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Abstract

This study analyzes ten districts of the province Punjab of Pakistan to investigate and compare the vulnerability of selected districts. Total Three sub-groups (socio-economic variables, adaptive capacity, bio-physical variables) are generated by using the data from Pakistan Social & Living Standard Measurement Survey (PSLM) and Pakistan Meteorological Department of the years 2014-15, to calculate total vulnerability. Using primary variables at the district level, this study determines each district's rural and urban areas' total vulnerability score. The results show that few districts, e.g., Rawalpindi has 0.74 total vulnerability score out of 1, are highly vulnerable compared to other districts despite having a better socio-economic situation. On the other hand, few districts, like Multan, have a low vulnerability to climate change and socio-economic factors.

Keywords: CO_2, socio-economic, bio-physical, environment, Vulnerability.

JEL Classification Codes: Q3, O13, P28.

1. Introduction

The earth's average global temperature will be increased by 1 to 3.5°C with an increase in the sea level from 15 to 95 cm till 2100. Moreover, every year the world has to face 400 to 500 disasters due to the hazardous impacts of global warming, floods, storms, tornadoes, and droughts (Maskrey *et al*., 2007).

Pakistan is the most vulnerable developing country to climate change because of its financial and technical low adaptive capacity to the hazardous impacts despite its lowest contribution in global greenhouse gas emissions, which is lowest in the world. Pakistan's climate has been volatile from the last decade, and maximum temperature of 54 °C was recorded in 2010; highest in Asia and 4th in World, while severe cold waves were recorded in winter of 2013.

Moreover, according to Pakistan meteorological department, the heaviest rainfall of 600 mm in twelve hours has been recorded on 23 July 2001 in Islamabad.

Climate change is turning out to be the biggest threat. Stern (2007) also referred to it as the "devastating externality the world has ever witness." New environmental issues have been spotted through climate change, including depletion of the ozone layer, desertification, droughts, land degradation, shortage of water, fisheries depletion, and deforestation are highly griped (Brown *et al.,* 2007). Around the whole globe, climate change is widely impacting, including Pakistan due to its mismanagement of resources and arid geography profile, which made it exceptionally vulnerable.

The concept of vulnerability to climate change and socio-economic indicators is being introduced in 1970. According to this concept, anthropogenic activities and socio-economic conditions are the sources of natural disasters' devastation. The empirical illustration of data suggested that the tendency of natural catastrophes and intensity of the destruction has been increased from the last 50 years. Consequently, and especially in underdeveloped countries, the loss of lives and damages of socio-economic conditions have been tremendous (O´Keefe *et al*., 1976). Some empirical findings have been put on a conceptual stage, and vulnerability has two sides: internal and external. People can simultaneously tackle different capacities whenever exposed to specific social and natural risks (Chambers, 1989).

Therefore, we attempt to identify the most vulnerable to climate change districts, sources of high vulnerability to climate change, sources of increased vulnerability to climate in rural and

urban segments of Punjab districts to overcome the several knowledge gaps of previous literature.

Following are the hypotheses of this paper:

H_0^1 : There is no difference in vulnerability to climate change among all districts.

H_1^1 : There is a difference in vulnerability to climate change among all districts.

H_0^2 : Socioeconomic vulnerability and adaptive capacity are equally contributing to vulnerability to climate change of various districts

H_1^2 Socioeconomic vulnerability and adaptive capacity are not equally contributing to vulnerability to various districts' climate change.

Thus, in this study District wise data of 10 districts of Punjab have been taken to make the index of vulnerability to climate change and socioeconomic factors. The index highlighted the difference in the vulnerability of districts' rural and urban areas during 2014-15. With the help of this index, identifying particular factors that mold the vulnerability is being made, and providing a simple reference for stakeholders is being captured in deciding the capability of each district to adopt or alleviate the impacts of climate change.

This paper's remainder is organized as follows: in the next section, we briefly highlight the previous literature. Section 3 describes the methodology used in this paper. Section 4 introduces the variables related to the model specification, and then we interpret the data. Section 5 details the results and presents the corresponding analysis. The sixth section draws some conclusions and provides a relevant recommendation.

2. Review of Literature

This section covers previous literature related to climate change and vulnerability to climate change and socioeconomic factors. The sublime focus of the literature review in this study is the individualistic and communal vulnerability to climate change and factors influencing vulnerability.

Vulnerability is a burning issue for the science of climate and policy. From the past several decades, numerous researchers have put swift insights into climate change assessment through development theory and assessment practice (Kelly & Adger, 2000; Preston *et al.,* 2011; Wamsler *et al.,* 2013; Arnott *et al.,* 2016; Koop *et al.,* 2017; Siders, 2019; Chayyani *et al.,* 2020). The review of vulnerability is a vital component of human dimension climate change. It depicts and identifies the factors that enhance climatic risks and identifies the adaptability factors (Ford & Smit, 2004; Fussel & Klein, 2006; Ford *et al.,* 2010; Dumenu & Obeng, 2016; Huang *et al.,* 2018; Nguyen *et al.,* 2019).

Persistent volatile climatic shocks to the crop and livestock have forced policy makers to reiterate the whole thinking process for the sustainability of the climate affected people such as farmers and livestock owning households (Wise *et al.,* 2014; Pandey & Kumar, 2018; Raman, 2020). Likewise, numerous studies are also carried out in Pakistan to highlight the relationship between climate change and vulnerability (Salik *et al.,* 2015; Ullah *et al.,* 2018; Qaisrani *et al.,* 2018; Fahad & Wang, 2019; Shahzad *et al.,* 2019; Ahmed *et al.,* 2020).

There is a greater need to study vulnerability because the first assessment of scale is critical to analyze the magnitude of the event so that certain groups can take some special steps to tackle these hazardous shocks. Secondly, information about potential consequences is required to determine the remedial measures for future long-term prospects, such as global warming at the precautionary stage (Hope *et al.,* 1993; Adger & Kelly, 1999; Knights, 2003; Molina *et al.,* 2009; Fankhauser, 2013; Rossati, 2017; Tabara *et al.,* 2018). Vulnerability is vital to different masses, but most consider the probability of impairment to people, places, and things that are important for them are also added frequently originating from destructive events such as floods, tornados, and hurricanes. Vulnerability is a function of three components: exposure, sensitivity, and adaptive capacity. Exposure is the degree to which people and places or things being valued are open to a potentially harmful event. This includes economic, cultural, and social infrastructure. Sensitivity is the degree to which people and the places or things they value can be

harmed by exposure. Adaptive capacity includes physical, social, economic, and other resources such as education, access to information/ technology, coping ability, and resilience (Yarnal, 2007; Jones *et al.*, 2010; Lemos *et al.*, 2013; Muttarak & Lutz, 2014; Scott *et al.,* 2015; Clinner *et al.,* 2018;).

Most of the climate vulnerability index has been made on country-level data with the induction of secondary variables. But this study employed primary variables at the district level, which determine the total vulnerability score of each district's rural and urban areas.

3. Methodology

3.1.Theoretical Framework

Exposure's outcome to dangers has been centered by the studies of vulnerability from climate change and tried to reveal the various impacts on different socio-economic states of the system, and this has fundamentally been the foundation of the approach of political economy to the assessment of climate change vulnerability (Obrien *et al.,* 2004).

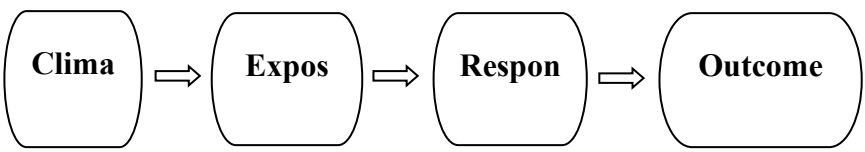


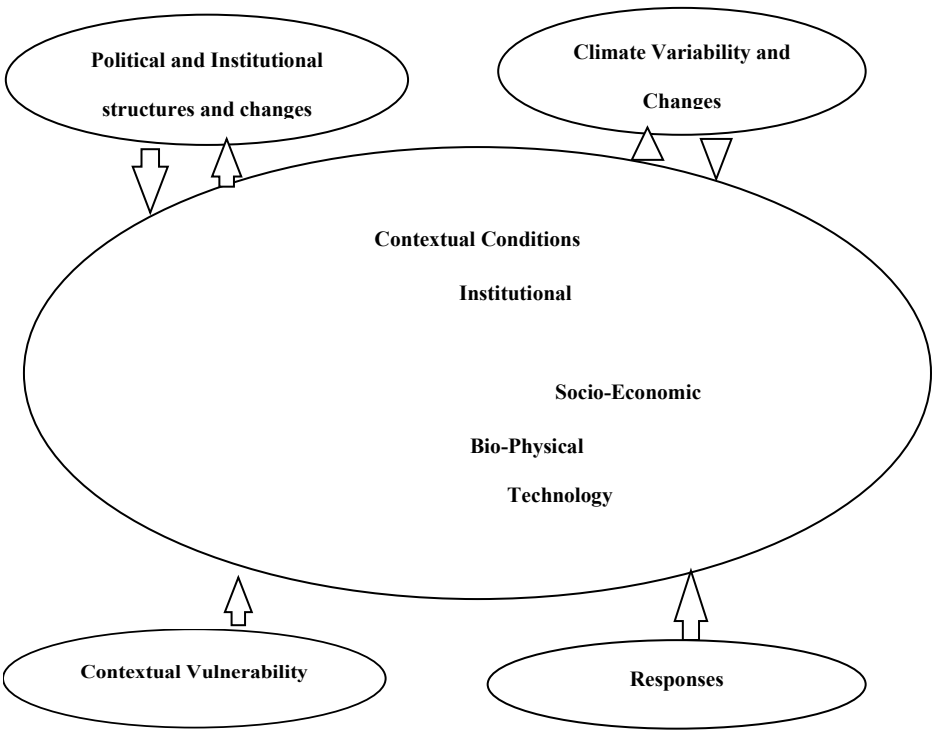
Figure 3.1: Climate change to vulnerability

According to the definition of (IPCC), climate change vulnerability is a function of exposure and sensitivity to climatic shocks. It also indicates how much adaptive capacity a system has to cope with unusual situations. Ultimately after responses, the outcome of vulnerability comes into account, which shows the situation's intensity.

Figure 3.2: Contextual Vulnerability

Contextually, vulnerability is comparatively dependent upon several aspects of climate change and interactions of society. The variability and climate changes are supposed to arise in a political, economic, social, and institutional context. Moreover, they

intermingle vigorously with contextual conditions connected with a specific 'exposure unit.'



The conditions which are contextual affect the exposure to climatic variations and also to the potential reactions. Responses can also influence both the contextual conditions and responses. Climate change is vital because of its ability to modify biophysical conditions, which change the context for reacting to several change processes such as political decentralization, economic liberalization, and epidemics spread. These processes, in response, change the context of climate change. Hence, from that perspective, vulnerability reduction includes changing alter the aspect through which climate change occurs. For that reason, groups and individuals can respond better to the changing conditions (Obrien et al., 2007).

3.2.Methodology

The assumption that the system does not entirely immunize to any hazards will exhibit value 1. If the system completely immunes to

any risk, then the value of vulnerability will be zero. Therefore, in this way, by following the (Rehman and Salman, 2013) the adaptive capacity equation is formed as given below.

$$\boldsymbol{Adaptive\ Capacity} = (\boldsymbol{Climate\ Change's\ vulnerability})(\boldsymbol{Socioeconomic\ vulnerability}) \quad (3.1)$$

It is very significant to assign equal weights to every indicator, while the social vulnerability index designed by every factor was dealt with as having a similar role in the country's vulnerability while having no sound method for the assignment of weights (Cutter *et al.,* 2003).

Vulnerability = (Biophysical vulnerability) + (Socioeconomic vulnerability) - Adaptive Capacity

Both biophysical and socioeconomic vulnerability have an incremental role in vulnerability. As much as biophysical variables tend to volatile, they will create vulnerability from climate change. Moreover, socio-economic vulnerability is dependent upon socioeconomic variables, and if any region has better socioeconomic variables, it will be less socioeconomic vulnerable. Adaptive capacity is a concept, which reduces the chances of being vulnerable. Those regions with strong adaptive capacity are known to be less vulnerable than those with low adaptive capacity. It offset the intensity of effects from biophysical and socioeconomic variables.

3.3. Estimation Technique

The Integrated Assessment Approach (IAA) is used by the Intergovernmental Panel on Climate Change (IPCC) in which the system's socio-economic, bio-physical, and adaptive capacity is considered. The interactions, feedback among multiple drivers, and impacts that link across-sector interactions between scales and types are taken into the IAA account (Solomon, 2007).

$$\boldsymbol{Vulnerability} = \int(\boldsymbol{Sensitivity}, \boldsymbol{Adaptive\ capacity}, \boldsymbol{Exposure} \quad (3.2)$$

Social vulnerability helps to illustrate those factors which determine the result of a hazard of a particular nature and intensity.

On the other hand, biophysical vulnerability is regarded as the function of exposure and risk. In climate change (bio-physical) vulnerability includes hazards, whereas socio-economic vulnerability doesn't have hazards, but the concepts of sensitivity and exposure are included (Metz, 2001).

3.4. Measurement of vulnerability from Socio-EconomicVariables

For 2014-15 PSLM surveys are cast-off in this study to develop socio-economic vulnerability and adaptive capacity variables. To measure the vulnerability for 2014-15, equal weights are assigned, and normalized values of any specific variable for a distinct are evaluated with normalized mean of the similar variable for the whole taken districts of Punjab which represents (Provincial mean). The standard deviation is being measured to calculate dispersion from the Provincial mean. Higher dispersion from the mean would indicate a larger socio-economic vulnerability (Rehman and Salman, 2013).

$$\boldsymbol{Socio-economic\ vulnerability} = \frac{\sum_{j=1}^{n_i}\left(SEF_{ij}^{1}-\mu_{SEF}1\right)^{2}}{n_i} \quad (3.3)$$

Moreover, adaptive capacity is also being determined from these socio-economic variables, but in this case, having larger dispersion from the mean would depict higher adaptive capacity. Having higher adaptive capacity reduces vulnerability to climate change and socio-economic factors. Adaptive capacity is calculated by using the equation derived by (Rehman and Salman, 2013).

$$\boldsymbol{Adaptive\ Capacity} = \frac{\sum_{j=1}^{n_i}\left(AC_{ij}^{1}-\mu_{AC}1\right)^{2}}{n_i} \quad (3.4)$$

3.5. *Measurement of vulnerability from Bio-physical variables*

Pakistan is one such country that enjoys the four seasons that are spring, winter, fall, and summer, which is a blessing in disguise.

$$\mathbf{Bio-physical\ Vulnerability} = \frac{\sum_{j=1}^{n_i}\left(Cc_{ij}^{1}-\mu_{cc}1\right)^{2}}{n_i} \quad (3.5)$$

While elaborating climate change, it is usually understood as the average weather over a long period. Moreover, a classical period for climate change is 30 years, sourced by the World Meteorology

Organization (WMO). This research has taken data on climate change from 1970 to 2000, and average values are calculated for this period. Further district wise variation for any climatic variables for 2014-15 was calculated by comparing the readings with the mean of the period 1970 to 2000 for the same variable, having far distance from the mean would be the indication of greater vulnerability and at the last standard deviations were being normalized on a scale from 0 to 1.

3.6. Normalization of Variables

All the variables used in this study are in different scales and units; hence normalization is compulsory. The normalization approach has been followed from the UNDP's human development index (Landovsky, 2006), and the scale ranges from 0 to 1. All the variables of socioeconomic factors are arranged according to their effects, whether positive and negative, while for the adaptive capacity factors, weights are assigned oppositely. Normalization has been done by following the (Neumayer *et al.,* 2011) methodology which is given below.

$$\mathbf{X_{ij}} = \frac{(\mathbf{X_{ij}} - \mathbf{min X_{ij}})}{(\mathbf{max X_{ij}} - \mathbf{min X_{ij}})} \tag{3.6}$$

3.7.Aggregation of variables to calculate the scores

As mentioned above, three sub-groups are formed to make an index of vulnerability to calculate the total vulnerability sub-groups are combined. The sources of vulnerability specified in the study are

1) Socio-economic variables
2) Adaptive capacity
3) Bio-Physical variables

4. Data

Data for climate (precipitation and temperature) has been taken from 1970 to 2000 for ten districts to calculate the mean value of 30 years. Whereas, to measure climate change of 2014-15 data only taken for these specific years. To measure socioeconomic vulnerability and adaptive capacity, the years of 2014-15 are considered only. Data has been arranged in a matrix in which

columns represent variables and rows represent the region. Sources for this study's data are given below.

i) PSLM 2014-15

ii) The Pakistan Meteorological Department.

Variables that are used to determine the socio-economic vulnerability and adaptive capacity are taken from the PSLM 2014-15 surveys. Bio-Physical factors which determine the Vulnerability and the data for climate change have been computed seasonally (Portmann *et al.,* 2009).

Table 4.1: Socio-economic factors that determine the vulnerability

Variables' Number	Variables' Name	Description of the Variable	Reasons for selecting Variables
SEF1	Literacy of adults	Literacy of an adult is taken as a binary variable with the value 1 if the person is literate and 0 otherwise. We used the definition of PSLM for the literacy of the adult.	Literacy of adults: Education helps to increase human capital, opens up employment opportunities, so in this way, vulnerability tends to reduce while having higher illiteracy will shift vulnerability up (o'Brien et al., 2004).
SEF2	Sickness from last two weeks	Health condition of a person from last Two weeks. Value is one if any illness and 0 if not.	A greater percentage of sick people is an indication of poor health and nutrition conditions, increasing vulnerability.
SEF3	Residential status	It is the indicator of possession. If a house is Owner Occupied (self-hired) 0, Owner-occupied (not self-hired) 1, Without rent 2, Subsidized rent 3, and on rent	In case of severe and extreme climatic events, there will be more chances of higher vulnerability for those who have not their own residency and stay on

		4.	rent or homeless.
SEF4	Employment status	It indicates the mode of earning. The employer with 10 or more employees 0, Employer with 1-9 employees 1, Livestock only 2, Paid employee 3 and unemployed 4.	It is particularly problematic for those who belong to agriculture and has fewer employment opportunities, such as women, children, and pastoralists (Paavola, 2008).
SEF5	Fuel used for cooking	Sources which are being used for cooking. If gas 0, firewood 1 and for Dung Cake 2.	Having gas for cooking is better than reliance on environmental goods such as crop residue, wood, and vulnerability.

Table 4.2: Socio-economic factors that determine the Adaptive capacity

Variables' Number	Variables' Name	Description of the Variable	Reasons for selecting Variables
AC1	The material used for construction	If the material which is being used of mud bricks/mud 0 and if the material is of burnt bricks/bricks 1.	House built with better materials such as Burnt bricks and blocks has less chance of being vulnerable from any hazardous climatic event but house with weak material such as mud bricks and bamboo can face high vulnerability.
AC2	Agriculture	If the person is the related agriculture sector, then 0, and if the person is not related to	Agriculture is the mainly vulnerable sector as it is inherently responsive to climatic conditions (Reilly and Schimmel

		agriculture, then 1.	pfennig, 1999).
AC3	Cattle	If the person has cattle in his possession, then 0 and 1 if he has not cattle in his possession.	Livestock holders are extensive customer resources that depend upon climate change and environmental variations, so having cattle depicts the vulnerability to climate change and weakens the adaptive capacity (Thornton et al., 2009).
AC4	Economic condition one year before	If a person has a much worse condition than the previous year, then 0, if a person has a worse condition then 1, for same as before 2, for better than before 3 and much better than before 4.	To attain high adaptive capacity while tackling the climatic events necessitates costs (Adger et al., 2005), whoever has better economic conditions will be efficient in enhancing adaptive capacity.
AC5	Toilet facility	If the toilet is connected to open drains then 0, if it is flush to sewerage then 1 and if it flushes to septic tank then 2.	The facilities level depicts the capacity of better and sound economic as well as a social condition.

Table 1.3: Description for the Temperature

Temperature	Explanation of the variable
CC1	Mean of March, April, and May.
CC2	Mean of June, July, and August.
CC3	Mean of September, October, and November.
CC4	Mean of December, January, and February.

Table 4.4: Description for the Precipitation

Precipitation	Explanation of the variable
CC5	Mean of March, April, and May.
CC6	Mean of June, July, and August.
CC7	Mean of September, October, and November.
CC8	Mean of December, January, and February.

5. Results & Discussion

From the last few decades, vulnerability to climate change and socio-economic factors are very important and have consistently urged in the literature to take in the account. Moreover, it explores vulnerability, especially for those whose economic well-being is severely dependent upon bio-physical indicators. Because of all this, it leads to the discrimination of socio-economic factors. It is also opined that climate change can be catalyzed by the dormant adaptive capacity of different areas. Therefore, this study has been conducted to analyze and compare several Punjab districts' adaptive capacity, socio-economic vulnerability, and biophysical vulnerability.

Results are given in the tables in which bio-physical vulnerability, socio-economic vulnerability, adaptive capacity, and total vulnerability to climate change and socio-economic factors are presented.

*5.1.**Bio-physical vulnerability***

There are multiple effects of bio-physical indicators on human health. Primarily, extreme temperature influences the health of children and elders. Numbers of diseases come to sight after the variability of temperature and precipitation in previous years, such

as dengue, cholera, and malaria. Moreover, food security is susceptible to these indicators as we have observed a shortage of quality food due to climate change (Thornton *et al.,* 2014).

*5.2.**Socio-economic vulnerability***

The literature explained socio-economic vulnerability as a group of characteristics that involve necessities such as health, resilience, livelihood, and education. Being poor or having fewer resources does not necessitate making vulnerable, but it ensures more vulnerability to climatic hazard. Hazardous economic conditions make individuals less able to invest in all items, including managing risk and increasing disaster protection (Brouwer *et al.*, 2006).

*5.3.**Adaptive capacity***

It is the capability of any system that can adjust itself according to the slight variations of climate or extremes to offset reasonable latent harms, get benefits of opportunities, and deal with the ultimate results. Moreover, access to and have power over human, natural, physical, financial, and social resources are the essential factors that shape households, individuals, and communities' adaptive capacity.

Table 5.2: Results for Biophysical vulnerability of Districts

Districts	CC 1	CC 2	CC 3	CC 4	CC 5	CC 6	CC 7	CC 8	Score	Rank
Bahawalnagar	0.57	0.66	0.65	0.50	0.20	0.35	0.57	0.66	0.65	6
Bahawalpur	0.00	0.43	0.50	0.42	0.04	0.00	0.00	0.43	0.50	9
Faislabad	0.13	0.05	0.15	0.05	0.40	0.67	0.13	0.05	0.15	8
Jhelum	0.30	0.19	0.15	0.10	0.86	0.76	0.30	0.19	0.15	5
Lahore	0.84	0.65	0.83	0.78	0.31	0.91	0.84	0.65	0.83	3
Mianwali	0.14	0.07	0.04	0.11	1.00	0.41	0.14	0.07	0.04	7
Multan	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.00	10
Rawalpindi	0.99	1.00	1.00	0.84	0.52	0.77	0.99	1.00	1.00	1
Sargodha	0.80	0.83	0.87	0.81	0.49	0.08	0.80	0.83	0.87	4
Sialkot	1.00	0.85	0.98	1.00	0.32	1.00	1.00	0.85	0.98	2

Table 5.3: Results for the socio-economic vulnerability of districts

Districts	SEF1	SEF2	SEF3	SEF4	SEF5	Scores	Rank
Bahawalnagar	0.443	0.587	0.265	0.448	0.549	0.458	2
Bahawalpur	0.479	0.507	0.334	0.389	0.696	0.481	1
Faislabad	0.472	0.478	0.201	0.258	0.318	0.345	7
Jhelum	0.421	0.425	0.219	0.277	0.261	0.320	9
Lahore	0.497	0.493	0.446	0.320	0.367	0.424	3
Mianwali	0.518	0.506	0.204	0.186	0.241	0.331	8
Multan	0.519	0.498	0.292	0.287	0.264	0.372	5
Rawalpindi	0.395	0.416	0.489	0.357	0.353	0.402	4
Sargodha	0.481	0.488	0.276	0.043	0.259	0.309	10
Sialkot	0.455	0.457	0.304	0.280	0.274	0.354	6

Table 5.3: Results for Adaptive capacity of districts 2014-15

Districts	AC1	AC2	AC3	AC4	AC5	Score	Rank
Bahawalnagar	0.734	0.77	0.559	0.322	0.261	0.5292	2
Bahawalpur	0.415	0.504	0.537	0.252	0.46	0.4336	3
Faislabad	0.212	0.431	0.425	0.214	0.449	0.3462	10
Jhelum	0.43	0.483	0.451	0.312	0.228	0.3808	5
Lahore	0.201	0.37	0.375	0.357	0.387	0.338	7
Mianwali	0.362	0.466	0.519	0.284	0.502	0.4266	4
Multan	0.374	0.39	0.401	0.366	0.335	0.3732	6
Rawalpindi	0.58	0.581	0.586	0.591	0.431	0.5538	1
Sargodha	0.234	0.41	0.433	0.381	0.431	0.3778	8
Sialkot	0.193	0.41	0.411	0.305	0.481	0.36	9

Analysis for 2014-15 Climate change has been observed through biophysical variables, and it has been observed tremendous volatility in the climate for 2014-15. Those districts which had a high biophysical vulnerability in 2014-15 also have a high biophysical vulnerability.

As presented in the above tables of Bio-Physical Vulnerability, Socio-economic Vulnerability, and Adaptive Capacity (5.1, 5.2, 5.3). Results show that those districts with dismal socio-economic conditions Bahawalpur and Bahawalnagar have low vulnerability scores (0.481and 0.458) than other districts

in Bio-Physical Vulnerability. Because Bio-Physical vulnerability of other districts which are at a better position in terms of socio-economic variables is high, especially in Rawalpindi, Sialkot, and Sargodha (1.00, 0.98, 0.87).

Moreover, when discussing all these districts' adaptive capacity, we observed high adaptive capacity in Rawalpindi, Bahawalpur, and Bahawalnagar (0.5538, 0.5292, and 0.4336). Those districts which are having high Bio-Physical vulnerability are actually due to high marginal effects.

Total Vulnerability Scores' table is showing little different and astonishing results for 2014-15. According to this table, Rawalpindi and Sialkot's topmost vulnerable districts with scores (0.74, 0.73) while Multan and Mianwali (0.04, 0.22) are the least vulnerable districts. Interestingly it is noted over here that those districts which are climatically more vulnerable are also vulnerable in the overall calculation. It means the intensity of Biophysical variables is exceptionally high and led these districts towards the highly vulnerable state.

Interestingly total vulnerability score for a few districts such as Bahawalpur and Faisalabad (0.22, 0.25) is low, while some districts remained on the deterioration side in terms of total vulnerability score. Slightly bigger changes occurred in 2014-15 for climate change, but it's a transparent indication of enhancing socioeconomic and adaptive capacity factors.

Table 5.4: Results for total vulnerability of Districts 2014-15

Districts	SEF1	SEF2	SEF3	SEF4	SEF5	CC1	CC2	CC3	CC4	CC5	CC6	CC7	CC8	AC1	AC2	AC3	AC4	AC5	Score	Rank
Bahawalnagar	0.44	0.59	0.27	0.45	0.55	0.57	0.66	0.65	0.50	0.20	0.35	0.12	0.54	0.73	0.77	0.56	0.32	0.26	0.38	6
Bahawalpur	0.48	0.51	0.33	0.39	0.70	0.00	0.43	0.50	0.42	0.04	0.00	0.00	0.00	0.42	0.50	0.54	0.25	0.46	0.22	8
Faislabad	0.47	0.48	0.20	0.26	0.32	0.13	0.05	0.15	0.05	0.40	0.67	0.22	0.33	0.21	0.43	0.43	0.21	0.45	0.25	7
Jhelum	0.42	0.43	0.22	0.28	0.26	0.30	0.19	0.15	0.10	0.86	0.76	1.00	0.29	0.43	0.48	0.45	0.31	0.23	0.40	5
Lahore	0.50	0.49	0.45	0.32	0.37	0.84	0.65	0.83	0.78	0.31	0.91	0.07	0.18	0.20	0.37	0.38	0.36	0.39	0.66	3
Mianwali	0.52	0.51	0.20	0.19	0.24	0.14	0.07	0.04	0.11	1.00	0.41	0.13	0.61	0.36	0.47	0.52	0.28	0.50	0.22	9
Multan	0.52	0.50	0.29	0.29	0.26	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.29	0.37	0.39	0.40	0.37	0.34	0.04	10
Rawalpindi	0.40	0.42	0.49	0.36	0.35	0.99	1.00	1.00	0.84	0.52	0.77	1.00	1.00	0.58	0.58	0.59	0.59	0.43	0.74	1
Sargodha	0.48	0.49	0.28	0.04	0.26	0.80	0.83	0.87	0.81	0.49	0.08	0.24	0.19	0.23	0.41	0.43	0.38	0.43	0.47	4
Sialkot	0.46	0.46	0.30	0.28	0.27	1.00	0.85	0.98	1.00	0.32	1.00	0.39	0.39	0.19	0.41	0.41	0.31	0.48	0.73	2

Table 5.5: Results for Rural Socio-economic vulnerability 2014-15

Districts	SEF1	SEF2	SEF3	SEF4	SEF5	Score	Rank
Bahawalnagr	0.52	0.55	0.22	0.43	0.59	0.46	2
Bahawalpur	0.51	0.58	0.39	0.30	0.73	0.50	1
Faisalabad	0.42	0.42	0.37	0.23	0.28	0.35	8
Jhelum	0.39	0.40	0.26	0.28	0.29	0.32	10
Lahore	0.32	0.52	0.41	0.42	0.45	0.42	4
Mianwali	0.49	0.49	0.25	0.19	0.25	0.34	9
Multan	0.45	0.45	0.78	0.28	0.27	0.45	3
Rawalpindi	0.42	0.38	0.37	0.35	0.30	0.36	7
Sargodha	0.45	0.45	0.37	0.19	0.26	0.34	5
Sialkot	0.45	0.45	0.36	0.27	0.28	0.36	6

Table 5.6: Results for Rural Adaptive capacity 2014-15

Districts	AC1	AC2	AC3	AC4	AC5	Score	Rank
Bahawalnagr	0.712	0.558	0.505	0.301	0.48	0.511	01
Bahawalpur	0.272	0.412	0.362	0.251	0.377	0.335	06
Faisalabad	0.216	0.335	0.307	0.205	0.339	0.280	10
Jhelum	0.34	0.368	0.339	0.31	0.398	0.351	04
Lahore	0.2	0.426	0.463	0.342	0.38	0.362	03
Mianwali	0.296	0.355	0.331	0.272	0.456	0.342	05
Multan	0.264	0.348	0.316	0.398	0.286	0.322	07
Rawalpindi	0.322	0.505	0.491	0.252	0.507	0.415	02
Sargodha	0.202	0.336	0.324	0.369	0.377	0.322	09
Sialkot	0.194	0.345	0.328	0.353	0.415	0.327	08

The above tables show the analysis of rural areas for socio-economic vulnerability and adaptive capacity for the year 2014-15. Rural areas of each district again show a more pathetic situation as compared to the whole district. In this particular year, rural areas of Rawalpindi and Jhelum (0.36, 0.32), (0.415, 0.351) improved a lot in socio-economic and adaptive capacity contexts. Faisalabad's

rural areas are not much improved in socio-economic vulnerability (0.35) and weak adaptive capacity (0.280). At the same time, Bahawalpur's rural areas are vulnerable in both aspects (0.50) (0.335).

This table shows the total rural vulnerability score for the year 2014-15, and it is found that rural areas have contributed more to the vulnerability than the total district.

Even though these selected districts are better than the districts of other provinces, these are not as good as developed countries, especially with poor human development indicators, including education, health, and infrastructure. These are highly vulnerable to the adverse effects of climate change as manifested in rising temperatures, increased monsoon variability, melting of glaciers, and an increase in the frequency and intensity of extreme weather events and natural disasters.

Table 6: Results for Rural total vulnerability 2014-15

Districts	SEF1	SEF2	SEF3	SEF4	SEF5	CC1	CC2	CC3	CC4	CC5	CC6	CC7	CC8	AC1	AC2	AC3	AC4	AC5	score	Rank
Bahawalnagr	0.52	0.55	0.22	0.43	0.59	0.57	0.66	0.65	0.50	0.20	0.35	0.12	0.54	0.71	0.56	0.51	0.30	0.48	0.40	6
Bahawalpur	0.51	0.58	0.39	0.30	0.73	0.00	0.43	0.50	0.42	0.04	0.00	0.00	0.00	0.27	0.41	0.36	0.25	0.38	0.34	7
Faisalabad	0.42	0.42	0.37	0.23	0.28	0.13	0.05	0.15	0.05	0.40	0.67	0.22	0.33	0.22	0.34	0.31	0.21	0.34	0.32	8
Jhelum	0.39	0.40	0.26	0.28	0.29	0.30	0.19	0.15	0.10	0.86	0.76	1.00	0.29	0.34	0.37	0.34	0.31	0.40	0.43	5
Lahore	0.32	0.52	0.41	0.42	0.45	0.84	0.65	0.83	0.78	0.31	0.91	0.07	0.18	0.20	0.43	0.46	0.34	0.38	0.63	3
Mianwali	0.49	0.49	0.25	0.19	0.25	0.14	0.07	0.04	0.11	1.00	0.41	0.13	0.61	0.30	0.36	0.33	0.27	0.46	0.31	9
Multan	0.45	0.45	0.78	0.28	0.27	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.29	0.26	0.35	0.32	0.40	0.29	0.17	10
Rawalpindi	0.42	0.38	0.37	0.35	0.30	0.99	1.00	1.00	0.84	0.52	0.77	1.00	1.00	0.32	0.51	0.49	0.25	0.51	0.84	1
Sargodha	0.45	0.45	0.37	0.19	0.26	0.80	0.83	0.87	0.81	0.49	0.08	0.24	0.19	0.20	0.34	0.32	0.37	0.38	0.56	4
Sialkot	0.45	0.45	0.36	0.27	0.28	1.00	0.85	0.98	1.00	0.32	1.00	0.39	0.39	0.19	0.35	0.33	0.35	0.42	0.77	2

The greater vulnerability of Pakistan to climate change is based on many important factors. *First*, it is a country highly dependent upon agriculture as a source of revenue and employment and in terms of ensuring the availability of food. Given that most agricultural land is rain-fed and the country is water stressed, any climatic variation that affects the pattern of rainfall is likely to have dire consequences for agriculture and the associated parameters of food, employment, and income.

Table 5.8: Results for Urban Socio-economic Vulnerability 2014-15

Districts	SEF1	SEF2	SEF3	SEF4	SEF5	Score	Rank
Bahawalnagar	0.64	0.28	0.37	0.40	0.18	0.37	5
Bahawalpur	0.84	0.72	0.27	0.30	0.72	0.57	1
Faisalabad	0.51	0.56	0.20	0.29	0.39	0.39	4
Jhelum	0.43	0.44	0.20	0.25	0.24	0.31	10
Lahore	0.28	0.49	0.54	0.19	0.30	0.36	7
Mianwali	0.54	0.53	0.18	0.19	0.24	0.34	9
Multan	0.64	0.56	0.39	0.29	0.26	0.43	3
Rawalpindi	0.38	0.43	0.59	0.35	0.44	0.44	2
Sargodha	0.50	0.50	0.18	0.26	0.37	0.36	6
Sialkot	0.47	0.47	0.20	0.29	0.27	0.34	8

Table 5.9: Results for Urban Adaptive capacity 2014-15

Districts	AC1	AC2	AC3	AC4	AC5	Scores	Rank
Bahawalnagr	0.80	0.65	0.68	0.38	0.44	0.59	1
Bahawalpur	0.47	0.56	0.64	0.25	0.56	0.50	3
Faisalabad	0.22	0.51	0.52	0.22	0.53	0.40	7
Jhelum	0.54	0.53	0.50	0.31	0.10	0.40	8
Lahore	0.20	0.32	0.29	0.35	0.41	0.31	10
Mianwali	0.39	0.52	0.64	0.29	0.52	0.47	5
Multan	0.49	0.46	0.52	0.33	0.38	0.44	6
Rawalpindi	0.82	0.68	0.71	0.26	0.28	0.55	2
Sargodha	0.42	0.56	0.51	0.39	0.50	0.48	4
Sialkot	0.19	0.48	0.50	0.23	0.56	0.39	9

Results for the urban regions are not much different from the rural areas, but districts' vulnerability is not as much as rural areas. Urban areas' socio-economic vulnerability is less than rural areas, while urban areas also have a strong adaptive capacity than rural areas.

Socioeconomic vulnerability and adaptive capacity depend upon the reliance of population areas' population on natural resource base as sources of their livelihood, health status, and sanitation facilities. Those urban areas with a dismal condition in these indicators depict high socioeconomic vulnerability and low adaptive capacity.

Multan (0.03) has achieved the most remarkable improvement in total vulnerability in 2014-15 compared to other districts. Furthermore, Sargodha (0.42), Jhelum (0.37), and Bahawalnagar (0.23) have also shown improvement. Only those urban areas are succeeded in lowering their total vulnerability, which focused on the socio-economic and adaptive capacity variables.

Looking at the tables representing vulnerability scores is showing that climatic variables such as CC1 to CC8 are the main factors of high vulnerability except in a few districts. In contrast, we know that developing countries such as Pakistan have weak socioeconomic and adaptive capacity factors that have failed to counter the climatic events' intensified vulnerability.

Table 7: Results for Urban total vulnerability 2014-15

Districts	SEF1	SEF2	SEF3	SEF4	SEF5	CC1	CC2	CC3	CC4	CC5	CC6	CC7	CC8	AC1	AC2	AC3	AC4	AC5	Score	Rank
Bahawalnagr	0.64	0.28	0.37	0.40	0.18	0.57	0.66	0.65	0.50	0.20	0.35	0.12	0.54	0.80	0.65	0.68	0.38	0.44	0.23	7
Bahawalpur	0.84	0.72	0.27	0.30	0.72	0.00	0.43	0.50	0.42	0.04	0.00	0.00	0.00	0.47	0.56	0.64	0.25	0.56	0.25	6
Faisalabad	0.51	0.56	0.20	0.29	0.39	0.13	0.05	0.15	0.05	0.40	0.67	0.22	0.33	0.22	0.51	0.52	0.22	0.53	0.24	8
Jhelum	0.43	0.44	0.20	0.25	0.24	0.30	0.19	0.15	0.10	0.86	0.76	1.00	0.29	0.54	0.53	0.50	0.31	0.10	0.37	5
Lahore	0.28	0.49	0.54	0.19	0.30	0.84	0.65	0.83	0.78	0.31	0.91	0.07	0.18	0.20	0.32	0.29	0.35	0.41	0.61	3
Mianwali	0.54	0.53	0.18	0.19	0.24	0.14	0.07	0.04	0.11	1.00	0.41	0.13	0.61	0.39	0.52	0.64	0.29	0.52	0.18	9
Multan	0.64	0.56	0.39	0.29	0.26	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.29	0.49	0.46	0.52	0.33	0.38	0.03	10
Rawalpindi	0.38	0.43	0.59	0.35	0.44	0.99	1.00	1.00	0.84	0.52	0.77	1.00	1.00	0.82	0.68	0.71	0.26	0.28	0.78	1
Sargodha	0.50	0.50	0.18	0.26	0.37	0.80	0.83	0.87	0.81	0.49	0.08	0.24	0.19	0.42	0.56	0.51	0.39	0.50	0.42	4
Sialkot	0.47	0.47	0.20	0.29	0.27	1.00	0.85	0.98	1.00	0.32	1.00	0.39	0.39	0.19	0.48	0.50	0.23	0.56	0.69	2

6. Conclusion & Policy Recommendation

Climate change is a reality that is expected to have significant impacts on Pakistan's economy with an increase in the frequency of extreme events, including floods and droughts and changing rainfall patterns. Being severely dependent on natural water resources, agriculture in Pakistan is particularly vulnerable to further climate change. Hence, suitable adaptation measures to climate change are essential. This study analyzes the vulnerability of masses, awareness, and adaptive capacities and measures climate changes.

To control vulnerability, adaptive capacity is vital since it will prevent the direct impact of global warming. In any climate change assessment, the construction of social adaptation is critical. Especially in the rural areas agriculture, livestock, and dependence on environmental goods such as crop residue, dung cakes, and wood have contributed a lot and weaken the adaptive capacity while on the other hand, urban areas have an advantage on this end. Hence every metropolitan area has better adaptive capacity than rural areas, but it is not enough for urban areas. If Pakistan wants to run on economic development, then such variables should be prioritized to strengthen the adaptive capacity, and they will give fruitful results in the long run.

Moreover, socioeconomic variables such as education, health, residential status, employment status, and mode of cooking are generally expected as the fundamental and primary objectives in economic growth, hence knowing their importance, these indicators are incorporated in this study to justify their role in the field of climate change. Countries, regions, or areas that are justifying and fulfilling these essentials are now in a better position and have high economic growth while facing the lowest vulnerability to climate change.

The government should be the primary motivator behind all these investors to adopt such technologies and strategies which reduce climatic and environmental degradation factors. Governments of any country can't single-handedly bring revolution, so civil societies should come forward and show their willingness while implementing these beneficial policies to help

out vulnerable and marginalized groups such as children, women, the sick, and elders.

There should be the implementation of Participatory and Learning Action in which societies are morally supposed to do such type of activities that can minimize harm to the climate. Institutions and communities themselves can promote socio-economic factors such as education and health. This approach has already been experimented with in several developing countries, and results have been fruitful, especially for the poor of rural areas. Through it, local natives would be able to prioritize and identify their issues through their knowledge.

6.1 Limitations of the Work

There are further aspects that are not covered in this study due to time and data constraints.

i) First and foremost, the indicators can be broadened for all the Punjab districts, if there are no time and data constraints, then the extension should be of all Pakistan districts.

ii) In this study, extreme events are not being included due to data's non-availability, but in the future, data can be extracted, and extreme events such as droughts, floods, and cyclones should be under consideration.

iii) Physical infrastructure such as canals and dams of all particular districts can be included in the future as it is now considering the backbone of economic activities.

iv) The inclusion of telecommunication and easy accessibility to the warning of sudden hazards should be included because having news before any disaster can strengthen adaptive capacity in a short period.

All these suggestions mentioned above should be considered for a more extensive and comprehensive analysis of vulnerability to climate change and socioeconomic factors.

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