HUMAN CLIMATE VULNERABILITY INDEX (CVI) OF THE COASTAL DISTRICTS OF THATTA AND SUJAWAL, SINDH, PAKISTAN

Noor Fatima[1], Aamir Alamgir[1], *Moazzam Ali Khan[1] and Muhammad Owais[2]

[1] Institute of Environmental Studies, University of Karachi, Karachi, Pakistan
[2] Institute of Business Administration, Karachi, Pakistan
**Corresponding author Email:sherwanis@hotmail.com*

ABSTRACT

CVI (Climate Vulnerability Index) was created and used to the Sindh coastal districts of Thatta and Sujawal, Pakistan. The study aimed to evaluate an integrated vulnerability with multiple indicators of climate variability and social systems, representing adaptive capacity, sensitivity, and exposure of the coastal communities. Both districts showed higher vulnerability with respect to exposure leading to adaptive capacity and sensitivity. In district Thatta, Ghorabari showed greater climate vulnerability (0.62) followed by Thatta (0.59), Mirpur Sakro (0.58) and Keti Bunder (0.52). Similarly, in district Sujawal, Shah Bunder (0.60) was the most vulnerable sub districts followed by Jati (0.59), Sujawal (0.58), Mirpur Bhatro (0.57) and Kharochan (0.56). Over the past 20 years, the coastal sub-districts have seen severe weather disasters and high temperatures. Inadequate livelihood strategies, less involvement in socio-political networks, resource dependency, and weak infrastructure were identified as weak components that needed to be improved in order to increase the adaptive capacity of the coastal communities. In terms of sensitivity, both districts showed high vulnerability to resource variability due to climate change. The study provided a useful CVI tool that is in tune with the livelihood perspectives, social context, and spatiotemporal character of coastal vulnerability. In order to increase adaptability, lessen sensitivity, and decrease exposure to climatic extremes, this can be employed in adaptation planning. Concerns about coastal communities' capacity to deal with current and impending problems related to climate change and rising insecurity are raised by the study.

Keywords: Climate change, Vulnerability, Coastal district, Thatta, Sujawal

INTRODUCTION

The vulnerability of communities and means of subsistence have already been severely impacted by recent climate change and temperature swings, especially in rural areas (IPCC 2014). Exposure to the climate, sensitivity to it, and the ability of populations to adapt are all factors that contribute to climate vulnerability (Stern, 2006). Floods, droughts, and heavy rains are considered to be the climate disasters that cause the most harm to communities who depend on agriculture, seriously endangering the farmers' livelihoods (Erda *et al.,* 2007; Winston *et al.*, 2013). As a result, numerous vulnerability analyses have been performed in various locations to safeguard vulnerable communities against climatological catastrophic events (Antwi-Agyei *et al.,* 2012; Reed *et al.,* 2013; Wiréhn *et al.,* 2015).

Major climate variability concerns in the coastal areas of Sindh are alteration in temperature (Rehman *et al.,* 2015), precipitation (Gajbhiye *et al.,* 2016) and other meteorological parameters (Fatima *et al.*, 2021a). These long-term and drastic changes in climatological parameters across multiple geographical areas have caused flash floods (Kazi, 2014), droughts (Khan and Gadiwala, 2013) as well as damage to multiple natural resources on which livelihood of the coastal communities are largely dependent. For instance, damage to agricultural crops (Fatima *et al.*, 2021b; Lohano and Mari, 2020), water resources and livestock are widely reported. The potential of climate change altered the prognosis for environmental elements in Sindh's coastal regions, having an impact on way of life, availability of natural resources, and other areas of life (Alamgir *et al.,* 2015). Few studies in Pakistan have evaluated livelihood vulnerability at the community level, despite the fact that climate variability and changes to climatological parameters in Sindh's coastal areas have been extensively studied in relation to their effects (Salik *et al.,* 2015; Sattar *et al.,* 2017; Qaisrani *et al.,* 2018). For 103 districts in Pakistan, a straightforward human vulnerability index (HVI) was created (Khan and Salman, 2012) to examine the country's geographical analysis of climate change hazards. The Pakistan Institute of Development Economics (PIDE) in 2013 provided a district level vulnerability index to climate change for 22 districts in Pakistan.

A vulnerability assessment model employed indicators as a stand-in for single measures to quantify complex problems. However, it cannot be described by a single static or singular indicator phrase; rather, it must be evaluated using a number of criteria inside a predetermined framework. The models are also more frequently employed to identify and map vulnerable regions (Hinkel, 2011). Communities that are vulnerable are given first priority, along with raising awareness of the need for adaption measures and developing mechanisms to assess their implementation (Luers *et al.*, 2003).

A Climate Vulnerability Index (CVI) for the coastal areas of Sindh was created as a result of this study. As coastal towns are more vulnerable to climate change, the study's goal was to identify and compare these vulnerabilities. The study looks at the potential for interventions to lessen vulnerability in areas that are vulnerable to climate change. This study examined household vulnerability in coastal areas, enhancing the knowledge on vulnerability assessment that uses indicators.

METHODOLOGY

Study Area

The coastal districts of Thatta, and Sujawal in Sindh were selected for this study and identified as vulnerable hotspot because they have substantial populations living in poverty and their socio-economic activities are heavily influenced by climate change issues. These districts are located in Pakistan's southern area, between 23°43' and 25°26' N, and 67°05' and 68°45'E. The districts have been exposed to high temperatures and significant climatic tragedies during the last two decades in terms of sensitivity and exposure.

Index Computation

Bu using primary data on households and secondary data on climate variability made it easier to calculate the index.

Selection of Indicators

Ten indicator baskets (Fig. 1) were grouped according to Adaptive Capacity in accordance with the tripartite model of vulnerability (IPCC, 2007): (1) Socio-demographic (SD), (2) Socio-political networks (SP), (3) livelihood strategies (LS), (4) infrastructure (IS), (5) resource reliance (RD), and (6) knowledge and skills (KS); sensitivity (HE), (8) natural assets (NA), and (9) resource variability (RV); exposure (Climate Variability) (10) (CV). In Table 1, the primary indicator basket and its subcomponent are defined and explained. The CVI was calculated using a total of 44 sub-indicators.

Data Collection

A preliminary survey was carried out to examine the practicality of collecting the required data through questionnaires. The coastal districts were stratified into sub-districts. A total 265 households were surveyed from 4 sub districts of Thatta (Thatta, Ghorabari, Keti bunder, Mirpur Sakro) and 5 sub districts of Sujawal (Jati, Kharochan, Mirpur Bhatro, Shah Bunder, Sujawal). The process by which each indicator was quantified and standardized is described in Table 2. Also included were secondary data on climate change indicators from the PMD (Pakistan Metrological Department), including average maximum monthly temperatures (^{0}C) and average monthly precipitation (mm) for the years 2001 to 2020.

Standardization and Weighting

To provide a uniform, equivalent scale for the indicators and to aggregate them into a single index, the CVI uses indicators that were scaled differently and standardized. By using the equation shown below, the subcomponents calculated on various scales were standardized:

$$\text{Index } S_i = \frac{S - S_{min}}{S_{max} - S_{min}} \quad (1)$$

Where Si is a sub-indicator of Indicator Basket i and S_{max} and S_{min} are maximum and minimum values, reflecting high and low vulnerability respectively. Equal weights were assigned based on the supposition that each indicator basket contributed equally to total vulnerability (Hahn *et al.,* 2009).

Composite Index Calculation

The value for the indicator baskets was computed by taking the average scores of the standardized subcomponent in each basket using Eq. 2:

$$\text{Indicator Basket Value} = \left[\frac{\text{Indicator}_1 + \text{Indicator}_2 + \ldots + \text{Indicator}_n}{n} \right] \quad (2)$$

where n represents the number of indicators for a specific basket. The values of the indicating baskets were calculated to obtain the CVI score for each coastal district (Eq. 3).

$$CVI = \left[\frac{W_1 Ib_1 + W_2 Ib_2 + \dots\dots\dots + W_n Ib_n}{W_1 + W_2 + \dots\dots\dots + W_n} \right] \quad (3)$$

Where, CVI is the computed climate vulnerability index with an exposure of climate variability. Ib1…...Ibn are the indicator baskets, and W1……Wn represent the number of indicators in each basket. The value for each basket and overall vulnerability score were computed for each coastal district and sub-districts. The CVI is scaled from 0 (least vulnerable) to 1 (most vulnerable). For CVI the equation 2 is defined as:

$$CVI = \left[\frac{W_{SD}SD + W_{SP}SP + W_{LS}LS + W_{IS}IS + W_{RD}RD + W_{KS}KS + W_{HE}HE + W_{NA}NA + W_{RV}RV + W_{CV}CV}{W_{SD} + W_{SP} + W_{LS} + W_{IS}IS + W_{RD} + W_{KS} + W_{HE} + W_{NA} + W_{RV} + W_{CV}} \right] \quad (4)$$

RESULTS AND DISCUSSION

Tables 3 and 4 show the combined CVI for the districts of Thatta and Sujawal. The CVI values spider diagram for all 10 major Indicators of vulnerability are shown in Fig. 2.

According to the vulnerability findings (Table 3 and 4), the districts of Thatta and Sujawal showed similar climate vulnerability indexes (CVI 0.59). Comparatively, district Thatta showed greater vulnerability in livelihood strategies (0.73), while Sujawal was more vulnerable in terms of socio-demographics (0.39), infrastructure (0.65) and resource dependency (0.70). However, the socio-political network and climate variability indices were higher for Thatta (0.61 and 0.70) than for Sujawal (0.59 and 0.67).

Fig. 3 shows the score of coastal districts in terms of adaptive capacity, sensitivity, and exposure. The coastal district Thatta and Sujawal showed similar vulnerability in terms of adaptive capacity (0.57). The coastal district of Sujawal is more vulnerable in terms sensitivity (0.49). Shifts in temperature and rainfall indices were generally similar for Thatta and Sujawal. However, the vulnerability score for exposure was a little higher for Thatta (0.70) than for Sujawal (0.69) due to high climate related losses to crops and livestock during extreme events.

The spider diagrams of vulnerability showing CVI values for the subdistricts of Thatta and Sujawal are given in Fig. 4 and 5. The results of the socio-demographic (SD) indicator basket indicated that the greater vulnerability in Thatta occurred in sub-district Keti Bunder (0.45), followed by Ghorabari (0.38), Mirpur Sakro (0.37), and Thatta (0.33). The age dependency ratio (SD1) was higher and similar in the subdistricts of Thatta and Keti Bunder, indicating a larger ratio of economically dependent populations to the productive parts of the population. During the survey, all household heads interviewed in Keti Bunder had never attended school, and the vulnerability score for education (SD2) was 1.0. Similarly, the households in other subdistricts were also uneducated, although they reported various years of experience in agricultural and fishing activities. In Sujawal, the age dependency ratio (SD1) was higher in Kharochan (0.30) than in Jati (0.20). However, other sub-districts showed a similar low vulnerability score (0.10). The vulnerability score for the education index was higher in Kharochan (0.90) and Sujawal (0.80), where more than 80% of household heads were uneducated but had more than two years of experience in their respective fields.

In the social-political network, Ghorabari (0.63) in Thatta and Mirpur Bhathro (0.66) in Sujawal were the most vulnerable subdistricts in the social-political network basket that did not have access to socio-political (SP) support during hard times. The majority of the respondents in these subdistricts are not members of any official local organization or group. More than 60% of households in each sub-district except Keti Bunder (Thatta) and Kharochan (Sujawal) did not approach the local government and NGOs in the last five years for any kind of assistance or external support. Most of them had no access to information about programmes for financial assistance, security, or climate change, and they had no interaction with the local government. In addition, the local authority gave those help and allowed them to borrow money. The inhabitants of all subdistricts cooperated when there was a lack of supplies or bad weather. Each sub district's households have access to social media and information via telephone, radio, and/or television, ranging from 40 to 75 % of them.

In Thatta, subdistrict Thatta (0.72) showed greater vulnerability in the livelihood strategy (LS) basket than Ghorabari (0.67), Mirpur Sakro (0.59), and Keti Bunder (0.50). Similarly, in Sujawal, subdistrict Shah Bunder (0.73) showed more vulnerability, followed by Mirpur Bhatro (0.72), Jati (0.71), Sujawal (0.67), and Kharochan (0.60). The majority of the households in these sub districts have not received remittance (LS1) in the last two years in the form of cash or in-kind support from family members or friends living in urban areas. The results showed a high vulnerability score for low annual net income (LS2) in Ghorabari (0.88) in Thatta and Kharochan (0.90) in Sujawal. Moreover, their accessibility to credit or loans from any financial institution to fund their activities is low.

In terms of savings to cope with natural disasters (LS3), high vulnerability scores (> 0.8) were observed in all subdistricts in Thatta and Sujawal. Moreover, more than 80% of households in Ghorabari, Keti Bunder, Jati, and Kharochan showed livelihood dependency (LS5) on fishing and farming as a principal source of income, making them more vulnerable to the consequences of climate change. In addition, recent floods also pushed landless farmers to rely on debit/loans, which they often obtained from landlords and private money lenders. During a field survey, more than 40% of households in each sub-district were found in indebtedness.

Table 1. Description of Indicators and functional relationship with vulnerability.

Vulnerability Indicators		Units	Description/Functional relationship with vulnerability
1. Adaptive Capacity 1.1 -Socio Demographic (SD)			
SD1	Age Dependency	Ratio	Households where presences of age groups more than > 50 or < 16 are more vulnerable and have low adaptive capacity.
SD2	Education	%	Households where head is not educated (qualification less than class 5) have low adaptive capacity and more vulnerable.
SD3	Experience	%	Years of experience. Households where head has ≤ 2 years of experience in farming/fishing/herding have low adaptive capacity.
SD4	Family Size	Number	A household where family size is more than 7 members is considered as large family and more vulnerable.
1.2- Socio-Political Networks (SP)			
SP1	Membership in association	%	Households that is not members of any organization or group have low adaptive capacity since social contacts provides assistance in terms of aids which reduce vulnerability.
SP2	External support	%	Households received no cash aid since last 10 years (private, government, NGO) are more vulnerable and have low adaptive capacity
SP3	Access to information	%	Households reporting no access to climate/security/aid-support information
SP4	Access to Government	%	Households that had contact to local government officials for help will highlight issues of particular areas and increase the sharing knowledge of coping strategies and reduce vulnerability.
SP5	Help from landlord	%	Households that contacted help from leader of the community and borrow money. High borrowing indicates financial stress and low adaptive capacity
SP6	Local cooperation	%	Households reporting less cooperation among groups/village folks during scarcity are more vulnerable
SP7	Access to social media	%	Households have access to TV/radio/telephone at home. Access to communication media means more awareness of natural hazards and preparation.
1.3- Livelihood Strategies (LS)			
LS1	Remittance	%	Households receiving remittance since last 2 years. It includes cash and in-kind goods received from family members, friends and colleagues living mainly outside the villages. Income diversification means more adaptive capacity.
LS2	Low Annual Income	%	Households with annual net income lower than Rs 200,000 to cover important expenses food, clothing and housing are more vulnerable.
LS3	Savings	%	Households that have no savings to cope with natural disasters are more vulnerable and low adaptive capacity.
LS4	Credit/loans	%	Households with no access to any financial institution for credit/loans.
LS5	Livelihood dependency	%	Households reporting crop cultivation/fishing/livestock herding as a main source of income. The other activities include trading, public services and private employment.
LS6	Dependency on debit/loans	%	Households that have to pay debit or loan are considered as more vulnerable.
1.4-Infrastructure (IS)			
IS1	Nearest vehicle station	%	Average time to reach nearest vehicle station (minutes). More time duration means low adaptive capacity.
IS2	Road condition	%	Households reporting village roads are not paved have less adaptive capacity
IS3	House structure	%	Households own/live houses that are unable to withstand a severe climatic event (e.g., heavy rains or winds) are considered as more vulnerable.

1.5- Resource Dependency (RD)			
RD1	Electricity	%	Households that are more dependent on electricity are considered to be more vulnerable and have low adaptive capacity.
RD2	Natural Gas	%	Households that are more dependent on natural gas are considered to be more vulnerable and have low adaptive capacity.
1.6- Knowledge and Skills (KS)			
KS1	Knowledge of Climate Change	%	Households not satisfied with local government efforts in sharing knowledge of climate change are more vulnerable.
KS2	Vocational Training	%	Household members who have not taken any kind of vocational training have low adaptive capacity and more vulnerable.

Table 1. (contd.) Description of Indicators and functional relationship with vulnerability.

2. Sensitivity 2.1 -Health (HE)			
HE1	Chronic Diseases	%	Households with members who have chronic diseases are more vulnerable and have low adaptive capacity due to weak immune system.
HE2	Access to Healthcare Facility	%	Households do not use health facility at all or once in a while due to access constrain (too far away, too costly, unsuitable, lack of tool/staff, not enough facilities) are considered to be more vulnerable due to their limited access to healthcare facilities.
2.2 -Natural Asset (NA)			
NA1	Water	%	Households that do not have backup for drinking/well water and do not have access to private well/piped water have low adaptive capacity and are more vulnerable due to inadequate water supply.
NA2	Land Ownership	%	Households that do not own the land where they currently live/farm/graze animals (or are unable to access/rent land legally) are more vulnerable.
NA3	House Ownership	%	Households do not own houses where they currently live are considered to be more vulnerable. Less house ownership indicates more vulnerability in the region.
NA4	Livestock Ownership	%	Households do not own livestock currently they are using for grazing have low adaptive capacity and are more vulnerable.
NA5	Food	%	Households that do not save grain crops and had food shortage in last 30 days are more vulnerable because they don’t have access to safe and adequate food supply that increases the vulnerability in the community.
2.3 -Resource Variability (RV)			
RV1	Public water system	%	Households do not receive water through public water system (water supply) are more vulnerable. Villages that have adequate supply of water are less vulnerable.
RV2	Water scarcity	%	Households that are facing problem of water scarcity are more vulnerable and have low adaptive capacity. Increase water scarcity issue indicates increase vulnerability in region.
RV3	Distance to water point	%	Households reporting long distance to water point ($\geq$ 30 minutes return trip): tap water, hand pump, motor pump, protected well, mineral water has low adaptive capacity. Shorter distance to water supply point reduces the vulnerability of community.
RV4	Income based changes	Extent	Decrease in water resources reduces income for livelihood which indicates low adaptive capacity. (1= No extent, 2= Some extent 3=High extent, use to quantify responses on income-based changes)

Table 1. (contd.) Description of Indicators and functional relationship with vulnerability.

3.1 -Climate Variability (CV)			
CV1	Shifts in Temperature	%	Households noticed any long-term shifts or changes (≤ 20 years) in temperature in area. Increase temperature fluctuation in the region indicates increase vulnerability index.
CV2	Shifts in Precipitation	%	Households noticed any long-term shifts in rainfall in area. Erratic changes in precipitation trend indicates more vulnerability in region.
CV3	Change in Maximum Monthly Temperature	(^{0}C)	Increase in maximum monthly temperature will be responsible for increase climatic events which makes the region more vulnerable to climate change.
CV4	Change in Monthly Precipitation(mm)	(mm)	Changes in rainfall pattern will reduce crop productivity and thus livelihood of the community will be affected which increases vulnerability in the region.
CV5	Hot Months	Count	Increase in hot months will increase vector borne diseases, increase health issues, aggression and conflict vulnerability in coastal regions
CV6	Climate related losses to crop damage	%	Households that reported crop damage due to floods/droughts/windstorms in the past 20 years are more vulnerable. Decrease crop production will affect the livelihood of affected communities that makes them more vulnerable.
CV7	Climate-related losses to livestock	%	Households that reported livestock losses due to droughts/floods and extreme climate in the past 20 years are more vulnerable because it will affect the livelihood of these communities.
CV8	Climate Induced Migration	%	Households that reported migration due to climate change and natural disaster during last 20 years have low adaptive capacity. Increase rate of migration will also increases the dependency on natural resources that is associated with more vulnerability.
CV9	Seawater Intrusion	%	Household that reported saline ground water resources and agriculture land due to sea water intrusion in last 20 years are more vulnerable. Increase sea water intrusion in coastal areas indicates more vulnerability in region because people don't have safe access to ground water resources.

Table 2. Example for calculating the major component of Resource Variability and CVI

Resource Variability (RV)			Units	Min-Max	Average Value	Weighted Value
RV1	Public water system	HHs do not receiving water through public water system (water supply)	%	0-100	73.3%	0.73
RV2	Water scarcity	HHs concerning water scarcity as a big problem	%	0-100	65.9%	0.66
RV3	Distance to water point	HHs reporting long distance to water point (≥ 30 minutes return trip): tap water, hand pump, motor pump, protected well, mineral water	%	0-30	42.2%	0.42
RV4	Income based changes	Decrease in water resources reduces income for livelihood (1= no extent, 2= some extent, 3= high extent used to quantify responses on income-based changes).	Extent	1-3	2.5	0.75

Notes: Calculating steps for indices of sub-indicators and major Indicator Basket as follows:
Step 1: Repeat for all sub-indicators (refer to Table 1)

$$\text{Index } S_{RV1} = \frac{S_{RV1} - S_{RV1min}}{S_{RV1max} - S_{RV1min}} = \frac{73.3 - 0}{100 - 0} = 0.73$$

Step 2: Repeat step 1 for subcomponents of other major components (refer to Table 2)and then use Equation (1) to calculate

$$RV = \frac{RV1 + RV2 + RV3 + RV4}{4} = \frac{0.73 + 0.66 + 0.42 + 0.75}{4} = 0.64$$

Step 3: Repeat for all other major components in step 2 for CVI (using equation 2)

Table 3. Climate Vulnerability Index (CVI) of coastal sub-districts of Thatta.

Vulnerability	Indicator Basket	Index Value				
		Thatta	Ghorabari	Keti Bunder	Mirpur Sakro	Total Thatta
Adaptive Capacity	Socio Demographic (SD)	0.33	0.38	0.45	0.37	0.36
	Socio-Political Networks (SP)	0.59	0.63	0.31	0.65	0.61
	Livelihood Strategies (LS)	0.72	0.80	0.60	0.68	0.73
	Infrastructure (IS)	0.60	0.69	0.60	0.65	0.63
	Resource Dependency (RD)	0.71	0.68	0.40	0.65	0.67
	Knowledge and Skills (KS)	0.36	0.39	0.30	0.38	0.36
Sensitivity	Health (HE)	0.31	0.36	0.20	0.38	0.34
	Natural Asset (NA)	0.51	0.49	0.56	0.36	0.45
	Resource Variability (RV)	0.64	0.78	0.68	0.63	0.64
Exposure	Climate Variability (CV)	0.71	0.68	0.70	0.68	0.70
Climate Vulnerability Index (CVI)		0.59	0.62	0.52	0.58	0.59

Table- 4. Climate Vulnerability Index (CVI) of coastal sub-districts of Sujawal.

Vulnerability	Indicator Basket	Index Value					
		Jati	Kharo Chan	Mirpur Bathoro	Shah Bander	Sujawal	Total Sujawal
Adaptive Capacity	Socio Demographic (SD)	0.39	0.44	0.30	0.35	0.37	0.39
	Socio-Political Networks (SP)	0.57	0.41	0.66	0.58	0.59	0.59
	Livelihood Strategies (LS)	0.71	0.60	0.72	0.73	0.67	0.70
	Infrastructure (IS)	0.70	0.67	0.64	0.61	0.64	0.65
	Resource Dependency (RD)	0.68	0.55	0.65	0.82	0.76	0.70
	Knowledge and Skills (KS)	0.37	0.35	0.38	0.36	0.34	0.36
Sensitivity	Health (HE)	0.42	0.35	0.38	0.36	0.40	0.38
	Natural Asset (NA)	0.42	0.50	0.32	0.53	0.43	0.42
	Resource Variability (RV)	0.69	0.75	0.62	0.68	0.68	0.67
Exposure	Climate Variability (CV)	0.70	0.71	0.67	0.71	0.70	0.69
Climate Vulnerability Index (CVI)		0.59	0.56	0.57	0.60	0.58	0.59

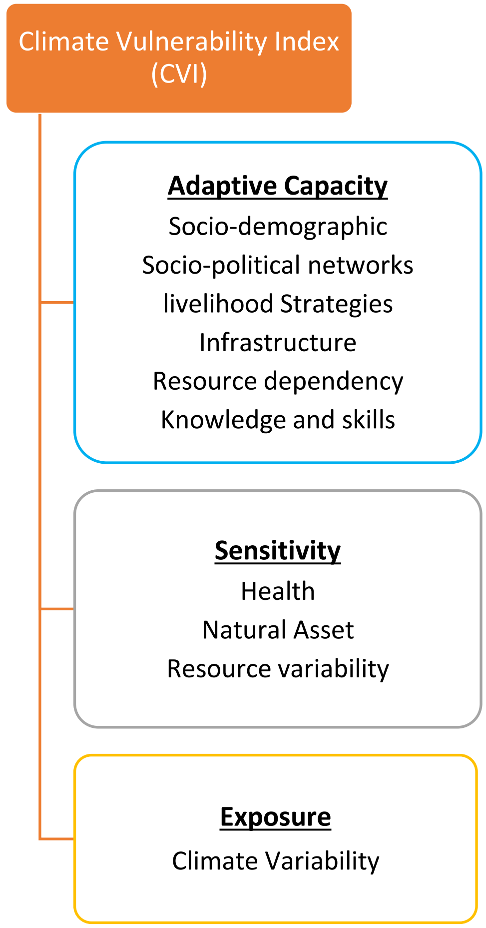

Fig. 1. Major Indicator Baskets used for CVI

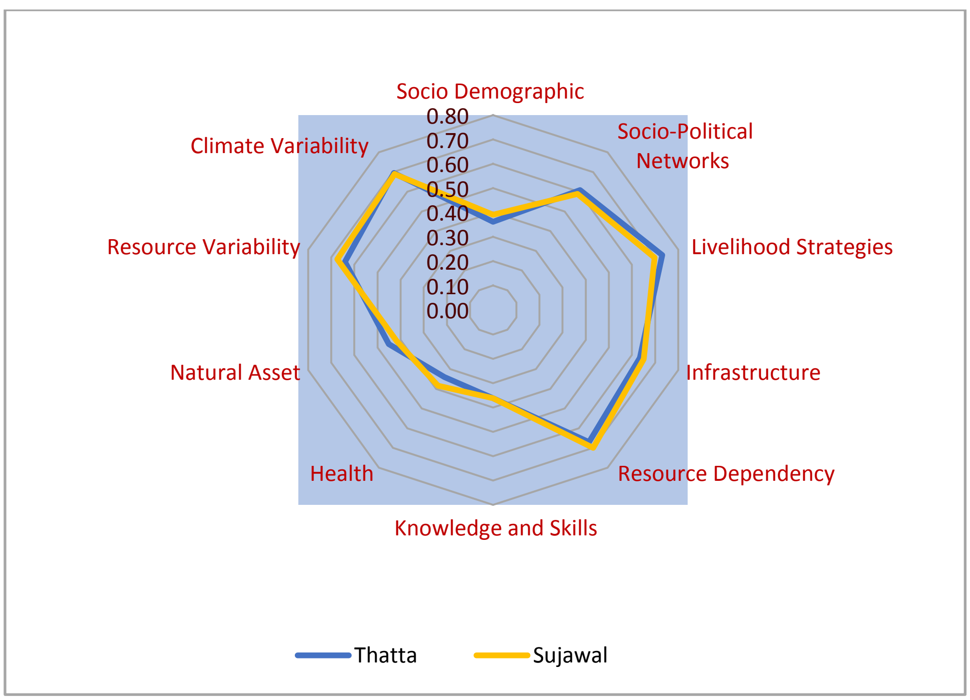

Fig. 2. The spider diagram of vulnerability showing CVI values for coastal districts

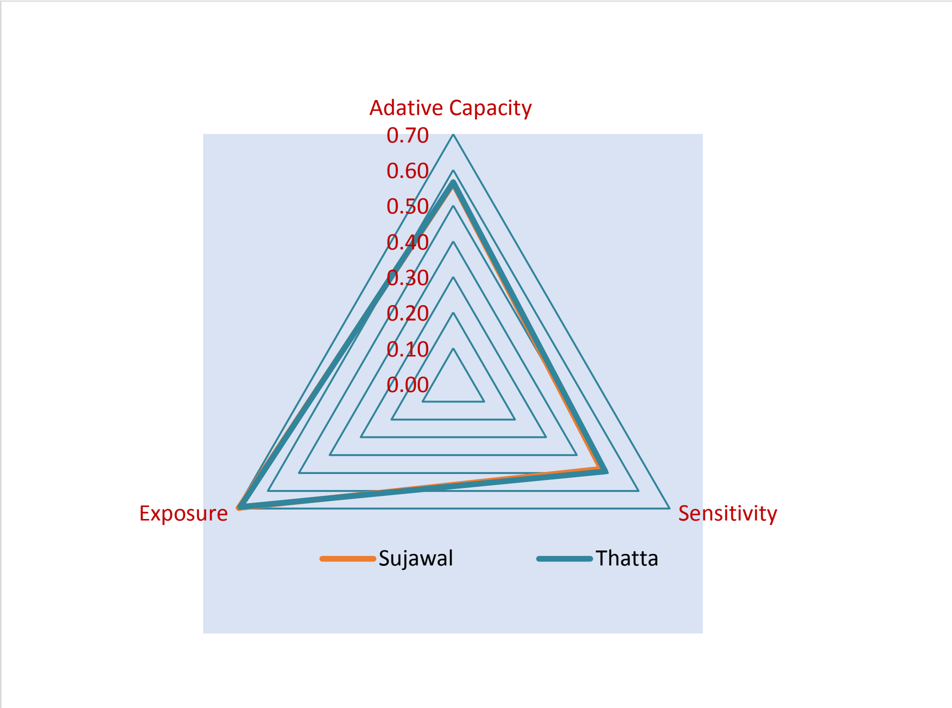

Fig. 3. The vulnerability triangle of Adaptive Capacity, Exposure and Sensitivity

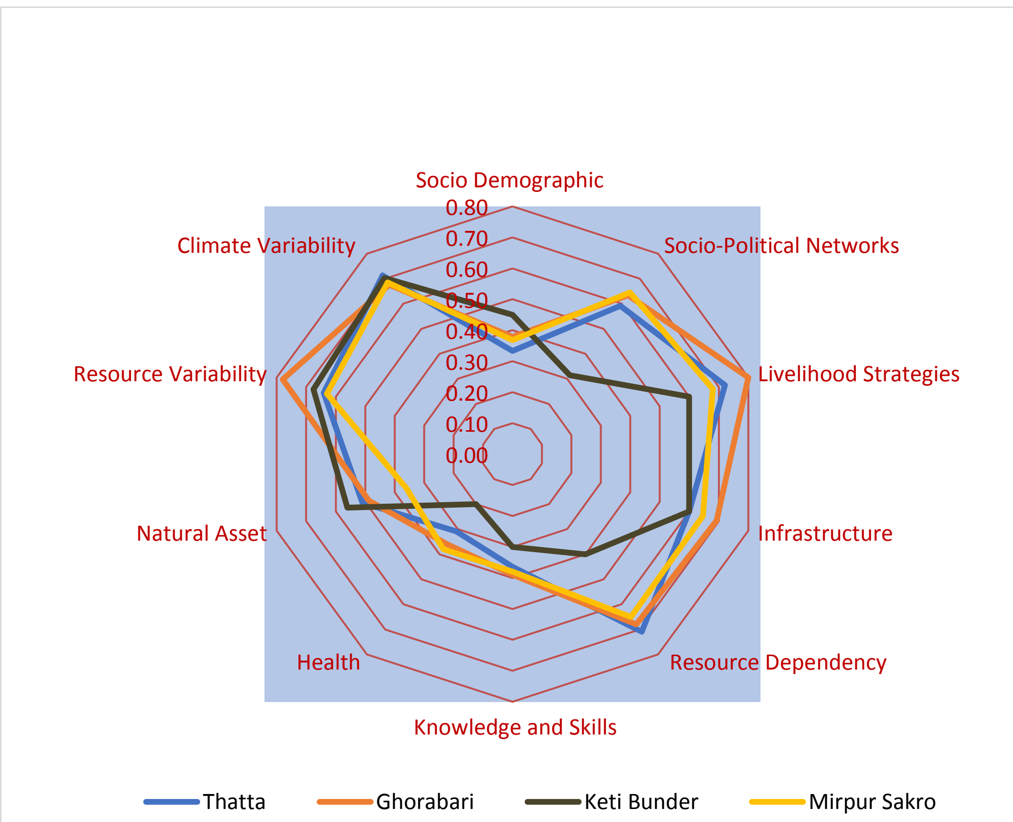

Fig. 4.The spider diagram of vulnerability showing CVI values for Subdistricts of Thatta

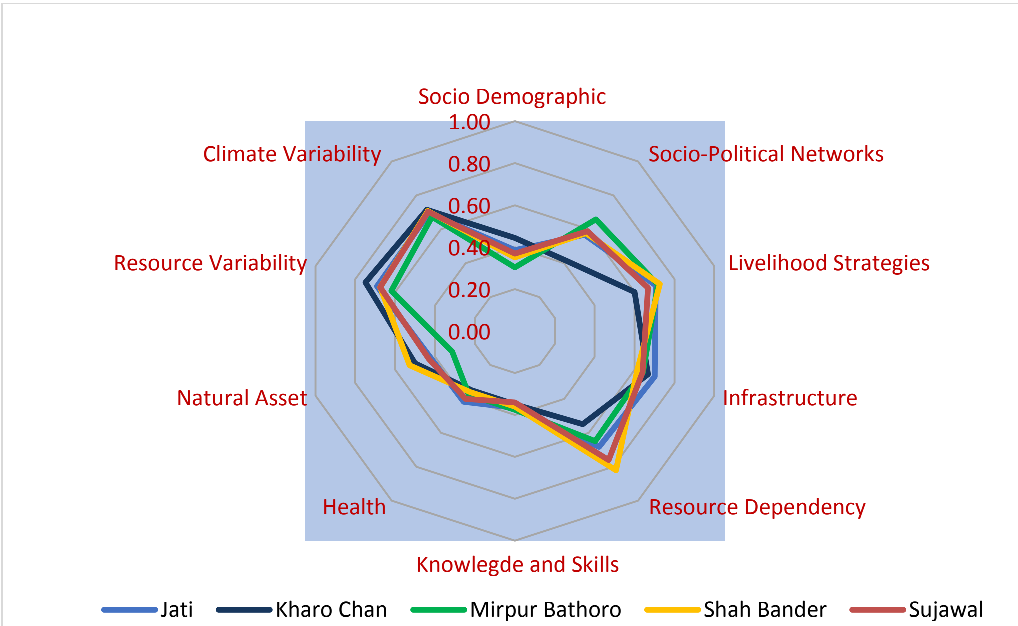

Fig. 5. The spider diagram of vulnerability showing CVI values for Subdistricts of Sujawal.

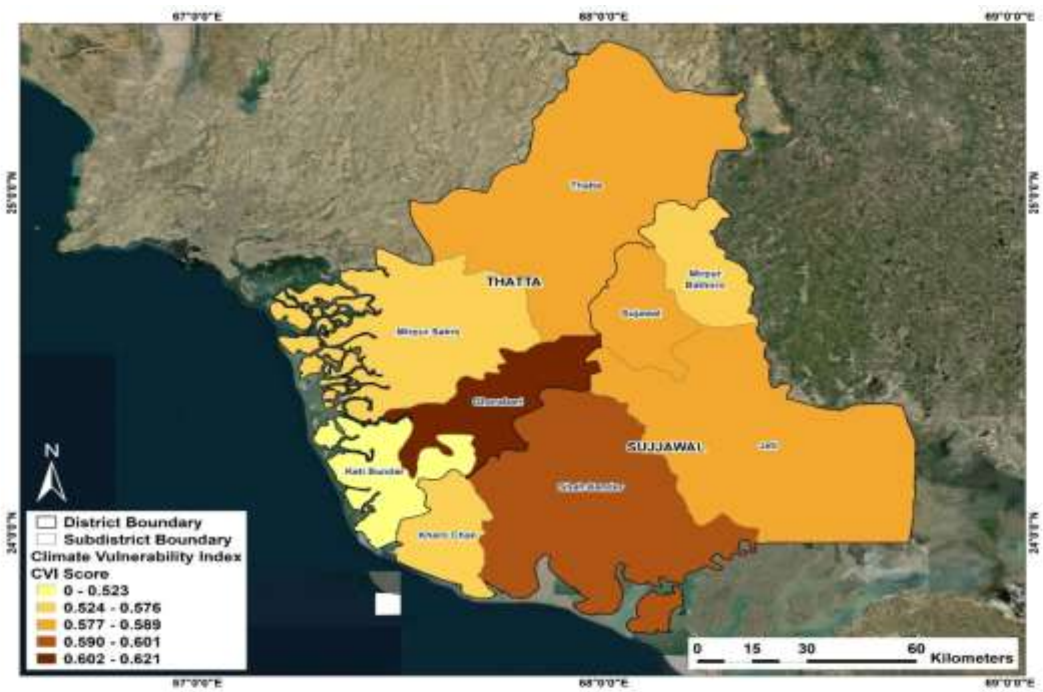

Fig. 6. The CVI mapping of the coastal sub-districts of Thatta and Sujawal.

The coastal subdistricts of Thatta and Sujawal showed greater vulnerability in terms of infrastructure (IS), which was inadequate to resist future climate-related extreme events. The majority of the households (more than 70%) reported unpaved roads and they travel a long distance (taking more than 30 minutes to reach the nearest vehicle station). The structure of houses in the districts was bamboo and wood-based roofs with mud brick walls that are susceptible to extreme climate events. Further, basic government facilities (schools, hospitals, markets, and telecommunications) were present but generally disseminated, inactive, and poorly equipped.

In terms of resource dependency (RS), the majority of the households in Thatta (56%) and Shah Bunder (80%) were dependent on electricity, and more than 80% of households in all subdistricts (except in Keti Bunder) were dependent on natural gas for their domestic use. The knowledge and skills (KS) results also showed that most households were happy with recent efforts made by local government and NGOs to share knowledge (KS1) of climate change, and that about 40% had not received any kind of vocational training to improve their skills (KS2) and make them more adaptable to sudden changes in livelihood.

Health basket vulnerability score was high in Mirpur Sakro where 30% households with members reported chronic diseases. However, it was comparatively low in all subdistricts of Sujawal. More than 40% households in all sub-districts did not use healthcare facility at all or once in a while due to access constrain (too far away, too costly, unsuitable, lack of tool/staff, not enough facilities).

The Index value for the Natural Asset (NA) was higher in Keti Bunder (0.56) and Shah Bunder (0.53). It was found that 60% of the households in Keti Bunder and Kharochan did not have access and backup to private well/piped water. In terms of land ownership (NA2), more than 70% households in Mirpur Sakro, Jati and Kharochan did not own the land where they currently live/farm/graze animals or are unable to access/rent land legally**.** However, the house ownership (NA3) was found in more than 70% household in all sub-districts. The highest livestock ownership was reported in Mirpur Sakro and Jati. Around 50% households reported that they did not save grain crops and had food shortage in last 30 days**.**

The influence of resource variability (RV) on the coastal communities and their livelihoods has also been studied with reference to water resources. The vulnerability score for the public water system was high in Keti Bunder (1.00), Ghorabari (0.90), Kharochan (0.90) and Jati (0.83). The households in all these subdistricts (except in Thatta and Mirpur Bhatro) reported long distances to water points (tap water, hand pump, motor pump, protected well, mineral water) and showed higher vulnerability. The majority of them considered resource scarcity as a big problem, showing a high vulnerability score in all subdistricts. Consequently, many farmers have experienced income-based changes resulting from the decreasing fresh water resources used for agriculture activities. The vulnerability score for livelihood changes during the last ten years was highest in Thatta (0.82) and Shah Bunder (0.86), showing large dependency on water.

Shifts in temperature and rainfall indices were generally similar for all sub-districts of Thatta and Sujawal. However, subdistricts Thatta, Kharochan, and Shah Bunder showed the greatest vulnerability in the climate variability (CV) basket. The majority of the households (> 85%) in both districts noticed long-term shifts or changes in temperature and precipitation in the last two decades. On the basis of the calculated mean standard deviation of the monthly average maximum daily temperature (CV3) and monthly average precipitation (CV4) for the last 20 years, the index value was the same for all subdistricts and was calculated as 0.32 and 0.21. However, the vulnerability score for the number of hot months with an average monthly temperature above 30 ^{0}C (2001–2020) was 0.8 for all sub-districts. However, the vulnerability score for the number of hot months with an average monthly temperature above 30 ^{0}C (2001–2020) was 0.8 for all sub-districts. The findings also indicated a high vulnerability score (0.80-0.96) for losses due to livestock and crop damage caused by climate change. Over 80% of homes in the last 20 years experienced ground water salinity brought on by sea water intrusion. Although their vulnerability score was low, some of the households also stated that the villagers had migrated owing to climate change and natural catastrophes.

Overall mapping of climate vulnerability findings for all subdistricts of Thatta and Sujawal is shown in Fig. 6. In district Thatta, Ghorabari showed greater climate vulnerability, followed by Thatta, Mirpur Sakro, and Keti Bunder. Similarly, in district Sujawal, Shah Bunder was the most vulnerable subdistrict, followed by Jati, Sujawal, Mirpur Bhatro, and Kharochan.

The prolong and drastic changes in climatological parameters in the coastal areas of Sindh have caused flash floods (Kazi, 2014), droughts (Khan and Salman, 2012)as well as damage to multiple natural resources on which livelihood of the coastal communities are largely dependent. Climate variability and alteration in climatological parameters in the coastal areas of Sindh have been widely studies in association with its impacts on water resources (Alamgir *et al.*, 2016a)particularly Indus Delta (Chandio *et al.,*2018)and also ground water resources (Alamgir *et al.*, 2016b). However, studies from socioeconomic perspectives are also being conducted to assess the impacts of climate change (Shah, 2016) and its vulnerability and adaptation options for the local coastal communities (Salik *et al.*, 2015). However, first time in this region, this study assessed an integrated vulnerability analysis with multiple indicators of climate variability and social system on the household level representing adaptive capacity, sensitivity and exposure of the coastal communities. Despite the fact that current data on temperature and rainfall show nearly identical climatic patterns for all coastal districts, community perceptions of climate variability revealed that local exposures, vulnerabilities and responses varied.

The results showed that district Thatta was more and equally exposed to climatological events and its losses. Thatta were better off in adaptive capacity through socio-demographic, adequate Infrastructure and resource dependency but highly sensitive in terms of natural assets. The households showed high access constraints to healthcare facility, less land ownership and high-water scarcity in Sujawal. Exposure of Sujawal to climate variability and climate related losses was comparatively low and it also showed less sensitivity in terms of natural asset. In 2017, Sujawal also categorized in a low human development category in terms of Human Development Index (PNHDR, 2017).

According to the results, the livelihood strategy and resource variability are two of the major contributors to the vulnerability index of the coastal districts. A similar result was observed in vulnerability assessment conducted in Mozambique (Hahn *et al.*, 2009) in which an emphasis was given on diverse approach for livelihoods. Livelihood vulnerability occurs due to less income diversification and a lack of education and knowledge. The results specify that households involved in greater than one livelihood activity, especially dynamic in socio-political networks are relatively less likely to be vulnerable. Vulnerable households have lesser access to local organizations, external support and NGOs than those less vulnerable (Agrawal, 2008). Similar research elsewhere has shown that involvement in a social organization enhances adaptive capacity (Smith and Wandel, 2006). In this study, this is applicable to the Ghorabari and Shah Bunder where households had low annual income, less savings, livelihood dependency and low remittance opportunity with limited involvement in political participation, causes of their low adaptive capacities. Furthermore, one of the factors also contributing livelihood vulnerability was a credit or loan that farmers had taken for crop inputs with a huge profit margin. They also bounded to sell their crops to input dealers at lesser than market price. Moreover, due to any constraint if the quality of crop is reduced and they did not pay the credit timely, the credit goes for the next crop season or year with an even larger interest. The higher vulnerability for credit/loan was observed in all subdistricts of Thatta and Sujawal.

Resource variability and natural assets (house, land, livestock etc.) could be easily converted into other assets and play a crucial role in determining sensitivity of the communities (Ospina and Heeks, 2010; Lemos *et al.*, 2013). Households in subdistricts of Tandobago, Ghorabari and Kharochan were the most sensitive in terms of resource variability and natural assets. Availability of water resources especially in agrarian regions, play a crucial role in the overall vulnerability. The coastal districts showed higher vulnerability to the public water supply, water related income changes and community perspective to water scarcity. The local government publicized number of water supply scheme but none of them are barely executed. The land ownership was rare in the region, which would rise their adaptive capacity by enhancing diverse crop productivity (Fischer *et al.*, 2007). Another important indicator of vulnerability is health (Lemos *et al.*, 2013) in terms of chronic diseases and access to healthcare Centre. Tando Bago, Mirpur Sakro and Sujawal are the most sensitive subdistricts in health Index. During field survey, it was observed that an increasing temperature has made most of the regions suitable for numbers of vectors and extended their season. In addition, water quality is also responsible for water borne diseases among the communities.

Climatological events also contributed major vulnerability in coastal districts of Sindh. Sub-districts Tando Bago, Thatta, Kharochan and Shah Bunder showed higher vulnerability to climate exposure as evidence by high losses of land, crops and livestock. Based on statistical evidence, it has been found that hot days frequency index in coastal areas of Sindh is significantly increased (0.15) during 36-year time period (Abbas *et al.*, 2018). Since rising temperature has already affected the natural resources in the area, particularly the agriculture sector, the livelihood opportunities in the area have become limited.

The decline of the Indus deltaic region is mostly due to diminished downstream flow, which has resulted in seawater encroaching over 1,700 km^2 of the delta over last five decades (Alamgir *et al.*, 2017). In the deltaic portion of the Indus River, the flow is inadequate to push the sea water back to its original place. The groundwater become also saline as a result of seawater intrusion. The soils in coastal areas are becoming salinized, rendering them useless for agriculture, resulting an involuntary migration of local population. If the Indus River's flow continues to dwindle, the scenario will become even more dangerous.

During monsoon high tides from the sea triggering breaching of drains, which is producing disturbing losses in the districts, Thatta and Sujawal. It has been reported that floods and tropical storm in the coastal areas might displace about 50,000 people by enforcing them to migrate (Mahessar *et al.*, 2019) Mass level migration and land acquisition will result in conflict over available land resources, probably over limited flood prone areas (Ali *et al.*, 2018). Furthermore, the constant and unending depletion of accessible natural resources prompted mass movement of people to metropolitan centers that were unprepared to absorb them, resulting in conflicts in the studied region.

Conclusion

In this study, the usefulness of the climate vulnerability index was assessed in relation to aspects related to the socioeconomic and human development of the communities and the many facets of climate change vulnerability. The CVI can be a useful instrument for investigating climatic interactions and contrasting the vulnerability of coastal communities and their ability to adapt to climate change. The tool's prescriptive design adheres to the vulnerability's distinctive social context and spatiotemporal characteristics and was developed in response to livelihood perceptions. The multi-step index computation and data collection methods provide complete numerical data on livelihood vulnerabilities as well as local insights into climate change consequences. The coastal district of Sujawal is more vulnerable in terms sensitivity (0.49) due to high resource variability poor health indicators of the district. Districts of Thatta and Sujawal showed similar vulnerability in terms of adaptive capacity (0.57). Thatta showed greater vulnerability in livelihood strategies (0.73), while Sujawal was more vulnerable in terms of livelihood strategies and resource dependency. However, the socio-political network and climate variability indices was comparatively higher for Thatta. Shifts in temperature and rainfall was generally similar for both districts. Moreover, vulnerability score for exposure was little higher for Thatta (0.70) than Sujawal (0.69) due to high climate related losses to crop and livestock during extreme events. The CVI calculated in this work can be applied to adaptation planning to increase adaptability, lessen sensitivity, and mitigate exposure to climate extremes. Concerns about coastal communities' capacity to handle current and forthcoming issues related to climate change and rising insecurity are also raised by the study.

REFERENCES

Abbas, F., I. Rehman, M. Adrees, M. Ibrahim, F. Saleem, S. Ali, and M.R. Salik (2018). Prevailing trends of climatic extremes across Indus-Delta of Sindh-Pakistan. *Theoretical and applied climatology*, 131(3): 1101-1117.

Agrawal, A. (2008). The role of local institutions in adaptation to climate change.

Alamgir, A., M. A. Khan, I. Manino, S.S. Shaukat and S. Shahab (2016a). Vulnerability to climate change of surface water resources of coastal areas of Sindh, Pakistan. *Desalination and Water Treatment*, 57(40): 18668-18678.

Alamgir, A., M. A. Khan, J. Schilling, S.S. Shaukat & S. Shahab (2016b). Assessment of Groundwater quality in the coastal area of Sindh province, Pakistan. *Environmental Monitoring and Assessment*, 188(2): 1-13.

Alamgir, A., M. A. Khan, S.S. Shaukat, T.M.A. Khan & S. Zubair (2017). Water quality appraisal of Keti Bandar and Shah Bandar creeks of Indus delta, Sindh, Pakistan. *Desalination and Water Treatment*, 70: 95-105.

Alamgir, A., M. A. Khan, S.S. Shoukat, F.M. Burfat & K. Mehmood (2015). Impact of climate change on the socioeconomic conditions: A case study of district Thatta, Sindh, Pakistan. *Bulletin of Environment, Pharmacology and Life Sciences*, 4(6): 93-10.

Ali, F., T. A. Khan, A. Alamgir & M. A. Khan (2018). Climate change-induced conflicts in Pakistan: From national to individual level. *Earth Systems and Environment*, 2(3): 573-599.

Antwi-Agyei, P., E.D. Fraser, A. J. Dougill, L.C. Stringer & E. Simelton (2012). Mapping the Vulnerability of crop production to drought in Ghana using rainfall, yield and socioeconomic data. *Applied Geography:* 32(2), 324-334.

Chandio, N. H., M.M. Anwar & Q.H. Mallah (2018). Impacts of climate change on coast line of Arabian Sea: A case study of Indus River Delta, Pakistan. *Sindh University Research Journal-SURJ (Science Series)*, 50(01): 147-152.

Erda, L., X. Yinlong and W. Shaohong (2007). China's national assessment report on climate change (II): climate change impacts and adaptation. *Advances in Climate Change Research*, 3(00): 6.

Fatima, S. U., M. A. Khan, R. Majeed A. Alamgir and S.S. Shaukat (2021a). Multi-Factoral OLSR and MLR Modelling of Climatological and Crop Production trends in coastal areas of Pakistan. *Pakistan Journal of Botany*, 53(2): 641-653.

Fatima, N., A. Alamgir, M.A. Khan and K. Mehmood (2021b). Conceptual Framework for Climate Vulnerability and Conflicts in the Coastal Districts of Thatta and Sujawal, Sindh, Pakistan. *International Journal of Biosciences*, 18(4): 60-76.

Fischer, G., F.N. Tubiello, H. Van Velthuizen & D.A. Wiberg (2007). Climate change impacts on irrigation water requirements: Effects of mitigation, 1990–2080. *Technological Forecasting and Social Change*, 74(7): 1083-1107.

Gajbhiye, S., C. Meshram, S.K. Singh, P. K., Srivastava & T. Islam (2016). Precipitation trend analysis of Sindh River basin, India, from 102- year record (1901–2002). *Atmospheric Science Letters*, 17(1): 71-77.

Hahn, M. B., A. M. Riederer, & S.O. Foster (2009). The Livelihood Vulnerability Index: A pragmatic approach to assessing risks from climate variability and change- A case study in Mozambique. *Global environmental change*, 19(1): 74-88.

Hinkel, J (2011). “Indicators of vulnerability and adaptive capacity”: Towards a clarification of the science–policy interface. *Global Environmental Change*, 21(1): 198-208.

IPCC (2014). Climate Change: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change.

IPCC (2007). Climate Change: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change.

Kazi, A (2014). A review of the assessment and mitigation of floods in Sindh, Pakistan. *Natural Hazards*, 70(1): 839-864.

Khan, F. A., & A. Salman (2012). A simple human vulnerability index to climate change hazards for Pakistan. *International Journal of Disaster Risk Science*, 3(3): 163-176.

Khan, M. A., and M.S. Gadiwala (2013). A study of drought over Sindh (Pakistan) using standardized precipitation index (SPI) 1951 to 2010. *Pakistan Journal of Meteorology*, 9(18).

Lemos, M. C., A. Agrawal, H. Eakin, R.D. Nelson, N.L. Engle, and O. Johns (2013). Building adaptive capacity to climate change in less developed countries. In *Climate science for serving society*, Springer, Dordrecht, 437-457..

Lohano, H. D., & F.M. Mari (2020). Climate Change and Implications for Agriculture Sector in Sindh Province of Pakistan. *Mehran University Research Journal of Engineering and Technology,* 39(3): 668-677.

Luers, A. L., D.B. Lobell, L.S. Sklar, C.L. Addams, & P.A. Matson (2003). A method for Quantifying vulnerability, applied to the agricultural system of the Yaqui Valley, Mexico. *Global Environmental change*, 13(4): 255-267.

Mahessar, A. A., A.L. Qureshi., I.A. Siming., S.M. Kori., G.H. Dars., M. Channa., and A.N. Laghari (2019). Flash flood climatology in the lower region of Southern Sindh. *Engineering, Technology & Applied Science Research*, 9(4): 4474-4479.

Ospina, A. V., and R. Heeks (2010). Linking ICTs and climate change adaptation: A conceptual framework for e-Resilience and e-Adaptation.

Pakistan Institute of Development Economics (2013). A District Level Climate Change Vulnerability Index of Pakistan. Centre for Environmental Economics and Climate Change Pakistan Institute of Development Economics, Islamabad, Pakistan.
Https://Www.Pide.Org.Pk/Pdf/Working%20paper/Ceecc%20working%20paper-5.Pdf

PNHDR (2017). Pakistan National Human Development Report Unleashing the Potential of a Young Pakistan. United Nations Development Programme (UNDP), Pakistan. ISBN: 978-969-8736-19-4.

Qaisrani, A., M. A. Umar., G.E.A. Siyal., & K.M. Salik (2018). What defines livelihood vulnerability in rural semi-arid areas? Evidence from Pakistan. *Earth Systems and Environment*, 2(3): 455-475.

Reed, M. S., G. Podesta., I. Fazey, N. Geeson, R. Hessel, K. Hubacek, & A.D. Thomas (2013). Combining analytical frameworks to assess livelihood vulnerability to climate change and analyze adaptation options. *Ecological Economics*, 94: 66-77.

Rehman, Z., S.J.H. Kazmi., F. Khanum., & Z. A. Samoon (2015). Analysis of land surface temperature and NDVI using geo-spatial technique: A case study of Keti Bunder, Sindh, Pakistan. *Journal of Basic & Applied Sciences,* 11: 514-527.

Salik, K. M., S. Jahangir., & S. Ul Hasson (2015). Climate change vulnerability and adaptation options for the coastal communities of Pakistan. *Ocean & Coastal Management*, 112: 61-73.

Sattar, R. S., S. Wang, M. Tahir and C. Caldwell (2017). Assessment of Smallholder Farmers Vulnerability Due to Climate Change in Arid Areas of Pakistan. *Appl. Ecol. Environ. Res,* 15: 291-312.

Shah, S. S. H (2016). Impact of Climate Change on coastal communities of Sindh, Pakistan. A descriptive case study of districts Thatta and Badin. *European Journal of Social Sciences Studies*. 1 (2): 34-63.

Smith, B., & J. Wandel (2006). Adaptation, adaptive capacity and vulnerability. *Global Environmental Change*, 16(3); 282-292.

Stern, N. (2006). Stern Review: The economics of climate change. *Modern Economy*, 7 (12).
http://mudancasclimaticas.cptec.inpe.br/~rmclima/pdfs/destaques/sternreview_report_complete.pdf

Winston, H. Y., Y.C. Yang., A. Savitsky., D. Alford, and C. Brown (2013). The Indus basin of Pakistan: The impacts of climate risks on water and agriculture. World Bank publications. PP.187.The World Bank 1818 H Street NW, Washington DC 20433

Wiréhn, L., Å. Danielsson and T.S.S. Neset (2015). Assessment of composite index methods for agricultural vulnerability to climate change. *Journal of Environmental Management,* 156: 70-80.

(*Accepted for publication January 2023*)