CLIMATE CHANGE IMPACT ASSESSMENT ON THE FLOOD RISK CHANGE IN KECH RIVER, TURBAT BALOCHISTAN, PAKISTAN

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ABSTRACT

According to the high risk of flood and drought conditions of Kech River, Balochistan, a research has been conducted to perceive the future scenario. A hydrological simulation based on the APHRODITE data showed inundation distribution comparable to MODIS data analysis, which validated the model. An assessment of the climate change effects on the flood and drought risk has been achieved through General Circulation Models (GCMs). Six GCMs whose historical climate reproduced better for the target area were chosen from the Coupled Model Intercomparison Project Phase 5 (CMIP5), and their bias were corrected on the APHRODITE data. The Representative Concentration Pathways 8.5 (RCP 8.5) scenario was selected for future scenario. The discharge and inundation in the projected climate were obtained through the simulation of the Rainfall-Runoff-Inundation (RRI) model. The increasing trend of inundation by global warming are used to assess upcoming conditions of the basin. Some of the GCMs showed large increase of rainfall in future suggested needs of more countermeasures for flood risk. The appropriate use of the information helps to mitigate the flood hazard.

Keywords: Climate change, RRI Model, MODIS, CMIP5, Inundation

INTRODUCTION

Pakistan is one of the most flood-prone countries in South Asia. Balochistan province of Pakistan is the largest in size and the smallest in population. The Province covers 34.7 million hectares, almost 44% of the country's land area, with a population of about 8 million people (12 persons per sq. km.). About 80% of the area can be classified as inter-mountainous. The remaining 20% consists of flood plains and coastal plains. Balochistan is an arid region characterized by low rainfall and frequent dry spells and persistent droughts. In Balochistan Province Kech has the second largest population after province capital Quetta. In Kech district there is high risk of flood as well as drought. The Kech River basin area is 12515 km^2. Southern parts of Balochistan have always been suffered by flash floods. Torrential rains during the monsoon season every year lead to flash floods in the districts of Kech. The district is experiencing heavy rainfall and disastrous floods during

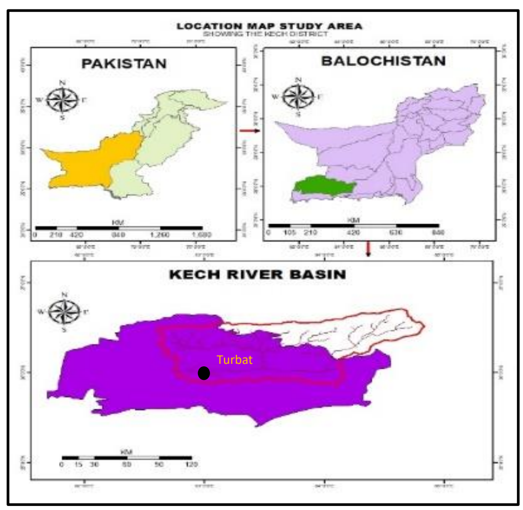

Figure 1: Location of Kech river basin

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last two decades resulted in the huge number of people losses, property, infrastructure, agriculture and livestock. Rainfall and flash flood occurred from June to October. On 26th June 2007 the Cyclone Yimyen hit the area which gives 172 mm of rainfall causes flash flood in the main city of Turbat. The water level rose to 8 meters resulting in destruction of muddy houses, orchards, infrastructure, livestock and water supply in the region. The main source of affected people depends on livestock which suffered a lot after the flooding period. After the event most of the people loosed their livestock and living in open sky in hot and humid weather. It is necessary to prepare evacuation centers for the people who lack knowledge where they can evacuate as well as for saving the livestock.

THEORY AND METHODOLOGY

The methodology of the study consists of three steps. Firstly, we set a hydrological model to make the inundation map of the study area. APHRODITE data were used in the hydrological RRI model and validated by MODIS data. Secondly, GCMs has been selected from the CMIP5 dataset based on the JRA-55 reanalysis data and GPCP precipitation products. The precipitation data were bias corrected based on the APHRODITE. Thirdly, the discharge and inundation distribution has been computed by RRI model. We have discussed the flood and drought risk change in future under the RCP8.5 scenario. The installation of evacuation centers are discussed as a probable countermeasures based on 50 years return period.

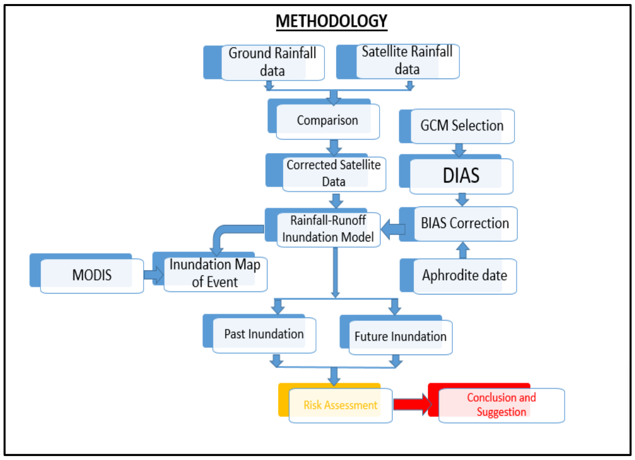

Figure 2: Methodology of study

(i) Analysis of Moderate Imaging Spectroradiometer (MODIS)

The Moderate Imaging Spectroradiometer (MODIS) is used to determine the flood inundation extent for the study area. The Modified Land Surface Water Index (MLSWI) was used to identify flooded areas and land area of the region. MLSWI is calculated by using the following equation.

$$MLSWI = \frac{1 - R_{NIR} - R_{SWIR}}{1 - R_{NIR} + R_{SWIR}}$$

Where NIR stands for near infrared reflectance and SWIR for shortwave infrared reflectance. R_{NIR} and R_{SWIR} are the reflectance values (R) of MODIS bands 2 and 7, respectively.

(ii) The Data Integration and Analysis System (DIAS) for selection of GCMs

The DIAS system has been used to select suitable GCMs for the study region from CMIP5. Historical period 1981-2000 and future period 2081-2100 with RCP8.5 scenario were selected to analyze the climate change effect. The GCMs for the selected study area were evaluated based on the seven meteorological parameters; precipitation, air temperature, outgoing longwave radiation, sea level pressure, zonal wind, meridional wind and sea surface temperature; through spatial correlation and RMSC index compared by JRA-55 reanalysis data and GPCP precipitation products. The six highest total index value were selected for the study area as shown in table 1.

GCM No.	GCM name	Index
1	CESM1(CAM5)	6
2	CESM1(BGC)	5
3	CMCC-CMS	4
4	MPI-ESM-LR	4
5	MPI-ESM-MR	3
6	MIROC5	3

Table 1: Selected GCMs

(iii) Bias Correction of GCM Data

As long term in-situ data of precipitation is not available for the study area, the biases of rainfall of the selected GCMs were corrected through online DIAS tool with respect to APHRODITE data. After that bias-corrected past (1981-2000) and future (2081-2100) data sets were obtained.

(iv) Discharge and Inundation Analysis

The corrected past and future rainfall data of the selected GCMs were provided in RRI model to simulate the projected discharge and inundation distributions. A comparison between the past and the future results of discharge and inundation was made.

(v) Frequency Analysis

Frequency analysis was done using Gumbel-PM distribution on the basis of past (1981-2000) and future (2081-2100) rainfall data. Annual maximum series (AMS) was developed for the whole range of climate data set and extreme rainfall values for 50 and 100 year return period were calculated for the study area.

(vi) Risk Assessment

According to the past observation, it had been noted that most of the effected people were no shelter to attain. Mostly effected people were stayed in open sky which were very hard in hot and humid weather. Considering the analysis climate data the intensity of flood will be increase in future. We propose to install more evacuation centers where people can evacuate shortly.

DATA

(i) Rainfall Data (Ground Rain Gauge, Satellite and APHRODITE Data Set)

The APHRODITE data was used as the baseline data for the period 1981-2000.

(ii) MODIS Data

The moderate resolution imaging spectroradiometer (MODIS) on the NASA Terra satellite captured the images of inundation from June 26, 2007 product MOD09A1 adjusted the resolution by GIS tool to calculate the near infrared and shortwave infrared reflection has been made to separate the land and water bodies.

(iii) Discharge Data

Kech River has no observed discharge due to dry region of the area. Therefore, the discharge was calculated using RRI model.

(iv) Topographic Data

Topographic data of USGS HydroSHEDS, which is a global data set provided by the United States Geological Survey (USGS), is used for RRI model setup. Digital Elevation Model (DEM) of 30 second was used.

(v) General Circulation Models (GCMs)

The General Circulation Models (GCMs) were used for climate change impact analysis on the Kech River basin. The precipitation data of these models BIAS corrected by APHRODITE data for past (1981-2000) and projected future climate in RCP8.5 scenario (2081-2100).

RESULTS AND DISCUSSION

(i) Inundation Map Analysis

An RRI model simulation of the 2007 flood event based on the APHRODITE provided comparable inundation distribution estimated by MODIS. The inundation area of satellite observation and simulation as shown in fig. 3 are consistent with the inundation record in a local report.

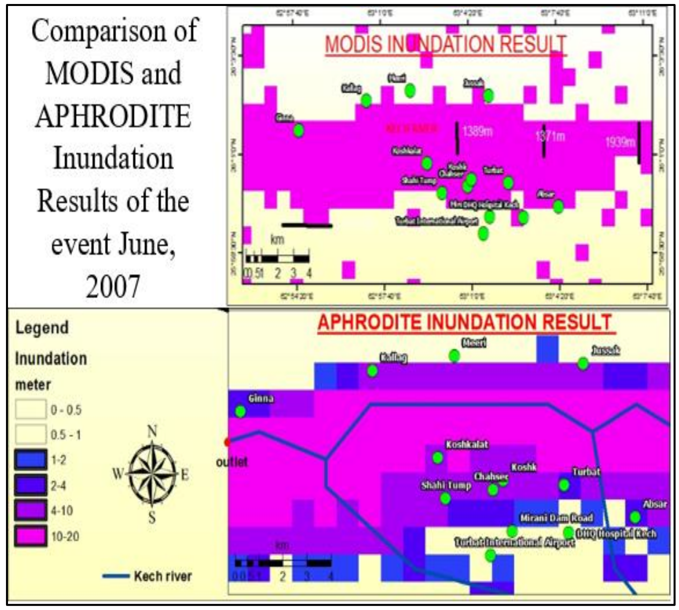

Figure 3: Inundation Map of the area

(ii) Rainfall trend Analysis of GCMs

The figure shows rank order comparison of past and future climate. The rainfall trend is depended on the GCMs. Three out of six GCMs, CESM1 (BGC), CESM1 (CAM5), and MIROC5 show large increasing trend especially in large rainfall part in future as shown in fig. 4-(a), (b) and (d) respectively. Two GCMs, MPI-ESM-LR and MRI-ESM-MR show increasing trend only in large rainfall part as shown in fig. 4-(e) and (f), whereas CMCC-CMS shows decreasing trend except the largest two points in future as shown in fig 4(c). So, the largest two increasing trend will be mentioned as a summary from past (1981-2000) and future (2081-2100).

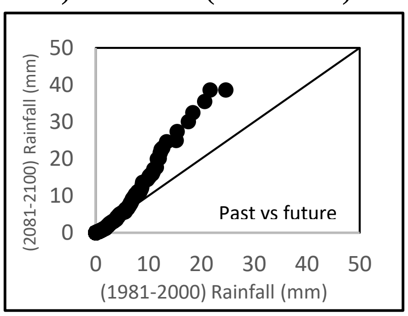

Figure 4(a): CESM1 (BGC)

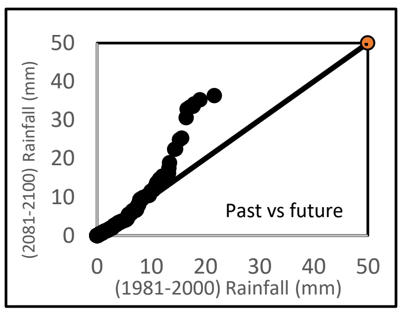

Figure 4(b): CESM (CAM5)

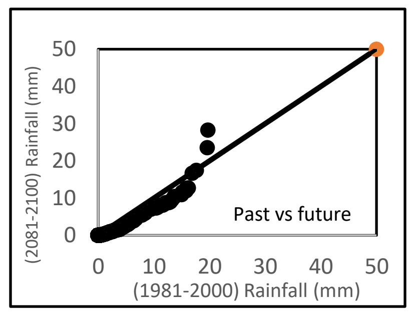

Figure 4(c): CMCC-CMS

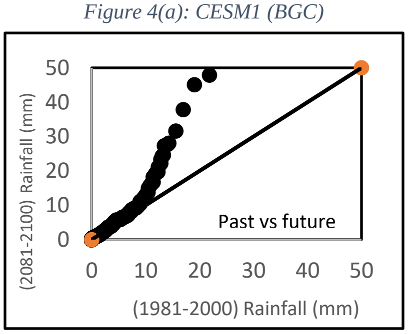

Figure 4(d): MIROC5

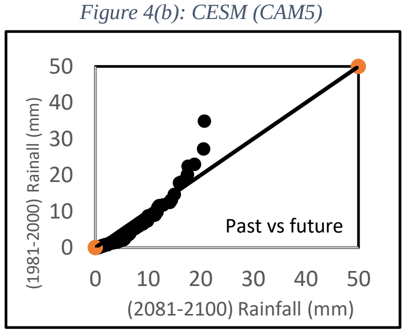

Figure 4(e): MPI-ESM-LR

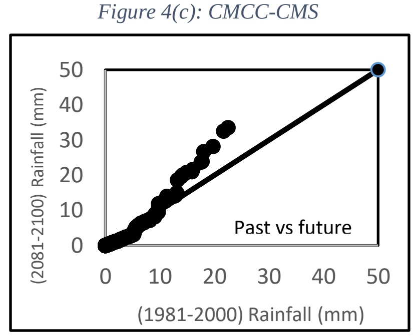

Figure 4 (f): MRI-ESP-MR

(iii) Discharge trend Analysis by GCMs Rainfall

The rainfall data obtained from GCMs was used in RRI model to simulate the discharge and inundation for past and future climate. The trend of discharge is shown in the figure 5-(a) to (f) which are similar as rainfall trend. Two out of six GCMs, CESM1 (BGC) and MIROC5 show the increasing discharge trend in future. So the two increasing trend result have been shown in fig 5-(a) and (d) below. Two GCMs, MPI-ESM-LR and MRI-ESM-MR show decreasing trend in lower discharge part but increasing trend in higher discharge part. CMCC-CMS shows decreasing trend in all the discharge part. The CESM1 (CAM5) show no change in the lower discharge part but increasing trend in larger discharge part.

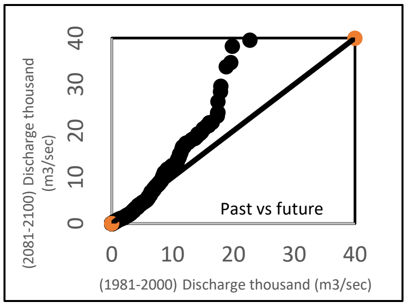

Figure 5(a): CESM1 (BGC)

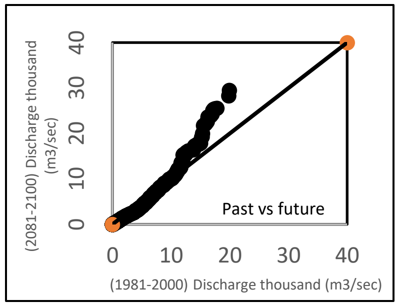

Figure 5(b): CESM1 (CAM5)

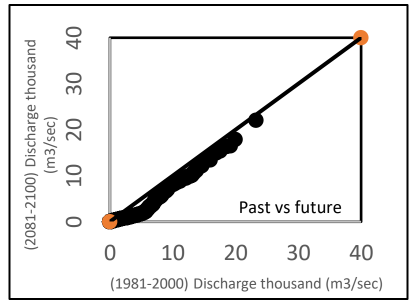

Figure 5(c): CMCC-CMS

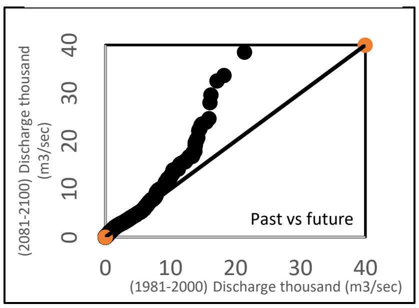

Figure 5(d): MIRCO5

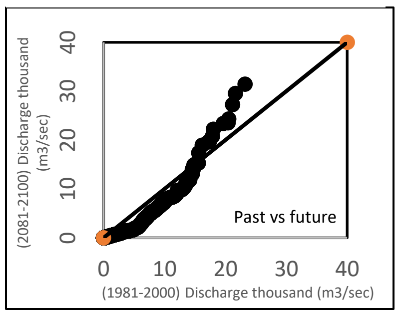

Figure 5(e): MPI-ESM-LR

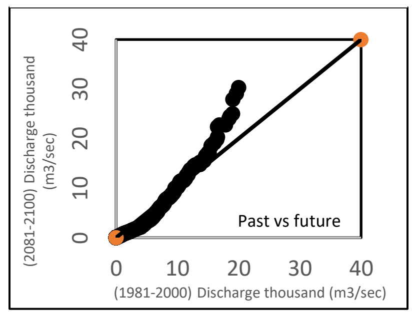

Figure 5(f): MPI-ESM-MR

(iv) Inundation Analysis by GCMs Rainfall

Two out of six GCMs model CESM1 (BGC) and MIROC5 inundation analysis shows an increase in the future maximum inundation depth in fig 6-(b) and 7-(b) respectively. The GCMs of increasing rainfall and discharge trend were selected for analysis to assess the maximum flood risk. The total inundation area, inundation depth 4-20 meter and duration combination determined the severity of a flood in the study area.

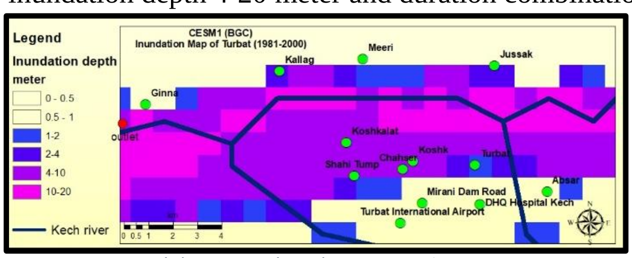

Figure 6(a): CESM1 (BGC) Past Inundation Map

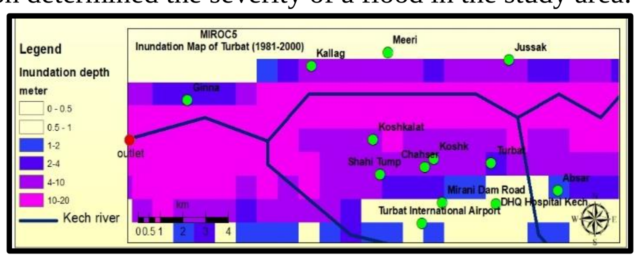

Figure 7(a): MIROC5 Past Inundation Map

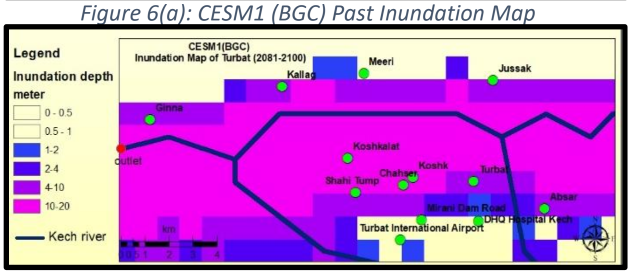

Figure 6(b): CESM1 (BGC) Future Inundation Map

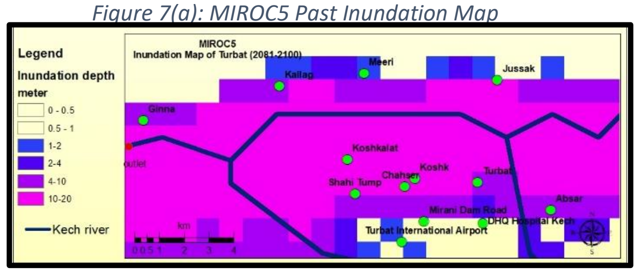

Figure 7(b): MIROC5 Future Inundation Map

(v) Frequency Analysis

For the most feasible future behavior of extreme rainfall events was performed by frequency analysis and hence floods, inundation depth and inundation areas has been performed as shown in table 2.

(vi) Risk Assessment to evacuation center

On the basis of inundation depth and area evacuation centers are necessary for protection of affected people in future. Five evacuation centers have been selected in the study area. Two centers are suggested south side of the river near main Mirani Dam road and one evacuation center has selected near Absar areas where no inundation possible in future as shown in inundation map fig 6-(b) and 7-(b). Similarly, two evacuation centers have been selected in north side of Kech River, near Ginna and Meeri areas.

Table 2: Return period of rainfall

Sr. No.	Climate Models/ Return Period	Past Climate		Future Climate	
		Gumbel-PM		Gumbel-PM	
		50 year	100 year	50 year	100 year
01	CESM1(BGC)	28.6	31.8	49.4	56.0
02	CESM1(CAM5)	29.1	32.4	50.0	56.9
03	CMCC-CMS	22.7	26.9	31.2	35.6
04	MIROC5	32.5	39.8	55.1	62.4
05	MPI-ESM-LR	26.6	30.2	36.6	42.0
06	MPI-ESM-MR	32.3	38.5	42.2	48.6

CONCLUSION AND RECOMMENDATION

Balochistan is the largest in size and smallest in population where the intensity of flood is increasing very rapidly and mostly effecting the poor people of the area. As the study area is under the influence of climate change, a number of hydrological and climatological analysis show the intensity of flood will be increased in future. According to the climate change the planning plays a key role for study area. To mitigate the flood risk, installation of rain gauge, river gauge and river monitoring for the study area should mandatory which is the scarcity in the region. The establishment of more than two stations with installation of model run and time calculation method will be very important in upstream which should be connected to main station (Wide Area Network). Nowcasting with C- and X-band weather radar is recommended to achieve accurate rainfall forecasting. Improvement of levee with good material is very important to protect nearby areas of the region. Evacuation centers should be government organization which is more convenient of the effected people for survivor. The awareness of the people about the flood is very necessary in this regard, quarterly basis training should be conducted.

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