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RESEARCH ARTICLE

Implications of climate change damage for agriculture: sectoral evidence from Pakistan

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Abstract This paper gives a projection of the possible damage of climate change on the agriculture sector of Pakistan for the period 2012–2037, based on a dynamic approach, using an environment-related applied computable general equilibrium model (CGE). Climate damage projections depict an upward trend for the period of review and are found to be higher than the global average. Further, the damage to the agricultural sector exceeds that for the overall economy. By sector, climatic damage disproportionately affects the major and minor crops, livestock and fisheries. The largest losses following climate change, relative to the other agricultural sectors, are expected for livestock. The reason for this is the orthodox system of production for livestock, with a low adaptability to negative shocks of climate change. Overall, the findings reveal the high exposure of the agriculture sector to climate damage. In this regard, policymakers in Pakistan should take seriously the effects of climate change on agriculture and consider suitable technology to mitigate those damages.

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Introduction

It is acknowledged that climate change is a global and long-term problem, which involves complex interactions between climate with the environment, institutions, economic, social and technological processes (IPCC 2001). It is also projected that the scale of seasonal variations in temperatures in many parts of the world will change, due to increases in the concentration of climate-related greenhouse gases (GHGs) (IPCC 2007). The causes of rising atmospheric temperature have been detailed in several studies, which primarily attribute them to human activities related to economic development. There is wide consensus that the earth is becoming more vulnerable to climatic damage, as reported by the Intergovernmental Panel on Climate Change (IPCC) (2011) and other related studies (COP21 2015; Stern 2007; UNFCCC 2015). While the pace and extent of global warming remains contested, time, events and country-specific developments influence climatic effects disproportionately (Moss et al. 2010). However, these effects vary in different parts of the world; for example, in Africa, climate impacts are severe, due to the diverse climatic conditions, the direction of change, availability of resources and the infrastructure to cope with the change (Calzadilla et al. 2013a; Di Falco and Veronesi 2013).

Within South Asia, Pakistan is considered the most vulnerable economy to climate change. It was ranked as the third and sixteenth most vulnerable economy out of 128 countries, according to the German Watch Report (2011) and the Global Climate Change Vulnerability Index (CCVI) for the 2010–2011 period, respectively. By virtue of its geographical location and large arid geographical profile, Pakistan is also highly susceptible to climate change. In addition, temperature increases in the case of Pakistan are expected to be higher than the global average (Griffiths et al. 2005). Since agriculture is the mainstay of the economy,[1] Pakistan is also becoming increasingly vulnerable to climate change as expectations of crop failures are high with rising temperatures and variable rainfalls. This is because global warming negatively impacts tropical and arid crop production, although it enhances agricultural production in temperate regions in the short term. The concerns about sustainable productivity of agriculture in Pakistan further add to the vulnerability of this economy (Sultana et al. 2009). As Cline (2008) points out, climate change has altered the farming system of Pakistan, which, in turn, has affected agricultural productivity, due to the underinvested and subsistence nature of the agriculture sector. The negative effects of climate change for Pakistan appear overwhelmingly to outweigh the positive impacts (Easterling 2007; Stern and Treasury HMs 2006).

The direct vulnerability impacts of climate change, therefore, can be related to the degradation of natural resources. Additionally, there could be some serious indirect damages (Al-Amin and Leal Filho 2014). For agriculture, more specifically, the impacts of climate change can be broken down into two categories: first, the biophysical effects on production and yields and second, the economic outcomes, including price, production and consumption changes (Calzadilla et al. 2013b; Wheeler and von Braun 2013). Consequently, they also disrupt the stability of global supply and demand (Kaiser and Drennen 1993). Among these concerns related to agriculture, Parry et al. (2004) conclude that regional differences in agricultural production are likely to grow stronger over time, despite stable global production. Developing countries, including Pakistan, are expected to suffer more, compared with the developed ones (IPCC 2007), due to their heavy dependence on agricultural activities. Hence, the effects of global warming and climate change are likely to threaten both the welfare of the population and economic development of these countries.

The resilience of agricultural production to climate change is therefore of high importance to Pakistan. As temperature changes guide the state of the climate in a particular region, the nature of agricultural practices can be strongly influenced by the latter. Generally, particular types of farming and groups of crops are considered productive in an appropriate climate. Changes in the mean climate away from the current states may cause discrepancies in productivity and in some cases, the optimum type of farming may change. Higher temperatures thus can significantly impact agricultural productivity, farm incomes and food security in Pakistan. The sustainability and productivity of crops, particularly cereals, are already projected to decrease, due to extreme climate conditions; for example, the crop damages for wheat, rice and maize are 18, 16 and 7 %, respectively (Lal et al. 2011; Sultana et al. 2009). Table 1 lists the major and minor crops of Pakistan, where livestock and fisheries are grouped into meat and milk production. The situation is somewhat worrying because most of the major crops of Pakistan have shown negative growth in production in recent years, implying low productivity (Mustafa 2011).

Climate change and variability undeniably present a challenge to ecology, economy, growth and development. Drought, floods and temperature fluctuations due to climate change can directly affect agricultural operations through damage to crops and livestock (Rasul et al. 2012). Recent extreme events, especially in the last two decades, have often resulted in large crop losses and other flood-related damages. The current observed trends toward increased temperature, precipitation and more extreme events are projected to intensify under future climate change, leading to a higher probability of flooding, and thus increased damages to agricultural production. Accordingly, climate change will substantially affect economic performance. Hence, there exists a correlation between climate change and economic outcomes.

The economic impacts are expected to be large, which then explains why it is necessary to identify which sectors, firms and workers will benefit or lose from which types of climate change. Nonetheless, it is difficult to understand the historical, contemporary and future economic consequences of climate change. Given the sensitivity of agriculture to such change, and its indirect effects on the economy, it is important to examine the effects of climate change on this sector (Ashraf and Iftikhar 2013; Babar and Amin 2014; Baig and Amjad 2014; Maryam et al. 2014; Shakoor et al. 2011; Siddiqui et al. 2012; Sultana et al. 2009).

It is clear from the above discussion that climate change has multiple effects on agricultural production, which makes it a complex phenomenon to study. Unfortunately, little attention has been paid to this sector in Pakistan, despite the fact that it is an important sector for the economy and the evidence that it is strongly exposed to climate and weather patterns. The quantitative impact of climate change on agriculture certainly warrants attention for the case of Pakistan. There is a dearth of research in Pakistan on how climate change impacts downstream agricultural sectors, from a climatic-agro perspective. Hence, the focus of this study is to address this gap in research, specifically by analysing the economic losses (damage) of the agricultural sector following climate change for the period of 25 years. The impact assessment is carried out using an environment-related applied computable general equilibrium (CGE) model of the Pakistan economy, based on the 2012 social accounting matrix (SAM). Since the SAM was constructed for the year 2012, it is also considered the base year for all the simulations. The main contributions of our study are

[1] For 2013–2014, the contribution of agriculture to the Pakistan economy was 21 % to the gross domestic product (GDP) and 44 % to employment.

Table 1 Major and minor crops of Pakistan

S. no.	Major crops	Minor crops	Meat and milk production
1	Rice	Potato	Livestock
2	Wheat	Fruits	Fisheries
3	Cotton	Other crops	
4	Pulses and grams	Vegetable and condiments	
5	Tobacco	Other productions	
6	Sugar cane	Forestry	
7	Oil seed		

twofold. First, it quantifies the impact of climate change on all the downstream agricultural sectors of Pakistan using a rigorous modelling exercise. The types of damages caused by climate change are disaggregated for Pakistan's major and minor crops, as well as for the non-agricultural sectors. Second, the potential climate change damages for agriculture are compared with the consumption and expenditure patterns of the government in the event of a climate damage to estimate the losses for the country.[2]

Study materials and methods

Data source

Two types of data are used in this study. The first set of data is macroeconomic in nature and comes from national sources (FBS Fbos 1990; GoP 1990, 2012).[3] The second set of data comes from climate change and meteorological parameters. The macroeconomic dataset represents the baseline economy and comprises an Input Output (I-O) table; a widely used framework to provide detailed information on the flow of goods and services, as well as on the structure of production costs. A SAM is constructed using the I-O 1990 table for Pakistan. The SAM is an extension of the I-O table and can be defined as an organised matrix representation of all transactions and transfers between different production activities. (The general sector classification of the economy and agriculture sector is provided in Appendix 1). By extending the I-O table and showing an entire circular flow of income at the macrolevel, the essential features of a SAM are captured. The National Accounts (NA) dataset for 2012 is used to update the SAM. The balancing of the SAM is done by using cross-entropy because it is a superior method compared with its counterparts. It is also a useful method when updating the internal coefficients and balancing of SAM is done simultaneously, with little available information (Debowicz et al. 2013). The updated and balanced SAM of Pakistan for the year 2012 is shown in Table 2, while the sector and commodity specification is presented in Table 3.

The second dataset, the meteorological data, is a combination of different parameters. We selected several sets of diverse scenario for temperatures, ranging between 0.73 and 0.83 °C, and carbon concentration (CO_2), with certain levels of fluctuation in (i) initial concentration in atmosphere, (ii) initial concentration in upper and lower strata, (iii) equilibrium concentration atmosphere, (iv) equilibrium concentration in lower and upper strata, (v) equilibrium temperature impact (degrees Celsius per doubling of CO_2), (vi) initial lower stratum temperature change (degrees Celsius from 1900), (vii) initial atmospheric temperature change (degrees Celsius from 1900) and (viii) climatic damage intercepts.

Model specification

This study is focused on estimating the impacts of climate change on the Pakistan economy, in general, and for the agricultural sector in particular. In doing so, we used a multidisciplinary framework that takes into account economic, earth science and ecological approaches on climate change over the long term.[4] To estimate climate damages, the impacts of climate change are principally converted into a common unit. Climatic change is a typical example of a public good that entails the global common good, and like any public good, any effort to reduce climate damage in one country will also bring benefits to other countries. Similarly, the damage done by climate change in one country can be experienced by other countries also. However, for this study we can make the assumption that all neighbouring countries will continue to reduce carbon emission levels, following the recommendations by IPCC (2007), Stern (2007) and Nordhaus (2008).

To analyse climate change and its potential impact, a dynamic CGE model is used in this study. An important feature of the model is that it links exogenous climatic factors, such as climatic damage, carbon cycle, temperature fluctuation, carbon emissions and carbon concentration, with economic growth. It also takes certain variables, such as national population and national growth rate, as specified exogenously. Moreover, by utilising an economic inquiry framework, it converts all economic activities and impacts into a common unit as monetary value based on present economic data generated from the SAM. Variables like capital stock, output, temperature change and climatic damage are generated by the model and are endogenous in nature. It is assumed that the economy is endowed with an initial stock of capital, labour

[2] This will provide the effects of modest and gradual climate disruptions on public finances through shifts in the economic structure (Leppänen et al. 2015).

[3] FBS and GOP are defined as the Federal Bureau of Statistics and the Government of Pakistan, respectively.

[4] This model is run using the CONOPT3, with geometric algebraic modelling system (GAMS) programming.

Table 2 Macro-SAM 2012

	Activity	Commodity	LAB	CAP	HOH	GOV	S-I	YTAX	STAX	TAR	ROW	Total
Activity		16,667,774										16,667,774
Commodity	1,811,321				10,390,895	2,816,259	2,598,794				2,006,607	19,623,875
LAB	1,331,999											1,331,999
CAP	13,524,455											13,524,455
HOH			1,331,999	13,524,445		536,550					1,308,150	16,701,154
GOV							2,365,965	743,600	836,700	216,900	263,9000	4,427,065
S-I					5,566,659	(348,900)						5,217,759
YTAX					743,600							743,600
STAX		836,700										836,700
TAR		216,900										216,900
ROW		1,902,501				1,423,156	263,000					3,578,657
Total	16,667,774	19,623,875	1,331,999	13,524,445	16,701,154	4,427,065	5,217,759	743,600	836,700	216,900	3,578,657	

Activity production activities, *Commodity* consumption goods/services, *LAB* labour (earning/expenditure), *CAP* capital (earning/expenditure), *HOH* households (earning/expenditure), *GOV* government (earning/expenditure), *S-I* saving investments, *YTAX* income tax, *STAX* sale tax, *TAR* tariff, *ROW* rest of the world (exports/imports)

Table 3 Commodity/activity and sector specification

S. no.	Sectors	Activities
1	SEC1-C	Rice
2	SEC2-C	Wheat
3	SEC3-C	Cotton
4	SEC4-C	Sugar cane
5	SEC5-C	Tobacco
6	SEC6-C	Other crops
7	SEC7-C	Pulses and grams
8	SEC8-C	Potato
9	SEC9-C	Fruits
10	SEC10-C	Vegetable and condiments
11	SEC11-C	Oil seed
12	SEC12-C	Others
13	SEC13-C	Livestock
14	SEC14-C	Forestry
15	SEC15-C	Fisheries
16	SEC16-C	Industry
17	SEC17-C	Services

and technology, and that all industries behave competitively. Each of the commodities produced in the model was assumed to be derived from a nested Cobb-Douglas production function with constant returns to scale. The economic dimension of the model is composed of a set of non-linear simultaneous equations. These are classified into five different blocks: price, production, commodity, institutions and system constraints (see Appendix 2) where the number of equations is equal to the number of endogenous variables (Lofgren et al. 2002).

The calibration of the model is done in order to reproduce the base year data as a model solution. However, for the key model parameters, the process of calibration is augmented from the literature. In practice, key model parameters are considered synonymous with elasticities, due to the extensive application of the Armington constant elasticity of substitution (CES)[5]/constant elasticity of transformation (CET) function[6] in the applied models (Scarf and Shoven 2008). Producers maximise profits subject to a two-level nested Cobb-Douglas and Leontief production function (Lofgren et al. 2002).

Each sector is assumed to produce a single composite commodity, for the domestic market and for the rest of the world (ROW). The Cobb-Douglas production function uses primary inputs; where each commodity is produced by the Leontief technology using intermediate input, from various production sectors. Similarly, to capture intra-industry trade features for a particular sector, domestic products and products from the ROW within the sector, are assumed to be imperfect substitutes, and their

[5] The constant elasticity of substitution is a neoclassical production function that displays constant percentage change in factor (for example, labour and capital) proportions due to a percentage change in the marginal rate of technical substitution.

[6] The CET is the corollary CES function, where the production possibilities of the industry are a function of different combinations of supply activities.

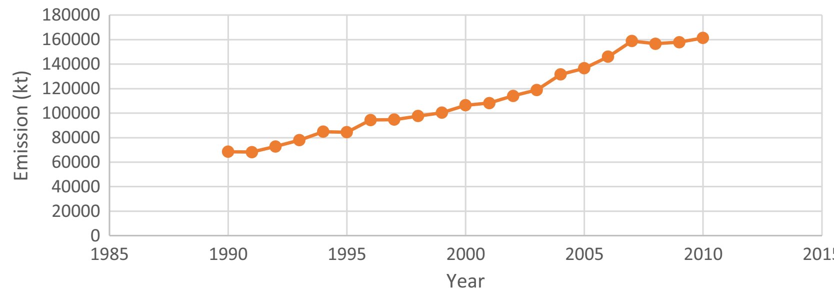

Fig. 1 CO_2 emmisions for Pakistan, 1985–2010 (kt)

allocations are determined according to the CES function. For domestic consumption, there are three domestic final demand sectors: namely, household, government and investment demand, from all production sectors. The allocation of output between the domestic market and ROW is carried out according to the CET function. On the demand side, a single household is assumed to maximise utility, subject to income constraint, according to the Cobb-Douglas utility function. The consumption demand is also the CES function for a sector's product of the domestically produced goods and imported products. Government expenditure is exogenously determined and specified, while sectoral capital investments are assumed to be allocated in fixed proportions among various sectors. In terms of macroeconomic closure, investment is savings driven, and all factors are assumed to be mobile and available in fixed supply, across activities.

The model presents a number of interactions that attempt to capture the major forces affecting climate change by converting them into monetary values. The monetarised value of aggregate gross damage is modelled as a function of the climate variable. The calibrated equation of gross damage as a function of the climate variable is as follows:

$$\epsilon_t = \alpha_i \Delta \mathcal{H}_t^2 \quad (1)$$

where:

€ Gross damages
$\mathcal{H}$ Climate variable

The quadratic nature effect of the climate variable allows for climate impact as a function of climatic factors as:

$$\mathcal{H}_t = \alpha_j \mathcal{H}_{t-1} + \alpha_k \aleph_t \quad (2)$$

where:

$\aleph$ Carbon emissions

In this study, an increase in emissions ($\aleph_t$) by a certain amount as a result of exogenous shocks leads to an increase in the climate impact function (T_t) compared with its existing level. It is assumed that gross damage grows linearly with level of output (η). Various additional factors can shift the

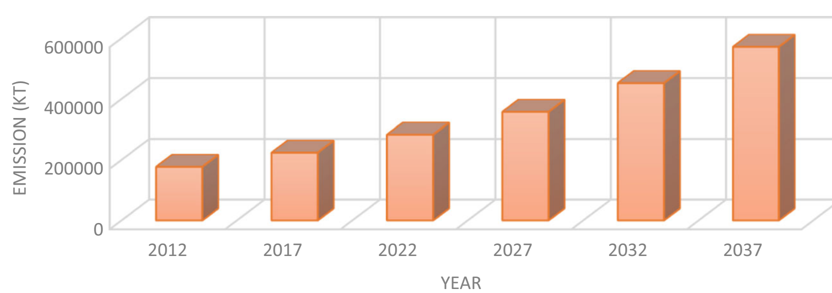

Fig. 2 Projection of CO_2 emmisions, 2012–2037 (kt)

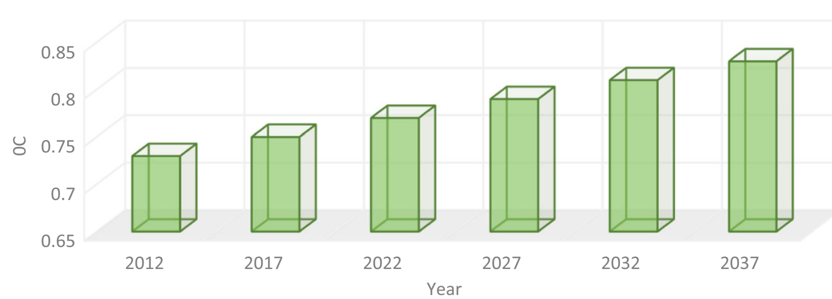

Fig. 3 Projections of temperature, 2012–2037

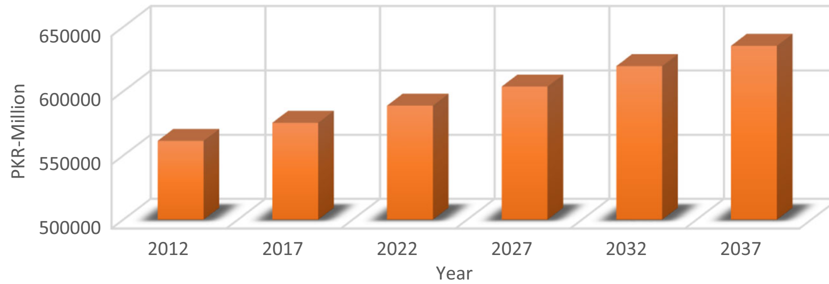

Fig. 4 Total damages, 2012–2037 (PKR million)

linear trend of gross damage. Factors that can cause shifts in the emission intensity are introduced in Eq. 3:

$$\aleph_t = \Omega \times \eta_{x_t}\left(1-\pi_t-\overset{\grave{E}}{E_t}\right) \quad (3)$$

where:

- Ω Output coefficient (constant fraction of national output of commodities)
- x Output
- π_t Mitigation efforts
- $¥_t$ Level of adaptation (in this model, the level of adaptation is considered to be zero)

Since gross damage (€) by and large depends on output ( ) and emission value (ω), it can be written as:

$$\frac{€_t}{\eta_t} = \omega \cdot M_t$$

Similarly, as a function of the climate variable, it can be represented as:

$$\frac{€_t}{\eta_t} = \alpha_1 \Delta\mathcal{H}T_t + \alpha_2 \Delta\mathcal{H}_t^{\alpha 3}$$

Equation 5 represents gross damage as a ratio of output, which depends on the residual damage and adaptation cost for a certain level of adaptation. Since the model does not allow for any adaptation, the value of net residual damage is equal to gross damage GD_t in the absence of any adaptation cost.

Empirical findings

In order to make some sense of the impact of future climate change, we simulate climate change impacts using the CGE model described in the preceding section. In order to understand how climate change impacts Pakistan, carbon emissions and temperature changes are plotted. Figure 1 shows the emissions trend, while Fig. 2 plots the cumulative emissions projection across the simulated time period. The CO_2 emissions will cause fractional climate changes. However, determining probabilistic climate changes for future emissions is challenging, as it requires a synthesis of uncertainties along the cause-effect chain from emissions to temperatures. Additionally, using the CGE model, we projected future temperature changes as shown in Fig. 3.

The projections in Figs. 2 and 3 indicate a continued and rapid increase in CO_2 emissions and temperature. However, for this study, we did not follow the optimal condition of CO_2 emissions as proposed by Stern (2007) and Nordhaus (2008). The trend and magnitude of CO_2 emissions and temperature for Pakistan suggest severe impacts of climate change on the economy. Therefore, we simulate the associated damage values for the overall economy in six different time segments (years), from 2012 to 2037. Thus, the estimated damages will vary, because the size and composition of the economy will also change with time. In the base case scenario, the overall gross damage is PKR 561,484 million,[7] which is 6.49 % of the country's real GDP. The damage shows an uptrend across all time segments, increasing by 11.62 % from the base year and reaching PKR 635,333 million in 2037 as shown in Fig. 4. The damage estimated for Pakistan is higher than the global average, which confirms its vulnerability to climate calamities. The losses are often incurred by the poor rural and semi-rural communities, as they have no insurance and lack the financial resources needed to regain their lost livelihoods. The true financial costs of climate change directly affect GDP, reduce consumption and increase government expenditure.[8] Therefore, it is estimated that the economic output would be PKR 10,082,124 million in 2037, while the total cumulative output would be PKR 56,123,814 million over the period of 25 years, as shown in Fig. 5.

Since the economy of Pakistan is predominantly agrarian, it is not surprising that it will bear significant losses. The climatic damages to the agriculture sector, presented in Fig. 6, show a trend rise to around PKR 260,662 million, which is 3 % of the real GDP. Therefore, it is estimated that agricultural damage would be PKR 1,690,601 million, over the period of 25 years. The growth rate of agricultural damage from the base year to the final segment is 13 %. Hence, it can be said that, comparatively, the damages to agriculture may grow at a faster pace than the overall damages to the economy. From

[7] The national currency unit for Pakistan is PKR, hence all the estimations are done in the same currency.

[8] The climate change damage depends strongly on assumptions about the functioning of the economy, for which the estimations are done. The detrimental impacts of climate change will be widespread, and cover sectors like agriculture, livestock, forest and fisheries (GoP 1990).

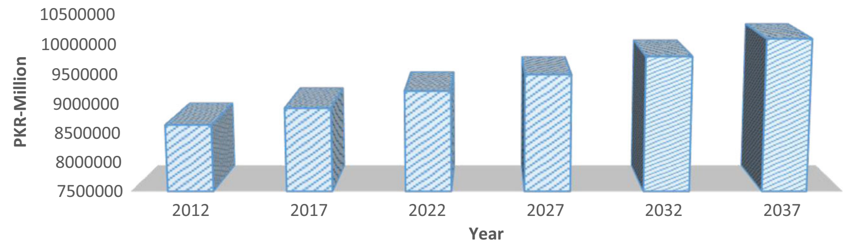

Fig. 5 Real GDP, 2012–2037 (PKR million)

Fig. 6, it is observed that climatic damages are anticipated to reach approximately PKR 301,301 million in 2037. Additionally, the magnitude of the damages in each time segment is found to be different, due to continued temperature change and emissions, apart from other factors such as economic and population growth.

The future prospects for agriculture look rather alarming as the yield gaps will be enlarged by the catastrophes of climate change, given the magnitude of the expected damages to the sector. Climate change can disrupt cropping patterns, livestock and fish productions, which in turn can further reduce agriculture productivity and result in food insecurity. Thus, an in-depth analysis by crop type is necessary, in order to estimate sector-specific damage. Additionally, these kinds of sector-specific damage will provide an overview of the vulnerability of specific sectors in agriculture. With this in mind, we categorised the agricultural sector into three sub-sectors: major crops, minor crops and meat and milk production. The estimated damage for these sub-sectors is presented in Figs. 7a, b and 8, respectively.

The main crops of Pakistan are classified into food crops and non-food crops, grouped as one, while the rest of the crops are considered minor crops. From the results in Fig. 7a, b, it is clear that both the major and minor crops of Pakistan appear to be threatened by a rise in the temperature and associated climate parameters, which account for the changing cropping pattern in Pakistan. The total economic damages for all major crops in the base year is estimated at PKR 109,196 million, with largest losses contributed by wheat (28.8 %), followed by cotton (16.1 %), sugar cane (14.5 %), rice (12.3 %), pulses and grams (11.3 %), oil seed (11 %) and tobacco (5.7 %). The total damages for minor crops are marginally lower than that for major crops, at PKR 98,610 million. The largest losses are within the minor crop category and are attributed to fruits (16.7 %), followed by forestry (15.2 %), vegetables and condiments (13.8 %), potatoes (12.4 %) and other crops (11.5 %).

The damages of climate change affect all crops, though disproportionately. Likewise, the change in climate and climate-related parameters also affect the production and yield of all crops. This increases the production costs, reduces the net farming income of the farmers and more importantly increases the vulnerability of the people engaged in this sector. The projected increase in temperature and variability in rainfall in the coming decades will severely damage crop productivity, as depicted in the projections. Due to the intense and variable rainfall pattern, the water availability of crops is also uncertain, which is a leading factor of future projected losses. On the other hand, the growing demand for food is also continuously depleting soil fertility, biodiversity and water resources and increasing the gaps between actual and potential crop yields.

Apart from the findings on climate damages to major and minor crops, the corresponding results for the livestock sector are indeed quite alarming. The livestock sector[9] in Pakistan projects maximum losses (40.3 % of the total damages), relative to the other two sectors. This is because the livestock production system in Pakistan is somewhat orthodox (Latif et al. 2010). Additionally, its subsistence nature of production does not lend itself to adapting to any negative shocks of climate change. Climate change is found to hit the core aspects of the livestock production system, namely, nutrition, animal health and animal productivity. High temperatures and frequency of extreme events, like floods and drought, badly affect the population and the productivity of animals. Therefore, it is not surprising that this sector projected the biggest losses.

In total, the effects of agricultural and non-agricultural damages from climate change will also influence government expenditure and private consumption decisions. Therefore, we estimated the gap between government expenditure and private consumption in two different scenarios: with and without climate change effects, as shown in Figs. 9 and 10, respectively. The results show that the government expenditure (Fig. 9) in an optimal scenario (without climate change) is lower relative to that with climate change, while the corresponding private consumption is higher in all simulations from 2012 to 2037. Additionally, climate damages are found to affect both private consumption and government expenditure negatively. The estimated results of government expenditure

[9] Livestock is one of the major sectors of the economy, accounting for 55.9 % of agricultural earnings and 11.8 % of GDP. It employs 35 million people and produces almost $500 million worth of products.

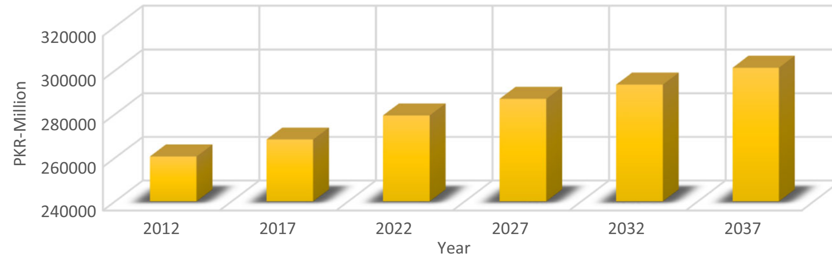

Fig. 6 Agricultural damage, 2012–2037 (PKR million)

and private consumption in the 'business-as-usual' scenario (with climate change) show that government expenditure will rise, while consumption will fall, across all the simulations. In short, in the long run, climatic damage will increase, with a significant lowering of agricultural productivity. Thus, policymakers in Pakistan should

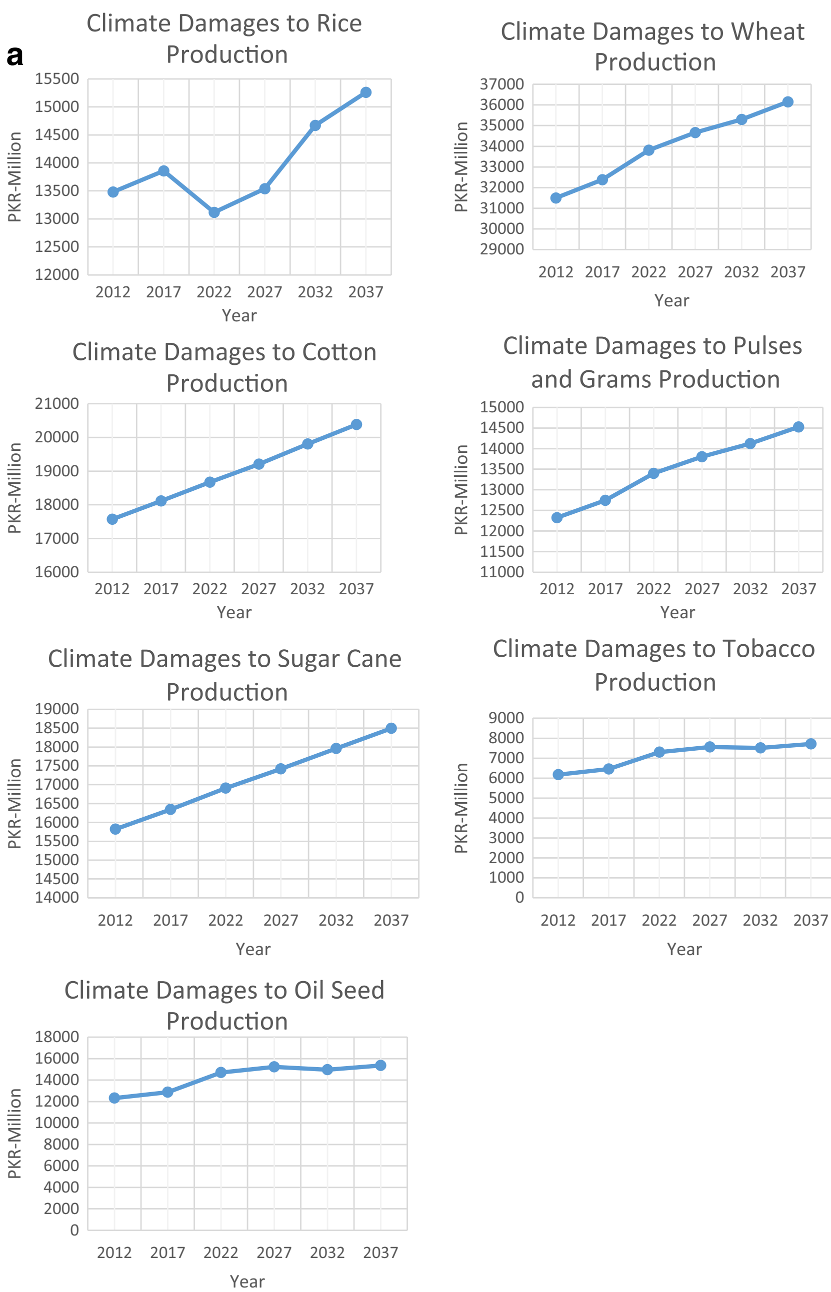

Fig. 7 **a** Damage for major crops (PKR million). **b** Damage for minor crops (PKR million)

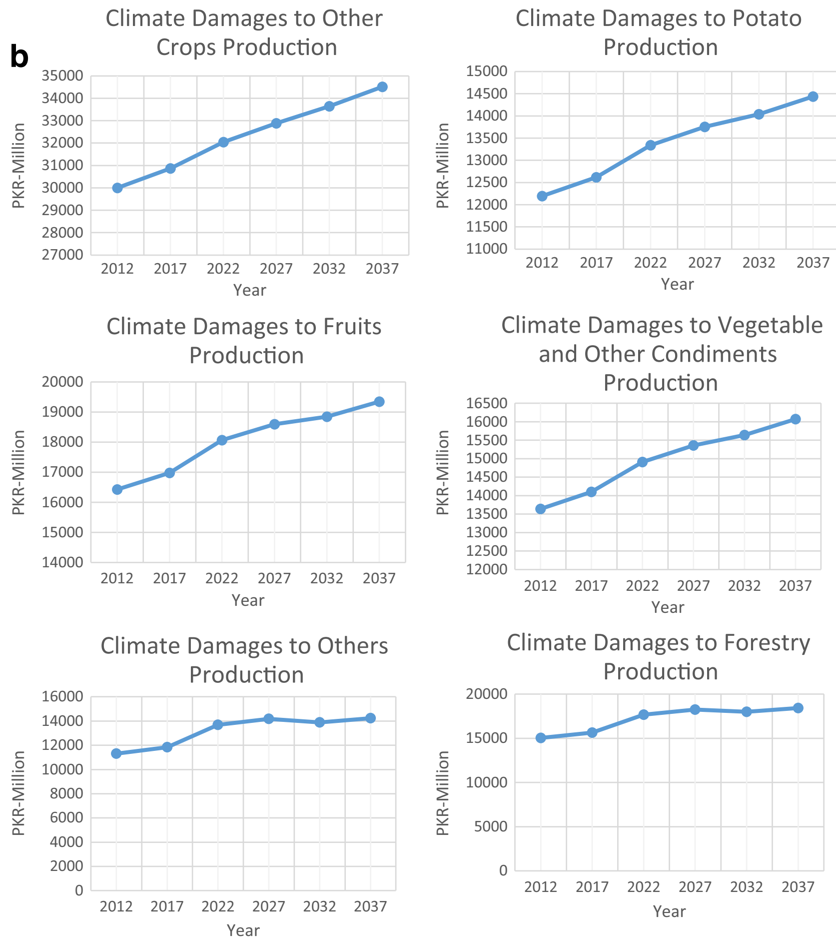

Fig. 7 (continued)

review the country's long-term climate policy choices in order to reduce economic losses.

Discussion and implications

The findings of this study suggest that the agricultural sector of Pakistan is highly exposed to climate change. The negative outcomes are significant, and they inform the debate on the importance of addressing climate change damages to the production of agricultural commodities. There is ample evidence that CO_2 emissions and temperature changes have been violating the 2010 Cancún Agreements[10]; in which the UNFCCC countries recommended a strong reduction of emissions for achieving a global temperature below 2 °C relative to pre-industrial levels. Furthermore, the temperature projection shows higher temperature changes in the coming decades. In fact, there is a pronounced increase in agricultural damages, which have caused real GDP to decline. Further reductions in GDP, typically associated with reductions in consumption and expenditure, are therefore expected with the negative effects of climate change.

The findings generally corroborate previous work (Ahmed 2015; Ingram 2014; Rehman et al. 2014) as the existing literature suggests that adverse climate change reduces the yield and productivity of agriculture by increasing the stress of weather inputs and the exposure to vulnerabilities of climate extremes (Byatt et al. 2006; Lomborg 2006; Mendelsohn et al. 2006; Nordhaus 1993, 2007; Schneider and Mastrandrea 2005; Stern 2007; Tol and Yohe 2006). Climate change is therefore identified as one of the biggest challenges for low-income agrarian developing economies. Unfortunately, these countries are major victims, though they are not the major driver of this global environmental change.

Several major points emerge from the study that contribute to the existing literature. First, climate change will exert negative effects on simulated agricultural production, with concomitant but disproportionate losses across crops. For Pakistan, climate change may increase disparities in wheat production, due to sustainable declines following large losses in the long run. Second, it is considered in general that the livestock sector is better able to withstand climate changes,

[10] Climate Analytics, Telegrafenberg A26, 14412 Potsdam (Wang et al. 2009).

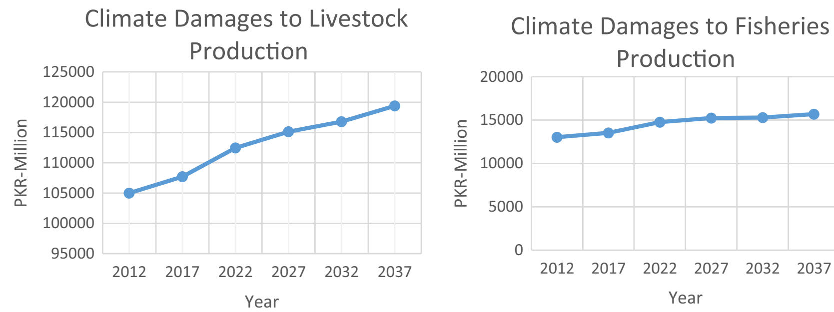

Fig. 8 Damage for milk and meat production (PKR million)

compared with crops. This is because the physiological make-up of animals allows them to adapt to extreme climate, due to their intense degree of behavioural expressions, compared with crops (Bryan et al. 2013). Quite surprisingly, for Pakistan, the livestock sector incurs the largest damages from climate changes, relative to major and minor crops. Climate change has far-reaching consequences for dairy, meat and wool production. It is therefore erroneous to assume a homogeneous impact of climate change across the globe. Climate change impacts grassland and rangeland productivity, while a heat catastrophe reduces the feed intake of animals and results in poor growth performance (Rowlinson 2008).

The broader effects of the conspicuous damages of climate change on the agricultural sector also need to be accounted for. As the majority of subsistence farmers are engaged in this sector, they will bear direct losses due to reductions in crop yield and livestock health. This will intensify rural poverty by undermining the socio-economic condition of the rural masses. Additional costs will also be incurred through an increase in government expenditure. Tackling losses and damages involves two aspects: first, decreasing avoidable losses and damages by reducing carbon emissions (mitigation) and averting climate change impacts (adaptation and risk reduction) and second, addressing unavoidable losses and damages through risk-transfer strategies, such as insurance, and risk-retention mechanisms (for instance, contingency funds and social safety nets).

However, multiple challenges for Pakistan exist to control emissions from all the sector; including agriculture to decrease avoidable losses (IPCC 2011). First, deforestation continues to reduce carbon sinks, where carbon emissions are continuously growing at an increasing rate. Second, national capacities remain abysmally low at all levels to generate mitigation potentials as no sound vulnerability analysis framework exists at the national level. Similarly, the challenges for addressing unavoidable losses are also the result of a lack of international cooperation and drive from the civil society. Moreover, a common platform is missing that can bring multiple stakeholders together to combat climate change. Financial aid is also flowing through a not responsible, transparent or responsive manner to the citizenry.

Conclusion

This study empirically models climatic change-related impacts on the agriculture sector using the CGE model. It accounts for the changes in temperature, carbon cycle, carbon emissions, climatic damage, carbon control, carbon concentration in the atmosphere and other related global warming factors up to the year 2037. In order to adapt the values of key variables, the study took on the recommendations of Stern (2007) and Nordhaus (2008) but downscaled them to account

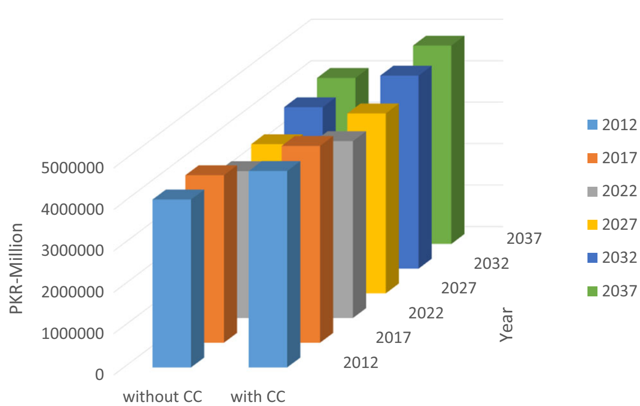

Fig. 9 Government expenditure estimates, 2012–2037

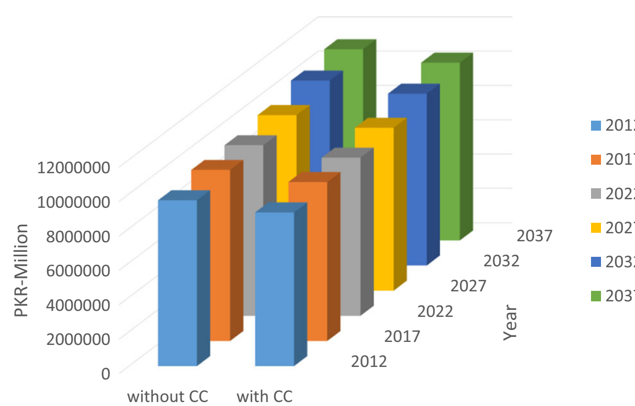

Fig. 10 Private comsumption estimates, 2012–2037

for the conditions observed in Pakistan. Our findings suggest that climate damages prevail across all sub-sectors of agriculture and their effects are substantial. The livestock sector shows the highest vulnerability in terms of climatic damage, because of heat stress, disease, lack of vaccination facilities and floods and droughts. Our findings are intended to provide information on the sectoral damage of climatic change within the agricultural sector, in order to alert policymakers in Pakistan to the importance of factoring in climatic effects when examining crop yields and agricultural productivity.

This study is assembled with the specific focus on Pakistan's agriculture sector; however, construction of the methodology is replicable to analyse climate damages specific to any sector and in any other developing country. It is clear that the CGE framework provides a simple foundation for evaluating a number of environmental policy aspects, and thereby adds a precise quantitative basis for the judgments. In the current methodology adopted, the limiting assumption is that of the exogenous technical change in the production function. It is, however, important to note that for the purpose of the study, the assumption of exogenous technical change does not affect the major outcomes of the study.

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