Schriften zur Internationalen Entwicklungs- und Umweltforschung

31

Herausgegeben vom
Zentrum für internationale
Entwicklungs- und
Umweltforschung
der Justus-Liebig-Universität Gießen

Mirza Nomman Ahmed

A Structural Ricardian Valuation of Climate Change Impacts on Agriculture in Pakistan

PL ACADEMIC RESEARCH

A Structural Ricardian Valuation of
Climate Change Impacts on Agriculture in Pakistan

Schriften zur Internationalen Entwicklungs- und Umweltforschung

Herausgegeben vom

Zentrum für internationale
Entwicklungs- und
Umweltforschung

der Justus-Liebig-Universität Gießen

Band 31

PL ACADEMIC RESEARCH

Mirza Nomman Ahmed

A Structural Ricardian Valuation of Climate Change Impacts on Agriculture in Pakistan

PL ACADEMIC RESEARCH

Bibliographic Information published by the Deutsche Nationalbibliothek
The Deutsche Nationalbibliothek lists this publication in the Deutsche Nationalbibliografie; detailed bibliographic data is available in the internet at http://dnb.d-nb.de.

Zugl.: Gießen, Univ., Diss., 2013

Library of Congress Cataloging-in-Publication Data
Ahmed, Mirza Nomman, 1982-
A structural Ricardian valuation of climate change impacts on agriculture in Pakistan / Mirza Nomman Ahmed. – [1st edition].
pages cm – (Schriften zur internationalen Entwicklungs- und Umweltforschung, ISSN 1615-312X ; Band 31)
ISBN 978-3-631-65014-1
1. Agriculture–Economic aspects–Pakistan. 2. Agriculture–Environmental aspects–Pakistan. 3. Climatic changes–Economic aspects–Pakistan. 4. Crops and climate–Pakistan. I. Title. II. Series: Schriften zur internationalen Entwicklungs- und Umweltforschung ; Bd. 31.
HD2075.5.A64 2013
338.1'3095491--dc23

2013041474

D 26
ISSN 1615-312X
ISBN 978-3-631-65014-1 (Print)
E-ISBN 978-3-653-03910-8 (E-Book)
DOI 10.3726/978-3-653-03910-8

PL Academic Research is an Imprint of Peter Lang GmbH.
Peter Lang – Frankfurt am Main · Bern · Bruxelles · New York · Oxford · Warszawa · Wien

This book is part of an editor´s series of PL Academic Research and was peer reviewed prior to publication.

www.peterlang.com

This thesis is dedicated to my parents.

Sadiqa Naeem & Mirza Naeem

Preface

In his work the author addresses a highly interesting topic from the perspective of agricultural economics and environmental policy. The contribution discusses the impacts of climate change on agriculture in developing countries, particularly in Pakistan. Pakistan's agriculture is considered to be notably vulnerable to changes in temperature, weather extremes and altered seasonal distribution of precipitation. In terms of content, above all emphasis is laid on addressing the question of 'how farmers adapt to changing climatic conditions'. Concerning this only sparse literature is available, especially for agriculture in developing countries. The economic valuation of changes in climate is complicated by the existence of significant temporal and spatial differences and that in many cases appropriate data for an empirically sound analysis is often unavailable. This is where Mr. AHMED's work commences from. On the basis of a comprehensive dataset which has been made available to him by the Pakistan Bureau of Statistics especially for the purpose of the research, the author works out which adaptation strategies farmers in different Agro-Ecological-Zones/ Districts/ Provinces select and which role i.e. annual seasons, water availability, soil quality, infrastructure, available technology, education, household size and the frequent flood catastrophes thereby play. With the help of sophisticated econometric models and a choice modeling approach he identifies the most important explanatory factors for adaptation behavior, derives the respective income effects and simulates the impacts of a future change in temperature and precipitation. In modeling the impacts of climate change on agriculture a prominent role is played by agronomic models, computable general equilibrium models and the Ricardian Approach. The author directs particular attention to the latter and points out the importance that the adaptation strategies of farmers and Local Traditional Knowledge (LTK) have and how the Standard-Ricardian Approach and the Structural-Ricardian Approach are distinguished. While the former rests upon land values as the dependent variable, the latter under consideration of a choice modeling approach tries to explain net crop revenues. For South America and Africa initial and extensive estimations on the basis of the Structural-Ricardian Approach are already available, whereas for South Asia no study exists. This is where the author by using the example of Pakistan breaks new ground.

This work presents a wealth of highly interesting findings regarding the impacts of climate change on agriculture of a developing country, which clearly extends beyond the literature so far. Methodologically as well new ground is broken by simultaneously applying the Standard-Ricardian Model and the Structural-Model on the basis of a uniquely comprehensive dataset to a South Asian developing country. This book distinctly contributes to advances in knowledge from a scientific perspective and can be recommended as reading matter to everyone interested in the topic.

Giessen, September 2013 Prof. Dr. Dr. h.c. P. M. SCHMITZ

Acknowledgements

This book is the outcome of my research engagement at the Justus Liebig University Giessen. I started my PhD studies in 2008 at the department of Agricultural and Development Policy under the supervision of venerated Prof. Dr. Dr. h.c. P. M. Schmitz. I would herewith like to take the opportunity to thank those who guided me through this challenging episode of my life and supported me whenever the ‘downs’ dominated the ‘ups’, and beyond. Foremost, I would like to express my gratitude to the lord of the heavens and the earth for giving me the strength, health, family and wisdom to achieve this milestone. From the bottom of my heart I thank my beloved parents Sadiqa and Mirza Naeem for making me the person that I am and facilitating this great success in every respect. Thank you for your prayers and giving me encouragement and hope whenever I needed it most. Words can’t describe how thankful I am to my beloved wife Usma and daughters Umaiza and Aliza for being endlessly tolerant and giving me the extra time in office that I needed. Thanks to my lovely sister Nadia for her support and advice. Thanks to my niece Serena and my brother (in-law) Shafaat for believing in me. I would also like to thank my parents-in-law Hafeez and Razia Bhatti for their kind support. My academic achievements would not have been possible without the valuable guidance and support of my mentor, teacher and supervisor, honorable Prof. Schmitz. He has paved the way to this success by granting me valuable advice right from the initial period of my academic studies. I thank him for his trust and belief in me. Surely, it is his understanding and support that has made this academic career so seamless and neat, my gratitude to him for trusting in my abilities and granting me a direct job entry at his department. By making me work on challenging tasks he has contributed to uncovering my hidden skills, nurturing my abilities and strengthening my self-awareness. I am also grateful to Prof. Schmitz for granting me the opportunity to coordinate the Climate Change Network for Central Asia. I would also like to acknowledge the support of my dear friends. Foremost, I am thankful to Tasleem Ahmed for having a sympathetic ear for everything that I had on my mind and heart. He always supported me and was always around whenever I needed him, thanks for sharing my grief as well as my joy. For his valuable input and discussions I am grateful to him and also would like to thank him for believing in me and pushing me to realize my true potential. I am also thankful to my friends Arslan, Puran, Ali, Zeeshan, Shahbaz, Jam, Sayeed and Ashok for their support, especially to Puran for helping me prepare for the final PhD defense. Without my dear colleagues this task would not have been possible to achieve, it is their support that has immensely contributed to this accomplishment. Foremost credit goes to respected Dr. Joachim Hesse for his advice, support and fruitful discussions that were instrumental for finalizing this piece of work. I am truly grateful to Viktoriya, Hendrik, Doniyor, Shavkat, Manuchehr, Juliane, Ira, Natasha, Nadia, Margot, Mrs. Bender, Nino, Sabine, Dr. Höher and Eli for making this working environment so wonderful.

Giessen, September 2013 Mirza Nomman AHMED

Table of Contents

List of Figures and Tables

Tables

1 Introduction and Problem Statement

Today there is a broad consensus on the anthropogenic involvement in climate change. The connection between human activity related green house gas emissions and their impacts on temperature and precipitation regimes has been subject of numerous studies. There seems to be enough evidence that changing climatic patterns will impact on economic well-being (DESCHENES AND GREENSTONE, 2007). Harmful effects of climate change are expected worldwide. However, especially to developing countries it poses a far more serious threat as many of their environmental and developmental problems are at risk of being exacerbated (UNFCCC, 2007; CLINE, 2007; MENDELSOHN AND WILLIAMS, 2004). Moreover, developing countries heavily rely on climate sensitive sectors to generate income, most importantly the agricultural sector. Labor in developing countries is highly abundant and relatively inexpensive, thus the economy mainly relies on labor intensive technologies, leaving less room for advanced adaptation options (MENDELSOHN et al., 2001). From a physiographic perspective developing countries located in tropical regions usually have a large share of soils that are unsuitable for agricultural purposes; this additionally increases their vulnerability to potential damage from environmental changes (MENDELSOHN AND DINAR, 1999).

Pakistan, situated in the South Asian region between 24-37°N of latitude and 61-76°E of longitude, with agriculture as its mainstay and responsible for almost 70% of the livelihoods of the population, directly or indirectly linked to the sector and home to a population of approximately 170 million with 32% living below the poverty line, is one such developing country with a high vulnerability towards present and future climate change (ESP, 2007). CRUZ et al. (2007) report evidence on serious increases in the frequency and intensity of extreme weather related events such as extended drought periods, tropical cyclones, flash floods and severe dust storms in the Asian region. In this context, both the frequency and the intensity of climate related extreme events in Pakistan have increased in the recent past. From 1998-2002 the province of Balochistan was hit by severe drought conditions, affecting 84% of the population directly, killing 76% of the province’s livestock and causing mass migration due to widespread hunger and disease. Of late in 2010, the country was struck and devastated in large parts by epic floods. Millions were left homeless and important harvest was destroyed, exacerbating issues of food security. In 2008 out of 309 million tonnes (mt) of carbon dioxide (CO_2) equivalent total Greenhouse Gas (GHG) Emissions, 39% were contributed by the agricultural sector (TFCC, 2010). Despite the fact that the country's share in global GHG emissions is marginal, there is enough reason for concern in future when having a look at the annual percentage growth rate of per capita carbon dioxide emissions from 1990 to 2007 (Figure 1.1).

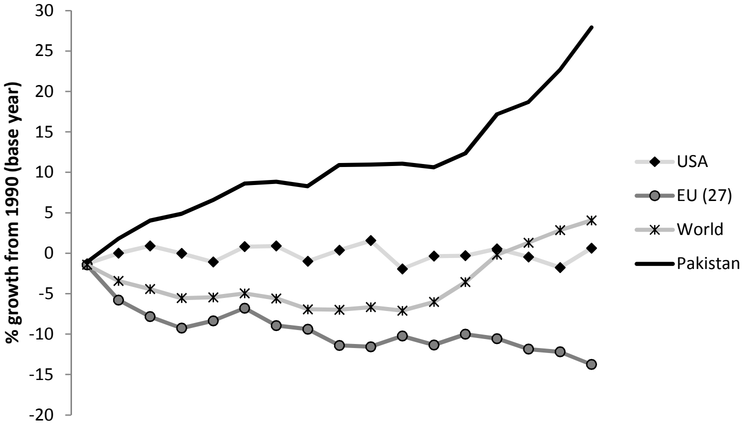

Figure 1.1 Per Capita CO_2 Emissions in selected regions of the world, 1990-2007
Source: own illustration after CAIT 8.0 (CAIT, 2011)

A detailed study conducted by the (Pakistan) Global Change Impact Studies Centre (GCISC) for the period from 1970 to 2000 found significant increases in both, daily minimum and daily maximum Temperatures in 80 percent of the sampled stations (SHEIKH et al., 2009). According to the final report of the country's Task Force on Climate Change (TFCC) published in 2010, mean annual temperature in Pakistan over the period of the last century, in accordance with the global trend, has increased by 0.6 degrees Celsius. Alarmingly, the last fifty years clearly indicate an increased rate of decadal warming, averaging 0.24 degrees Celsius/ decade. Furthermore, data from the Climate Research Unit (CRU) in the United Kingdom relative to the national scale indicate a higher increase in mean annual temperature for Northern Pakistan. In addition, based on data from 1951 to 2000 the TFCC report highlights the general warming trend in mean and maximum temperatures for the summer season (April and May), this throughout the country. For the same time period, the Monsoon Season that spans from July to September has generally shown a decreasing trend in temperatures.

The LEAD Climate Change Action Plan of Pakistan declares the country to be highly vulnerable to climate change. According to the vulnerability index

Pakistan is ranked 12th globally, economic losses of approximately 4.5 billion dollars are anticipated, grassland productivity and consequently crop and livestock yields are expected to suffer severely from climatic change manifested in significantly higher temperatures and decreased surface water availability and changing precipitation patterns (LP, 2008).

In spite of these concerns and forecasts, not many studies have been undertaken in Pakistan on the economic losses and social welfare impacts that are expected to result from climate damage to agriculture, more or less owing to the fact that in the majority of the developing world subsistence farming still remains a pivotal part of agriculture, complicating the economic analysis of environmental change (CHAMBWERA AND STAGE, 2010). Despite an internationally extensive interest in the measurement of the economic impacts of climate change, the empirical research on Asia remains scarce. By using two different climate response functions, one derived from a cross sectional Ricardian study of India (MENDELSOHN et al., 2001) and the other estimated from agricultural-economic simulation results (ADAMS et al., 1999), the Yale University study entitled "Climate Change Impacts on Southeast Asian Agriculture" based on a GIM (Global impact Model) tries to compute the economic impacts of climate change and extrapolates the results to all countries in the region (Bangladesh, Bhutan, Cambodia, China, India, Indonesia, Laos, Malaysia, Nepal, Pakistan, Philippines, Taiwan, Thailand, Vietnam). In summary the study finds that the agricultural impacts of a change in climate are dependent on four factors: the response function, the size of the agricultural sector, the initial temperature and precipitation, and the climate scenario. The study provides some initial evidence on the impact of climate change in this region, predicting losses in the range of two to sixteen billion dollars (mild & extreme scenario) for Pakistan's agriculture until 2100, while at the same time stressing the need for further empirical research in this region, particularly mentioning the need to include more countries than just India, which was used as a proxy for all Southeast Asian Countries. More research is clearly needed to refine the estimates of impacts in this vulnerable region. Potential adaptation measures have to be indentified for both, farmers and governments (MENDELSOHN, 2005). The agriculture sector is facing several issues that can be further aggravated by climate change. Amongst others these problems include: low relative productivity of most crops, slow productivity growth, expansion of cultivable land is no longer possible, fertilizer use is leveling off (less returns to intensification), and productivity growth through technological progress appears to have lost momentum since the green revolution. Increasing temperatures, changes in average precipitation, water stress, monsoon variability, constrained irrigation water availability and increased frequency of extreme events are of particular concern for the agriculture sector and define the magnitude of its vulnerability. Although climate change studies for Pakistan have been carried out, they so far have concentrated on warming science itself, not addressing the economic impacts of climatic change on the agricultural sector. Crop simulation approaches have assessed future impacts on the basis of current yields, not including adaptations made by farmers. Therefore, these estimates from an economic perspective appear to be rather crude, as they assume that farmer's will continue with the same practices, regardless of climate change. Developing country studies are in short supply, especially studies that address the costs of climate change and analyze likely adaptation measures (MARGULIS et al., 2008).

Although models have been constructed to assess the economic impact of global warming on agriculture, a clear consensus on the methodology and impacts has not yet evolved. According to MENDELSOHN (2000) the literature so far (not much has changed) suggests that over the next hundred years global food supplies in aggregate will not be harmed. In an extensive study for the FAO MENDELSOHN (2000) also states that "..*warming is not expected to affect aggregate production in most developing countries*". However, at the same time results suggest that productivity declines will be inevitable, especially in regions where temperatures are expected to increase and precipitation is predicted to decline. Using an extensive literature survey WASHINGTON et al. (2006) found that Asia alongside Africa, the Middle East and South America has been a neglected region as far as climate research is concerned. They concluded, that this shortcoming is detrimental to climate risk assessment, planning of adaptation and decision making in developing countries. For Pakistan a deficit in climate change research has been identified. To this effect government authorities and research institutions have appealed to the wider research community to fill this gap. On the occasion of a conference organized by the World Meteorological Organization (WMO) the director of the Pakistan Meteorological Department (PMD) clearly stressed the need for intensifying research to study the adverse impacts of climate change on different socio-economic sectors such as water resources and agricultural production in Pakistan (ALAM, 2009). Moreover, he has recommended to enhance capacity building in the use, development and modification of mathematical models for use in climate change related studies. Based on research on climate change in a multiplicity of sectors, the Global Change Impact Studies Centre (Pakistan) has called for developing clear cut government policies to counter the adverse impacts from climate change (ALI et al., 2009). Changes in yield have to be studied further as no clear evidence exists in which direction aggregate effects will move. Furthermore, shifting rainfall patterns have to be studied. Detailed impact assessment studies are called for, as without research in this direction adaptation strategies will be hard to formulate (WORLD BANK, 2011). In general, the shortage of studies for Pakistan is also reasoned in the fact that it is highly diverse with respect to climate, socio-economy, and environmental characteristics. Not only on the country level but also on the inter and intra provincial scale.

1.1 Objectives

With reference to the above mentioned problems and gaps in the research on the economic impacts of climate change on agriculture for developing countries, and in particular for Pakistan, this study's mandate is to address these shortcomings by developing two different econometric models to assess the economic impacts of climate change on the country's agricultural sector. By using the Ricardian valuation approach developed by MENDELSOHN et al. (1994) as a basis, first a model is constructed for Pakistan, accounting for a multiplicity of shortcomings of the initial model. A unique model is constructed which is adapted to the country's socio-economic and environmental circumstances. The first model's mandate is to unveil the economic impacts for farmers on the aggregate district scale. For this farm level data is aggregated. The analysis focuses on estimating the impacts and their spatial spread, covering districts, provinces and Agro-Ecological Zones. The standard model thus captures implicit adaptations made by farmers and unravels climate sensitivities. Using a micro-level farm dataset a second two-staged structural model is build to understand the true nature of adaptations for the crop sector of the country. The structural model provides additional insights as it models farm level data using a revealed-preference (choice) approach. After estimating the farm-specific choices given certain climatic and socio-economic features, the model also estimates the expected impacts on farm incomes, conditional on the choice made by the farmer. The study specifically mandates to uncover adaptations that farmers are most likely to make with a change in climate and create options for developing relevant policies to facilitate these beneficial adaptations. Global Circulation Model predictions computed by the IPCC are used to simulate future impacts on farmer choices and on farm incomes. The choice model is constructed in order to explore the results from different modeling perspectives, this in particular to the background of a variety of different approaches that are used for modeling climate impacts on the sector with their respective strengths and weaknesses. This study examines the intensity of the impacts to farmers, tries to pinpoint the different zones and regions in the country that will suffer most and elaborate on farmer adaptations. By considering two different approaches, adaptations outside agriculture shall also be analyzed (*note: land values capture adaptations outside the agriculture sector*). Departing from an intelligent farmer's scenario, where adaptation has ever since taken place, and in conjunction with the research question of how farmers will be affected by Climatic Change and how they will respond, the specific objectives of the study are to identify the impacts of climate change on agricultural production, specifically incomes, to understand the spatial patterns of the impacts, to analyze the seasonality of the impacts (beneficial vs. detrimental impacts), to understand important features that besides climate play a key role in determining agricultural performance, understanding the observed preferences of farmers conditional on climate and other factors, to model their possible future adaptation behavior, and last but not least, to simulate the impacts of climate change on the agricultural sector using GCM scenarios. All these objectives are directed towards the goal of providing a useful starting point for policy interventions on the farm or district level. Given the anticipated changes in climate policymakers and analysts can use these projections to identify policy measures that can make it easier for farmers to switch to new production patterns. Ultimately, the identification of the production patterns that famers are likely to switch to in the wake of global warming shall serve as valuable input for designing a policy guide for planned adaptation by understanding autonomous adaptations.

1.2 Conceptual Approach

Upfront a detailed account on the importance of the Agricultural sector is provided, including geophysical, climatic, hydrological, economic and structural dimensions. This thorough review is followed up by deliberations on the nexus between climate and agriculture, with the aim to clarify interdependencies and present plant-physiological processes that are related to climate and how they can be altered. Ensuing, a historical review on the country's past climate aims at uncovering the vulnerability of the region to specifically climate related extreme events. Subsequent deliberations discuss the different available techniques to estimate the drawn interdependency between agriculture and climate. In fact, the idea is to depict approaches to analyzing the vulnerability of the sector using quantitative research methods. After the review of empirical approaches to the estimation of the economic impacts of climate change, the selected model is presented in detail using a thorough review of existing model related literature. This is followed up by a conceptual description of the standard model. Particular relevance is given to adaptation with its different manifestations in an intersecting literature review. Following this review, and given the weakness of the first model not to reveal specific adaptations, a conceptual description of the advanced approach termed “Structural Ricardian Model” is presented. After presenting the theory and the revised models for the application to Pakistan (model specification), the data and study area are described. Further deliberations present the empirical or econometric strategy, model estimations alongside specification and robustness tests and discussion of results. A final chapter runs climate change simulations to assess the future sensitivity of the sector to global warming. Ultimately, the study concludes by summarizing the key findings, presenting policy implications, addressing shortcomings of the study and highlighting relevant fields where further research attention is greatly required.

2 The Agriculture Sector of Pakistan

Pakistan is a predominantly agricultural country with a diverse climate that can be distinguished into ten broad agro-climatic zones. The topography ranges from high mountain peaks in the north to wide stretching plains in the south. A significant portion of the population depends on the agricultural sector with its backward and forward linkages. To this effect, the country's agricultural policy plays a pivotal role for guaranteeing the functioning of markets and the facilitation of trade, all directed towards the ultimate goal of providing food security for the approximately 170 million inhabitants. Moreover, the country is home to the largest irrigation network that at the same time is also the largest glacial melt fed system worldwide. Key crops are wheat, cotton, rice, sugarcane, maize and vegetables. This chapter is devoted to revealing the importance of the sector by starting off with the explanation of the country's geography and soils and climatic diversity, which is followed by an overview on the water resources. Furthermore, land use patterns, major crops, land reforms and tenurial systems are discussed alongside deliberations on the importance of the sector for the economy, which also includes an overview on agricultural policies.

2.1 Geography and Soils

Pakistan is located in Southern Asia between 24-37°N of latitude and 61-76°E of longitude. The 36th largest country of the world, spreads over a total geographical area of 796.000 km^2 and is bordered by the four independent states India (East), Iran (Southwest), Afghanistan (West) and China (Northeast). In the south the country has a 1046 km stretching coastline on the Arabian Sea (CIA WORLD FACTBOOK, 2011).

The country has various diverse landscapes, ranging from the extremely arid deserts and rocky plateaus of the provinces Balochistan (West) and Sindh (South) and the fertile irrigated areas of the Indus Basin to the high snow-covered mountain peaks (e.g. Godwin-Austen K2 – 8611m) and seven large glaciers of the Himalayan belt. Pakistan geologically expands over the Indian and the Eurasian tectonic plates. The provinces Balochistan and NWFP lie on the Eurasian Plate and the provinces Punjab and Sindh are located on the northwestern corner of the Indian plate (AQUASTAT, 2011). Physiographically the country can be divided into three different regions or two different provinces, respectively (Figure 2.1).

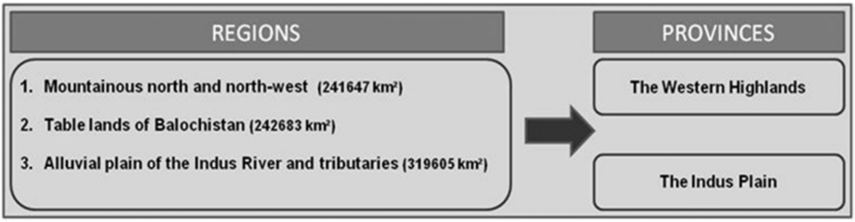

Figure 2.1 Physiographic Division of Pakistan
Source: own illustration after FRAMJI et al. 1982 and AKRAM, 2004

Both physiographic provinces of Pakistan are very distinct. Stretching from the Makran coast in the south to the Pamir Plateau in the north, the Western Highlands cover significant parts of the provinces North-West-Frontier-Province (NWFP) and Balochistan and also some parts of the Punjab province. The Indus Plain is the country's most important region in terms of agricultural production. More than 20 million hectares of land are located in this physiographic province and large quantities of water are available through the Indus River and its tributaries flowing across the agriculturally most important administrative provinces Sindh and Punjab. The majority of the total area consists of plateau and mountain, with a comparatively smaller share of plains and deserts (Figure 2.2).

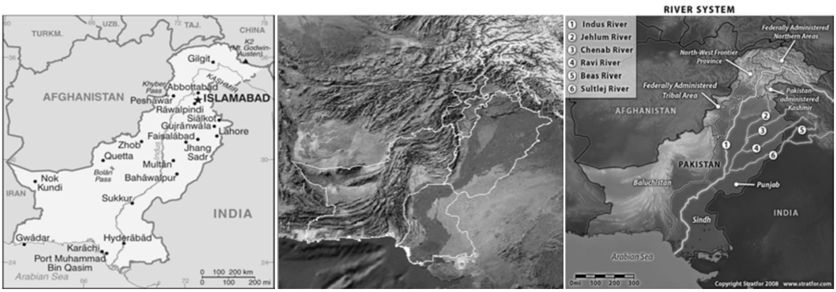

Figure 2.2 Pakistan – Boundaries and Geographical Features
Sources: CIA WORLD FACTBOOK (2011); ESRI (1999); STRATFOR (2008)

The country's diverse landscape and its long latitudinal stretch from the southern coastline with the Arabian Sea to the Himalayan mountain ranges are important factors that have contributed to the soil development and diversity in the country. In this regard, specific factors important for soil development in general can be summarized as follows: time, topography, parent material, flora, fauna, climate, human settlement, water availability and their interactions (PLASTER, 2008). The following review is based on the findings of the study by the Soil Survey of Pakistan (SSP, 1985). As far as soil types are concerned the country can be divided into nine ecologic or geomorphic zones (Table 2.1):

Table 2.1 Soil Related Ecological-Geomorphologic Division of Pakistan

1	Northern Mountainous Region
2	Western Mountainous Region
3	Potwar Upland
4	Sandy Deserts
5	Piedmont Plains
6	Old River Terraces
7	Subrecent River Plains
8	Recent River Plains
9	Indus Delta

Source: AHMAD (1985) and MIAN AND SYAL (1986)

The northern mountainous region over most parts is characterized by higher precipitation levels, lower temperatures and a distinct flora, setting it apart from the rest of the country's terrain. As far as the geological pattern is concerned, the area is split into high mountain ranges and narrow valleys. The valleys normally throughout the year do not freeze, whereas in the high mountains perennial snows are common. The natural vegetation distribution is changing from the foothills of the terrain to the slopes, with open scrub in the lowest parts followed by a coniferous trees zone that lastly transitions into areas of alpine pastures. Considerable soil leaching is observed. The soil types are decalcified with low base saturation. Soil salinity or sodicity is absent. Loamy soils with a high amount of rock fragments are found in the mountain slope zones, whereas the valley soil material is deeper and mostly of alluvial nature. The loamy soils, although high in rock and gravel content are rich in organic matter, whereas the valley soils are generally calcic and cambic.

The western mountainous region is the largest geographic division of the country. The region is characterized by moderately high mountains and wide valleys. Rocky outcrop is most present and therefore the soil parent material contains calcite. The area is generally arid with some semi-arid parts. The central and northern parts of this zone are characterized by harsh winters and relatively mild summers. As a result of several biotic disturbances the vegetation comprises only low shrubs and grasses. This constrained biological activity is also reflected in the soil pattern. The mountain slopes are affected by heavy erosion, the respective soils are therefore thin and patchy. Erosion originating from the mountain slopes gives the intervening valleys their characteristic soil pattern, dominated by a mixture of stones and gravel and out-washed alluvial fill. With distance from the mountain ranges, the soil pattern changes to silty and clayey. The overall soil profile is weakly developed and entirely base saturated. The organic content is low and salinization processes are active. Desert soils (Aridisols) are most prevalent in this particular ecological division. The Potwar upland Zone's surface is characterized by low hilly ranges and flat surface. Loess deposits, sandstone and bedrock based surface material, silty and loamy alluvium form the soil material. Eroding waters have shaped the Potwar zone's landscape. The northern part of this zone is located at the foothill of the outer Himalayan range, with higher amounts of precipitation. Temperatures favor plant growth throughout the year, thus extensive dry-farmed arable cropping is practiced. Soil development differs with the amount of precipitation. In areas closer to the Himalayan Ranges, where the area is wetter, soil development is more pronounced. The flat table lands are characterized by well-developed deep soil profiles. The slopes closer to the mountain ranges show a weaker soil development. The major diagnostic soil features are cambic and calcic horizons. The dominant soil types comprise Inceptisols, Entisols and Aridisols. The Thal, Chagai-Kharan and Thar-Cholistan deserts form the Sandy desert zone, characterized by a ridge valley pattern, which was formed by seasonal winds. A further characteristic is the vegetation made up of scrub and perennial grasses that are mainly used for extensive grazing. The soil material is highly permeable with a fine textural gradation from heavy sandy loam in the subsoil to lighter fine sands in the lower stratum. The area is mainly dominated by aridisols and entisols. Alluvial sediments are the main feature of the vast Piedmont plains zone, which in the upper reaches is dominated by a mixture of sandy loam and gravel. In the middle ranges of the zone, sandy deposits are the most common picture, whereas further down silty sediments dominate. A large part of the Piedmont plains zone is uncultivated, specifically owing to the limited water availability. Seasonal cropping is practiced subject to water availability. Low shrubs and grasses represent the main vegetation in this zone. Water scarcity and low vegetation have led to a weak soil development with occasional presence of high salinity levels. From a soil genetic perspective cambic and calcic horizons are a dominant feature of this zone. Generally aridisols typify this zone as a dominant soil type. A flat surface characterizes the old River Terraces zone, which is formed by river alluvia from the Himalayas. The northern parts are rich in loamy sediments, whereas the southern part is silty. Diversified irrigated cropping is the dominant land use type in this zone, owing to the morphologic features of the soil. Inceptisols, Aridisols, Alfisols and Vertisols are the characteristic soil types of this particular zone. Young soils with a moderate depth are most prevalent in the Subrecent River Plains zone, whereas Recent River plains zone is dominated by Entisols. Dominant soils of the Indus Delta zone include silt loams with a relatively weak structure and saline soils. Re-irrigation in this area is complicated by the rapid rate of re-salinizaton. Aridisols and Entisols are common in this zone. The upcoming chapters are devoted to the analysis of Pakistan's climate and water resources.

2.2 Climate and Water Resources of Pakistan

Pakistan's geographical location gives it a unique climatological character, with great temporal and spatial variation. With summer temperatures averaging 32°C and in parts winter temperatures below the freezing point the country can be classified into 5 different climatic zones. The range is from arid in most parts to humid in the northern region. As far as water resources are concerned, the country heavily depends on glacial melt to feed the Indus River System. In the wake of climate change water scarcity is of growing concern.

2.2.1 Climate

Pakistan is located in the sub-tropics and partially in the temperate region between latitudes 24° and 37°N and longitudes 61° and 76°E. It has a long latitudinal stretch from the Arabian Sea in the south to the Himalayan Mountains in the north. As alteration in latitude is associated with variations in atmospheric composition, this large latitudinal stretch amidst a diverse geography with different topographical characteristics is responsible for a great variability in climatic parameters on both temporal and spatial scales (BARRY AND CHORLEY, 1987). There are many approaches to classifying a regions climate such as empirical, genetic, functional technical, to name a few. A recent study conducted by KHAN et al. (2010) has classified the climate of Pakistan by focusing on the distribution of temperature and precipitation and other relevant climatic variables such as i.e. evapotranspiration. In following, based on the study by KHAN et al. (2010), contributions from the Pakistan Meteorological Department concerning the country's seasons (PMD, 1985) and the study by ZAHID AND RASUL (2011) on the thermal classification of Pakistan, the country's important climatic features shall be framed.

Although other variables are likewise important in the classification of climate, first and foremost priority is given to precipitation and temperature for delimiting climatic boundaries. Thus, using long term observations of monthly and annual means of temperature and precipitation with reference to the KÖPPEN (1936) climate classification, the country can be divided into five different broader zones comprising tropical semi-arid climate, tropical arid climate, cold semi-arid climate, snow forest climate and extreme cold climate. In vast parts of the country in the south and north arid climates are found. Arid climates are generally characterized by significantly low levels of precipitation, with annual total rainfall well below 250 mm. Depending on humidity levels, evapotranspiration, sunshine and the temporal extent or stretch of the seasons several climate subtypes and micro-regions can be distinguished. Thus, for the arid climates, 7 subtypes and 23 micro-regions have been defined (KHAN et al., 2010). In the arid zones the maximum temperature measured in June can exceed 32°C. Average humidity ranges between 35% and 60%, with higher humidity levels recorded for the districts Dera Ismail Khan (D.I. Khan) of the NWFP, Hyderabad of the Sindh province and Skardu and Gilgit of the Pakistan administered Kashmir region. Generally lower humidity levels for the arid climate zone are found for the Balochistan province's districts Khuzdar and Nushki. Mean annual summer temperatures for the arid climates can range between 20°C and 25°C, whereas winter temperatures can vary between 0°C in the northern mountainous region of Kashmir and 15°C in the district of Chitral in the NWFP. Dry summers are encountered in most of the Balochistan province's districts such as amongst others Kalat and Loralai. Precipitation in these regions generally occurs in the winter months. Dry winters are common in most parts of the Sindh province. The semi-arid climates are characterized by a total annual rainfall between 250 mm and 500 mm, comprising parts of the upper Punjab province, lower NWFP and Balochistan. A further division into 4 climate subtypes and 10 micro-regions has been made. Semi-arid climates generally have higher humidity levels between 50% and 65%, such as for instance in the Punjab districts of Faisalabad and Sargodha. Another characteristic feature of the semi- arid zones is that the precipitation or rainfall patterns are much more uniform as compared to arid climates. However, local seasonal maxima exist, that are fluctuating between summer (Punjab and Balochistan) and winter (Northern Areas).

As far as the temperature regimes in the semi –arid climates are concerned, they more or less follow the same path as in the arid zones. Areas with an annual rainfall between 500 mm and 1000 mm, such as parts of the upper Punjab, Kashmir and upper NWFP are referred to as sub-humid, thus these regions are parts of the sub-humid climate zone. The sub-humid climate zone can be further divided into 3 climate subtypes and 6 micro-regions. Generally humidity levels are high with 60-65%. Dry areas do not exist; rainfall is received throughout the climatic zone with highest total annual rainfall recorded for the Punjab province's districts Sialkot and Jhelum and the northern district of Jammu. A considerable part of the rainfall is received in the summer season, winter maxima are for instance found for the NWFP's districts Malakand, Lower Dir and Kohat. Humid climates are found in the extreme north of the Punjab province, NWFP's Malakand Division and both parts of Kashmir. The total annual rainfall ranges between 1000 mm and 2000 mm. Relative humidity varies between 65% and 70%. Generally the northern parts of the country are located in the humid zone including the capital city of Islamabad and further northern situated districts Upper Dir and Balakot. The summer temperatures range between 20°C and 25°C, with occasional maxima exceeding 30°C in June. In the winter season temperatures vary between 0°C and 15°C, with January being the coldest month. Undifferentiated highland climates are encountered in the mountainous north of the country at altitudes above the 2500 m level. These climates are generally characterized by perpetual snow and ice with temperatures around or below 0°C throughout the year. As the name suggests, the climate is rather uniform at these altitudes.

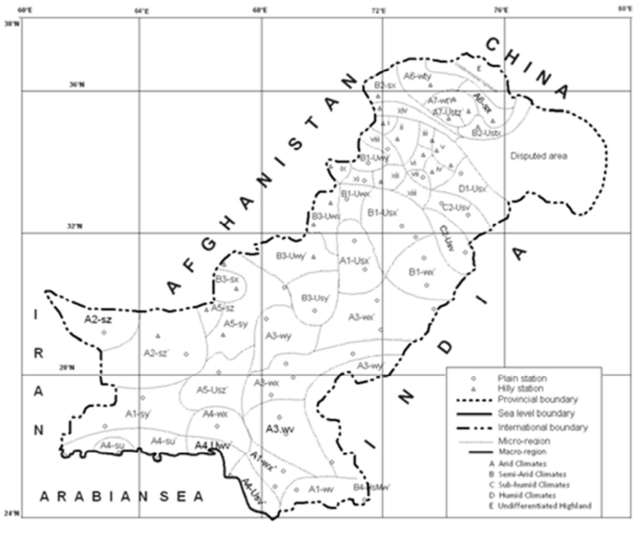

Figure 2.3 Climatic Classification of Pakistan
Source: modified after KHAN et al. (2010)