-scale farmers and between canal head districts (i.e., Mirpurkhas) and tail end districts (i.e., Badin) is very important to promote CSA knowledge in Badin and Dadu for the sustainable use of water in the agriculture sector.

People in Badin and Dadu have lost their freshwater lakes due to repeated natural disasters like floods. Some efforts have been made by NGOs and UN agencies to rehabilitate few lakes in Badin without the support of the government, but more efforts are needed to rehabilitate these lakes to overcome the water shortage for surrounding communities. Such efforts at the local level will not only reduce the frustration of the farmers who migrate but also it will encourage and motivate to restart their agriculture farming.

Research shows that farmers of Badin and Dadu are aware of old techniques (chapter 4, section 4.2.2) of CSA for sustainable water use (i.e., water storage and seeds that require less water, etc.) and have been practicing their customary knowledge for numerous decades. Mirpurkhas on the other hand, have only recently realized the importance of sustainable water use in agriculture, given greater access to water resources (see chapter 4 - section 4.2.2). A respondent (Hanif, farmer/member of Farmer Organization, Mirpurkhas, 7 May) explained that efforts are needed to introduce and disseminate integrated knowledge (customary and scientific knowledge) in all three study districts in which water is a central issue.

In all three districts, farmers at the local level highlighted the need for new knowledge and updated information under each category (i.e., seed and crop management, soil management and water use). For example, farmers highlighted the need for timely information about the weather conditions, knowledge about trusted pesticides, safe fertilizers, crop diseases, seed storage, soil analysis, rehabilitation of damaged soil after disasters and salinity and land treatments, etc. Farmers also highlighted the need for credible and authentic knowledge sources and a platform where they can discuss their issues, learn about CSA and prepare themselves for future climate insecurity or disasters.

Table 6.1: Key efforts needed for CSA "interventions"

Effort needed	Practices and interventions
What is needed	• How the co-produced knowledge of CSA is translated and implemented at the local level aligned with the local needs to enhance agriculture productivity, including seed and crop management, soil management and water use in agriculture
Knowledge into action	• How CSA knowledge is translated into action through different CSA interventions. • Use of both customary and scientific knowledge for CSA interventions. • To ensure that farmers understand the CSA technologies and practices
Local needs are addressed through different CSA interventions	• CSA interventions are integrated in a way that different climate change, socio-economic, water governance, political needs are taken care of. • Farmers have all the basic needs to understand and implement CSA in their day to day farming (i.e., availability of water, food, and shelter). • DRR is the major component of CSA related trainings
CSA interventions provide incentives	• CSA interventions provide different incentives, where farmers can learn about CSA technologies and practices that are packaged with other training including education and health facility, vocational training for embroidery, stitching, kitchen gardening, hygiene.
Approved CSA interventions	• CSA interventions are aligned with the CSA policy and guidelines. • CSA interventions are approved by the relevant authorities and only approved CSA interventions are promoted. i.e., approved seed varieties.

	• Private and public extension services follow the same guidelines of CSA to ensure consistency and quality of CSA interventions.
Measuring the impact of CSA interventions	• CSA interventions are monitored and revisited through regular field visits by the public and private extension services to access to the usefulness and relevance. • Researchers and scientists are connected with extension services and farmers to monitor regular changes in the soil, water, seed and crop conditions to ensure future modifications of CSA technologies and practices

Source: Semi structured interviews and focus groups discussions in Badin, Dadu and Mirpurkhas

Table 6.1 highlights the first dimension of knowledge governance after analysing the different drivers and stakeholders involved for the implementation of CSA in the case study areas. It also highlights what is needed to ensure that "intervention" efforts are blending well with the second and thrid dimension, and that each contributes towards knowlegde governance for CSA in the case study areas. The table highlights how different forms of knowledge (i.e., customary and scientific knowledge for CSA) in the case study areas are combined together, whether or not the intervention and the related knowledge serves the local needs of the farmers and the agriculture sector, introduced CSA practices and technologies at local level are approved and aligned with the CSA policy and if there is any mechanism to continously monitor the impact of CSA at local level to further imporve them in future.

6.3.2 Institutional arrangements for knowledge co-production in Sindh

Cash et al. (2003) explains three basic characteristics important for knowledge system - legitimacy, salience and credibilit. Legitimacy explains the fairness to all the stakeholders involved in the system, salience refers to the relevance of action taken, and credibility indicates how scientifically credible the action is. These characteristics can be considered as foundations (in the context of case study areas) that define the institutional and organizational arrangements for scientific findings and translating them into lay terms for local actions. For example, the scientifically-developed CSA technologies and practices should be translated in such a way that local farmers should be able to understand the relevance and importance of these technologies and practices in their day to day farming practices. Knowledge systems for CSA should also be able to meet the local conditions and requirements of all the stakeholders as a knowledge system also sets the boundary between science and action. I assess and reflect on each of these features of knowledge governance.

a) Legitimacy

After the 18th amendment (see chapter 5 - section 5.4), environment and agriculture have become a provincial subject, yet practical implementation of the 18th amendment is still in process. The Sindh provincial government has a very limited institutional capacity and expertise to produce provincial policies, including a policy for CSA. Another main challenge of the provincial government is the lack of funds for the agriculture sector, which also hinders the institutional arrangements for CSA. For example, after the 18th amendment, powers are delegated from national to provincial ministries (including the agriculture and environment ministry) but funds are still under the control of the federal government (see chapter 5, section 5.4). Therefore, the provincial government is not fully equipped and supported to handle CSA. CSA being a new concept, requires more research at the provincial level but due to lack of institutional capacity and resources, Sindh province is not progressing with the implementation of CSA. As articulated by a government respondent, (Mr. X, Sindh Irrigation Development Authority, Narra Canal Division Mirpurkhas, 3 May) *"Sindh is facing lot of challenges mainly due to climate change and extreme events. CSA is one of the solutions and there are many isolated efforts to promote CSA but individual efforts don't count. There is a need of strong coordination between different stakeholders for the implementation of CSA and CSA related policies"*. Research institutions at the provincial level and district government have good knowledge and understanding of the local conditions, issues, and challenges but they have limited resources to connect the expert and customary knowledge to establish a comprehensive knowledge governance system for CSA in Sindh. A respondent, (Mr. Y, Sindh Irrigation Development Authority, Mirpurkhas, 7 May) explained that, *"Currently there is supply based model that exist in Sindh agriculture sector to introduce any new technology. Instead there should be demand based model of agriculture sector, like Israel model of agriculture which makes it one of the best in agriculture research. Similarly for CSA, there should be well connected and coordinated efforts at provincial and district level"*.

As noted, there is a significant need to strengthen the provincial government and institutional structure at the provincial level by providing necessary funds for CSA research and implementation. In addition to that, there is also a need to strengthen the public as well as private agriculture research institutions to enhance research on CSA, and to share the scientific knowledge of CSA with other stakeholders as well as within the different layers of research institutions. In Sindh, there is a specialized agriculture research institution - Sindh Agriculture University Tandojam - and also a Sindh Agriculture Research Council (SARC) at the provincial level. However, the CSA-related research produced by these institutions is not reaching relevant stakeholders that are involved in decision making and policy making for CSA. As highlighted by a respondent, (Mr. X, Sindh Irrigation Development Authority, Narra Canal Division Mirpurkhas, 3 May), research instituions should share the important research findings at a local level with the government so that these findings are considered while making policies and decision at the provincial level. Research also suggests that the effectiveness of the CSA research should be evaluated to see how the local problem is defined and framed and how the options to deal with the issues are considered, rather than simply implementing a CSA technology to handle agriculture problems in study districts. This tension was also highlighted by respondents, and it was noted that it could help to increase the credibility of the knowledge of research, as well as other stakeholders, involved in the decision and policy making.

A systematic governance mechanism is needed where local government institutions (i.e., irrigation and agriculture departments) are held accountable for not being transparent and benefiting primarily more powerful individuals and or those with more resources. For example, key findings of the focus group in Badin noted that the irrigation department needs to be more transparent in the distribution of water to the 'head and tail' districts, while fertilizer companies are required to follow their mandate without exploiting the poor farmers and selling poor quality seeds at high prices (by disseminating limited and incorrect information) (focus group discussions: Badin 17 April and Dadu 23 May). Such poorly governed institutions discourage the dissemination of appropriate CSA knowledge to farmers, especially those that are more marginalized. It also demotivates farmers to continue agriculture as their primary source of livelihood.

b) Salience

The primary aim of transmitting CSA knowledge to farmers should be to translate the research and scientific knowledge into action for better farming practices. However, according to Smith (2009), such information must be accessible, available and affordable. In all the case study areas, farmers expressed mistrust and dissatisfaction about the CSA knowledge as the knowledge provided by the public and private extension services is inadequate, it is contrary to their customary practices, and it does not address the local soil and weather conditions (see chapter 4). Similarly, my research also indicated that private extension services from the fertilizer industry require proper checks and balances to ensure that only right and relevant CSA knowledge (i.e., knowledge according to the local needs and conditions) is transferred to the farmers and that the field staff is trained.

Contrary to the myth that farmers are 'stuck' in the old practices of farming and have a rigid mindset towards learning new technologies and practices of CSA, my research findings show that farmers in the case study area are keen to learn and gain the knowledge of new technologies and practices (Program Head, FAO, Hyderabad, 31 May). Farmers are deeply interested in learning CSA technologies and practices in a way that helps them to transform their old farming techniques to meet the changing requirements of agriculture production. But there is no platform or institutional arrangement that allows farmers to gain new CSA knowledge that also compliments their customary knowledge. In the case study areas, farmers indicated that the information about CSA is not designed for local needs (focus group discussions Badin 17 April and Dadu 23 May).

To foster salience, CSA in Sindh requires an integrated social and group learning process and inclusive and coordinated efforts to co-produce knowledge for CSA, as emphasized by a respondent (Program Manager, Land Tenure FAO, Hyderabad, 28 March). In the case study areas, there are limited institutional arrangements available to promote social learning at the community level (Lalji, farmer, Mirpurkhas, 07 May; Amna, female social organiser, Dadu, 24 May; Engineer Sindh Irrigation Development authority, Mirpurkhas, 1 June). There is a need to facilitate the social and group learning processes, and this can be done by encouraging the existing NGO community networks and extension services to collaborate on initiatives for communities. For example, increasing the capacity and providing the right resources to NGO community networks working on CSA, as well as public extension services, will increase their presence at the community level. Similarly enhancing the training and group learning can be achieved through field schools, where farmers can also interact with others to share their issue and gain knowledge about CSA technologies and practices (World Bank 2017).

Research shows that farmers are very much comfortable in group learning as local practices like "Baythak" or "Kachehri" (i.e., where people sit together for tea and gossiping) are the norm and which provide traditional ways of learning. Research also shows that group learning is also famous in female farmers (see chapter 4, section 4.4). Another outcome highlighted in the case study areas is that there are numbers of best practices for CSA (i.e., innovative research based on local environment and conditions), but there is no platform and established knowledge system to share best practices around for CSA. Institutional arrangements are required to encourage group learning that is very much within the cultural and traditional norms of the local communities. For example, female farmers are more comfortable to participate in female groups only, where they have the freedom to speak openly about their issues.

c) Credibility

Agriculture research institutions are considered the most credible source of CSA knowledge in the case study area. However, research institutions in these areas have limited access at the local level, and as a result, these institutions lack a critical understanding of specific requirement of the CSA in their local contexts. Further, there is no check and balance to see if the authentic research is reaching policy makers and farmers or not. Focus group discussions (Badin 17 April, Mirpurkhas 19 April, Dadu 28 May) highlighted that a specific institutional setup is required to ensure that these agriculture research institutions have regular and easy access to the agriculture communities of the study districts, where they build an understanding of customary knowledge from the farmers, and also share their scientific knowledge of CSA based on the evidence collected at a local level. Such efforts will bridge the boundaries that hinder the integration of customary knowledge accrued by farmers over many generations with insights and modern methods developed through scientific research (see Cash et al. 2003). There are also clear disconnects and weak linkages among research institutions, extension services, NGOs and donors (see chapter 4 - section 4.4). My research indicates that there is a need of institutional arrangement to ensure that all the stakeholders have a credible and authentic CSA knowledge with a clear understanding of roles and responsibilities of different stakeholders to ensure dissemination of CSA knowledge at the community level (Focus group discussions, Badin 17 April, Mirpurkhas 19 April, Dadu 28 May).

Credible CSA technologies and practices introduced in the case study areas have to be knowledge smart, policy smart and climate-smart. Knowledge smart means CSA should be co-produced with all different stakeholders after thorough and regular consultation, it should be transparent so that anyone should have access to all the information, and it should be legitimate and authenticated through scientific research. Policy smart means that CSA technologies and practices should be backed by provincial and national CSA policies. Such CSA policy should be integrated and aligned with other provincial and national policies (i.e., economic, social and political policies). Disconnected CSA policy will have a strong impact as it may not cover the aspects of economic, social and political policies. Finally, climate smart means the CSA technologies and practices are relevant and specific to the biophysical and climate situation (noting that these issues are all a little different across the three sites).

Table 6.2, explains the second dimension of the knowledge governance framework. Specifically, it highlights what is required in the case study area to ensure the co-production of knowledge for CSA through effective institutional arrangements. Effective institutional arrangements include the need understand what type of knowledge systems contribute to CSA co-production processes, how to co-produce (i.e., what are the important points to keep in mind to co-produce knowledge for CSA), who would be involved to co-produce knowledge for CSA, and what is the right time to co-produce that information to enhance agricultural outcomes.

Table 6.2: Key efforts needed for "institutional arrangements"

Efforts needed	Institutional arrangements
What is needed	• Co-produced knowledge has scientific accountability to society and ensures the co-production of knowledge after combining the scientific knowledge, customary knowledge and the perspectives and experiences of other stakeholders/ actors.
Why co-produce	• To ensure that customary knowledge, experiences and knowledge of different stakeholders are taken into consideration. • To ensure that new knowledge of CSA is negotiated and agreed with all the stakeholders. • To ensure that the concerns and needs of different stakeholders are considered before deciding what can be/can not be compromised.
What to co-produce	• Knowledge system for CSA to enhance agriculture production based on the comprehensive assessment of scientific and customary knowledge. • Co-produced knowledge about i) seed and crop management, ii) soil management, iii) water use. • Knowledge system that can help to outline the CSA policy, where CSA technologies and practices clearly outlined based on local needs of different districts.
How to co-produce:	• CSA technologies and practices negotiated and discussed with different experts through several consultation processes under systematic institutional arrangement at the local, provincial and national level. • To ensure only the authentic and right knowledge is shared by a different governing institution working on CSA. • Institutional arrangement to support knowledge system of CSA and co-production is an ongoing process that evolves with the changing socio-economic, water governance, political and climatic drivers.
With whom to co-produce:	• Stakeholders that are directly or indirectly influenced the decision and policy-making processes of CSA (i.e., researchers and government entities). • Stakeholders that will be directly or indirectly benefited through the CSA technologies and practices (i.e., farmer and non-farmer communities). • Stakeholders that are financing in the CSA technologies (i.e., donors, NGOs, private investors, fertilizer companies).
When to co-produce:	• Co-production of CSA knowledge should be an on process and requires regular consultation with different stakeholders. A healthy knowledge co-production process evolves with changing environmental and anthropogenic conditions.

Source: Semi structured interviews and focus groups discussions in Badin, Dadu and Mirpurkhas

6.3.3 Civic-epistemology for CSA

The third dimension of the knowledge governance framework for CSA explains the broader conditions of agriculture sector in Sindh in the context of CSA. This section will explain the governance challenges within which CSA knowledge systems operate, and in relation to a complex set of drivers and multiple stakeholders. Specifically, civic epistemology represents a broader concept involving the social-economic, political and cultural formal and informal rules governing the knowledge system and related practices. Civic epistemology focuses on societal features like social patterns, mentalities, collective behaviors, cultural and political patterns - i.e., how we can learn about and know the context in which knowledge co-production for CSA is situated. In turn, this understanding is needed to support institutional arrangements, related action-oriented interventions and knowledge systems associated with environmental science frameworks. This research highlights and analyses the influential aspects civic-epistemology and explains how this layer helps to explain the governance system that supports effective CSA knowledge systems.

Landholding patterns have an important role in the implementation of CSA technologies and practices. According to one estimate, 86% of the farmers in Pakistan are small-scale farmers that usually hold 4 to 5 acres of land and 14% are large scale farmers (Amjad 2010). Land size or land holding is an important aspect that explains the demotivation of farmers to learn about new CSA technologies and practices. Land that was previously used to meet the food requirement of one family is now being divided in accordance with the inheritance law. As a result, the land size owned by each family is very small. Farmers are engaged into multiple sources of income (i.e., livestock, fishing, or services rendered to other farmers) which distract them from learning new CSA technologies and practices.

There is a need for an effective governing system with the agriculture and irrigation department to ensure that farmers get their subsidies and bank loans on appropriate terms and conditions without extra interest as noted by Abdullah Jatt and Farooq Jafferi, literate farmers and community leaders (Hyderabad, 28 February). Processes to apply for bank loans and other agricultural benefits are required to be simple and easy for illiterate farmers and should be available at the doorstep. This will encourage farmers to adopt some of the CSA technologies and practices (i.e., fertilizers and seeds) which they cannot afford otherwise (Amma Hawa, female farmer, Badin 28 April). Agriculture and irrigation department also need to establish such mechanisms where small farmers can easily rent heavy machinery for a short period of time. My research shows that currently, small farmers are renting tractors and harvesting machines from their landlord and other private service providers at a very high price because no such government facility is available. Sometimes improper use of expensive fertilizers and heavy machinery doesn't produce high yield, simply because farmers do not have the right knowledge about the use of machinery and fertilizers (see chapter 5, section 5.3). The government can also facilitate farmers to learn about the proper use of machines, fertilizers, and seeds that they are using to avoid extra cost.

Literacy has a huge impact on the knowledge system of CSA. Research shows that learning of CSA technologies and practices has a positive correlation with education. *"In Mirpurkhas, farmers understand the new technologies and practices of CSA"* as stated by

(Chairman FO Kaho Minor, Mirpurkhas 16 April). Mirpurkhas are in general prosperous and happier because they are not trapped in the vicious circle of poverty. Farmers have an influence on local decision making and are aware of their multiple rights. For example, exploitation of farmers by landlords and other influential entities is limited in Mirpurkhas as compared to the other two districts. In Badin and Dadu, research results indicate that most of the farmers are illiterate, poor and are stuck in the poverty cycle. Therefore, it is very important to educate and train illiterate farmers through field schools. Incentives (monitory or otherwise) should be given to the farmers to send their kids to school through special provision for farmers in education policy. As explained by Amma Sara, female farmer, Mirpurkhas, 7 May*), "Poor farmers have many worries and responsibilities to take care of, if farmers are encouraged through different incentives, they will learn CSA technologies and practices. Government should provide basic necessities of life to poor farmers including education facility for the kids of the farmers who attend field schools so that farmers can learn new technologies with free mind*". In addition to that women and men who are interested in vocational training should be encouraged through establishment of field schools and strengthening the existing field schools. Field schools should provide multiple trainings to the farmers including kitchen gardening and handicraft for women and technical training for men. Such initiates will motivate the farmers to attend field school and learn about CSA technologies and practices. For example, one female farmer (Shahida, Mirpurkhas, 5 June) indicated that many female farmers are interested to learn handicrafts and kitchen gardening, besides learning CSA practices and technologies in the field schools, because these trainings help them in their day to day work. My research shows that some farmers are engaged with NGOs to train other farmers through demonstration plots and kitchen gardening. However, such initiatives require strong institutional support from the local and provincial government to establish links with donors who can fund such initiatives, and with other stakeholders who can monitor such initiatives. Such initiatives also need provision in the provincial and national level CSA policy by introducing incentives for the farmers to meet their basic needs and by introducing CSA training packaged with other trainings that farmers need (i.e., handicraft, DRR, first aid and hygiene trainings).

Disaster risk reduction and management is an important component of CSA as explained by FAO (2018). My research indicates that farmers and their agriculture lands in the case study areas are severally affected by natural disasters making them more vulnerable to adapt new CSA technologies and practices. Farmer's focus is mainly to survive the disasters and desire to learn about strategies to prepare themselves for future disasters as a part of CSA techniques and practices. Government (i.e., agriculture and irrigation department) and non-government (i.e., donors and NGOs working on early recovery) authorities need collaboration to ensure that DRR training programs are a part of CSA policy at the provincial level. There is also a need of strong knowledge integration between authorities like Provincial Disaster Management Authorities (PDMA), Pakistan Metrological Department (PMD) and agriculture authorities at the local level to ensure that up to date information about future disasters and events are shared with each other and with farmers. Collaboration and knowledge sharing by multiple stakeholders will allow authorities to plan and take timely action that will provide maximum safety to the farmers and their agriculture lands.

As stated by National Program Manager, UNDP-GEF SGP (Hyderabad, 15 March), *"The poor existing governance system within the various government departments (i.e., agriculture* *and irrigation department at the local level) does not provide an environment to establish a platform that promotes co-production of CSA knowledge"*. For example, the agriculture extension department in Sindh has well-spread structures at union council level and village level but agriculture extension services are facing capacity as well as training issues. The presence of extension service staff in the field is very limited. The poor performance of extension services is linked to the fact that public extension services are poorly managed due to lack of funds, lack of infrastructure, lack of training for the new technologies and lack of accountability (Antholt 1994). Provincial and local government can establish a governance system to regulate the presence of extension services in the field and capacity building of extension services staff. Relevant authorities can also ensure that funds dedicated to the agriculture sector including extension services are utilized in a transparent and effective manner and in case of negligence, concerned authorities are held responsible (Mr. X, FAO Hyderabad, 4 April). As highlighted by a respondent (Mr. X, FAO Hyderabad, 4 April), for an effective governance system, transparency and accountability of funds is important, which can be done through regular communication and surprise audit checks of different projects and agriculture community services.

Fertilizer companies and other private agriculture service providers are major players in the agriculture sector and influence the knowledge system to a greater extent. There is also a need for a governance system where interventions and information sharing at the local level is controlled and monitored by creating different layers of rules and procedures for the private sector. These rules and procedures must be supported by the CSA policy and other related policies (i.e., seed policies). For example, currently there is no check and balance mechanism for the stakeholders (i.e., fertilizer companies and private extension services) who are disseminating knowledge about different seed varieties, fertilizers and different CSA technologies. Such interventions should be approved by the government as highlighted by a respondent (Mr. X Program Head, FAO, Hyderabad, 31 May). Similarly, a well-spread network of NGOs at the community level can be effectively utilized and authorities can monitor the different activities of NGOs in the agriculture sector (i.e., field schools, training material, seed distribution, etc.) to make sure that their work in agriculture sector is aligned with CSA and other related policies.

Authorities require a set of multiple rules and regulation ensure the transparency of funds utilization, the progress of different private and public sector institutions involved in CSA. Having a proper mechanism of accountability and transparency will direct different government and non-government institutions to work in collaboration for the promotion and successful implementation of CSA without corruption and unjustified favors to their favorites. For example, two respondents (Professor 5, Extension Services, Sindh Agriculture University Tandojam (SAUT) Sindh, Hyderabad, 1 May; National Program Manager, UNDP-GEF SGP, Hyderabad, 15 March), highlighted three steps to coordinate efforts for CSA in Sindh. A first step would be having a CSA policy with detailed guidelines for CSA practices and technologies. Second, there should be proper mechanisms of introducing CSA practices and technologies through collaboration with donors, NGOs, extension services and local government authorities. Third, there should be regular monitoring through local authorities, of all the CSA interventions and their results.

Civic epistemology in this research also includes the overall governance structure of different institutions and bodies (i.e. irrigation and agriculture department, agriculture research institutions, extension department, FOs etc.) involved directly or indirectly in the knowledge governance for agriculture and water sector in Sindh. As articulated by Mr. X, Ministry of Climate Change, (Islamabad, 24 February), all these institutions and bodies are responsible for the successful dissemination and implementation of CSA knowledge at village level. Although all the stakeholders are sharing common challenges like water shortage, natural disasters, and other political and economic issues, directly and indirectly, there is no coordination between them to solve their common problems. A respondent (Mr. X, Ministry of Climate Change, Islamabad, 24 February) also highlighted that there is a lack of communication and coordination at different levels and between different stakeholders in all three study districts. All the different stakeholders are working on their own agenda which they are not flexible enough to share with other stakeholders. For example, the irrigation department is the most powerful government authority at the provincial and local level with plenty of funds and staff. Unfortunately, this department is not working in close collaboration with the agriculture sector and other CSA stakeholders. Similarly, there is substantial scientific research on CSA practices and technologies but due to lack of government interest, that research is never utilized to solve the problems at the local level. Sharing of information and regular coordination between the key stakeholders like irrigation department, agriculture department, fertilizer companies, etc. is the key for a smooth, effective and transparent knowledge co-production for CSA.

Political powers and big landlords in the case study area indirectly control the overall functioning of the agriculture department, irrigation department and local market (see chapter 5 - section 5.4). They also have a strong influence on the decision making and policy making in the agriculture sector. In all three study districts, corruption and misuse of authority by these influential groups restrict the implementation of CSA technologies and practices in many ways. Both formal and informal knowledge system of CSA is also under the strong influence of powerful community groups, landlords and political powers. Such projects and policies that are not in favor of few but influential groups, will not be easily approved and are discouraged. Research shows that for the effective governance of knowledge system for CSA, it is important that all the relevant department and decision-making authority in the agriculture sector are independent and are not under the influence of any powerful group or entity. Such governance system also requires that government authorities, NGOs, donors, and other private sector actors are corruption free and fulfill their responsibilities without any discrimination.

In table 6.3 below, I explain the key efforts needed in the epistomology dimension of knowledge governance framework based on the thorough analysis of drivers of change and complex involvement of different stakeholders in the existing knowledge system of CSA in the case study areas. It explains how epistomology dimension more broadly explains knowledge governance and its connection with the "instituional arrangement" and "intervention" dimension. It explains the need of CSA policy at national and provincial level which is aligned with the other policies (i.e. agriculture policy, seed policy, economic and education policy etc.). Based on the research findings it also highlights the empowernment of provincial and district government who would be involve in the implementation of CSA policy and who would ensure the transparency in the knowlegde co-production process.

Table 6.3: Key efforts needed at "epistemology foundations"

Efforts needed	Epistemological foundations
What is needed	• What are the deep-seated patterns that structure the governance of knowledge including social, economic, political and climatic drivers of change in CSA and clearly identified the role of the provincial government in CSA? Carefully designed and approved policy is in place
The need for CSA policy	• CSA technologies and interventions are systematically introduced through strong CSA policy at the national level and provincial level with the distinctive role of the national and provincial government. • CSA policy should be based on local, provincial and national needs and incorporates success stories from different regions with the same challenges and conditions. • An effective governing structure at the provincial and district level should be in place to implement CSA policy and access the policy time to time for revision.
Analyzing the drivers of change in CSA	• To ensure that CSA is not just climate-smart but it is knowledge smart and policy smart. • Different drivers that are impacting the CSA, are analyzed, discussed and taken into consideration to ensure that efforts to implement CSA are not wasted. • Socio-economic, political, water governance and climatic drivers are properly addressed and measures are outlined to handle these drivers in CSA policy.
Interconnected policies	• CSA policy is designed in a way that it is interconnected with other national and provincial level policies (i.e., education, employment, economic policies, etc.) or at least with the policies that can impact CSA (i.e., seed policy, export, and import policy, etc.)
Empowerment of provincial and local government	• To ensure that local and provincial governing institutions understand the technical aspect and challenges associated with the implementation of CSA policy. • To enhance the capacity of the provincial and local governing institutions through strong institutional arrangements and sufficient funding
Transparency and accountability	• For strong knowledge governance, it is important to ensure accountability and transparency in the processes that support the CSA knowledge system. and accountability at all levels (i.e., policy and implementation level). • To ensure that decision and policy-making processes are transparent. • To ensure that the set goals are completed as per CSA policy and desired result are shared with the stakeholders involved in the implementation of CSA.

Source: Semi structured interviews and focus groups discussions in Badin, Dadu and Mirpurkhas

6.4 Conclusion:

The term CSA is a new concept in Pakistan that emerged in the last five to seven years, to mitigate the challenges of climate change on agriculture production. However, CSA practices existed even before "CSA" as a development and donor 'concept' was introduced in Sindh under different labels (i.e., sustainable agriculture, agro-ecology, customary agricultural practices). Still, the constantly changing conditions require modifications of existing technologies and practices. This is where co-production of knowledge of CSA can play an important role. It is also important to see the requirements of CSA from the local and national perspective keeping in view multiple effects of changes (i.e., climate change, water governance, socio-economic, etc.) and how the governance system at the national, provincial and local level is playing a role to promote CSA in Pakistan.

A process for co-production of knowledge for CSA is needed in Sindh to ensure the input of different stakeholders and it is also taking into account the local needs of the farmers. In the case study areas, local needs are different based on different socio-economic and weather conditions. In this regard, co-produced knowledge can better help to design solutions according to the needs of each district and to prepare national and provincial level CSA policy inputs.

A strong knowledge governance structure is needed to align the agriculture sector to the needs of different stakeholders as well as the different drivers involved in each case study area. Knowledge governance will ensure that climate-smart agriculture is assisted by a set of smart policies, effective use of resources and efficient co-produced knowledge which is based on the feedback of different stakeholders. Knowledge governance is an important tool in this research to ensure the credibility and relevance of the co-produced knowledge of CSA in a local context where climate impacts and other drivers are actually confronted. Effective knowledge governance will also help to restore the efficiency of various government departments including the public service extension services and research institutions by providing the right resources and training to meet the local needs and changing conditions for agricultural productivity.

There is literature that criticises and discusses the limitations of CSA (explained in chapter 3, section 3.2). Broadly, this body of scholarship questions the need of new terminology when there are already several sustainable agriculture practices and technologies available. As well, the 'three pillars' of CSA may or may not be acheieved in every CSA technology and practice or atleast is debateable. Therefore, it is important to highlight that the purpose of this research is not to support or advocate CSA as a 'concept', but rather it highlights the need of 'knowledge co-production' for sustainble agriculture outcomes. CSA is used as a productive entry point in this research as it is becoming popular in several countries, including Pakistan, and as a way to promote sustainable agriculture. Another argument is that for developing countries like Pakistan, any new concept that involves even the basic criteria that can imporve the agriculture sector or lives of agriculture communities is always in need. To discuss and challenge CSA as a 'concept' falls in the domain of developed or donor countries where advanced research is originated.

Chapter 7 – Conclusions

7.1 Introduction

In this chapter I provide an overall set of conclusions organized as follows: (1) Section 7.1 revisits the objectives of the research and how they have been addressed throughout the thesis; (2) Section 7.2 synthesizes the key empirical and theoretical contributions of this research; (3) Section 7.3 provides selected recommondation based on the research findings and will also highlight the opportunities for the future reseach; and (4) Section 7.6 offers final reflections on the research.

7.2 Research objectives

My research sought to critically assess the role of knowledge (scientific and customary) in the development of climate-smart agricultural practices/technology for conditions of water scarcity in the Sindh province of Pakistan. This research involved three main objectives:

1) To characterize the present-day knowledge system and the role of different stakeholders in the study regions as they relate to agriculture and water sector interactions and the development of climate-smart agriculture.

2) To identify key social, cultural, political and economic drivers e.g., the 'landlord system (patron-client arrangements)' that affect how different types and sources of knowledge influence the emergence and implementation of climate-smart agriculture.

3) To assess if and how different actors and organizations in the water-agriculture sectors can engage in the collaborative production of knowledge to enhance the governance of climate-smart agriculture.

My first objective was addressed by examining the present-day knowledge system within the agriculture and water sector interactions and the role of different stakeholders in the present day knowledge system. To meet this objective, I analysed different types of knowledge in the case study area through different data collection techniques (see Chapter 3) including semi-structured interviews, focus group discussions and informal discussions with the locals, government officials and different stakeholders (i.e., NGO, researchers, funding agencies etc.). This helped me to understand: i) how different types of knowledge (i.e. scientific, customary knowledge) have been used to understand different dimensions of agriculture and water sector interactions; ii) how this knowledge has been used to develop climate-smart agriculture system in the case study area; and iii) role of different stakeholders that influence and impact the knowledge system of CSA in the agriculture sector.

My second objective was to examine and assesss the drivers and factors influencing the different types and sources of knowledge associated with introducing, developing and implementing climate-smart agriculture. To meet this objective, I first identified different drivers influencing the knowledge system in the case study areas. This was done through consultation with local research partners (UNDP-GEF SGP and Agriculture University Tandojam). This step was challenging as a number of drivers were involved including social, cultural, political and economic, environmental drivers. With the help of local research partners, I identified and grouped these drivers into five main categories, i.e. climate change, socio-economic, political and power structure, and water management. I then explored each of these drivers with the help of interviews, and published reports to understand how people understand and how CSA adaptation measures at a local level are influenced by these drivers in the study area.

My third objective involved identifying how different actors and organizations in both agriculture and water sectors may be involved in the collaborative production of knowledge to enhance knowledge governance for CSA. To meet this objective, I aimed to connect all the parts/informtion collected in the first two objectives and sought to analyse the role of knowledge co-production in the implementaion of CSA in the presence of all the different drivers. I analysed the role of knowledge governance using a conceptual framework (discussed in chapter 6) to identify the role of different actors and organizations in producing new knowledge to achieve a common goal (i.e. climate-smart agriculture). Most of the informtion required to meet this objective draws on previous analyses (Chapters 4 and 5), however, I interviewed government officials, local communities, researchers, and scientists to further understand the knowledge governance dimensions and the role of different organizations, including government institutions, community-level associations, universities, and other research institutions in knowledge co-production.

7.3 Key contribution to the literature

Climate-smart agriculture has emerged as a strategy intended to align international and national efforts to increase agricultural productivity, mitigate greenhouse gas emissions, and reduce farmers' vulnerability to climate change (Meinzen-Dick 2013). CSA provides several benefits, including drawing attention to risks associated with climate change, reduce existing vulnerabilities (Grainger-Jones 2011; World Bank 2011) and introducing new agricultural technologies and practices at the farm level (Scherr, Shames and Friedman 2012) for adaptation, mitigation, and food security. However, the question arises whether it also considers other social, political and cultural dynamics shaping farmers' decisions to adapt climate-smart practices?

In the literature, many scholars note that: a) CSA has a limited knowledge of social, cultural and political dimensions of climate change in the agriculture sector resulting in degradation of cultural heritage, increased social inequity or long-term ecosystem instability (Schilling et al., 2013; McCarthy et al. 2012, Roncoli et al. 2008). There is a clear "divergence between farmers' needs and preferences and the scale, format, accuracy, and content of available CSA technologies" (Vermeulen et al. 2012). In CSA, local farmers need a variety of information in order to adapt to climate change and other related emerging issues, however, information available to the local farmers is often ill-suited for local agro-ecological conditions, unreliable, narrowly focused and is unaffordable to the local farmers (Levine, Ludi and Jones 2011; Warburton et al. 2011; Newsham and Thomas 2011).

As my research shows, there is a need to recognize the knowledge gap and segregated information (see also Glendenning et al. 2010; Adolwa et al. 2012; Chaudhury et al. 2012) in the agriculture sector and CSA. Efforts are also required to recognise the importance of knowledge of different stakeholders (Berkes 2009; Zheng, Zhang & Du 2011; Armitage et al. 2011; Robinson and Berkes 2011; Watson 2014), their involvement and enhancement of their role in CSA (Martins and Richards 1995; Ostrom 2009; Steele and Gleeson 2009; Van Der Hel 2016; Bremer and Meisch 2017). The presence of strong knowledge system is now being highlighted as a main pillar for the promotion of right knowledge of CSA. A recent study by FAO (2018) highlights the need for awareness raising and strong knowledge for CSA. According to this report agriculture is the main and crucial source of livelihood for many people in developing countries, and therefore, it is important that they are aware of right knowledge of CSA (FAO 2018). My research highlights the role and importance of collaborative production of knowledge for effective implementation of CSA in Sindh-Pakistan.

Most of the climate and environmental change literature in the Sindh agriculture sector emphasizes the biophysical and economic relationships between climate change and agriculture (e.g. Hussain and Mudasser 2007; Hanif et al. 2010b; Ashfaq et al. 2011; Ahmed and Schmitz 2011; Abid et al. 2017). There is some recent research done highlighting the role of CSA in Pakistan (Imran et al. 2018;), but no research has been done to understand the role of knowledge systems (particularly knowledge co-production) in addressing the complexity involved in the implementation of CSA in Pakistan. To my knowledge, this would be the first case study to examine the role of knowledge co-production in climate-smart agriculture in Sindh- Pakistan, and advance specific specific insights.

7.4 Recommendations

In the context of CSA and its implementation, two main challenges in the case study areas are highlighted:

1) There are a large number of stakeholders in the agriculture sector besides extensive outreach of government extension services. For example, there are many private extension services, multinational companies, and NGOs involved and contributing towards the implementation of CSA, and potentially positioned to equip farmers (large and small) with new CSA technologies and practices. However, due to the weak and disconnected process thought which to co-develop and share knowledge, pathways to CSA are limited at different levels leading towards inappropriate and untimely actions.

2) There are a number of drivers of change involved in the agriculture sector that impact the knowledge system for CSA, and ultimately, the implementation of CSA. For example, in the case study areas, drivers like natural disasters, socio-economic shifts, political and power structures, and water governance arrangements, have an important role in CSA.

Keeping in mind the complexity and diverse nature of problems emerging from the two main issues highlighted above, and with reference to the case study areas, this research identified the following recommendations:

1) In Sindh, CSA is an emerging concept, where government, donors, researchers at the national and provincial level are putting a lot of effort to understand how CSA can help to overcome issues confronting the agriculture sector. CSA policy is currently in draft form

and a number of consultations between government, UN agencies (i.e., FAO) and provincial governments are happening to consider what should be included in CSA policy and what not. It is very important and crucial at this stage to involve and collaborate with different stakeholders and local communities through different consultative workshops. These collaborations will help to understand the different context, issues and their solution. Such consultations will also help to further identify key areas that emerge as more stakeholders consider CSA implications.

2) Many developing countries, including Pakistan, are facing recurrent disasters which are a main driver of change in the livelihood and food security issues in Sindh. Therefore, to handle food security issues and manage disaster risks, relevant and integrated policies are needed. It also suggests that to make effective and successful development plans and policies for CSA, disaster risk reduction (DRR) and disaster risk management (DRM) should be embedded in those plans and policies. CSA policy should be integrated with other related policies (i.e., seed policy, agriculture policy, and water management policies).

3) In the case study areas, agriculture extension services are considered vital for rural development because of their indispensable role in agricultural development through sustainable farming, agriculture diversification, advanced technology and integration of small and medium farmers into dynamic markets. Agriculture extension services in Sindh may also play a very important role for the dissemination of appropriate knowledge of agronomic techniques and new seed technology (Hanif, Khan & Nauman 2004) for improved agriculture production (Nagel 1997; Jalvi 1996). Many authors have discussed the crucial role of agriculture extension in improving the production and farming techniques through the dissemination of useful knowledge and providing skill and knowledge-based training to the farmers in the case study areas (Picciotto and Anderson 1997; Feder et al. 2004; Spielman et al. 2008). However, there are a number of issues and challenges (i.e. lack of training facilities, lack of regular monitoring, corruption, etc.) faced by the agriculture extension services, and which limit the ability to foster CSA. Considering the importance of agriculture extension services and their extensive reach at a village level, strengthening of agriculture extension services in Sindh is very important. This can be done through proper regular training of extension service staff, providing facilities to the staff at union council level to encourage their presence in the community and connecting the extension staff with the agriculture university, NGOs and researchers on regular basis, and encourage extension services to be a catalyst of collaborative process.

4) The Sindh Agriculture University Tandojam (SAUT) is the main academic and research institution working with all relevant stakeholders in the agricultural sector in Sindh, including Agriculture Extension Sindh. To this end, SAUT is providing technical support to disseminate knowledge among farmers through articles, preparation of extension messages for farmer community, and through radio programs and training sessions. However, these efforts are very limited and are only available to only a few districts of Sindh, and connect with a limited set of farmers. Most of the CSA-related research is not reaching at the community level. There is a need for strong and regular coordination

between SAUT and other stakeholders to identify the diverse nature of agriculture-related issues at the community level (i.e., water scarcity, poor quality seed distribution, demotivated farmers migrating to other places, etc.) and to ensure that CSA interventions are aligned with these issues.

5) Another important aspect highlighted in this research is to promote and protect the customary knowledge and technologies of farmers at the community level, which is also often already 'climate smart'. My research shows that farmers in the case study areas are involved in many climate smart practices and have their own way of living guided through their own customs, traditions, and practices. For instance, they have their own customary knowledge about agriculture practices (i.e., water and seed strorage techniques, green manuring etc.) and handling the problems of agriculture production. Such customary knowledge itself is very rich and covers a good portion of CSA knowledge in the case study area. There is a need to create such a platform and enabling environment where farmers are encouraged to share their customary knowledge and experience with the other stakeholders and ensure that such knowledge is embedded in CSA practices and technologies. It is noted that there is a unique customary knowledge in all the three study districts and could be very helpful in designing or introducing the tailored CSA practices and technologies for each district based on their issues and needs.

6) Changing the farmer's perception of CSA is another crucial element highlighted in this research. For example, research revealed that poverty and small land holdings are also the main hindrance to acquire the knowledge about modern CSA technologies and practices (Naseer et al. 2016; Sattar 2012; Aslam 2016), mainly because farmers' perception about the CSA technologies is that it is costly for their small land holdings (i.e. 3 to 5 acres of land), and they do not feel motivated to learn CSA techniques. It is important to foster the knowledge of CSA with farmers by sharing and introducing such techniques and practices that are affordable and related to their customary knowledge and practices in agriculture.

7) Power relations in Sindh are impacting and constraining the emergence of "pro-poor" form of agriculture development and therefore CSA (Karlsson et al. 2018). In the case of the Sindh agriculture sector, it is noted that that policy reforms are geared to benefit larger land holders. This trend is expected to happen with CSA policy unless a different approach is considered. CSA policy and interventions should meet the requirement of the majority of the population (i.e., small-scale farmers in rural areas including vulnerable groups like minorities, female, etc.) and not the few influential and powerful groups (i.e., landlords, politicians, etc.). This can be done through understanding and addressing the basic needs of small-scale farmers, involving them in the process of decision making, and enabling them to adapt CSA practices and technologies by valuing their knowledge and co-producing novel insights.

7.5 Final reflection

This research provides a unique case to discuss the role of knowledge co-production in the implementation of CSA. My research suggests that the concept of 'knowledge co-production' is both relevant and appropriate to the challenging agricultural conditions in Sindh, and it provides a comprehensive solution to produce new knowledge in collaboration with different stakeholders (i.e., government, farmers, NGOs, extension services, etc.). These different stakeholders can analyze the different drivers (i.e., natural disasters, socio-economic, political and water governance, etc.) and their impact on CSA based on their expertise. Under the complex and continously conditions of case study areas, knowledge co-production process can help to find a combined solution in a more integrated way to implement CSA (Ehrmann and Stinson 1999). To overcome the disagreement and lack of coordination between different stakeholders in the case study area for the implementation of CSA technologies and practices, knowledge co-production process will encourage discussion and negotiation between different stakeholders.

Ultimately, this research suggests a need for stronger policy that climate smart agriculture interventions in Sindh should focus on the three main pillars of CSA - i) increasing agriculture productivity and income, ii) building resilience to climate change, iii) reducing green house gases emissions – as well as ways to enhance the right knowledge (i.e., local, customary and scientific) for CSA. In other words, there is a need for ‘knowledge-smart’ interventions that should facilitate and encourage stakeholders to co-produce knowledge for CSA and farmers to learn and adopt CSA practices and technologies in Sindh.

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Appendix 1:

Interview protocol for semi-structured interviews - Experts in agriculture sector

Demographics and general information about CSA:

Since how long you have been associated with agriculture sector?
What is your view of the history of local agri communities living in the study area?
What environmental changes have you noticed in the last one decade and what is the impact of those changes on agriculture lands in the study area?
Did you notice any change in the land productivity over the two decades?
How vulnerable are farmers to climate change?
What measures have been taken to for that?
What are the present-day practices of the people in the study area after climate change impact?
How do the changes in environmental conditions affect household heads' intentions to migrate and to diversify their income options?
How do the land borrowing trends in the study region link (directly or indirectly) to climate change?
In your opinion what is the value of adapting climate-smart agriculture technology and what specific technology should be in focus?
How does it affect food productivity, crop income and addressing water scarcity?
How does farmers' decision-making about climate-smart agriculture change under different social, cultural and political changes?

History and present-day knowledge system in agriculture and water sector at community level. Knowledge system to promote climate-smart agriculture at local level.

In your opinion how do people share their knowledge in agriculture and water sector?
How do people interact with each other at local level and share their knowledge?
What kind of knowledge does generally exist with old practices at local community level?
With the different environmental and climatic changes, what change did you notice in the existing knowledge system?
Do you think there is a new knowledge system after climate impact and how people get to know about this new knowledge?
What are the different challenges faced by the local communities in the current and previous knowledge system?
How do they understand climate-smart agriculture and what are the constraints and factors in your opinion which create impact the adaptation and decision-making at farm level with regards to climate-smart agriculture?
How information was/is usually collected from the farmers to use it for any decision-making at local level?
Is platform was/is used to gather, combine and disseminate knowledge about CS agriculture practices (past and present practices)?

    Yes or No.
    If yes what kind of plateform is it

In your opinion who can play an important role for sharing and collecting knowledge at a community level in agriculture sector?

    Individual farmer
    Extension services
    Farmer’s union / network
    Village agriculture council
    Other (please specify)

Do you think extension services can do more to in increasing coordination and better knowledge sharing at community level?

Yes or No. if yes how?

If No who else can play this role.

How can the role of local actors in the adaptation process in CSA be enhanced (i.e. training etc.)?

Interview protocol for semi-structured interviews - Farmers and other local community

Demographics and general information:

What is your name, age, occupation and since how long you have been living in this place?
How many family members you have and what is your source of livelihood?
Are you associated with agriculture-farming because it is your family occupation or you have recently adapted agri-farming?
Who is the decision maker in your family? If it's you then do you attend village meetings often?
What particular experience you have in agriculture sector?
What climate changes have you noticed in the last two decades?
What is the impact of climate changes on crop damage and what is the extent of damage in acres?
Did you notice any change in the land productivity after CC impact? What measures have you taken to for that?
Did you receive any compensation from the government for your crop damage?
Have you taken any loan from bank to support your agri-farming and why?

History and present-day knowledge system in agriculture and water sector. Knowledge system to promote climate-smart agriculture.

As a member of a local community, have you been involved in the decision-making process at village or community level?
What platform was/is used to share and disseminate knowledge about agriculture practices.

Other farmers
Forefathers
Extension services
Farmers union
Other (please specify)

How information was/is usually collected from the farmers to use it for any decision-making?
How do you understand climate-smart agriculture?
What kind of technology you are using for CSA, how did you come to know about this technology?

Efficient use of water
Highly productive and environment friendly seed
Pest and disease management
Salinity free soil techniques
Other environmental friendly practices (Please elaborate)

What is the CSA technology transfer mechanism at farmer level?

Other farmers
Extension services
Farmer's union
Other (please specify)

Are you satisfied with this knowledge sharing mechanism about CSA?

If No why and what should be done?

What is the credibility of the source from where you receive information about CSA technology?

What is the mechanism for adaptation of technology at farmer level? (i.e. training etc)
What is the role of extension services in providing knowledge about CSA technology?
Are you satisfied with the extension services currently being provided at a community level?
Yes or No. If No why?
What challenges do you face after the new technology being implemented?
In your opinion what is the value of adapting climate-smart agriculture technology and what specific technology should be in focus?
How does it affect food productivity, crop income and addressing water scarcity?
In your opinion what is the new knowledge you gained after CC impact and CSA implementation? Is it helpful?

Knowledge governance. Role of knowledge co-production in climate-smart agriculture. Role of different institutions and local communities in knowledge co-production to promote and implement climate-smart agriculture.

What role local actors or institutions play in sharing, collecting and disseminating knowledge about climate-smart agriculture?
How does farmers' decision-making about climate-smart agriculture change under different social, cultural and political changes?
How can the role of local actors in the adaptation process be enhanced (i.e. training etc.)?
In your opinion what should be done to improve the knowledge system at local level and policy level?

Knowledge governance. Role of knowledge co-production in climate-smart agriculture. Role of different institutions and local communities in knowledge co-production to promote and implement climate-smart agriculture.

For government sector, researchers and academics NGOs, and other?

What are the gaps in the existing knowledge system about CSA at all levels?
How information is usually shared between the farmers, local and provincial government officials, scientists and researchers?
After 18th Amendment what is the role of provincial government and are they fully independent to perform their role.
In your opinion what role of NGOs, civil society organizations, donors and private sector play in sharing, collecting and disseminating knowledge about climate-smart agriculture?
How does farmers' decision-making about climate-smart agriculture change under different social, cultural and political changes?
What is the role of researchers and academics in spreading the knowledge about climate smart agriculture?
Are they working with government to improve the knowledge system in agriculture sector?

Appendix 2

<u>Interview protocol for focus-groups discussions - Farmers and other local community</u>

History and present-day knowledge system in agriculture and water sector at community level. Knowledge system to promote climate-smart agriculture at local level.

In your opinion how do people share their knowledge in agriculture and water sector?
How do people interact with each other at local level and share their knowledge?
What kind of knowledge does generally exist with old practices at local community level?
With the different environmental and climatic changes, what change did you notice in the existing knowledge system?
Do you think there is a new knowledge system after climate impact and how people get to know about this new knowledge?
What are the different challenges faced by the local communities in the current and previous knowledge system?
How do they understand climate-smart agriculture and what are the constraints and factors in your opinion which create impact the adaptation and decision-making at farm level with regards to climate-smart agriculture?
How information was/is usually collected from the farmers to use it for any decision-making at local level?
Is platform was/is used to gather, combine and disseminate knowledge about CS agriculture practices (past and present practices)?

Yes or No.
If yes what kind of plateform is it

In your opinion who can play an important role for sharing and collecting knowledge at a community level in agriculture sector?

Individual farmer
Extension services
Farmer's union / network
Village agriculture council
Other (please specify)

Do you think extension services can do more to in increasing coordination and better knowledge sharing at community level?

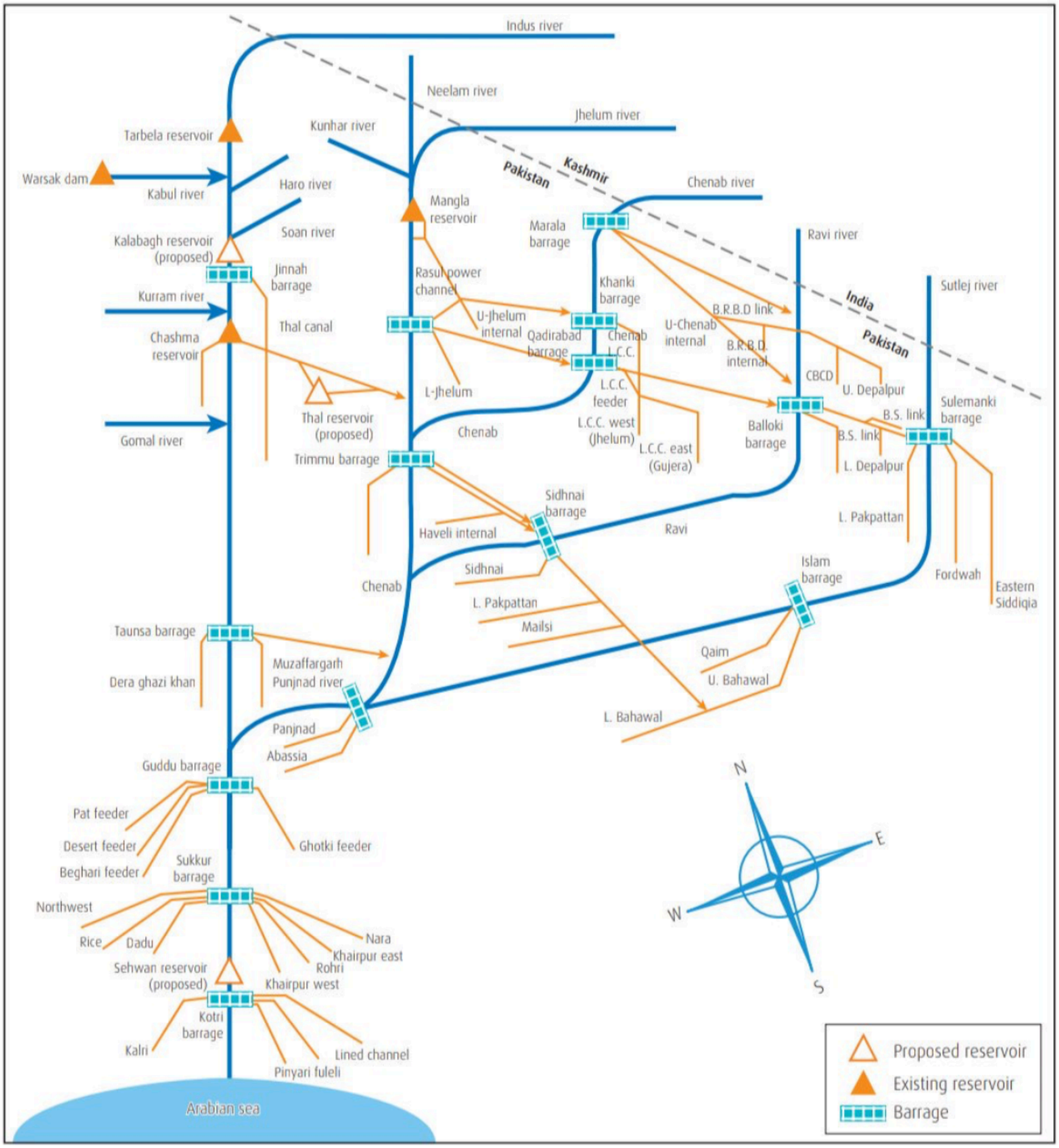
Yes or No. if yes how?
If No who else can play this role.

How can the role of local actors in the adaptation process in CSA be enhanced (i.e. training etc.)?

Knowledge governance. Role of knowledge co-production in climate-smart agriculture. Role of different institutions and local communities in knowledge co-production to promote and implement climate-smart agriculture.

What role local actors or institutions play in sharing, collecting and disseminating knowledge about climate-smart agriculture?
How does farmers' decision-making about climate-smart agriculture change under different social, cultural and political changes?
How can the role of local actors in the adaptation process be enhanced (i.e. training etc.)?
In your opinion what should be done to improve the knowledge system at local level and policy level?

Appendix 3: Indus Basin Irrigation/Canal system of Pakistan



Source: FoDP 2012.

Appendix 4: Extension services in Pakistan

History of Extension Programs in Pakistan

1) The Village Agricultural and Industrial Development Program (V-AID), 1952-1961
2) The Basic Democracies System (BDS), 1959-1970
3) Rural Works Program (RWP), 1963-1972
4) The Integrated Rural Development Program (IRDP), 1970-1978
5) The People's Works Program (PWP), 1972-1975
6) Inputs at Farmers' Doorsteps Approach, 1970 -1978
7) Training and Visit system (TandV), 1980-1994
8) Farmer Field School (FFS)

Structure and responsibilities of Extension services

Provincial Directorates General of Extension

In spite of devolution, the Directorate-General of Agriculture and Applied Research still exists. This office carries out various duties including advice on agriculture sector to the provincial government, implementation of provincial projects and maintenance of links with the district governments for agricultural extension matters. The responsibility for livestock extension lies with the Veterinary Officers and Veterinary Assistants of the provincial Livestock and Dairy Department. A Directorate-General for On-Farm Irrigation exists at provincial level. But like the Directorate-General of Extension, it also provides policy advice to the provincial government.

District level extension organization

Under the District Coordination Officer are a number of Executive District Officers (EDO), and one of them is for agriculture, called Executive District Officer for Agriculture (EDOA). The EDOA coordinates agricultural activities with other departments at district level. Under the EDOA is a District Officer for Agriculture (DOA) who is also based at district level, and is responsible for overall agricultural extension work in the particular district. At district level, the Livestock and Dairy Department has more or less the same structure as the Department of Agriculture, staffed by District Livestock Officers, Veterinary Officers and Veterinary Assistants. The Irrigation and On-farm Water Management Directorate provides extension advice on relevant matters mainly through Water Users Associations. Within the districts, extension offices are located at the following lower layers of bureaucracy:

Tehsil level extension offices

Under the DOA are many Deputy District Officers for Agriculture (DDOA), based at tehsil level. Their number corresponds with the number of tehsils in the particular district. The DDOAs handle agricultural extension activities in their respective tehsils.

Markaz level extension offices

Under the DDOA, there are many Agriculture Officers (AOs) based at markaz level. These numbers correspond with the number of markaz in the particular tehsil. The AOs are responsible for carrying out agricultural extension responsibilities in their respective markaz.

Union Council level extension offices

Under each AO are several Field Assistants (FA) based at Union Council level. Their number corresponds with the number of Union Councils in the particular markaz. The FAs are frontline agricultural extension workers. Extension advice is provided in the areas of crops, fruit, vegetables, livestock, fisheries, and marketing. Under each FA are two Beldars who are fieldworkers. They are more laborers than technical persons, and help the FA in daily agricultural activities.

Source: GFRAS Pakistan (2012) https://www.g-fras.org/en/world-wide-extension-study/92-world-wide-extension-study/asia/southern-asia/315-pakistan.html#extension-providers

Appendix 5: Sub unit of analysis for agriculture production (Additional Notes)

Soil management

In many countries of East and Southeast Asia, the yield potential is stagnant from last many years and the crop yields have already approached to their maximum limit of production, hence the rate of yields is declining (Cassman 2001). The major challenge in increasing the yield to meet the growing demand for food is the continuous crop production systems with two or three crops per year, affecting the crop rotation cycle, which ultimately affects the health of the soil. Therefore, it is important to steadily increase the yield potential ceiling for at least the major food and cash crops to allow the soil to recover naturally. In countries like Pakistan, the yield gap indicates that it could have significantly increased the yield through the appropriate use of CSA and other agriculture technologies. In some countries, including Pakistan, agriculture also heavily influenced by the use of fertilizers for high-yield but at the same time use of fertilizers i.e. Nitrogen fertilizers, increase the emission of greenhouse gas i.e. Nitrous Oxide, causing air pollution. Solution includes crops like Rice that are the most important anthropogenic sources of greenhouse gas methane (Ehhalt et al. 2001).

Another solution to increase the productivity of soil could be the reliance on organic nutrient sources but this process is very slow as the slow release of nutrients from organic compost or green manures cannot match the crop demand of nutrients. Organic matters have a capability to maintain a stable structure, high water holding capacity and excellent nutrient storage ability (Tegene 1998). There are several other techniques to enhance the productivity of crops without affecting the soil quality like multiple cropping systems through crop rotation or intercropping. Intercropping is the technique of growing two or more crops simultaneously. Agroforestry is another technique, where trees are included in the cropping system to improve the soil nutrients and reduce the erosion. Unfortunately, the soil has been degraded due to overuse and poor quality of fertilizers, soil erosion, continuous cropping, insufficient nutrients and poor land management (Oldeman 1994). For example, in many cases, the soil is also greatly damaged by the use of other heavy machinery which causes a decline in the soil organic matters (Naylor 1996). Some of the ways through which soil and degraded land can be restored include crop rotation, reduced tillage, cover crops, fallow periods, manuring and balanced fertilizer application.

Water use

Water efficiency in the agriculture sector can only be improved through investment in the right technology and access to the knowledge about improved water management and use combined with technology and knowledge about improved soil and improved seeds (FAO 2016b). For example, techniques like low or zero till, alternate wetting and drying, enhanced seeds and rice intensifications already exist but require technology like soil moisture sensors and evaporation measurement to improve water efficiency in the agriculture sector.

Contemporary theories of learning and change indicate that for knowledge or information is only effective and useful if it relates to the situation and experience of the users and if it can provide new knowledge to expand on the existing knowledge and/or practices (WRC 2016-17). Several projects conducted by the Water Research Commission of South Africa indicate that considering local and indigenous knowledge for coping drought and water scarcity is very important (WRC 2016-17). One of the examples relates to the indigenous communities of Himachal Pradesh, where people, for over a millennium, have adopted a large number of practices related to soil and water management system suitable for different agro-climatic conditions of the state (Lal and Verma 2008).

FAO (2016b), also identify that farmers around the globe hold a tested solution for coping with water scarcity in agriculture and producing more with less use of water, but they lack the support of an appropriate policy, the right mix of public and private investment and access to knowledge. There are several other techniques to reduce water use in agricultural productivity. For example, deficit irrigation, in which crops are irrigated only during most drought-sensitive periods and avoiding irrigating in other periods. The Global Framework for Action to Cope with Water Scarcity in Agriculture in the Context of Climate Change aims to stresses upon actions at the local level for promoting knowledge, good practices, technologies and mechanisms under the two pillars of knowledge & innovation and policy & investment (UNFCCC).

Seed and crop management

Application of chemicals for pest and disease control and predicting the losses due to these chemicals is still a challenge for the scientific community (Donatelli et al. 2017). Agrochemicals, such as insecticides, herbicides, antibiotics are helpful for pest and disease control (Tilman et al. 2002), only if combined with conventional practices with proper knowledge and information to the farmers. Old methods of protecting crops from diseases include crop rotation and crop diversity. One best example of crop rotation is a plantation of two different varieties of rice in alternate rows, which not only helped to control pathogen but also reduced the use of pesticides (70). Similarly, the multiline technique is another technique, where crop genotypes with different disease-resistance are intermingled and planted to decrease pathogen. Approaches like integrated pest management (IPM) play an important role to overcome crop diseases and weed control (Tilman et al. 2002).

Appendix 6: Ethics Approval

UNIVERSITY OF WATERLOO

OFFICE OF RESEARCH ETHICS

Notification of Ethics Clearance of Application to Conduct Research with Human Participants

Faculty Supervisor: Prateep Nayak **Department:** Environment, Enterprise and Development
Faculty Supervisor: Derek Armitage **Department:** Environment & Resource Studies
Student Investigator: Sajida Sultana **Department:** Environment & Resource Studies

ORE File #: 22668

Project Title: Examining the role of knowledge co-production in climate smart agriculture in Badin district of Sindh, Pakistan

☑ *Human Research Ethics Committee (HREC)* ☐ *Clinical Research Ethics Committee (CREC) is pleased to inform you the above named study has been reviewed and given ethics clearance.*

Approval to start this research is effective on the ethics clearance date which is: 2-7-18 *(m/d/y)*

University of Waterloo Research Ethics Committees are composed in accordance with, and carry out their functions and operate in a manner consistent with, the institution's guidelines for research with human participants, the Tri-Council Policy Statement for the Ethical Conduct for Research Involving Humans (TCPS, 2nd edition), International Conference on Harmonization: Good Clinical Practice (ICH-GCP), the Ontario Personal Health Information Protection Act (PHIPA), the applicable laws and regulations of the province of Ontario. Both Committees are registered with the U.S. Department of Health and Human Services under the Federal Wide Assurance, FWA00021410, and IRB registration number IRB00002419 (HREC) and IRB00007409 (CREC).

The above named study is to be conducted in accordance with the submitted application (Form 101/101A) and the most recent approved versions of all supporting materials.

Ethics clearance for this study is valid until: 2-7-19 *(m/d/y). Multi-year research must be renewed at least once every 12 months unless a more frequent review has otherwise been specified by the Research Ethics Committee (Form 105). Studies will only be renewed if the renewal report is received and approved before the expiry date. Failure to submit renewal reports by the expiry date will result in the investigators being notified ethics clearance has been suspended and Research Finance being notified the ethics clearance is no longer valid.*

Level of review:
☑ *Delegated review*
☐ *Full committee review meeting date:* ____________ *(m/d/y)*

Signed on behalf of: ☑ *HREC Chair* ☐ *HREC Vice-Chair* ☐ *CREC Chair* ☐ *CREC Vice-Chair*

Joanna Eidse
____

☐ *Julie Joza, Acting Chief Ethics Officer, jajoza@uwaterloo.ca, ext. 38535*
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☐ *Karen Pieters, Manager, kpieters@uwaterloo.ca, ext. 30495*
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