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The Impact of Climate Change on Flood Risks Using Climate Models : a Review

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Abstract:

Climate change is It stands among the most significant challenges confronting the world today. In recent years, the problem of climate change has evolved from a narrowly focused scientific concern, relevant to a limited group of researchers, into a top priority on the global political agenda. Among the most significant impacts of climate change are the increasing recurrence and intensity of floods, resulting from changes in precipitation patterns and snowmelt, as well as rising sea levels that threaten coastal areas. Although Iraq contributes only a small fraction to global greenhouse gas and carbon dioxide emissions, It is classified among the countries most affected by Changes in climate patterns. This study aims to provide a comprehensive review of the Methodologies and techniques used for flood risk analysis and prediction, utilizing Global Climate Models (GCMs) under Shared Socioeconomic Pathways (SSPs) scenarios. The study emphasizes the integration of projected climate data into the development of hydrological models, highlighting the importance of bias correction techniques to increase the accuracy of climate models. The results of this study contribute to the improvement of effective strategies for flood risk management and planning for adaptation to future climate change.

Keywords: *Global Climate Models, Bias Correction, Coupled Model Intercomparison Project Phase 6, Flood Risk Analysis.*

1 INTRODUCTION

In the face of an ongoing shift in climate attributed iargely to such global warming, the Record increase in the temperature of the earth's surface due to rising concentrations of greenhouse gases that are being emitted into the atmosphere by human activity, especially the burning of fossil energy sources such as, e.g., coal and oil, Global Warming Sectionour planet is heating up. This intensifies and accelerates in the release of rainfall and thus alters the hydrological system such as river basins and augments the threat of flash floods. Shifts have also been evidenced in the temporal and spatial characteristics of precipitation and evaporation, and redistribution of moisture within the atmosphere (Guo, Guan, and Yu 2021). Flood is a natural hazard that has great influence on human societies and losses on humans and economics especially in resent years. The threat of floods has broadened to include not just direct effects on both natural systems and humankind (Aerts et al. 2018). In this regard, climate model data from the phase 6 of the Climate Model Intercomparison Project (CMIP6) driven Based on varying levels of greenhouse gas emissions provides a useful resource for flood risk analysis. These models help to predict the magnitudes of future floods and vulnerable locations, respectively. Figure1 presents a global temperature change rate, based on the shared socio-economic pathways (SSPs) scenarios, that could occur via the global climate system.

Managing climate change risk, including flood risk, requires highly accurate climate projections along with a comprehensive understanding of the associated biases (Abadla et al. 2024). The GCMs used within the framework of the Climate Model Intercomparison Project (CMIP6) serve as a valuable source of spatial and temporal climate data, providing researchers with a clear understanding of climate cycles. This type of data and information is difficult to obtain solely from observational station records (Hamed et al. 2022).

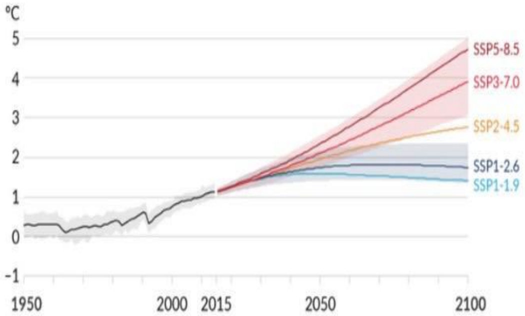

Figure 1. illustrates the change in Earth‹s temperature Based on expected scenarios of shared social and economic changes (SSPs) scenarios.

2 LITERATURE REVIEW

In recent years, many researchers have studied flood risk analysis and prediction using climate models (GCMs), which rely on simulating the climate change on rainfall patterns and surface runoff. These models are employed to estimate future flood magnitudes and to identify vulnerable areas. Such studies are essential for water management planners and flood mitigation strategists. This review highlights the most significant studies and previous research focusing on flood risks, categorized into three main areas.

2.1 Flood Risk Analysis and Prediction using Plimate Models:

(Fouli et al. 2016) estimated peak runoff values at selected site in Riyadh using three different ways, the Soil Conservation Service Dimensionless Unit Hydrograph (SCS-DUH), hydrological modeling within the Hydrologic Engineering Center Hydrologic Modeling System (HEC-HMS), and the Talbot empirical equation. The study used records of rainfall from three stations located in the vicinity. The modified Talbot equation gave the largest peak discharges followed by the SCS-DUH and HEC-HMS methods peak discharge and runoff volume evaluation were comparable.(Hoseini, Azari, and Pilpayeh 2017) studied the surface runoff from rainfall in Simily Plain, SW Iran by means of a Watershed Modeling System (WMS). The research focused on peak streamflow estimation with the HEC-1, TR-55 and TR-20 approaches. The experimental values were only obtained by the TR-55 method. A more recent study by (Mashaly and Ghoneim 2018) analyzed the risk of flash floods in the Ambaji Valley in Egypt. The study thus integrated the use of Sensor technology and HEC-HMS technology. The latter results indicated that the flow discharge could reach 875 m³/s for rainfall depths of 30–60 mm, causing flooding of buildings and infrastructure in Al-Qusair city, Egypt. (Umaru and Adedokun 2020) evaluated flooding exposure in the Benue River Basin, Nigeria, by means of GIS and remote sensing. The results areas situated less than 6 km away from the river were shown more More vulnerable. The study called for the creation of land-use policies and to build dams to safeguard the communities. (Thai et al. 2021) developed a method to assess flooding risk in Quang Nam Province, Vietnam, that couples multi-criteria analysis with a deep learning algorithm. The research achieved good results of the ability to correctly identify flood-prone areas with hybrid developed models like Deep Neural Networks (DNNs) integrated with MCDA and will help in risk management.

In Iraq,(Hamdan, Almuktar, and Scholz 2021) used applying hydrological modeling (HEC – HMS) and "Digital Elevation Map" (DEM) for studying the flood risk for Diyala river basin. Data comparison revealed high accuracy of observed and simulated runoff with determination coefficient as 90% and proved that the model could provide an effective hydrological simulation result. Finally, (Al-Juboori 2022) introduced a hybrid model for the daily discharge of Koumel River in north of Iraq, which combined Generalized Linear Model (GLM) with Group Method of Data Handling GMDH, In figure 2, we can consider the building process of the Configuration of the model. Results showed that the hybrid model performed well and the model coefficient of determination (R2) of 0.92 in the training stage, and 0.88 in the validation stage was obtained, indicating efficient performance of hybrid model.

In Vietnam, the study by (Bui et al. 2023) used machine learning and the AHP toestimate flood risks in the Quang Binh River Basin. The DLA showed superior performance with an AUC of 0.984, which generated high resolution flood risk maps.

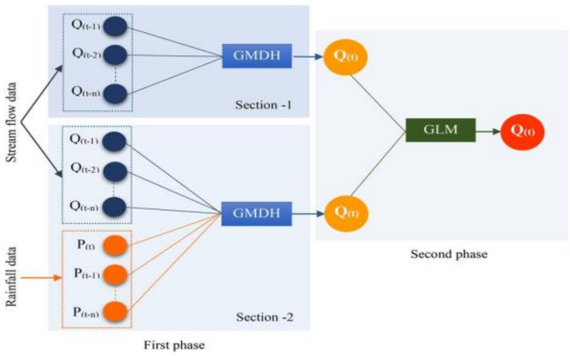

Figure 2. Hybrid model building structure (GMDH-GLM)

Similarly, the study of (Mohammed-Ali and Khairallah 2023) applied hydraulic modeling to estimate the behaviour of Tigris River flooding over the urban settlement of Tikrit. The study also found that the city was more vulnerable to flooding on the eastern side, which is at a lower elevation.

In Pakistan, the study by (Khan et al. 2024) worked on an artificial intelligence model to predict the flood hazards of the Indus River Basin. Of the algorithms tested, the SVM performed best, with an accuracy of 82.40%. In Turkey, Şen and Kahya (2017) (Şen and Kahya 2017) combined hydrological and hydraulic model for evaluation of flood risk. The research illustrated the strong influence of DEM resolution on the accuracy of flood estimation. Additionally, the research conducted by (Peker et al. 2024) employed HEC-HMS and HEC-RAS models with GIS in a study of flood hazard estimation in the Jusco River Basin. It was suggested that updating flood mapping more frequently was needed in order to enhance flood risk management. Finally,(Nguyen et al. 2024) studied the interacting effects of climate change and land use changes on flood risks. Results showed rise in such susceptible locales over period, which draws attention to the dynamic nature of flooding risk under the altered climatic scenarios.

In trapzon Governorate, the research with (Koralay and Kara 2024) has employed the GIS-based analytic hierarchy process (AHP) to identify and classify flood risks and direct remedial measures. In case of jorden a study performed by (Al-omari et al. 2024) remote Sensor technology system and Geographic Information System (GIS) to categorize flood risk areas withen King Talal Dam Basin. In Algeria demonstrated the study (Allali et al. 2022) the superriority of the ClARK-UH method in hydrological modeling for estimating flood peaks in the Oued Oran Basin.Fainlly the sudy by (Hasan 2020) analyzed flood frequencies in the Tigris River Basin in northern Iraq and found that the Long-pearson Type III distribuation the more exact for perdicting future risks.The study aimed submitted by (Saeed, Mustafa, and Aukidy 2021) analyze the flood recurrence of the Euphrates River using three probability: Long-pearson Type III, Generalized Extrem Value(GEV), and Gumbel distribuation, by analyzing maximum value per year discharge data from the Al-Qaim and stations, the results indicated the suitability of all three disterbuation with the GEV method outperforming in predicting future flood risks.While the study by (Hommadi, Al-Fawzy, and Al-Mohammed 2023) analyzed flood risks for the Greater Zab River at the Aski Kalak station using multiple statistical distribuation including GEV and Gumbel, the results showed consistency among method used except for the long-Normal and GEV distribuation, which provided higher estimates for peak flood frequency at 1000-year return period, This highlights their improtance in predicting potential maximum discharges. Figure 3 shows the maximum annual discharges of the river in unit m^3/s during the time series used in the study.

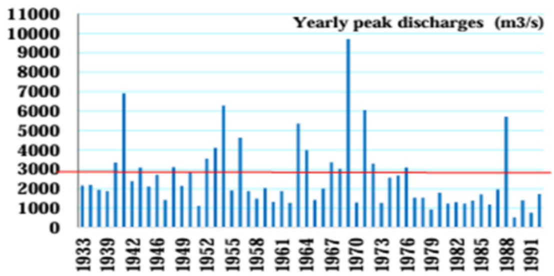

Figure 3. illustrates maximum annual discharges of the Greater Zab River at the Aski kalak station.

2.2 Studies related to biases correction of model data:

Despite technological advancements in simulating climate variables through (GCMs), identifying the impact of future changes On the recurrence pattern of extreme hydrological events, such as floods, Measuring the impact of climate change on water resources and hydrological systems remains a major challenge. This is because of large biases inherent in the outputs of GCMs which cannot be easily transferred to local scales. Hence, a bias correction step is needed to convert their results to improve data accuracy and match with observed values in an unbiased way. The studies below contribute to work on bias correction methods for climate model data.

In another work (Lafon et al. 2013), the effectiveness of four popular precipitation bias removel approaches were evaluated over the global climate model HadRM3. 0-PPE-UK over Britain was evaluated. These approaches were: linear correction, non-linear correction, gamma-quantile mapping, and empirical quantile mapping. The linear approach was the weakest, adjusting for the mean only, as observed in the results. On the other hand, gamma-based quantile mapping was found to work best for the precipitation data which are gamma distributed. In some cases, the non-linear method was the best in terms of reducing bias to zero, while empirical quantile mapping was the most consistent overall.

(Maraun 2013) stressed the necessity for good implementation of error correction methods for daily precipitation data produced from long-term (GCMs) simulations, particularly for the Harz region in Germany. Quantile mapping is frequently used in this situation, using this method, however, when the difference between observed and simulated categories is large, it may not be appropriate. In these situations, it was suggested to apply stochastic bias correction to improve model predictions.

Similarly, (Fang et al. 2015) compared different bias removel approaches to reduce the mismatches between RCM-generated daily climate data and observations in the Kaidu River Basin, China. power transformation (PT), Linear Scaling (LS), and Quantile Mapping (QM) were used as methods. The PT and QM techniques also showed the greatest success in removing biases, while (LOCI) was optimized to perform best at the shorter time scales. (Ajaaj, Mishra, and Khan 2016) evaluated five Methods for reducing bias in monthly rainfall over Iraq and compared their results with observations from the Global Precipitation Climatology Center (GPCC). Results showed that QM and the Mean Bias Ratio (MBR) method achieved the best overall performance, particulary during the wet period. Nevertheless, the authors suggested considering several correction methods to identify those most suitable for the local climate.

In the Kali Gandaki River Basin of Nepal, (Shrestha, Acharya, and Shrestha 2017) compared Linear Scaling and Quantile Mapping with monthly data. No implication was drawn from the analysis and it was concluded that Linear Scaling is applicable to hydrological modeling on monthly time scale. (Emami and Koch 2018) performed a “Double Correction” to mitigate bias in precipitation estimates estimated from Japan's GSMaP satellite data over Turkey. This strategy was successful without shifting extremely low values and does not produce unrealistic results. In another study, (Emami and Koch 2018) considered the bias correction methods themselves when downscaling future climate change to hydrologic models based on daily temperature and rainfall data in Iran. They concluded that QM was superior to SDSM in terms of all statistics considered in the study. (Tan et al. 2020) contrasted conventional and mixed bias removel approaches techniques for temperature and precipitation series over the Lijiang River in China. The ECDF was observed to be the best individual method whereas, VARI-ECDF hybrid was identified as the best combination. (Holthuijzen et al. 2022) presented a new hybrid approach, EQM-LIN, combining EQM and LIN. This was intended to remove systematic bias from daily precipitation totals in the US Northeast. It was superior to the conventional EQM in minimizing the error of extreme events based on evaluation indicators, such as mean absolute error (MAE), MAE for extreme events (MAE95), and Kolmogorov-Smirnov test.

In Egypt, (Gado, Mohameden, and Rashwan 2022) investigated the influence of climate change with four bias correction approaches: Linear Scaling (LS) and Variance Scaling (VARI). The results showed that VARI was more suitable for the simulation of daily average and maximum temperature, confirming its usefulness for enhancing the skill of regional climate models. The study advocated for VARI’s broader application in climate impact assessments. (Jose 2022) compared six four bias correction applied to CMIP6 model outputs, including Empirical Quantile Mapping (EQM) and Quantile Delta Mapping (QDM), to decrease biases in minimum and maximum temperature simulations over the Netravati Basin. The results showed that QDM was the most effective in analyzing future trends in daily maximum and minimum temperatures . In contrast, Linear Scaling (LS) demonstrated lower effectiveness in reducing bias. (Li and Li 2023) evaluated two bias correction methods Scaled Distribution Mapping (SDM) and Quantile Delta Mapping (QDM) for adjusting daily maximum and minimum temperature data in Canada. They found that QDM was able to reproduce the observed date, whereas SDM performed better when preserving the future climate signature.

In a separate study, (Gumus, Oruc, and Yucel 2023) dealt with biases in daily precipitation and temperature data over Turkey for future climate patterns using three bias correction techniques involving QM, QDM. It was found that QDM performed best of all techniques in terms of bias reduction for precipitation indices, but all of the methods were found to give good and consistent results. (Andari et al. 2024) discussed bias removel approaches of daily satellite-based precipitation for Indonesia by performing comparison of three methods: Linear Scaling, Local Intensity Scaling, and Empirical Quantile Mapping. The results showed that LS and EQM were much better than other models in terms of hydrological applications. Lastly, (Huang et al. 2024) proposed a new paradigm based on deep learning, which involves a Cycle-Consistent Generative Adversarial Network (CycleGAN) model, to enhance and correct daily precipitation of CMIP6 climate model projections. Their experimental study shown significant enhancement compared to the state-of-art approaches including QM and CNN. This procedure greatly improved predicted precipitation fields and thus has significantly improved accuracy of climate model simulations, a large step forward in the post processing of climate data.

Thus, it is clear that modern research has recognized a wide range of strategies to combat bias in climate datasets. Of these, the methods which have been found to be particularly effective include, Quantile Delta Mapping-Linear (EQM), Empirical Quantile Mapping-Linear (EQM-LIN) and Variance Scaling (VARI). These methods have the benefit that, in addition to helping to reduce biases, they also can show very large improvements in the simulation of observed data contrasted with the climate model results, in particular in the important variables such as the temperature and precipitation patterns. The new techniques, including deep learning (CycleGAN), illustrate the or high-throughput efficiency at preparing from data of the future and retaining characteristic climate signals. The results emphasize the need to determine the optimal method according to the nature of the data and the spatial setting for precise climate forecasting.

2.3 Studies based on the results of (GCMs) for the projection of flood risks:

These studies are analyses of several greenhouse gas emission scenarios affecting extreme climatic events, such as floods. Researchers will be able to calculate changes in temperature and precipitation patterns, allowing them to improve flood risk management and find adaptation and mitigation solutions to answer the challenges of climate change. Cutchen et alTrends in global flood risk models using climate change scenarios over the period 2020-2024The following studies are related to the research which works on application of global climate models on flooding risk prediction:

The study by (Pokhrel et al. 2020) was a study predicting floods in the future by employing the climate model data for Neuse River in United States. The analysis included Scenario SSP5-8. 5, which was characterized by maximum precipitation. Using the L moments distribution, flood discharges According to time periods of up to 500 years were generated, and flood and risk maps were developed in HEC-RAS software. The study recommends leveraging these data to enhance future floodplain management strategies. Likewise, a study by (Jiménez-Navarro et al. 2021) that investigated the effects of climate change-related effects on water resources in Sweden using the SWAT model* Long-term changes in precipitation extremes over land using CMIP6 data for the recent historical period and two future SSPs scenarios: (SSP2-4.5) and (SSP5-8.5) According to the results, detectable temperature rise between 2 to 4 degrees Celsius and Precipitation rise of 6 to 20% has subsequently caused the increase in surface runoff. These results are work in with the study by Pokhrel that predicted similar climatic changes and an increase in surface runoff, the study by (Aryal, Acharya, and Kalra 2022) used CMIP6 data to predict the future floods of the Rock River using the (HEC-RAS) program to create flood risk maps describing three scenarios: (SSP1-2. 6), (SSP3-3. 7), and (SSP5-8.5). Increased inundation areas were seen in the study in comparison to current emergency management maps, which supported Pokhrel's findings of predicted future flood zone expansion. For instance, in Iraq, (Magdy Hamed et al. 2022) integrated 21 models from the CMIP6 ensemble for regional precipitation and temperature to assess the variability of drought. The study found that the northern region of Iraq is most susceptible to drought. the result aligns with the climate changes described in the previous studies, which predicted a big climate shift that could have considerable consequences for the aquatic resources in the region. In contrast, the study of (Zarei 2023) assessed climate change impacts on current and future flood patterns in the Kashkan River basin in Iran. CMIP6 datasets, (HEC-RAS) software, and advanced artificial intelligence methods were used in the study. outputs, infer that it improved the accuracy of model extremes floods, and highlighted the benefit of using such methods as Long Short Memory (LSTM) networks for the accuracy of future flood forecasts. These findings parallel those of earlier studies, in which hydrological models exhibited effective parameter optimization leading to higher descriptive reliability. Using the (HEC-HMS) software, the study of (Imran and Haque 2024) aimed to compute historical and forecasted river discharges for the Dhaka River, in the context of Bangladesh. The study included CMIP6 data and different Shared Socioeconomic Pathway (SSP) scenarios (in total three unique SSP scenarios). The results emphasized the model's ability to accurately predict flooding events and also reinforcing the essential role of simulation of hydrological processes and climate change assessment in improving flood adaptation measures a across distinct and different areas. The result is similar to findings in previous research that highlighted the benefits of such methods in solving flood- related problems. The study by (Oyelakin, Yang, and Krebs 2024) employed CMIP5 and CMIP6 datasets to assess flooding risks in three different urban regions of China. The study projected more extreme flooding events for the years 2070-2080. The results derived from the study corroborate with and confirm the findings established from the others which emphasise on the influences of climate change on increasing occurrence and severity of flooding occurrences. Based on CMIP6 data, (Abuzwidah et al. 2024) in United Arab Emirates conducted flood risk assessments and contributed with a analytical Hierarchy Process (AHP) methodology study for analyzing impact and effect of climate change scenarios. Results indicated that scenario 5 (SSP5-8. 5) compared with Scenario 3 (SSP2-4. 5). It is important to use advanced analytical methods for accurate flood risk prediction. (Rasheed, Al-Khafaji, and Alwan 2024) Finally in Iraq, a study was Conduct a study to estimate the effect of climate-induced changes in sediment movement in Mosul Dam reservoir reservoir using CMIP6 data. The findings suggest they could keep doing so, at varying rates depending on future climate scenarios, Figure 4 shows that changing the scenario leads to changing the sedimentation rate. for between 95 and 109 years after October 2023. These results highlight the importance of preparation for the future climate, which may affect the vulnerability of infrastructure.

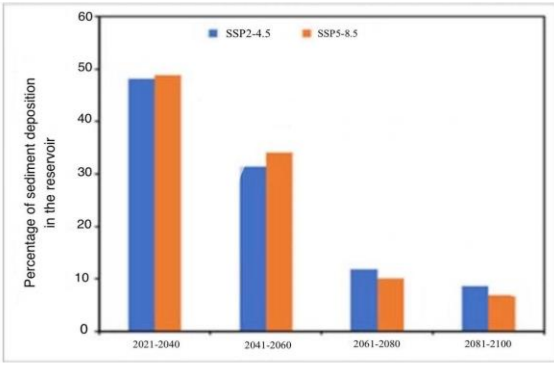

Figure 4. Changing the scene changes the rate at which sediment is deposited.

In a recent study, (Yalcin 2024) projected the impacts on future flood events of the Bitlis Creek River site in Turkey based on CMIP6 climate model data. Results indicate future discharge rates increase substantially from 2025 to 2099, findings that corroborate those of prior studies regarding climate change and flood damage to different hydro-climatic regions. Similarly, (Gholami et al. 2024) evaluating effects of climate fluctuationson flood occurrence have been studied in the Tajan Basin, northern Iran, using the Canadian climate model (CanESM5) that is part of CMIP6. They found an increased likelihood of flooding in central and lower reaches. The study also integrated machine learning techniques such as support vector machine (SVM) and random forest (RF) with RS in order to enhance the flood risk mapping. This combination highlights the increasing need of artificial intelligence approaches to improve the accuracy of the prediction of future floods. These studies in total demonstrate the importance of projected climate data, hydrological modeling, and machine learning in flood risk analysis as well as future risk estimation. These methods are crucial for developing strong adaptive measures to moderate the outcome of climate change in varied locations. Table 1 summarizes the contents of a selected set of papers that concentrated on flood risk analysis employing GCMs.

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Table 1. The summary of studies on flood risk analysis in the using (GCMs) models.

no.	Study area	References	Utilized model	The phase	Scenarios	Analysis method	The software used	Study results
1	Neuse River in the United States	(Pokhrel et al. 2020)	CNRM-ESM2 CNRM-CM6-HR CNRM-CM6	CMIP6	SSP5-8.5 SSP3-3.7 SSP2-45 SSP1-2.6	Hydraulic Modeling	HEC-RAS	Development of flood inundation and hazard maps
2	Lake Arken in Sweden	(Jiménez-Navarro et al. 2021)	EC-Earth-Veg BCC CanESM5 GFDL MiroC6 MRI INM- CM5	CMIP6	SSP2-45 SSP5-8.5	Hydrological Modeling	SWAT	Expect an increase in surface runoff between 5-30%
3	Rock River in the United States	(Aryal, Acharya, and Kalra 2022)	CNRM-CM-1HR CNRM-CM6 CNRM-ESM2	CMIP6	SSP1-2.6 SSP3-3.7 SSP5-8.5	Hydraulic Modeling	HEC-RAS	creation flood risk maps
4	Kashkan Watershed in western Iran	(Zarei 2023)	TaiESM1 ACCESS-ESM1-5 MPI-ESM1-2- HR ACCESS-CM2 INM-CM5-0 EC-Earth3 INM-CM4-8 LR FGOALS-g3 GFDL_ESM4 EC-Earth3-Veg	CMIP6	SSP1-1.3 SSP5-8.5	Integrating Hydrological Modeling with Artificial Intelligence	HEC-HMS MATLAB	The hybrid model outperforms the program
5	Dhaka River in Bangladesh	(Imran and Haque 2024)	ACCESS-CM2	CMIP6	SSP1-2.6 SSP3-3.7 SSP5-8.5	Hydrological Modeling	HEC-HMS	Effectiveness of the model for developing effective flood control strategies
6	three urban areas in China	(Oyelakin, Yang, and Krebs 2024)	CESM2 bcc-csm1-1 MPI-ESM-MR CanESM ACCESS MPI-ESM1-2-HR BCC-CSM2-MR ACCESS	CMIP5	RCP8.5 SSP5-8.5	Hydrological Modeling	SWMM	Extreme events are increasing, with the most severe floods occurring between 2070 and 2080.
7	United Arab Emirates	(Abuzwidah et al. 2024)	CanESM5 MIROC6	CMIP6	SSP2-45 SSP5-8.5	Hierarchical analysis methodology	GIS	Increased flood risk in Scenario SSP5-8.5 compared to SSP2.-45
8	Proposed Makhoul Dam in Iraq	(Rasheed, Al-Khafaji, and Alwan 2024)	Model name not mentioned	CMIP6	SSP2-45 SSP5-8.5	Integrating Hydrological Modeling with Hydraulic Modeling	SWAT HEC-RAS	The reservoir's lifespan could range between 95 and 109 years

9	The reservoir's lifespan could range between 95 and 109 years	(Yalcin 2024)	21 Models	CMIP6	SSP2-45 SSP5-8.5	Hydrological Modeling	SWAT	significant increases in future discharge rates between 2025 and 2029
10	Tajan Basin in northern Iran	(Gholami et al. 2024)	CanESM5	CMIP6	SSP2-45 SSP5-8.5	Using artificial intelligence with remote sensing technology	MATLAB	Create flood susceptibility maps for the study area

3 COMPARE GLOBAL (GCMS) AND LOCAL (RCMS) CLIMATE MODELS.

Although climate change is a global phenomenon, its impact varies from region to region, so data from (GCMs) must be used at local spatial scales to assess its impacts and risks. Climate models are generally divided into two types: Global Climate Models (GCMs), which are used to simulate the climate system on a large scale, and (RCMs), which are used to adapt the results of GCMs and generated more realistic climate data at local scales.

Global climate models(GCMs) are characterized by their ability to cover climate processes over the entire globe including the oceans, while their regional climate models (RCMs) cover a specific geographic area within the boundaries of the local region (Version 2021). They are low spatial resolution models (GCMs) typically (50-300 km), while regional (RCMs) spatial resolution models provide high spatial resolution (1 to 50 km), enabling them to better represent topographic features and the climate system (Mottram et al. 2021). Regarding the ability of models to represent topography and local factors,(Sharma 2009) indicates that (GCMs) show significant limitations in representing fine topographic features, especially in complex terrain such as mountains and valleys. On the other hand, the RCMs have a better representation of the local relief and local climatic factors, due to its higher spatial resolution. (GCMs) are typically used to examine a globally or continentally-scaled climate and compare future scenarios, but RCMs are used to study the impact of climate change at a local level including river basins, dam sites, and cities on (Eden et al. 2014). As weaknesses, the non-local nature of GCMs hampering a fine localized analsysis, not provided that their information is bias-corrected, where these models are derived from the physical equations of the atmosphere and oceans, and the global model rcp based that provides the initial and boundary information to RCMs, therefore the effectiveness of this tool depends on the quality of the global model data, data that can also be applied a bias correction in the data obtained(Iles et al. 2020) . Regarding future scenarios, both kinds of models are defined according to socioeconomic trajectory scenarios (SSPs). Table 2 presents an overall comparison between general circulation and regional climate models (GCMs, RCMs).

4 CONCLUSIONS

The previous studies present a useful knowledge platform for how to interpret the signals of the flooding/drought intensity changes over a diverse geographic area using the advanced climate models. From these studies, several important inferences can be made to improve adaptation measures against these events.

4.1 Increased Flood and Drought Risk Due to Climate Change:

All assessed studies conclude that future climate change will amplify risk for flooding and drought. For instance, as in (Pokhrel et al. 2020) the SSP5-8. 5 urges US a higher precipitation amount than the 8S-5 scenario by the SSPs, and in turn, higher flood discharges are simulated to the return periods of 100 and 500 years. Similarly, (Magdy Hamed et al. 2022) stated that northern Iraq is projected to encounter a decrease in the frequency of wet-year to wet-year events because of the shifts in the temperature and precipitation coverage.

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Table 2. The table shows the comparison of the (GCM_S) and (RCMs).

no.	Criterion	Global Climate Models (GCMs)	Regional Climate Models (RCMs)
1	Locational coverage	Coverage extends to the entire globe	The coverage area is specific to a local area
2	Spatial Resolution	Low resolution of (50-300) km	High resolution of (1-50) km
3	Inputs	Grounded in mathematical and physical principles	Use outputs from GCMs as boundary conditions
4	Ability to represent terrain and local factors	Limited - does not accurately represent accurate terrain	High - able to represent local terrain such as mountains
5	Model applications	Global climate analyses and comparison of scenarios on a continental or global scale	Studying climate change at the local level (e.g. river basins, dams or cities)
6	Examples	CanESM, ACCESS, BCC-CSM2-MR, CESM2,MPI-ESM1-2-HR, ACCESS	WRF, RegCM4, ALADIN, COSMO-CLM
7	Limitations	Unsuitable for local analysis needs data bias removel approaches	It depends on the quality of the global model data (used as an input source) and bias correction can be performed on the data

4.2 Analysis on the importance of mixing climate data with predictions of future climate:

Hydrological models have been improved dramatically through data that use the (GCM_S) under the sixth phase of the Coupled Model Inter-comparison Project (CMIP6). For instance, (Jiménez-Navarro et al. 2021) employed CMIP6 data to project climate dynamics effect on the Lake Erken basin in Sweden. Their research showed that runoff was likely to increase between 5% and 30% as part of climate change. This emphasizes the crucial necessity for future climate models to refine simulation of climate related risks.

4.3 The use of artificial intelligence in enhancing prediction is:

Application of artificial intelligence to improve prediction: Several publications have reported the application of AI in improving predictive performance. For instance, the study of (Zarei 2023) in Iran revealed that employment of Long-Short Term Memory (LSTM) neural networks led to highly accurate hydrological modeling systems including the HEC-HMS software, in simulating peak flood events. This illustrates how new technologies can prevent errors and increase the credibility of modelling frameworks.

4.4 Local impacts of Climate Chang:

It has been found in studies that the changes in climate will not remain same for different regions. Adopting this model, (Huang et al. 2024) investigated the runoff trends of the Daka River Basin in Bangladesh and concluded that rising annual discharge would contribute to increased frequency of flooding in the basin. Similarly, (Gholami et al. 2024) reported that flood frequency is predicted to increase in the northern part of Iranian Tajan Basin as a consequence of climate-induced changes. Confirmed these results the importance of targeted study specific to the local climate and environmental condition.

4.5 The Importance of Planning Future Adaptation Strategies:

An article is calling for immediate planning to combat the ongoing and anticipated effects of climate-induced changes. For example, (Rasheed, Al-Khafaji, and Alwan 2024) highlighted the importance sustainable water management and infrastructure development which is vital for reducing the risk of future floods in Iraq as well as for minimizing the risk of potential damage to structures. Similarly, (Abuzwidah et al. 2024) has proposed in the UAE to develop flood hazard maps with Geographic Information Systems (GIS) to precisely locate areas that are at high risk from flooding. Such tools are critical to advance forward-looking and forward-reaching responses in the face of climate challenges.

4.6 Diversity of Climate Scenarios (SSPs) in Future Projections:

Studies in the literature have highlighted the need for inclusion of multiple climate scenarios in for the purpose of increasing the precision of future forecasts. For instance, (Yalcin 2024) found that within the elevated-emission SSP5-8.5 scenario, the discharge rates of the Bitlis Creek River in Turkey are expected to increase significantly between 2025 and 2099.

All studies emphasize the crucial role of advanced global climate models, artificial intelligence techniques, and sophisticated statistical analyses in enhancing future predictions of floods and droughts. These tools provide accurate insights necessary for developing effective climate adaptation strategies. Therefore, decision-makers must integrate these scientific methods and technologies into their future adaptation plans and sustainable development policies.

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