Using the Ricardian Technique to estimate the impacts of climate change on Crop Farming in Pakistan

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Abstract

This study uses the Ricardian valuation technique to estimate the effect of climate change on the crop farming sector in Pakistan. As a main contribution this paper uses a large household level dataset comprising 3336 farming entities to analyze long-term climate impacts on farm net crop revenues. In particular temperature increases in key growing seasons can be harmful. Annual losses for crop farming ranging from 100-200US$ can be expected. Given an average crop net income of 450US$ per hectare, these impacts can be devastating for farmers. The climate impacts will vary across geographic regions. Temperature is found to be the detrimental factor for farming in Pakistan. Precipitation changes seem to have a rather negligible effect.

1. **Introduction and Problem Statement**

Pakistan is situated in the South Asian region between 24-37°N of latitude and 61-76°E of longitude. The Agricultural Sector in Pakistan still remains the most important sector of the economy, responsible for almost 70% of the livelihoods of the population, directly or indirectly linked to the sector. Having a population of approximately 160 million with 32% living below the poverty line, the country has serious challenges to overcome (ESP, 2007). Especially vulnerability of the poor to food insecurity will increase as an indirect effect of decreasing food crops' yields. The countries climate can be classified as continental with great diversity due to different topology and altitude (KHAN et al., 2010). The agriculture sector consists of crops, livestock, fishing and forestry. Major crops include wheat, cotton, rice, sugarcane and maize. There are two agricultural seasons in Pakistan named "kharif "and "rabi." The kharif season refers to the summer growing period from May to November, with the major crops cultivated being rice, corn and cotton. The rabi or winter growing season runs from November/December through April, with the major crops being wheat, barley and millet (USDA, 2009). Weather and climate are key factors influencing agricultural productivity. For example, weak monsoon rains in 1987 caused large shortfalls in crop production in India, Bangladesh, and Pakistan, contributing to reversion to wheat importation by India and Pakistan (WORLD FOOD INSTITUTE, 1988). 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 has been struck and devastated in large parts by epic floods. Millions have been left homeless and important harvest has been destroyed, exacerbating issues of food security. According to the (North American) National Center for Atmospheric Research (NCAR) the abnormal increase in the monsoon rain in Pakistan and the rest of the subcontinent originated from the warming of the Indian Ocean's surface waters by two degrees Fahrenheit over the last forty years. The air is heated up and holds more moisture which adds approximately eight percent more water vapor into monsoon systems over land stirring up storms and causing them to pull additional water, which then can cause devastation (TRENBERTH, 2010).

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 $ 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). Despite 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. It was not until 2002 that a research center devoted to research on climatic and environmental change could be established in the country, the Global Change Impact Studies Centre (GCISC). The center serves as a think tank in aid of the national decision makers and planners in areas such as climate change and environmental degradation, since 2005 it has been recognized as an autonomous body that alongside the ministry of Environment serves as a Secretariat to the Committee on climate change (UNFCCC, 2008). To date the center in its eight years of existence has produced only three articles published in international journals, none of them addressing the economic impact of climatic change on the agricultural sector specifically considering implicit adaptation. The center has primarily made use of the following simulation models: Regional Climate Models (e.g. RegCM3); Watershed Models (e.g. WatBal); Crop Simulation Models (e.g. CROPGRO).

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 titled "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 main objective of this paper as a part of an ongoing study is to assess the economic impact of climate change on Pakistan's Agriculture using a cross sectional Ricardian Valuation Model and to simulate the expected effects of a selected Global Circulation Model (PRECIS) for the Region (KHAN, 2010).

Using cross-sectional data for the 2007/2008 farming season, this study is a first attempt to assess the economic impact of climate change on agriculture in Pakistan by applying the Ricardian technique. The estimated Ricardian model is then used to assess the marginal effects of climate change and predict the range of impacts on the agricultural sector under one selected climate change scenario for the region. An assessment is also

under- taken on differences in spatial impacts and on the different agricultural systems. The rest of the paper is organised as follows. Section 2 presents the analytical framework for assessing the economic impact of climate change on Pakistan's agriculture. Section 3 discusses the data and the empirical approach. The estimated model is presented in Section 4 and Section 5 concludes the paper.

2. **Analytical framework**

Modeling the economic effects of climate change in general and specifically on the agricultural sector of a country is a formidable challenge. These models have to simultaneously incorporate environmental changes and value judgments. During the last decade two major contributions to evaluate the impact of climate change on the agricultural sector have been made by the production function approach (ROSENZWEIG & IGLESIAS, 1994), and the Ricardian valuation approach (MENDELSOHN et al., 1994).

The production-function approach predicts environmental damage by relying on experimental (e.g. crop yield models such as CERES) and empirical production functions. By changing certain input variables such as temperature and precipitation in an underlying production function the results often indicate severe reduction in yields. However, as this approach does not take the different adaptations into account which farmers make facing changing environmental and economic conditions, it is exposed to critique as it generally tends to overestimate the damages (MENDELSOHN et al., 1994). The Ricardian approach is a cross-sectional model used to study agricultural production by measuring climate change damage as a reduction in net revenue or land, thereby relying on long term adaptation of farmers to climate conditions. The costs and the benefits of different adaptation options that farmers choose are estimated. The core assumption of the Ricardian Approach is that if growing rice is more profitable than growing wheat, and if the climate becomes more suitable for rice than wheat, then those farmers will adapt to the changed climate by drawing on the experiences of rice farmers elsewhere and switching from wheat to rice (POLSKY 2004). In the Ricardian setting a difference in net revenue implies that based on climate variables (while controlling for other influences) the farmer has adapted better to his local climatic conditions. Thus, cross-sectional models are intended to measure farm performances across climatic zones (MENDELSOHN et al. 1994; 1996). In order to estimate the structural relations between historical climate observations and agricultural net-revenue (crops and livestock) and to assess the economic costs of adaptation, econometric models are manipulated with climate change scenarios developed by the IPCC (Intergovernmental Panel on Climate Change). These relations are cross-sectional (i.e., the units of observation in the proposed study are agro-ecological zones, provinces and farms) and the geographic variation in Net-crop or Net-livestock revenue is assumed to be partly regulated by differences in the quality of climate inputs. The key model outputs are potential changes in regional or national cropping patterns, land prices, production, revenues, and profits.
Following are the key model assumptions:

Key model assumptions:
- There is perfect competition in both product and input prices (no public intervention on market and no monopoly)
- The land values have attained the long-run equilibrium associated with each region's climate
- Market prices are unchanged as a result of change in environmental conditions
- Adaptation takes place by all means including the adoption of new crops or farming systems.

Following (MENDELSOHN et al., 1994 and MENDELSOHN and DINAR, 2003), the approach involves specifying a net productivity function of the form:

$$V = \int P_{LE} e^{-\delta t}\, dt = \int \left[\sum P_i Q_i(X, F, Z, G) - \sum RX \right] e^{-\delta t}\, dt \qquad \text{(EQ 1)}$$

Where the variables are defined as follows: P_{LE} is the net revenue per hectare, P_i is the market price of crop i, Q_i is the output of crop i, F is the vector of climate variables, Z is the sets of soil classification, G is the set of economic indicators such as market access and access to capital, X is the vector of purchased inputs (other than land), R is the vector of input prices, t is the time and d is the discount rate. The farmer is assumed to choose X to maximize net revenues given farm characteristics and market prices. Cross-sectional observations, showing spatial variation in normal climate and soil related characteristics can be used to estimate climate impacts on production and land value.

The standard Ricardian model relies on a quadratic formulation of climate:

$$V = \beta 0 + \beta 1\ F + \beta 2\ F^2 + \beta 3\ Z + \beta 4\ G + u \qquad \text{(EQ 2)}$$

Where V is the net revenue per hectare, F is a vector of climate variables, Z is a set of soil variables, G is a vector of socio-economic variables and u is an error term.

In several studies it has been observed that when the linear term is negative and the quadratic term is positive, the net revenue function is U-shaped vice versa hill-shaped. For a thorough discussion of several other possible shapes see KAUFMANN, 1998.

Following (KURUKULASURIYA et al., 2006) in Ricardain Valuation Models the marginal impact of the climate variables *(fi)* on the net revenue/ha is evaluated as follows:

$$E\left[\frac{dV}{df_i}\right] = E\left[\beta_{1,i} + 2 \times \beta_{2,i} \times f_i\right] = \beta_{1,i} + 2 \times \beta_{2,i} \times E(f_i) \qquad \text{(EQ 3)}$$

For showing mean climate level effects on Pakistani Agriculture, the present study uses the mean of the climate variables $E\ (f_i)$.

Pakistan is classified as a developing country with imperfect markets and thus imperfect land value records. Other Ricardian studies for developing countries in the Southeast Asian region such as India (KUMAR AND PARIK, 1998), Sri Lanka (KURUKULASURIYA and AJWAD, 2006) have used net farm/crop revenues per hectare as the dependent variable instead of land values. According to these studies net revenue as a response variable has been found to incorporate all possible adaptations in agricultural activities. The only major concern that has been raised is that adaptation outside the farming sector is lost. As the analysis is focusing on a country dominated by agriculture, outside adaptations therefore might be negligible.

3. Data:

A large dataset is constructed by combining the detailed farm-household level information from the Pakistan Living Standards Measurement Survey (PSLM) 2007-2008 (FBSP, 2010) with climate and soil data from the Food and Agriculture Organization (FAO, 2010) the Pakistan Meteorological Department and the National Oceanic and Atmospheric Administration (USA). The PSLM survey covered all 106 administrative districts (4 provinces) in the country between 2007 and 2008. The dataset includes interviews of 70,000 farm households. Farming households in the sample were administered a detailed farm production (input and output) questionnaire. Based on land ownership 3500 farm household were selected covering all Agro-Ecological Zones in the country. When weighted, these household represent a great majority of the farmers in the country. The dependent variable net crop revenue per hectare is constructed by valuing all variable inputs (except land) and outputs at the market price, as provided by the Federal Bureau of Statistics Pakistan. Total annual farm income in this paper includes annual earnings from crop farming only. The livestock sector could not be included due to data constraints. Additional earnings by hiring out labor and equipment were only partly reported and thus are excluded. The total costs are estimated by considering variable costs associated with hired labor, seeds, fertilizer and chemical sprays, tractor charges, irrigation costs, transport/packaging costs, other incidental farm expenses, rent paid to sharecropped land, costs of maintaining livestock (including feed, veterinary fees, other costs). Net revenues per hectare are defined as the difference between revenues and costs divided by the number of hectares farmed. We combine the household data with data on long-term climate normals. In particular, we rely on FAO data that provides weather station measurements of temperature and rainfall over the period 1947–2004 (excluding some regions). The meteorological station coverage in Pakistan is particularly good, thus almost every district is represented in the dataset provided by the sources mentioned above.

Table 1: Summary Statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
Crop Net revenue per hectare (US$)	3336	474.2645	379.1528	.1877842	2840.1
Summer Temperature	3336	31.82547	3.480764	22.06667	36.96667
Fall Temperature	3336	28.2782	3.197648	19.23333	32.23333

Variable	Obs	Mean	Std. Dev.	Min	Max
Winter Temperature	3336	14.47882	3.859515	3.066667	20.76667
Spring Temperature	3336	19.64061	4.401126	7.566667	25.93333
Summer Precipitation	3336	39.82394	37.6116	4.666667	190
Fall Precipitation	3336	37.75931	36.92341	2	154.3333
Winter Precipitation	3336	13.51659	16.0173	1.333333	75.33334
Spring Precipitation	3336	28.36934	36.07408	2	198.9
Calconic Regosols	3336	.6954436	2.544157	0	10
Calcic Xersols	3336	.1372902	.5057751	0	2
Calcic Yermosols	3336	.3776978	.9953566	0	3
Cambic Arenosols	3336	.5983213	1.426852	0	4
Eutric Cambisols	3336	.5395683	1.551589	0	5
Gleyic Cambisols	3336	.1438849	.9180736	0	6
Haplic Xerosols	3336	.5833333	1.934988	0	7
Haplic Yermosols	3336	.1342926	1.027922	0	8
Rock Outcrop Xerosols	3336	3.188849	4.305397	0	9
Irigated Farms (1/0)	3336	.7946643	.4040073	0	1
Farmtype (Large Scale 1/0)	3336	.4241607	.494289	0	1

Source: author's own composition

The estimated net crop revenue per hectare across Pakistan for the 2007/2008 farming season was US$ 474. Irrigated farms had net revenues of US$ 498 and non-irrigated farms US$ 340. As expected summer temperatures were the highest and the winter temperatures the lowest, at still 14.5 °C. Precipitation in Pakistan is mainly occurring in the Summer and Fall periods, which is closely linked to the Monsoon season in the subcontinent. Although the country is in the monsoon region, it is arid, except for the southern slopes of the Himalayas and the sub-Mountainous tract which have a rainfall from. Balochistan is the driest part of the country with an average rainfall of 21 cm. On the southern ranges of the Himalayas, 127 cm. of precipitation takes place, while under the lee of these mountains (Gilgit and Baltistan) rainfall is hardly 16 cm. Rainfall also occurs from western cyclonic disturbances originating in the Mediterranean (KHAN et. al, 2010). A large part of the precipitation in the northern mountain system is in the form of snow which feeds the rivers. Out of several Soil Classes in the country, 9 have been used in the model based on FAO classifications.

Typical of most cross-sectional regressions are the problems of (i) endogeneity, (ii) heteroscedasticity in the error terms, (iii) multicollinearity among explanatory variables, and (iv) the impact of outliers. The problem with endogeneity was dealt with by estimating a reduced form of the net revenue model rather than the structural model. Multicollinearity, was handled through exclusion of irrelevant and insignificant variables. To estimate the final model and to minimize issues related to heteroscedasticity in the

error terms quantile or median regression was used. The qreg (including median) fits least absolute value models LAV. The objective is to estimate the median of the dependent variable, conditional on the value of the independent variables Qreg additionally corrects for outliers, an issue most prevalent in cross-sectional datasets. The qreg produces a pseudo-R, similar to the R^2 produced by the ordinary regression with the same interpretation (STATACORP, 2003).

The analysis was undertaken by using a step-wise approach. First, a climate only model was estimated. Step by step climate variables were added to assess the impact of climatic influences on net crop revenues in Pakistan. The results of the full model (incorporating climate, soils and hydrology variables) are discussed. Separate analysis has been undertaken for irrigated and non-irrigated farms. With respect to the scale of farming separate models have been estimated for large and small scale farms, although in Pakistan the average farm size is 7,5 acres. Small scale is defined as <5acres and large scale >5.

4. **Discussion of Results**

The estimated models for the full sample and the four types of farm systems are presented in Table 2. As indicated by the results all included climatic and soil variables show a high relevance for explaining changes in crop net revenue per hectare. This effect is also highlighted by the higher pseudo-Rs in the separate models. The estimated models in Table 2 indicate that climate variables have significant influences on crop net revenues in Pakistan. The assumed non-linear relationship between climate variables and farm income is also proven, foremost in the case of precipitation. Generally, with some exceptions the signs of the temperature and precipitation coefficients are robust in the considered models. A majority of the variables in the model is significant, in line with other Ricardian Studies. The coefficients for the fall and winter seasons indicate a positive trend towards farming in Pakistan. These months refer to the winter growing season and the results indicate that higher temperatures in the early part of this farming season could be beneficial to crop growth. Especially the spring temperature is indicating the hill-shaped trend between climate variables and crop revenues. To a certain extent warming could be beneficial to crop growth, but after a certain extent it could be harmful. For the different farm types analyzed, increasing winter season temperatures are indicating a negative trend (Squared Terms), again proving that the fall season is positively impacted by rising temperature, whereas when the hill shaped curve reaches its peak, the effect can be harmful. Higher summer temperatures have a significantly negative impact on farming in Pakistan. The non-irrigated farms are very few in numbers, and mainly use the Rabi season for farming, thus the results are indicating a positive coefficient for these farm types. In general, the different soil types show a positive impact on net crop revenues. Only Xerosols seem to have a negative impact on crop farming in Pakistan.

Table 2: Quantile Regression Results-Full Model

Variable	Full Sample	Irrigated	Non-Irrigated	Large scale	Small Scale
NCR_ha					

Variable	Full Sample	Irrigated	Non-Irrigated	Large scale	Small Scale
TempWin	-30.45378***	252.5566***	236.2392***	259.0011***	49.83401
TempWinSq	.4119793	-11.88261***	-10.47908***	-10.29824***	-3.736398
TempSpring	25.552**	-321.2305***	-533.1066***	-512.1035***	-270.4697***
TempSprsq	-.3729202	10.62565***	15.00001***	13.42958***	8.654189***
TempSumm	-.1877227	-1827.022***	585.1514	-1865.699***	-781.9527
TempSummsq	-.7603019***	25.74671***	-10.13692	27.29318***	12.76566
TempFall	34.13681**	1603.051***	-118.6893	1895.555***	1151.304*
TempFallsq	1.05354***	-24.21865***	3.835133	-30.01983***	-20.7686**
PrecipWin	-3.356994**	25.86544***	26.23644***	34.49252***	32.34692***
PrecipWinsq	.0368041*	-.3787313***	-.3691067***	-.5076098***	-.3977582***
PrecipSpring	4.148803***	5.105675***	.1233202	-9.097222***	-2.603981
PrecipSprsq	-.0118582***	-.0291585***	.0003719	.0109157	.0186949*
PrecipSumm	2.14063***	.4195256	-10.28219***	3.344069*	.166367
PrecipSummsq	.0106257***	.0307895***	.0497468***	-.0170343	.0189918
PrecipFall	.3806731	1.221113	7.285252***	.3281082	-1.097805
PrecipFallsq	-.0118653	-.0232196*	-.0154144	.0264864**	-.0060965
Soil1	-2.303354	-17.2895***	1.114601	-9.805283**	-19.18992***
Soil 2	18.87346				
Soil3	68.72223***	109.9635***	90.93539***	75.7755***	64.56901***
Soil4	7.785727	48.28285***	32.14741*	21.73272**	24.6081
Soil5	3.768431	15.87703	24.87509*	7.175334	-35.30529***
Soil6	41.12074***	7.697767	75.1336***	-51.74192***	24.31734*
Soil7	31.14684***	20.90389***	18.64556**	5.942744	7.179451
Soil8	-19.77325***	-9.548808	7.40753	-26.73133**	-18.28978*
Soil9	1.622691	16.45658***	9.350614	7.361097*	-2.732454
_cons	-848.9486***	7010.188***	-4725.376***	5360.605***	-1772.891
Pseudo-R	0.0760	0.1280	0.1511	0.1266	0.0857
Obs.	3336	2651	685	1415	1921

Source: own composition

Table 3 presents the marginal impacts of a 1°C Temperature increase and a 1mm/month precipitation increase on the net crop revenues per hectare of the respective farm types in the different seasons.

Table 3: Marginal Climate impacts on crop net revenue

	Full Model	Irrigated	Non-Irrigated	Large Scale	Smale Scale
1 °C increase in temperature on crop net revenue (US$/ha)					
Winter Temperature	-18.52	-91.54	-67.21	-39.20	-58.36
Spring Temperature	24.09	96.16	56.11	15.43	69.48
Summer Temperature	-48.58	-188.22	-60.07	-128.46	30.59
Fall Temperature	93.72	233.33	98.21	197.74	-23.29
1 mm/month increase in precipitation on crop net revenue (US$/ha)					
Winter Precipitation	-2.36	15.63	-36.21	20.77	21.59
Spring Precipitation	3.48	3.45	0.14	-8.48	-1.54
Summer Precipitation	2.97	2.81	-6.42	2.02	1.64
Fall Precipitation	-0.52	-0.53	6.12	2.33	-1.56

Source: author's own composition

Higher winter and summer temperatures tend to reduce the income from crop farming. This is explained with the hill shaped behavior of temperature towards crop net revenue. Sowing seasons and months are positively impacted, whereas growing seasons in summer and winter suffer from increased temperatures. The precipitation trend is positive for the spring season, whereas negligible losses are anticipated for the other seasons. Temperature effects in Pakistan clearly seem to be of greater relevance for farming.
In following the aim is to present the marginal impacts calculated by forecasting based on a Global Circulation Model (PRECIS-A2). The model predicts a temperature change of 4.38°C and a precipitation change of 3,5% for Pakistan until 2080.

Table 4: GCM-PRECIS A2 Scenario Forecast for Pakistan, 2080

	Climate Only (present)	Full Model	Irrigated	Non-Irrigated	Large Scale	Smale Scale
4.38 °C increase in temperature on crop net revenue (US$/ha)						
Winter Temperature	-13.01	-67.25	-53.92	-3.16	-61.66	-14.89
Spring Temperature	-9.15	53.35	51.01	-7.76	47.76	17.18
Summer Temperature	-85.22	-85.12	-108.78	21.20	-114.97	14.01
Fall Temperature	134.36	123.07	135.18	-29.72	148.22	-13.21
3.5% increase in precipitation on crop net revenue (US$/ha)						
Winter Precipitation	8.57	22.52	14.68	10.14	16.78	19.44
Spring Precipitation	-4.15	-1.37	0.20	-3.77	-6.96	-3.88

Summer Precipitation	2.47	2.38	3.42	-7.08	2.03	2.94
Fall Precipitation	0.23	-1.22	-2.20	4.81	-0.37	-17.70

Source: author's own composition

The results of the climate simulation indicate high losses for farmers throughout all farming systems, especially the warming in summer and winter will reduce net crop revenues. Increased spring precipitation is expected to be harmful for crop farming in the country, most likely through creating excess-surface-runoff.

5. Conclusion

This study attempted to assess the impact of climate change on crop-farming activities in Pakistan using a Ricardian model that examines how long-term farm profitability varies with local climate, such as temperature and precipitation, while controlling for other factors such as soil types. Estimations were undertaken for a set of different farming system, including irrigated farms, non-irrigated farms, large scale and small scale farms. Additionally, marginal impacts of climatic variables were tested, to assess unit-wise increases on farming activities in Pakistan's crop farming sector. A selected climate scenario was used to predict the extent to which projected climate changes will affect net revenues in 2080. The results indicate that there is a significant difference between the impacts of climate on irrigated and non-irrigated farms. The scale level differences could not be thoroughly assessed, as the main impacting factor remained irrigation in the sample. That is, whether a farm is irrigated or not seems to be more relevant in climate analysis than the scale of the farm. A non-linear relationship between climate and net revenue could be verified. Thus, increases in climate variables seem to be beneficial to crop farming up to a certain extent, but beyond a certain limit the impacts will be clearly negative, as suggested by the results. Especially temperature is detrimental in Pakistani Agriculture. Sowing, harvesting and growing seasons show different responses to climatic change. Different soil types can be important in climate research, as better soils tend to compensate for adverse climatic impacts. For a more detailed overview, the study will have to include all Agro-Ecolgical Zones and test more GCM Scenarios to develop robust assessment. One key issue requiring a deeper insight is the hydrological cycle of Pakistan, especially the availability of water for irrigation will be a key aspect for determining the future impacts of climate change on yields in Pakistan. For glacial-melt-water fed river systems, the differentiation between long-and short term effects will have to be undertaken. Especially, keeping in mind that a developing country like Pakistan is most likely more suitable for adaptation to climate change than mitigation. Further research aims at developing the model and including a set of socio-economic control variables, at this point the main focus was to assess the vulnerability to climatic change, the real extent remains to be tested and evaluated to formulate targeted policies and adaptation measures. Adaptation can include new cropping-patterns, introduction of heat and drought resistant crop varieties, water harvesting, especially in years where weather developments are indicating water shortages from precipitation. Nevertheless, in order to successfully implement adaptation strategies, the respective agencies, such as agricultural extension services will have to be strengthened, their outreach will have to be significantly increased. A closer cooperation between government agencies and research institutions will have to be established, to guarantee a thorough understanding of climate

change and a consequently a sound scientific basis for the implementation of either adaptive or mitigative measures. In this context good governance will have to be ensured, as any additional obstacle to development will consume valuable resources, which could be devoted to tackling climate change.

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