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ADAPTATION STRATEGIES TO CLIMATE CHANGE AND THEIR IMPACT ON AGRICULTURAL PRODUCTION IN PUNJAB, PAKISTAN

GHULAM MUSTAFA

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By

GHULAM MUSTAFA

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfillment of the Requirements for the Degree of Doctor of Philosophy

June 2017

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DEDICATION

This research work is dedicated to the following important personalities for their love, care and support throughout my studies and indeed to my entire life: my father, Malik Muhammad Latif; my mother, Zubaida Latif; my brothers, Malik Muhammad Ramzan, Malik Muhammad Saddique, Malik Umar Farooq, Malik Ali Murtaza; my sisters, Sughrah Nasir and Salma Shakkar; and my ideal personality and second caliph of Islam Hazrat Umar bin Al-Khattab.

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Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfillment of the requirement for the Degree of Doctor of Philosophy

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By

GHULAM MUSTAFA

June 2017

Chairman : Ismail bin Abd Latif, PhD
Faculty : Agriculture

Climate change (increase temperature and erratic rainfall patterns) has brought about possibly permanent alterations to our planet's ecological, biological and geological systems. One way to handle climatic variations is the adaptation to climate change. Studies have found that adverse impacts of climatic adversaries can easily be muted by adaptation to climate change. But, how effective adaptation strategies in response to climate change vulnerabilities are is a crucial question confronting farmers across the world especially in developing countries. Whereas literature has found the effectiveness of adaptation strategies based on perceptions of farmers but one cannot generalize this method as the perceptions vary from region to region and even from person to person. This study ranked the adaptation techniques based on actual efficiency of each adoption measure. There are different socio economic, demographic and institutional factors that affect farmers' awareness of and adaptation strategies to climate change that further need to be explored. The study in hand found these determinants in Pakistan's context.

Multi stage purposively random sampling technique was used for data collection. At first we selected Punjab as for overall study. Second stage, the study selected purposively Central Punjab (Mixed cropping zone-Faisalabad and Sheikhupura districts) and Southern Punjab (Cotton Zone- Multan) of Province Punjab in Pakistan. At third stage four Tehsil were selected randomly (two from each zone). At fourth stage the study selected four Union Councils selected randomly from each district. At fifth stage two villages were selected from each union council randomly. At sixth and last stage 7 farmers were randomly chosen. Hence, our total sample size was 224 and data was collected during July 2016 to August 2016.

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For analysis the study used Binary Logistic Model for factors affecting awareness of and adaptation strategies to climate change whereas two stage least square is used to capture the impact of adaptation strategies on yield of wheat crop. Further, adapters and non-adapters to climate change were separated for each farm level strategy. Data Envelopment Analysis was applied to each adapter of strategy and non-adapters to calculate their efficiencies.

Using action theory we delineated three stages of adaptation and found that 71.4% of farmers perceived CC where 58.5% farmers planned to adapt while 40.2% actually adapted. It was found that farmers were aware to climate change where education, experience, farm assets and institutional services and farmers' linkages have significant positive influence on it. The farmers adopted to climatic vagaries through change crop variety (56.3%), change crop type (38.8%), change planting date (44.6%), plant shaded trees (37.5%), increase/change fertilizer (17.9%), soil conservation (38.4%), increase irrigation (39.7%) and diversification (49.2%). It was also found that awareness, education, landholding, access to credit and farm tools has positive significant effect on the majority of adaptation strategies while distance to output markets has significant negative impact.

Factors from high rank theory such as membership of farm organization, contact with middle man, farmer-to-farmer extension and contact with extension service agent also contribute to the adaptation to climate change. Membership of farm organization has positive and significant relationship with adaptation to climate change though change crop variety and change planting dates. Similarly, contact with middlemen help farmers to keep abreast from awareness about climate change. The contact with middlemen has positive and significance association with awareness about climate change and hence indirectly contributes to the adaptation to climate change. However, farmer-to-farmers extension found negatively significant relationship with change/increase fertilizer and diversification suggesting farmers ties should be strengthen more. Similarly, contact with extension services provider has negative and significant association with change crop variety. This is common in developing countries where extension agents have old traditional knowledge while adoption measures through new knowledge changes with climate changes.

Further it was found that most of adapters are technically more efficient than non-adapters with diversification most and soil conservation least productive. Adaptation strategies such as change crop variety, change crop type and change planting dates have positive and significant impact on yield of wheat crop. Hence, adaptations can increase the food products. However, adaptation process is slow due to some constraints such as lack of resources and information about climate change. The study recommends that government should create awareness through information system to gear-up the adaptation process and build farmers' adaptive capacity with monetary incentives. The study also recommends that training need analysis should be done for updating the extension agents' knowledge about agricultural practices. Access on marketing of produce has positive relationship with all the adaptation strategies while significant associations with majority of these strategies. Therefore,

the study recommends that the government should provide the access of farmers to marketing of produce.

There some limitations in the current study. For instance, study only found the efficiencies of adapters and non-adapters however future research requires to see the benefit cost analysis of each adoption measure. The study compare the efficiency of diversification through mango-wheat intercropping and wheat monoculture but future research requires to compare the efficiencies of mango monoculture, wheat monoculture and mango-wheat intercropping.

Keywords: adaptation strategies; climate change; technical efficiency; vulnerability; Punjab, Pakistan.

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Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia
sebagai memenuhi keperluan untuk Ijazah Doktor Falsafah

STRATEGI ADAPTASI PERUBAHAN IKLIM DAN KESANNYA TERHADAP PENGELUARAN PERTANIAN DI PUNJAB, PAKISTAN

Oleh

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Jun 2017

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Perubahan iklim (peningkatan suhu dan corak hujan yang tidak menentu) telah membawa perubahan yang mungkin kekal kepada sistem ekologi, biologi dan geologi planet kita. Salah satu cara untuk menangani perubahan iklim adalah adaptasi kepada situasi tersebut. Kajian lampau telah mendapati bahawa kesan buruk daripada perubahan iklim dengan mudah akan diselesaikan oleh adaptasi kepada perubahan iklim tersebut. Tetapi, bagaimana mengubah strategi adaptasi yang berkesan sebagai tindak balas kepada perubahan cuaca adalah menjadi persoalan kritikal yang dihadapi para petani di seluruh dunia terutamanya di negara-negara membangun. Kajian lampau telah mendapati keberkesanan adaptasi strategi berdasarkan persepsi awam terhadap petani tetapi kita tidak boleh secara umum menerima kaedah ini kerana persepsi adalah berbeza dari rantau ke rantau dan dari orang perseorangan. Kajian ini di menilai teknik adaptasi berdasarkan kecekapan sebenar setiap langkah yang diambil. Terdapat pelbagai sosio ekonomi, demografi dan institusi faktor-faktor yang mempengaruhi kesedaran petani dan strategi adaptasi untuk iklim perubahan itu lagi perlu diterokai. Kajian di tangan mendapati faktor penentu ini dalam konteks Pakistan.

Teknik persampelan rawak menyenai peringkat yang pelbagai telah digunakan untuk pengumpulan data. Pada mulanya kami memilih Punjab bagi keseluruhan kajian. Peringkat kedua, kajian ini memilih menyenai Punjab Central (campuran tanaman Faisalabad zon dan Daerah Sheikhupura) dan Selatan Punjab (kapas zon-Multan) Wilayah Punjab di Pakistan. Pada peringkat ketiga Tehsil empat telah dipilih secara rawak (dua dari setiap zon). Pada peringkat keempat kajian dipilih empat Majlis Kesatuan yang dipilih secara rawak dari setiap daerah. Peringkat kelima dua buah kampung telah dipilih dari setiap Majlis Kesatuan secara rawak. Peringkat keenam dan terakhir 7 petani telah dipilih secara rawak. Oleh itu, saiz sampel keseluruhan kami adalah 224 dan data yang dikumpulkan semasa Julai 2016 untuk Ogos 2016.

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Bagi analisis lanjut, kajian menggunakan Model logistik binari faktor yang mempengaruhi kesedaran dan strategi adaptasi untuk cuaca berubah manakala two stage least squares digunakan untuk mendapatkan kesan adaptasi strategi hasil tanaman gandum. Di samping itu, penerima dan bukan penerima untuk perubahan iklim telah dipisahkan bagi setiap strategi di peringkat ladang. Data Envelopment Analysis digunakan untuk setiap penerima dan bukan penerima perubahan cuaca untuk mengira tahap kecekapan mereka.

Menggunakan teori tindakan yang dinyatakan sebagai tiga peringkat penyesuaian, mendapati bahawa 71.4% petani merasai perubahan cuaca dan di mana 58.5% petani merancang untuk menyesuaikan diri manakala 40.2% sebenarnya mengadaptasi. Ia telah didapati bahawa petani memang tahu tentang perubahan cuaca, di mana pendidikan, pengalaman, aset ladang dan perkhidmatan institusi serta keahlian Pertubuhan Peladang mempunyai pengaruh positif di atasnya. Petani yang menyesuaikan diri dengan iklim melalui perubahan pelbagai tanaman (56.3%), menukar jenis tanaman (38.8%) menukar tarikh (44.6%) penanaman, menanam pokok teduh (37.5%), peningkatan/perubahan baja (17.9%), tanah pemuliharaan (38.4%), meningkatkan saliran (39.7%) dan mempelbagaikan (49.2%). Juga didapati bahawa kesedaran, pendidikan, saiz ladang, kedapatan kredit dan ladang mempunyai kesan besar yang positif ke atas majoriti strategi adaptasi manakala jarak untuk keluaran ke pasaran mempunyai kesan negatif yang amat ketara.

Faktor-faktor dari teori high rank seperti keahlian pertubuhan ladang, hubungan dengan manusia pertengahan, lanjutan petani-petani dan hubungan dengan agen perkhidmatan penegmbangan juga menyumbang kepada adaptasi kepada perubahan iklim. Keahlian pertubuhan ladang mempunyai positif dan hubungan yang bererti dengan penyesuaian perubahan iklim walaupun perubahan kepelbagaian tanaman dan perubahan tarikh penanaman. Begitu juga, hubungan dengan peraih membantu petani untuk mengikuti perkembangan dari kesedaran tentang perubahan iklim. Perhubungan peraih mempunyai perkaitan yang positif dan kepentingan dengan kesedaran tentang perubahan iklim dan dengan itu secara tidak langsung menyumbang kepada adaptasi kepada perubahan iklim. Walau bagaimanapun, khidmat pengembangan petani ke petani mendapati hubungan negatif yang signifikan dengan baja perubahan/peningkatan dan kepelbagaian yang mencadangkan hubungan petani harus menguatkan lebih. Begitu juga, hubungan dengan pembekal perkhidmatan lanjutan mempunyai perkaitan yang negatif dan signifikan dengan kepelbagaian tanaman perubahan. Ini adalah biasa di negara-negara membangun di mana ejen penegembangan mempunyai pengetahuan tradisional yang lama manakala penggunaan langkah-langkah melalui perubahan pengetahuan baru dengan perubahan iklim.

Selanjutnya didapati bahawa kebanyakan penyesuaian adalah teknikal yang lebih cekap daripada penyesuai dengan kepelbagaian kepakaran. Tempahan dan tanah pemuliharaan-kurangnya produktif. Adaptasi strategi seperti menukar kepelbagaian tanaman, perubahan jenis tanaman dan perubahan tarikh penanaman mempunyai kesan yang positif dan signifikan ke atas hasil tanaman gandum. Oleh yang

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demikian, adaptasi dapat meningkatkan produk makanan. Walau bagaimanapun, proses adaptasi adalah perlahan disebabkan beberapa kekangan seperti kekurangan sumber dan maklumat mengenai perubahan iklim. Kajian ini mengesyorkan bahawa kerajaan patut mewujudkan kesedaran melalui sistem maklumat untuk gear-up proses adaptasi dan membina kapasiti mudah suai peladang dengan insentif kewangan. Kajian juga mencadangkan bahawa analisis keperluan latihan yang perlu dilakukan untuk mengemaskini pengetahuan ejen pengembangan mengenai amalan pertanian baik. Capaian pada keluaran pemasaran mempunyai hubungan positif dengan semua strategi adaptasi. Oleh itu, kajian ini mencadangkan bahawa kerajaan perlu menyediakan akses untuk petani bagi pemasaran hasil.

Terdapat beberapa masalah dalam kajian semasa. Sebagai contoh, kajian hanya mendapati kecekapan penerima dan bukan penerima perubahan cuaca. Kajian masa depan memerlukan penyelidikan analisis faedah kos setiap langkah penerimaan impak perubahan cuaca. Kajian ini membandingkan keberkesanan kepelbagaian melalui mangga-gandum intercropping dan gandum monoculture tetapi memerlukan kajian masa depan yang membandingan kecekapan monoculture mangga, monoculture gandum dan mangga-gandum intercropping.

Kata kunci: penyesuaian strategi; perubahan iklim; kecekapan teknikal; kelemahan; Punjab, Pakistan.

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I certify that a Thesis Examination Committee has met on 9 June 2017 to conduct the final examination of Ghulam Mustafa on his thesis entitled "Adaptation Strategies to Climate Change and their Impact on Agricultural Production in Punjab, Pakistan" in accordance with the Universities and University Colleges Act 1971 and the Constitution of the Universiti Putra Malaysia [P.U.(A) 106] 15 March 1998. The Committee recommends that the student be awarded the Doctor of Philosophy.

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LIST OF ABBREVIATIONS

BAP	Biodiversity Action Plan
BURs	Beinnial Update Reports
CBD	Convention on Biological Diversity
CC	Climate Change
CDM	Clean Development Mechanism
CITES	The Convention on International Trade in Endangered Species of Wild Fauna and Flora
CRS	Constant Return to Scale
CTCN	Climate Technology Centre and Network
DEA	Data Envelopment Analysis
DMU	Decision-making unit
EIA	Environmental Impact Assessment
FOs	Farm Organization
FY	Financial Year
GDP	Gross Domestic Product
GHG	Green House Gas
GOF	Goodness-of-Fit
GOP	Government of Pakistan
GSL	Growing Season Length
IEE	Initial Environmental Examination
NAPs	National Adaptation Plans
NAMAs	National Appropriate Mitigation Actions
NDMP	National Disaster Management Plan
NGOs	Non-government Organizations

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PAK-EPA	Pakistan Environmental Protection Agency
REDD+	Reducing Emissions from Deforestation and Forest Degradation
R&D	Research and Development
SE	Scale Efficiency
SLM	Sustainable Land Management
TAP	Technology Action Plan
TE	Technical Efficiency
TNA	Technology Needs Assessment
UNDP	United Nation Development Program
UNFCCC	United Nations Framework Convention on Climate Change
UNCCD	United Nations Convention to Combat Desertification
UNO	United Nations Organizations
VRS	Variable Return to Scale
WWF	World Wide Foundation

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CHAPTER 1

INTRODUCTION

1.1 Background of the Study

Climate change (CC) has brought about possibly permanent alterations to our planet's ecological, biological and geological systems. Pakistan is also not exception where farmers are likely to experience the food insecurity of many rural households. It is expected that Pakistan would be one of the most affected country by CC among South Asia countries as forecasts suggest that future temperatures in the region will increase by 2-3 ^{0}C between years 2046 and 2065. The nature of Pakistan rainfall climatology differ and erratic significantly across the country, with estimates showing that average annual rainfall will decrease over time (Stocker, Dahe and Plattner, 2013). The vulnerability of CC has recently been highlighted by the experience of heavy flooding in 2010, 2011, 2013 and 2015 in Pakistan. The key question for Pakistan's economy is whether farm-level adaptations are enough to cope with the potential effects of CC on future crop productivity?

Pakistan lies in arid to semi-arid region with 68 million hectares of land lying in regions where the annual rainfall is less than 300 mm. Almost 50% Pakistan's land area is at risk due to CC and 25% of land area, which is suitable for intensive agriculture, is threatened by flood, waterlogging, salinity, loss of organic matter, wind and water erosion. Seven great Asian rivers are in danger due to climate change as these have been fed by Himalayan glaciers. And, it is expected that these glaciers would completely melt down in the next 50 years. Moreover, due to their socioeconomic fragility and geographical location developing countries are the ones that most vulnerable to climate change (GOP, 2016 and Zaffar and Khan, 2015).

1.2 Agriculture in Pakistan

Agricultural is the backbone of the Pakistan economy with 42.3% labour force attached to it. Throughout its history since independence in 1947, agriculture in Pakistan has been the mainstay of the economy. This sector contributed 19.8% of Gross Domestic Product (GDP). However, during Financial Year (FY- Pakistan's financial year is from June to June) 2016, the performance of agriculture sector remained dismal and posted negative growth of 0.19%, while it was 2.53% during the same period last year (GOP, 2016).

There are two principal crop growing seasons in Pakistan, namely the "*Rabi*" or winter crops (Rabi means spring) refer to agricultural crops sown in autumn and harvested in the winter season or simply crops sown during October to December and are harvested during March to April; and "*Kharif*" or summer crops (Kharif means autumn), the sowing season of which begins in April to June and harvesting

during October to December. Wheat, mustard, barley, tobacco, gram, lentil and rapeseed are "*Rabi*" crops while cotton, sugarcane, rice, maize, mash, mong, jowar, bajra and barseem are "*Kharif*" crops.

The agriculture sector is divided into four sub-sectors such as crops, livestock, forestry and fishing. First sub-sector (crop sector) depicted a decline of 6.25% growth; however, other three sub-sectors (livestock, forestry and fishery) showed positive growth of 3.63%, 8.84% and 3.25%, respectively.

The crops sub-sector further categorized according to crop-type such as; (1) important or major crops (Wheat, paddy, maize, cotton and sugarcane), (2) other or minor crops (Tobacco, Rapeseed & Mustard, Barley, Gram, Jowar and Bajra) and (3) cotton ginning. These entire three sectors remained negative as it posted a growth of -7.18%, -0.31% and -21.26%, which impacted negatively on crops. As a result, it became the reason for the negative growth of agriculture sector in last two decades except FY 2000-01 (GOP, 2016).

Furthermore, clear picture of growth rate according to crop-type is given Table 1.1 (rows 4, 5 and 6). As compared to negative growth of 0.52% in FY 2015, important or major crops with negative growth of 7.18% accounts for substantive decline in cotton production (27.83%), rice production (2.74%) and a small reduction in maize production (0.35%) contributed 23.55% in agricultural value added in FY 2016. Although production of sugarcane and wheat witnessed a positive growth of 4.22% and 1.58%, respectively, as compared to the same period last year. Agriculture value added 11.53%, other crops or minor crops witnessed a decline 0.31% during FY 2015-16 in contrast positive growth of 3.09% during the same period last year. This is due to the fact declines 12.49%, 9.56% and 2.48% in the production of pulses, oilseeds and fruits, respectively. With substantive decline (27.83%) in cotton production, cotton ginning could only get the share of 2.32% in value added by agriculture in FY 2016. With enormous decline 21.26% in FY2016, cotton production suffered badly compared to 7.24% during the same period last year (GOP, 2016).

The livestock, fishing and forestry sectors' growth were recorded as 3.63%, 3.25% and 8.84% during FY 2016 as compared to 3.99%, 5.75% and 10.43% during the same period last year. Moreover, these sectors share in agriculture is 58.55%, 2.17% and 2.06%, respectively in the livestock, fishery and forestry. The agriculture and its sectors' growth can be seen in Table 1.1.

Table 1.1 : Agricultural Growth in Pakistan, 2010-2016

Sector	2010	2011	2012	2013	2014	2015	2016
Agriculture	0.23	1.96	3.62	2.68	2.50	2.53	-0.19
Crops	-4.16	0.99	3.22	1.53	2.64	1.04	-6.25
i. Important Crops	-3.74	1.50	7.87	0.17	7.22	0.52	-7.18
ii. Other Crops	-7.24	2.27	-7.52	5.58	-5.71	3.09	-0.31
iii. Cotton Ginning	7.29	-8.48	13.83	-2.90	-1.33	7.24	-21.26
Livestock	3.80	3.39	3.99	3.45	2.48	3.99	3.63
Fishing	1.40	-15.20	3.77	0.65	0.98	5.75	3.25
Forestry	-0.07	4.76	1.79	6.58	1.88	-10.43	8.84

Agriculture Growth Percentage (Base =2005-06)
(Source: GOP, 2016)

1.2.1 Yield, Production and Area of Wheat, 2002-2016

Wheat contributes 2.0% of agriculture GDP and 9.9% value added in agriculture (Government of Pakistan, 2016). It is the staple food of Pakistan like many other countries. Good production in wheat ensures food security in Pakistan to a great extent. During world food crises in 2008-09, Pakistan insulated from this crisis because most of the rural people store grain for a whole year after harvest.

Table 1.2 : Yield, Production and Area of Wheat, 2002-2016

Years	Yield (Kgs/Ha)	Production (000 Tonnes)	Area (000 Ha)
2002-03	2388 (5.6%)	19183 (5.2%)	8034 (-0.3%)
2003-04	2375 (-0.5%)	19500 (1.6%)	8216 (2.3%)
2004-05	2568 (8.1%)	21612 (10.8%)	8358 (1.7%)
2005-06	2519 (-1.9%)	21277 (-1.6%)	8448 (1.1%)
2006-07	2716 (7.8)	23295 (9.5%)	8578 (1.5%)
2007-08	2451 (-9.8%)	20959 (-10.0%)	8550 (-0.3%)
2008-09	2657 (8.4%)	24033 (14.7%)	9046 (5.8%)
2009-10	2553 (-3.9%)	23311 (-3.0%)	9132 (1.0%)
2010-11	2833 (11.0%)	25214 (8.2%)	8901 (-2.5%)
2011-12	2714 (-4.2%)	23473 (-6.9%)	8650 (-2.8%)
2012-13	2796 (3.0%)	24211 (3.1%)	8660 (0.1%)
2013-14	2824 (1.0%)	25979 (7.3%)	9199 (6.2%)
2014-15	2726 (-3.5%)	25086 (-3.4%)	9204 (0.1%)
2015-16	2752 (0.9%)	25482 (1.6%)	9260 (0.6%)

Note (%) = percentage change
(Source: GOP, 2005, 2009, 20013, 2016)

Yield, production and area of wheat increased from 2007-08 till 2012-13 because farmers enjoyed high support price in addition to wheat sowing campaign. The wheat sowing campaign started by the chief minister of Punjab with the collaboration of

agricultural universities and extension department in Punjab. Yield and production decreased in 2013-14 and 2014-15 and remained negative in later year to -3.5% and -3.4%, respectively as shown in Table 1.2. An increase growth of 1.6%, wheat production remained 25.482 million tonnes in FY 2016 as compared to 25.085 million tonnes in same period last year. Similar trend can be seen for area of wheat which dominates other crop areas with an increase of 0.6% in 2016 as can be seen in Table 1.2. Production increased from 2002-2016 with an increased in area but yield remained stagnant due to the climate change with addition to traditional agricultural practices as shown in the Figure below. This necessitates the adaption to climate change with latest technology that would enhance the wheat yield.

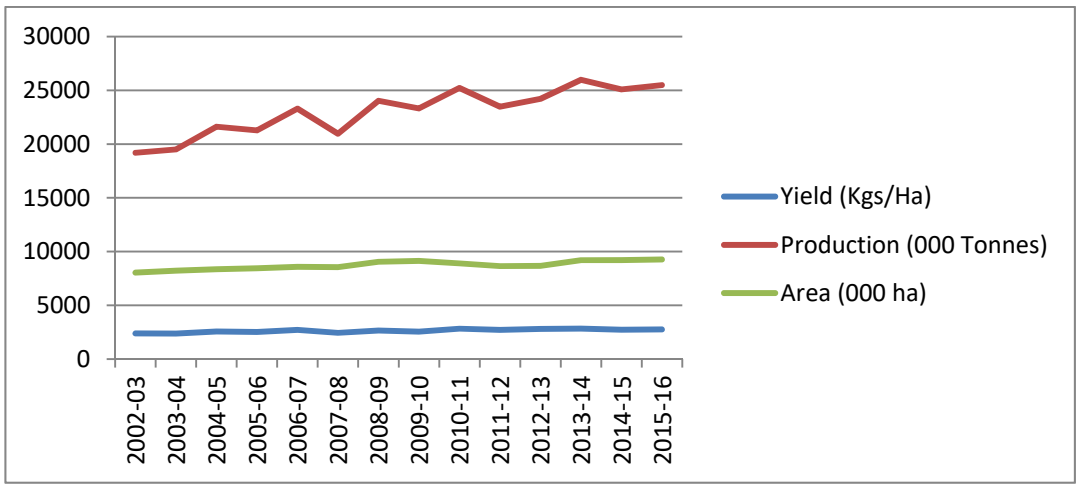

Figure 1.1 : Yield, Production and Area of Wheat Crop, 2002-2016
(Source: GOP, 2016)

1.2.2 Yield, Production and Area of Rice, 2002-2016

Rice (both paddy and basmati) alone feeds almost half of the world. It is second staple food and important cash crop in Pakistan. Wheat-rice is an important crop rotation in the country. The rice accounts for 0.6% in agricultural GDP and 3.1% in value addition in agriculture (GOP, 2016). Sweet and pleasant fragrant Basmati rice is a specialty Gujranwala and Sheikhupura districts of Punjab and famous around the world.

Table 1.3 : Yield, Production and Area of Rice, 2002-2016

Years	Yield (Kgs/Ha)	Production (000 Tonnes)	Area (000 Ha)
2002-03	2013 (0.6%)	4478 (-15.3%)	2225 (5.2%)
2003-04	1970 (-2.1%)	4848 (8.3%)	2461 (10.6%)
2004-05	1995 (1.2%)	5025 (3.6%)	2519 (2.3%)
2005-06	2116 (6.1%)	5547 (10.4%)	2621 (4.0%)
2006-07	2107 (-0.4%)	5438 (-2.0%)	2581 (-1.5%)
2007-08	2212 (5.0%)	5563 (2.3%)	2515 (-2.5%)
2008-09	2346 (6.1%)	6952 (25.0%)	2963 (17.8%)
2009-10	2387 (1.7%)	6883 (-1.0%)	2883 (-2.7%)
2010-11	2039 (-14.6%)	4823 (-29.9%)	2365 (-17.9%)
2011-12	2396 (17.5%)	6160 (27.7%)	2571 (8.7%)
2012-13	2398 (0.1%)	5536 (-10.1%)	2309 (-10.2%)
2013-14	2437 (1.6%)	6798 (22.8%)	2789 (20.8%)
2014-15	2422 (-0.6%)	7003 (3.0%)	2891 (3.7%)
2015-16	2479 (2.4%)	6811 (-2.7%)	2748 (-4.9%)

Note: (%) = percentage change
(Source: GOP, 2002-2016)

Yield and production remained negative in 2006-07 and 2010-11 but witnessed increase growth in 2011-12 with 17.5% and 27.7%, respectively. However, area of rice crop showed a high variability from negative 17.9% to positive 20.8%, respectively in 2010-11 and 2013-14 (GOP, 2007; 2011; 2014 and 2016). It can be observed from Table 1.3 that rice crop showed the cobweb phenomenon as this crop is highly linked with price for being food and cash crop. Moreover, farmers have the opportunity to substitute fodder and maize crops for the rice crop.

During 2015-16, rice was harvested on an area of 2748 thousand hectares with 6811 thousands of the rice production as compared to 2891 cultivated area and 7003 thousand tonnes of production in 2014-15. This showed a decline of 4.9% and 2.7%, respectively in cultivated area and production of the rice. During 2014-15 rice prices decline both domestically and internationally. This caused rice area decreased due to less economic returns to the rice farmers and hence rising costs of production in addition to depressed prices encouraged the farmers to substitute rice with maize and fodder. The heavy rainfall also affected paddy cultivation in July 2015. The abundant rice supply was there due to healthy crop in both FY 2014 and FY 2015. But, the sharp drop in prices in addition to sluggish exports particularly of Basmati mainly reflects pressure of large carryover stock from a record FY 2015 rice harvest that led to a steep rise in rice stocks.

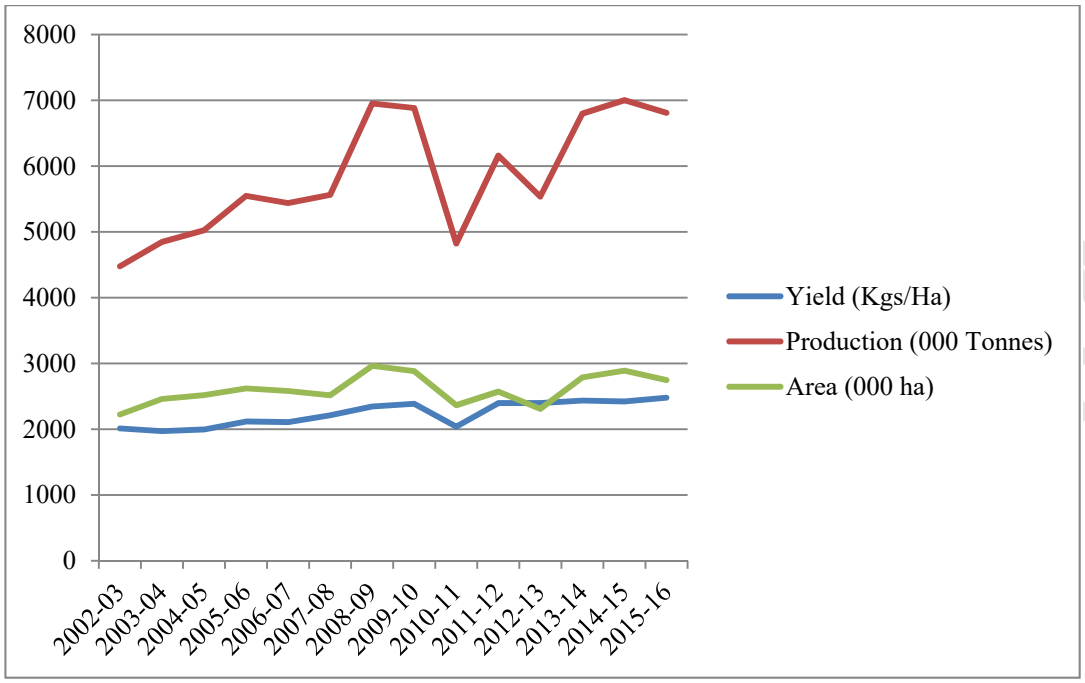

Figure 1.2 : Yield, Production and Area of Rice, 2002-2016
(Source: GOP, 20016)

Pakistan's Basmati rice exports are already facing tough competition from India in the world markets especially United Arab Emirate. As for the export of non-basmati varieties is concerned, Thailand is the largest exporter of it. However, Pakistan has the opportunities to increase export due to severe drought in Thailand. Further, the area, production and yield of rice for the last fourteen years are shown in Table 1.3 and Figure 1.2

1.2.3 Yield Production and Area of Cotton, 2002-2016

Cotton is a very important cash crop for Pakistani farmers and contributes around 5.1% in agriculture value addition and shares 1.0% in country GDP. It is an essential source of raw material to the textile and enables Pakistan textile industry to sustain and expand its base. However, the country has suffered huge financial losses due to yield reduction in cotton crop caused by the severe attack of pink bollworm and prolonged and frequent rains. On the other hand, low prices discouraged farmers from investing in pesticides and fertilizer. The yield, production and area of cotton for the last fourteen years are shown Table 1.4.

Table 1.4 : Yield, Production and Area of Cotton, 2002-2016

Years	Yield (Kgs/Ha)	Production (000 Bales)	Area (000 Ha)
2002-03	622 (7.4%)	10211 (-3.8%)	2794 (-10.3%)
2003-04	572 (-8.0%)	10048 (-1.6%)	2989 (7.0%)
2004-05	760 (32.9%)	14265 (42.0%)	3193 (6.8%)
2005-06	714 (-10.3%)	13019 (-8.7%)	3103 (-3.0%)
2006-07	711(-0.4%)	12856 (-1.2%)	3075 (-0.9%)
2007-08	649 (-8.7%)	11655 (9.3%)	3054 (-0.7%)
2008-09	713 (9.9%)	11819 (1.4%)	2820 (-7.7%)
2009-10	707 (-0.8%)	12913 (9.2%)	3106 (10.1%)
2010-11	725 (2.5%)	11460 (-11.3%)	2689 (-13.4%)
2011-12	815 (12.4%)	13595 (18.6%)	2835 (5.4%)
2012-13	769 (-5.6%)	13031 (-4.1%)	2879 (1.6%)
2013-14	774 (0.6%)	12769 (-2.0%)	2806 (-2.5%)
2014-15	802 (3.6%)	13960 (9.3%)	2961 (5.5%)
2015-16	587 (-26.8%)	10074 (-27.8%)	2917 (-1.5%)

Note: (%) = percentage change
(Source: GOP, 20016)

Further, trend of yield, production and area of cotton crop can be seen in Figure 1.3. Yield of cotton crop remained 585 kg per hectare as compared 802 kg per hectare last year with negative 26.8% in 2016 growth rate as compare same period last year. Similarly, production remained 10074 thousands bales in 2016 as compared 13960 thousands bales as compared to 2015 and depicted negative growth rate of 27.8%. Whereas with slight decline in area of cotton crop, it remained 2917 thousand hectares in 2016 as compared to 2961 thousand hectare in 2015 with negative growth rate of 1.5% as compared to positive growth rate of 5.5% in the same period last year as can be seen in Table 1.4 and Figure 1.3. Pakistan achieved highest yield growth rate in cotton in 2012 with 12.4% (815 kg per hectare), production growth rate of 42% (14265 thousands bales) in 2005 and area growth rate of 10.1% (3106 thousand hectare) in 2010.

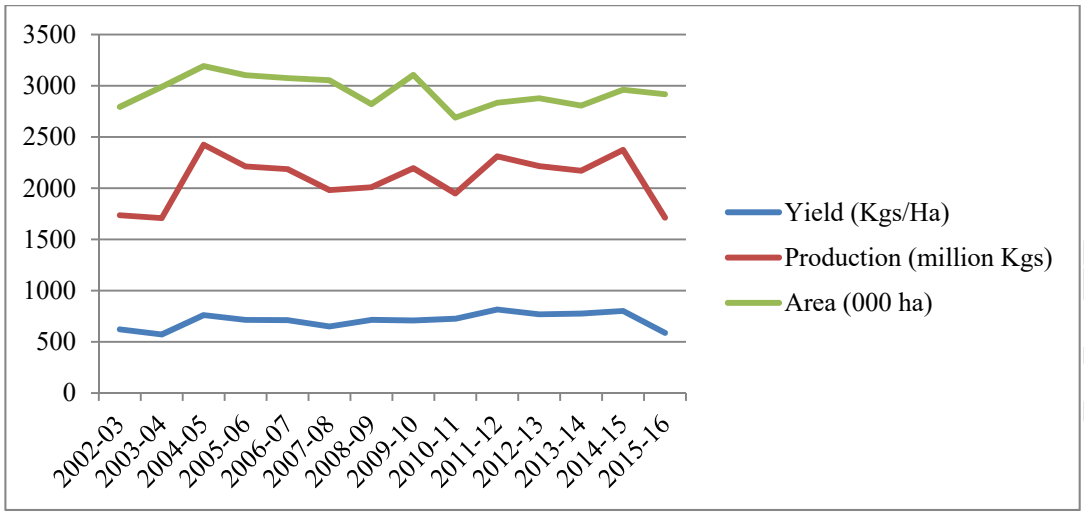

Figure 1.3 : Yield, Production and Area of Cotton, 2002-2016
Note: 1 bale = 170 kg in Pakistan
(Source: GOP, 2016)

1.2.4 Climate Change and Agriculture of Pakistan

The adverse impacts and effects of CC on Pakistan's agriculture could cause havoc in the country with a 30% loss of agriculture production. Even the industrial sector of the country depends upon the agriculture; hence these climate changes have a direct effect on Pakistan's economy (Zaffar and Khan, 2015). Of all the impacts of projected climate change on Pakistan's economic sectors, perhaps the most vulnerable sector is agriculture. For example, as per GOP (2016), an increase in temperature will lead to shortening Growing Season Length (GSL) for rice and wheat crops in all the selected Basmati rice tract and wheat growing districts of Pakistan. Further, crop simulation models based studies show that the rice yield is expected to reduce by 11.4%, 15.8% and 21.5%, respectively by 2020s, 2050s and 2080s under A2 scenarios while it is expected to be declined by 10.4%, 16.5% and 17.8% under B2 scenarios by 2020s, 2050s and 2080s, respectively in Basmati rice tract. Similarly, wheat yields will be reduced by 3.4% to 12.5% in the semi-arid irrigated areas (Sheikhupura and Faisalabad) and 3.8 – 14% in arid (Badin and Hayderabad, Multan and Bahawalpur) areas under both A2 and B2 scenarios towards the end of 21st century. Even the recent floods have caused a loss of 2.6 million acres of land resources whereas the wheat yields are estimated to decline by 6 to 9% and have given rise to food inflation (Zaffar and Khan, 2015). As for cotton is concern, as predicted by Raza and Ahmad (2015) in their study using district level panel data from 1981 to 2010, the impact of CC differs according to life cycle of cotton as well as region to region. In case of Punjab increasing temperature lead to positive net impact on the productivity- i.e. 1 ^{0}C increase in temperature during growing season length would cause the increase in productivity by 2.6%. However, rise in the temperature by 1^{0}C during vegetative and flowering-fruiting stages of growth would reduce yield by 24.14% and 8%, respectively in Bt and Conventional varieties. While in Sindh net impact is negative with 2.26% reduction of yield with 1^{0}C increase in temperature. Adverse impact of CC (increase in temperature) has been observed in

neighbouring countries. For example, in India the decline in yields of major crops (Wheat, Rice and Maize) were observed due to 1 ^{0}C increase in the temperature is expected to 5% to 20% decline in the yield of wheat, 4% to 20% yield reduction of rice and 32% to 50% reduction in yield of maize, respectively (GOP, 2016). Further, forecasts have revealed that temperature of Pakistan has increased (Abid et al., 2015) as can be seen in Figure 1.4.

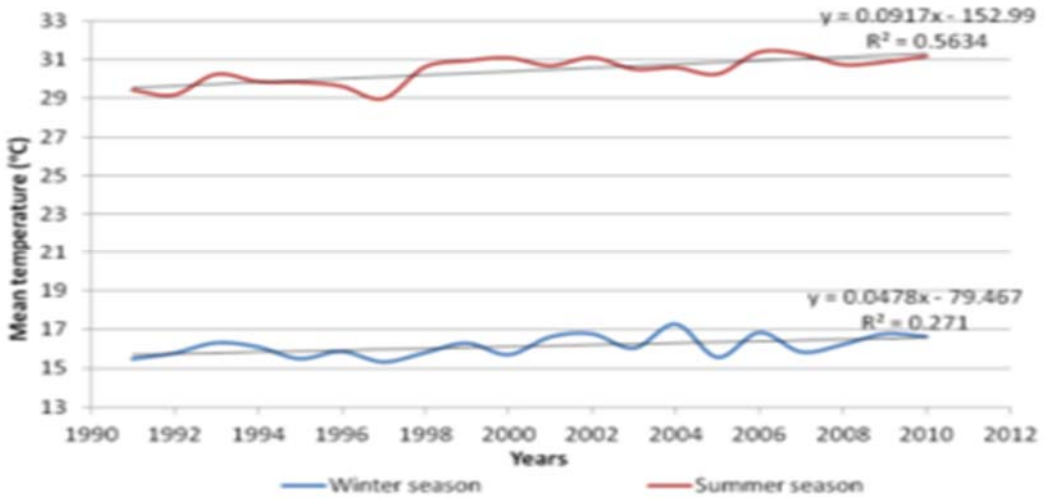

Figure 1.4 : Winter and Summer Temperature of Pakistan, 1990-2012
(Source: Abid et al., 2015)

The results suggest that the aggregate impact of climatic parameters affect-given that the use of technology and management practices remain unchanged- the agriculture differently: impact of CC varies from region to region, impact of CC varies from crop to crop either positively or negatively and changes in rainfall and temperature exerted an overall negative impact on cereal crop in Figure 1.4 and Figure 1.5, respectively.

Moreover, Figures 1.4 and 1.4 shows that trend lines oscillate thus, it is very hard to catch up either temperature/rainfall increased or decreased. That is why trend lines with regression results are given (Abid et al., 2015). The signs of slopes (for both summer and winter temperature/rainfall) show that temperature increased while rainfall decreased.

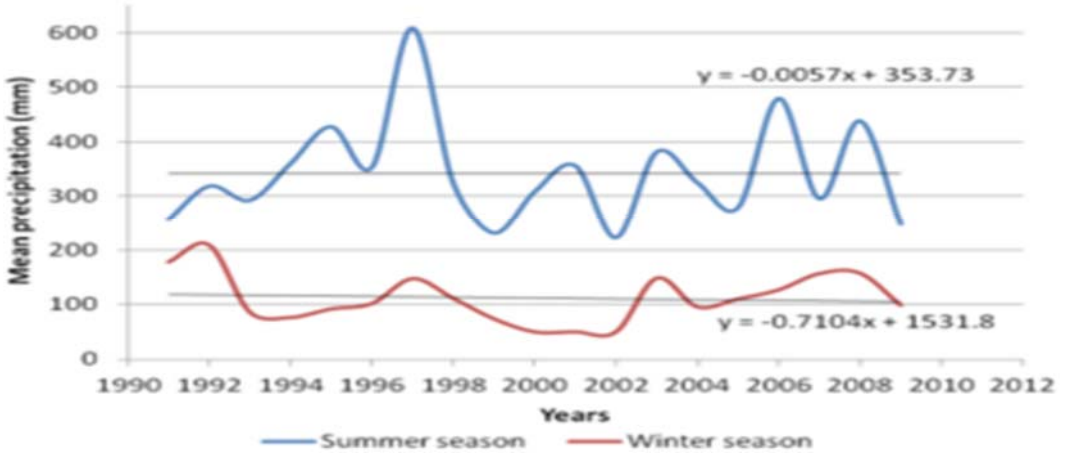

Figure 1.5 : Summer and Winter Rainfall Patterns in Pakistan, 1990-2012
(Source: Abid et al., 2015)

1.3 Adaptation to Climate Change of Pakistan's Agriculture

There are two principal ways to reduce the adverse impacts of CC change: mitigation and adaptation. Mitigation efforts to reduce sources or enhance the sinks of greenhouse gases will take time. Adaptation is therefore critical and of concern in developing countries where vulnerability is high because the ability to adapt is low (IISD, 2007 and IPCC, 2012). For example, Pakistan is facing the brunt of CC related damages at a high cost to its economy despite being a low Green House Gas (GHG) emitter (<1% of global per capita emissions). This situation requires concerted efforts to adapt to the adverse impacts of climate change and relatively fewer efforts to carry out mitigation measures.

A better understanding of farmers' concerns and the manner in which they perceive CC is crucial. This helps to design effective policies for supporting successful adaptation of the agricultural sector. That is why Deressa et al. (2011) and Abid et al. (2015) were on the opinion that in the process of adaptation to CC in agriculture perceiving climatic adversary is the first step. It is also important to have detailed knowledge about the extent and type of adaptation measures being carried by farmers and need for further advances in existing adaptation setups. Hence, understanding how farmers perceive changes in climate, how they get information on vulnerabilities and risk and what factors shape their adaptive behavior are useful for adaptation research. However, it is important to engage stakeholders with different backgrounds, experience and knowledge in reaching and tackling a shared approach to addressing the challenges in framing an adaptation approach (Tompkins and Eakin, 2012; Fünfgeld and McEnvoy, 2011; Weber, 2006; Tompkins et al., 2010; Mertz et al., 2009 and Preston and Stafford-Smith, 2009).

Pakistan is an agriculture based country and CC has potential effects on it but farmers are not even aware of it. Pakistan's agriculture is on decline and farmers' inclination towards the agriculture is not the same as it was a decade ago. They do not know that the current cropping pattern may face desperate changes in the coming 2-3 decades because of ever increasing temperatures. Farmers are still following traditional methods of farming (Zaffar and Khan, 2015). In this situation adaptation to CC becomes necessary.

The choice of adaptation measures by farmers depends on different economic, social and environmental factors (Bryan et al., 2013 and Deressa, 2007). This knowledge will ultimately enhance the credibility of policies and their strength to handle the serious issues being foisted by climate change on farmers (Deressa et al., 2009). Adaptation will require the involvement of multiple players from various sectors such as farmers and local communities, those in the private welfare organizations and agricultural extension services, as well as research and policy (Bryan et al., 2013).

Smit and Skinner (2002) claimed that adaptation approaches need to follow the government level, technological level, and farm level. Government of Pakistan with the help of Non-Government Organizations (NGOs), Inter-governmental NGOs and United Nations Organizations (UNO) such as UNEP, IUCN, WWF and Leads took many initiatives for government level adaptation and mitigation (also called planned adaptation) on environmental issues and has implemented many projects in capacity building on environment rehabilitation and climate change adaptation. Ministry of Climate Change has taken many initiatives to increase the awareness and to change the attitude of people regarding environmental issues as well as strict compliance of government regulations to achieve environmental sustainability targets.

Pakistan adopts a "precautionary principle" and "no regret" policy, which could be taken to mitigate and adapt to climate change, even though there are still scientific uncertainties. Hence, at government level adaptation to climate change is very crucial and government of Pakistan took many initiatives through Pakistan Environmental Protection Agency (PAK-EPA), Biodiversity Action Plan (BAP), National Disaster Management Plan (NDMP), Sustainable Land Management (SLM) with the help of UNDP, Green Pakistan Program, Reducing Emissions from Deforestation and Forest Degradation (REDD+) with the help of UNFCCC, and Forest Carbon Partnership facility with help World Bank as can be seen in Table 1.5. Pakistan also committed to adapt and mitigate against environmental issues through Beinnial Update Reports (BURs), Nagoya Protocol, Clean Development Mechanism (CDM) - a project of UN Framework Convention on Climate Change (UNFCCC) - and Conference and Protocols (UNCCD, CITES, CBD, CMS, Ramsar, Nagoya Protocol, Cartagena Protocol on Bio-safety). Salient features of these initiatives through national and international projects are given as: formulating national policy, strategy and action plan to address and adapt to CC; recommending and discussing position and ranking of Pakistan on issues related to CC in international fora; formulating and coordinating a national implementation plan related to CC;

formulating and coordinating national action plans to meet commitments as agreed upon in the UNFCCC; and serving as the national focal point for external financial and technical assistance for CC programs.

Government also took planned actions for adaptation to CC such as water resources (water conservation strategies, water management and capacity building), forestry and biodiversity (forest management, community participation and habitat conservation), agriculture and livestock (resource management, genetic modification and technology), disaster preparedness such as preparedness, management, forecasting and warning system and recovery and rehabilitation and human health (resource management, monitoring and forecasting of outbreak, training and capacity building and plans and policies (GOP, 2016). These planned actions are very important and even interlinked with technological level adaptation and farm level adaptation discussed in following parts.

To boost up technological adaptation and hence, increase adaptation capacity of farmers, Government of Pakistan also took various adaptations to CC and mitigation programs through National Adaptation Plans (NAPs), Nationally Appropriate Mitigation Actions (NAMAs) and Technology Action Plan (TAP) through Technology Needs Assessment (TNA) with the help of Ministry of Climate Change. With climate public expenditure and institutional review, it established climate change fund, climate change authority, climate change council and task force on climate change. TNA is a systematic approach for carrying out technology needs assessments in order to identify, evaluate and prioritize technological means for both adaptation and mitigation. It also gives methodologies and processes for reducing gaps in enabling frameworks and capacities and for formulating a national action plan to overcome them, as part of overall climate change strategies and plans such as NAMAs and NAPs. With the support of Climate Technology Centre and Network (CTCN), Ministry of Climate Change is carrying out TNA in Pakistan. The objective of this activity is to enable Pakistan to conduct TNA process and produce implementable TAP in line with current best practices as can be seen in Table 1.5.

Studies have found that awarenss to climate change is necessary for adaptation to climate change (Abid et al., 2015; Mandline and Anim, 2011 and Hassan and Nhemachena, 2008). Moreover, climate change is the fact but most of developing countries are in the denial stage of climate change grief whereas science has proven that climate change is totally an anthropogenic factor. This might be the reason government of Pakistan with the help of Ministry of Climate Change and Extension Department of Agriculture is creating the awareness about climate change. Pak-EPA and Mass Afforestation and Tree Planting Campaigns are the two projects particularly focusing on creating/increasing awareness level of Pakistani people.

Table 1.5 : National and International Policies for Adaptation and Mitigation in Pakistan

	Project and Organization	Salient Feature/s	Purpose
1	Pakistan Environmental Protection Agency (PAK-EPA)- GOP	• Through EIA/Monitoring PAK-EPA prepares Initial Environmental Examination (IEE) reports and Environmental Impact Assessment (EIA) reports. • Through LAB/NEQS it curb environmental pollution caused by plastic bags, monitoring industrial areas, dams, certified laboratories, waste companies, traffic, factories pollution and brick kiln. It also handles legal and enforcement. • Create awareness about climate change	Environment Protection
2	Reducing Emissions from Deforestation and Forest Degradation (REDD+)- UNFCCC	• Controlling deforestation • Compensate forest dependent communities	Mitigation
3	Forest Carbon Partnership facility (FCPF)- World bank	• Support developing countries to undertake readiness activities to be eligible result-based payments.	Mitigation
4	Mass Afforestation and Tree Planting Campaigns- Ministry of CC	• To reduce GHGs • To create awarenss about climate change	Mitigation
5	Mangroves for the Future (MFF)-GOP	• coastal zone management for tsunami	Mitigation
6	National Biodiversity Strategy & Action Plan (NBSAP)	• Establishment of provincial focal committees for monitoring, implementation and coordination of CBD in all the provinces	Environment Protection
7	Biodiversity Action Plan	• Reducing biodiversity loss	Mitigation
8	National Disaster Management Plan (NDMP)	• Minimizing the effects of disasters and Increasing the surveillance and forecasting capacity of Pakistan Metrological Department	Environment Protection
9	Sustainable Land Management (SLM)- UNDP	• To combat land degradation and desertification	Environment Protection
10	Green Pakistan Program	• To improve wildlife and forestry sectors	Adaptation Mitigation
11	Nationally Appropriate Mitigation Actions (NAMAs)- GOP	• limiting GHG emissions	Mitigation
12	National Adaptation Plans (NAPs)- Ministry of CC and CTNC	• Conducting TNA	Adaptation

(Source: Own illustration based on Environmental policies of Pakistan)

As mentioned previously agriculture is most affected sector in Pakistan. Despite the government level adaptation and technological level adaptation, farm level adaptation has significance importance for adaptation and even for mitigation. Literature has found that farmer react to climate change adversaries through farm level adaptation through different latest and traditional practices for resilience of agricultural production and even to increase production (Carter, 1997; Tol Fankhauser and Smith, 1998; Selvaraju etal., 2006 and Abid et al., 2015). However, delaying action for adaptation will certainly lead to increased cost and eventually greater risk to the vulnerable communities.

Adaptation reduces the negative impact of climate change (Kurukulasuriya and Mendelson, 2006). Adaptation to climatic variation and farm strategies in Pakistan is already happening (Abid et al., 2015 and Gorst, Groom and Dehlavi, 2015). Advance techniques and latest agricultural practices in order to cope with climate change will be imperative in order to meet and continue meeting the growing agricultural product demand for industrial sectors of Pakistan. However, speed of adaptation is less as compared to the incentive provided by the government. Evidence shows that farming systems and farming technologies within the region have been changing in response to the effects of climate change (Adebayo et al., 2011 and Abid et al., 2015). It is believed that these strategies are supposed to help the farmers improve their personal productivity and efficiency in food crop production and also raise their returns to farming as a business.

Studies further showed that diversification and technology choices affect production efficiency (Donald and Frank, 2002) clearly indicating that adaptation does affect production efficiency. Moreover, studies indicate that farmers have adapted to climate change (Deressa et al. 2009; Deressa and Hassan, 2009 and Corst et al, 2015) are more efficient as compared to non-adapters. Therefore, in this study, it is argued that these adaptive behaviors in responses to climatic factors do affect productive efficiency in Pakistan. To what extend farmers can take advantage through adaption can be measured and compared by technical efficiency of adapters and non-adapters farmers.

1.4 Statement of Problem

Farmers face challenges of tragic crop failures, reduced agricultural productivity, physical damages and diseases to crop due to CC. The declining agricultural productivity in Pakistan is a real challenge and worrisome for Government. On one hand it is impacted the crop that causes physical and monetary losses and on the other hand these variations are affecting farmers awareness about CC through poverty, working in hot sun and health issues.

Studies have found that awareness and/or perception is the first step for adaptation. However, perceptions can be wrong under changing climate as climatic variations take time to be visible whereas the farmers of developing countries are poor and

illiterate. It is very hard for farmers to perceive the climatic variations. Hence, the study in hand argues that awareness about CC can be best initiator for adaptation. Moreover, how information about climate change is generated and distributed at local level, among the farmers, especially with regard to agricultural producer still need to address. Awareness about climate changes of general public has been studied in different countries however; farmers' awareness to climate changes is still need to be addressed as they are most vulnerable to these variations. Some institutional, internal, external and geographic factors significantly contribute to farmers' awareness that need to be explored.

Due to negative impact of climate change it is necessary to adapt to climatic adversaries. Developing countries are most vulnerable to climate changes and even predictions suggest that in future agriculture of developing countries will severely be impacted by climate changes. Hence, adaptation in developing countries becomes more necessary as compared to past. Delay in adaption action can cause adaptation deficit as per IPCC reports and farmers may face increase cost due increase risk and vulnerability.

Two ways are there to reduce the adverse impact of climate changes; adaptation and mitigation. Mitigation whose main function is to reduce the sink of GHG and it takes time while adaptation in hand is the main concern of developing countries. As per Government of Pakistan, it requires concerted efforts to adapt to the adverse impacts of climate change and relatively little efforts to carry out mitigation measures as being low emitter of GHG (<1% of global per capita emission) like any other developing country. Most of Pakistan's policies are regarding mitigation. Lesser intention has been given to adaptation to CC specifically in agriculture. But, case is reverse in Pakistan as well as in other developing countries. Adaptation is the bottom up approach and consider more effective in which whole community involves. Adaptation in agriculture is not only consider reactive but also proactive strategy against climatic variations.

Many studies have been done on adaptation to climate change at farm-level across various disciplines in different regions which explored farmers' adaptive behavior and its factors. Little work has been undertaken so far in Asian countries despite internationally extensive research on adaptation to climate change in the agriculture sector. Similarly in Pakistan, the scope of research linking climate change to agriculture is very restricted and under research. To date, studies on agriculture and climate change in Pakistan have been entirely limited to potential effects of climate change on particular sectors or crops. None of the studies examined farmers' perspectives of adaptation to climate change for major crops of Pakistan. Hence, this study is designed to fill the existing research gap in Pakistan with respect to adaptation to climate change in the major crops. Moreover, little collaborative work has so far focused on the nature and dynamics of farm-level coping and adaptation processes and how they influence responses. Additionally, climate changes is the process with no known ends mean but unfortunately adaptation to climate change was not consider as a process. The study in hand, study the adaptation process and

proved it empirically. There are different factors that affect the farmers' decision to adapt against climatic variations. Many studies considered different factors but there is still need to explore the factors affecting adaptation to CC as climate changes vary from region to region and even between the region and hence, adaptation and their determinants do vary.

Lastly, how effective adaptation strategies are is the crucial question confronting the world. The study in hand, using impact analysis, found the effectiveness of adaptation and shed a light on impact of adaptation on the yield of major crop. The adaptation is the highly positive externality where farmers get less while community gets more. The study in hand also incorporated the ranking of adaptation techniques based on the efficiencies of these adaptation strategies. Previous studies ranked the adaptation strategies based on perception however, perceptions vary from region to region ad even from person to person and hence, one cannot generalize this method. Another technique was there to suggest the adapting the least effective crops and suggesting more climatic suitable crop. One disadvantage of such method is that what if the replacing crop is the food crop and this can create the problem of food insecurity. There is paucity of information on the influence of CC adaptation strategies on production of agriculture because climate even varies in the same region Hence, this study attempts to look at the effects of CC adaptation strategies on major crops production in stated region of Pakistan to fill these existing knowledge gaps through comparing efficiencies of adapters and non-adapter.

In the view of the foregoing concerns, this study strives to develop a quantitative model for the adaptation to CC of Pakistan's agriculture to examine the relationship between a number of important geographical, social, economic and institutional variables and to investigate the likely impacts of these factors on adaptation to CC on Pakistan's agriculture industry. To revamp the Pakistan agriculture industry largely depends on the ability of the government to adopt appropriate policies that can improve the competitiveness of the industry. Thus, it is important to conduct a research on the estimation of determinants regarding awareness of and adaptation to CC strategies and their likely impact on agricultural production in Pakistan. It is envisaged that this study will provide the tool for anticipating and evaluating the likely impact of changes in government policies and decision on the agriculture industry regarding CC and adaptation to CC.

1.5 Research Questions

This study will provide answers to the following questions for better understanding of awareness of and adaptation to climate change strategies and technical efficiencies of adapters and non-adapter of agricultural farmers in Pakistan;

1. To what extent farmers perceive long term changes to the local climate?
2. What are the major coping strategies farmers are using against CC?
3. What are the drivers which encourage farmers to adapt to climate change variability?

4. What are the constraints to adaptation to CC?
5. What are the potential benefits of adaptation to CC? and
6. Is there any difference of technical efficiency scores of adaptors and non-adaptors of climate change variability?

1.6 Objectives of the Study

The general objective is to explore the adaptation to climate change strategy and its impact on technical efficiency of agricultural production in Punjab, Pakistan. The specific objectives are:

1. To explore factors affecting the farmers' awareness about climatic vagaries;;
2. To determine the factors affecting the crop level adaptation to climate change in case of agriculture;
3. To estimate the technical efficiency of adapters and non-adapters to climate change; and
4. To construct the contingency model for adaptation to climate change.

1.7 Significance of the Research

Keeping the above mentioned limitations in the literature, another study is required for development of crop level adaptation to climate change and technical efficiency of the Pakistan's agriculture farmer. In this study not only adaptation to climatic variability of major crops will be discussed but also problem related biasedness, policy assessment and hence, technical efficiency of farm under different scenarios will be discussed.

It is hoped that funding institute i.e. government and private agencies that fund the development of technology to adapt to climate change will be able to take help from this study when determining the net benefit of such funding. Additionally, outreach efforts to growers can take into consideration that, even though feasible technologies to climate changes are available, it may not be economically optimal for growers to adopt it because of high adaptation costs necessitate delayed adoption. Students and environmental agencies who wish to conduct research on efficiency of crops under adaptability to climate change can take help from this study.

1.8 Organization of the Study

Overview of the study is discussed in this chapter with addition to detail information about Pakistan's agricultural sector. Major crops productions, yields and areas were also given this chapter with likely impact of CC on these crops. Losses in yields of these crops due to CC changes were also shown. To overcome these losses government and international policies regarding Pakistan can also be seen this

chapter. Final problem statement, research questions and objectives and significance of the study is provided in this first chapter.

In the chapter two complete theoretical and methodological background of the study will be presented. Different theories of adaptation to CC will be provided in the chapter with most appropriate underpin theory on which this study will be based. Awareness of and adaptation to climate change strategies with their factors influencing them will also be presented in this chapter. Hence, economic benefits of farm level adaptation to CC for adapters will also be discussed in detail in this part. Moreover, models (methodological and empirical) to delineate the factors of awareness and adaptation strategies and efficiencies of the adapters and non-adapters to climate change will also be found in the chapter two. At the end gaps in the literature will be given.

Chapter three will shed a light on theoretical framework, sample size, sampling technique and study area. Based on methodological literature in chapter two the study will give complete methodologies for logistic model for determinants of awareness and adaptation to CC strategies, data envelopment analysis (DEA) to calculate efficiencies of adapters and non-adapters to CC and two stage least square for impact of adaptation on yield of wheat.

In the chapter four socioeconomic, demographic and farm level characteristics of farmers will be presented. Descriptive statistics and frequency destruction of major factors will be given in this chapter. The study also presented farmers' observation regarding CC and hence their awareness about CC. Farmers' awareness about each climatic variable such as drought, flood and temperature will be presented in this chapter. Empirical results of awareness and adaptation strategies' factors through logit model will be presented in this chapter and hence efficiencies of adapters and non-adapters of climatic vagaries. At the end adaptation process to climate change will be proved based on the results in hand.

The chapter five will give the overall summary of the manuscript and policy recommendations for government, funding institutions, international institutions and anthropologists who concern about CC. Limitations of the study and future research will also be presented in this chapter.

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