

## A Review of Potential Impact of Climate Change on Global Water Resources

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**Abstract:** *This paper discusses the various impact of global climate change on global water. Anthropogenic activities and therefore the industrial revolution have contributed more to global climate change impact in hydrological cycle and Water balance components. Various studies were supported out in concern with the availability of surface water, groundwater resources, seawater intrusion, and snowmelt. This paper reviewed the impact of global climate change on various scenarios on surface water, groundwater resources and snowmelt in cold regions, and hydrological variability of surface and groundwater resources. Rise of Seawater level is additionally another critical issue and thus global climate change mitigation and adaptation are predominant in managing blue-green and greywater. Formulating global climate change policies within the world would require an integrated approach that might assess the multiple interlinkages within the Energy, Land, Water, and Climate (ELWC) nexus and extricate the impacts of worldwide global climate change from that of regional human anthropogenic activities.*

**Keywords:** *Climate change, groundwater, MODFLOW, seawater intrusion, snow melt, surface water, SWAT.*

### I. Introduction

The extensive human interventions in the Energy, Land, Water, and Climate nexus significantly impact the water resources of the world. In the present climate scenario it is indeed to study the impact of climate change. It is known from the context the earth has 97% saline water and 3% freshwater. Out of the 2% freshwater, 79% of water is available in the form of ice and glaciers and 30% is available in the form of groundwater and only 1% is available as freshwater in rivers, lakes, ponds, and reservoirs. In regards to the amount of water available on the earth the quality of water also needs to be taken into account. Intergovernmental Panel of Climate Change(IPCC) [1] has synthesized Assessment Report 5 (AR5) about changes in the global surface temperature, precipitation, sea-level rise, and water cycle based on the various representative concentration pathways this deals with radioactive forcing of the earth. IPCC synthesis report has summarized the following points for policymaking (i) Observed Changes and their Causes (ii) Future Climate Changes, Risks and Impacts (iii) Future Pathways for Adaptation, Mitigation and Sustainable Development (iv) Adaptation and Mitigation. The projected change for the period of 2046-2065 in global mean surface temperature for the mid- and late 21st century, relative to the base period 1986–

<sup>1</sup>2005 for the different Representative Concentration Pathways (RCP's) 2.6, 4.5, 6 and 8.5 is 1, 1.4, 1.3 and 2 in degree Celsius. Projected mean surface temperature for the period of 2081-2100 for RCP 2.6, RCP 4.5, RCP 6, and RCP 8.5 are 1, 1.8, 2.2, and 3.7 in degree Celsius. The projected change for the period of 2046-2065 in global mean sea level rise for the mid- and late 21st century, relative to the base period 1986-2005 for the different Representative Concentration Pathways (RCP's) 2.6, 4.5, 6 and 8.5 is 0.24, 0.26, 0.25 and 0.3 in meters. Projected mean sea level rise for the period of 2081-2100 for RCP 2.6, RCP 4.5, RCP 6, and RCP 8.5 are 0.4, 0.47, 0.48, and 0.63 in meters.

According to IPCC, Climate change impacts over the 21st century are projected to reduce renewable surface water and groundwater resources in most dry subtropical regions, increasing rivalry for water among sectors. In the dry region the frequency of droughts is likely to increase by the end of the 21st century under the RCP8.5 scenario. In contrast, surface and groundwater resources are projected to increase at high latitudes. The coupled effect of temperature rise, high-intensity rainfall, and sea-level rise will lead to increased sediment transport in the river, increased concentration of pollutant during drought, disruption of sewage and drinking water treatment plant during a flood will reduce raw water quality and groundwater recharge rates and this leads high risk to water quality and water quantity available for various sectors. Climate change impacts in urban areas lead to increase risks for people life and their assets, economies, and ecosystems, including risks from heat stress, storms, extreme precipitation, inland and coastal flooding, landslides, pollution, drought, water scarcity, Sea Level Rise (SLR) and storm surges. Climate change impacts in rural areas lead to experience major impacts on water availability and supply, food security, infrastructure, and agricultural incomes, including shifts in the production areas of food and non-food crops around the world. Multi-model and multi-scenario approaches can be assessed for the water resource management process in a regional watershed scale.

The impact of future climatic change may be felt more severely in developing countries such as India whose economy is generally dependent on agriculture and is already under stress due to present population growth and associated demands for energy, fresh water, and food. The effect of human activities due to population growth and economic development cause severe impact on the natural water cycle. The interaction among the atmosphere, land biosphere, and ocean surface layer results in conflicting future projections by Global Climate Model (GCM). The various impacts of climate change on surface water, groundwater, seawater intrusion, and snowmelt are discussed in the below section.

## **II. Impact of climate change on surface water**

The study about the impact of the future climate on global water resources is highly prioritized to make the adaptation strategies and policy implications. The impact of future climate change on surface water can be studied by the hydrological simulation model. The hydrological simulation model can be of a physical model or numerical model. The hydrological simulation model, Soil and Water Assessment Tool (SWAT) was a widely used physical model in regional-scale studies to predict the water balance component and drought index. Hydrological simulations performed in upper Kharun catchment in Chhattisgarh, India by SWAT using projected climate change data which was downscaled from the available GCM to required regional scale [2]. The strong effect of the projected increase in rainfall increase the surface runoff coefficient and cause flooding in low lying areas. Based on the temperature projections the actual evapotranspiration showed an increase in trends. The effect of climate change on sediment load, nitrate, phosphate, and agriculture fertilizer residues was investigated in San Joaquin valley watershed of California. The research on climate change impact on freshwater availability in Africa was studied. The mean total quantity of water resources was likely to increase[3]. The number and frequency of dry days would increase drought events in Africa and poses an additional challenge to the agricultural sector. Evaluated changes in

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terms of temperature and precipitation might interpret into changes in water availability and droughts in Guajoyo River Basin[4].

Six bias-corrected downscaled GCM data for the Zambezi River Basin in the Southern African were used as inputs for hydrological modeling with the SWAT model to determine the impact under two future climate scenarios[5]. Water resource utilization in rice production from multiple perspectives was quantified[6]. The study carried out in Kaifeng irrigation and drainage station and Kunshan irrigation and drainage station provides insight into broadly understand the influences of climate change on food security and adopt a regional strategy for future water resource management.

The changes in future precipitation and air temperature was projected from five downscaled GCMs under three RCPs in Loess Hilly-gully Watershed in Jinghe River Basin[7]. By analyzing the changes in hydro-biogeochemical cycles under projected climate and evaluated impacts of future climate change on the water-carbon coupling processes and net variability of precipitation in Net Primary Production -Evapotranspiration coupling. The historical and future climate change situation using 19 extreme climatic indices of daily precipitation and temperature in the Banas River Basin of Rajasthan, India[8]. An outcome of new hydrological insight showed high rainfall initial abstraction due to high initial infiltration capacity of the highly permeable volcanic soil when compared with the continental watersheds with the study area Heeia Watershed in Hawaii[9]. Predicted global climate change scenarios showed decreases in rainfall during the wet season and peripheral increase in the season has imparted the general decreases in water balance components. The groundwater flow component may also decrease concerning the predicted precipitation and temperature change by 2100 can cause a serious impact on groundwater availability in the watershed.

### **III. Impact of climate change on groundwater**

Predicting groundwater recharge and discharge conditions under future climate and land-use changes were necessary for integrated water management and adaptation. Coupling of SWAT-MODFLOW studies to address the need for long term anthropogenic impact of agro-ecosystem [10]. A modeling framework “SWATmf” was developed to link and integrate the SWAT with the MODFLOW, a groundwater model. Streamflow and groundwater levels using the SWATmf was simulated and it was well agreed with the observed data[11]. The direct impact of climate change on surface water and groundwater was water availability and water security. The groundwater level behavior was assessed in the Geum River Basin of South Korea[12]. The hydrological model was used to assess the behavior of future groundwater levels by future climate change scenarios and estimated future groundwater use based on groundwater use monitoring data under the different climate scenario. The investigation on the future groundwater level has a direct effect on groundwater recharge and it was dependent on the seasonal and spatial precipitations in the basin.

Bias-corrected data was fed to the SWAT model to estimate monthly groundwater recharge values and inputted to the MODFLOW model to predict future groundwater level distribution Kosynthos River watershed[13]. The study showed that a climate change adaptation strategy was necessary for the study area to prevent the significant reduction in groundwater level that would lead to groundwater shortage for the satisfaction of irrigation needs and groundwater quality deterioration resulting from increased lateral inflows of water with high salt content from the south-eastern boundary. A three-dimensional transient groundwater flow model MODFLOW to simulate the impacts of three climate scenarios under an average of a long-term rainfall, predicted rainfall during the period 2015-2030 and three years moving average rainfall on groundwater recharge and groundwater levels[14].

The long term behavior of groundwater resources in Klela Basin, Southern Mali was evaluated within the context of regional climate change scenario and population growth for water demand using socio-economic facts for calculating groundwater recharge using the Thornthwaite model[15]. The study concluded that groundwater recharge, as well as storage was decreasing over time especially in the 2030s it could lead to severe agricultural droughts in 2031–2035 for the RCP4.5

period. Groundwater resources was subsequently affected by climate change and population growth is important for decision-makers to plan adaptation strategies although they were impacted by uncertainties caused by the models as well as by the observed input data. Future groundwater recharge was simulated in the Upper Colorado River Basin (UCRB)[16]. Groundwater recharge was likely to be greater than the historical average in most decades. Increases in groundwater recharge in the UCRB are significant with projected increases in precipitation, counteracting reductions in recharge that would result from projected increased temperatures. Climate change mitigation and adaptation achievement in India must make a transition from surface storage to managed aquifer storage as the center pin of its water strategy with proactive measures in demand and supply-side management components[17].

An integrated hydrological model, MOHISE was developed to review the impact of regional climate change on the hydrological cycle in representative Geer basins in Belgium. The chalky aquifer in the Geer basin tested scenarios shows no enhancement of the seasonal changes in groundwater levels. [18]. Variations in recharge was studied in Grand Forks aquifer, southern British Columbia under the different climate-change scenarios have a much smaller impact on the groundwater system than changes in river-stage elevation of rivers that flow through the valley[19]. The study area was modeled under steady-state conditions have a much smaller impact on the groundwater system than changes in river-stage elevation of rivers that flow through the valley. Groundwater level was assessed in 2030 under the future climate scenario was carried out over a 37,200 km<sup>2</sup> area in south-western Australia and has implicit consequences that why some areas of the study aquifers might be less sensitive to climate change than others.[20].

The simulations were performed using FEFLOWV6.1 considering variable-density flow and solute transport under saturated-unsaturated conditions. A simulation study was conducted along a Grande Entree Island to assess the individual and combined impacts of sea-level rise, coastal erosion, and decreased groundwater recharge on the position of the saltwater freshwater interface[21]. The studies explored the seasonal effect of the change in the biogeochemical process for the redox-sensitive ions and metals to evaluate the groundwater quality of the shallow coastal aquifer of Eastern Dahomey Basin in southwestern Nigeria. The influence of the redox process for both wet and dry season has a higher impact in the dry season through the variation of concentration shown decreases with an increase in depth. The geochemical diagram revealed nitrate as the controlling biogeochemical process over Iron in most of the sample wells. The study in the shallow coastal aquifer of Eastern Dahomey Basin in southwestern Nigeria suggested the need for strategic groundwater management policy and planning to ameliorate groundwater quality deterioration[22].

#### **IV. Impact of climate change on sea water intrusion**

Seawater intrusion caused by overexploitation of groundwater extraction was already impacting diverse regions of the globe. Synthesis Report of AR5 and detailed simulations have predicted that rising sea levels might negatively impact coastal aquifers through saltwater intrusion into confined aquifer and may also cause inundation of coastal regions. SimCLIM climate model to project Sea Level Rise for the Tamil Nadu and Puducherry coast in India for four periods of time namely 2025, 2050, 2075 and 2100 for scenarios RCP 2.6, RCP 4.5, RCP 6.0 and RCP 8.5 of IPCC AR5.[23].

Climate change impacts on SLR and freshwater recharge a rate in a part of coastal groundwater systems in South Korea was investigated using Saturated-Unsaturated TRAnsport (SUTRA) model. The tide gauge station data were used to project SLR based on polynomial regressions. The hydro geochemical facies of groundwater monitoring well in Byeonsan2 for seawater intrusion was selected as monitoring site. Various scenarios in evaluating SLR projection and estimated freshwater recharge rates using SUTRA including the base period and the projected period were done. The study concluded that a better understanding of the climate change impacts on seawater intrusion by considering both SLR and freshwater recharge rates and adaptation strategies can be done in the coastal area. [24]. The impact of regional climate change was studied on seawater

intrusion in coastal aquifer located north Chennai, India. The groundwater head was increased in the year 2030 due to the increase in precipitation and the chloride concentration also has decreased by Managed Aquifer Recharge systems.[25].

## **V. Impact of climate change on snowmelt cold area**

Glaciers are vital sources of freshwater and considered a key component of the hydrological cycle in the cold region. Glacial melting initially leads to flooding, but over time, as the snow melts there will be a risk of drought in summer. Utmost of the run-off water comes from snow and glaciers melt in the glacier region. This causes major changes in water supplies, hydropower, industry, agriculture, and biodiversity [26]. The trend analysis in a hydro climatic variable such as temperature, precipitation, and streamflow in the eastern Anatolia, Turkey by non-parametric trend tests of Mann–Kendall and Spearman's rho of the for the historical records period of 1970 to 2010. Based on the regional high emission scenario timing of the peak flows would continue to shift to earlier days, increasing the fraction of winter runoff while decreasing the fraction of spring runoff in the year throughout the entire basin. [27]. The relationship between historical data and future streamflow projections in the Colorado River Basin was derived and it was beneficial to quickly regulate where and when large changes in hydrology will occur from future warming. [28].

The impact of climate change on the water balance and hydrological regime of the snow-dominated Kaligandaki Basin was studied[29]. Future projected climate variables like precipitation and temperature from downscaled CMIP5 GCM models for the RCP 4.5 and RCP 8.5 were forced into a SWAT to review the impact of projected regional climate change on the hydrological regime of the Kaligandaki basin. The synergetic effect of a rise in temperature and precipitation showed an increased effect on the discharge and water yield with an increase outlet of the basin. Snowmelt largely adds to the increase in discharge according to the anticipated increase of snowmelt during the 2090s. The reduction in snow depth as a result of a rise in black carbon concentration, local warming, and decrease in precipitation lead to in the decrease of Kolahoi glacier.[30].

## **VI. Conclusion**

Climate change is one of the serious threats that have to be met by global society in this decade. Change in weather and climate events was observed in this decade. Natural and human-influenced anthropogenic activities made the changes including a decrease in cold temperature, an increase in warm temperature, sea level rise, and heavy precipitation events in some regions. The impact of climate change on global water could lead regions from arid to semi-arid regions, or even deserts. The direct impacts of climate change on the regional scale have affected both water supply and demand. The demand versus supply curve is wide apart. Predicting the long-term effect of a dynamic system is very difficult because of limitations inherent in the models, and the unpredictability of the forces that drive the earth. Physical or numerical models need to be developed by interlinking surface water, groundwater, and seawater intrusion. The model should reasonably predict the water quality and water availability based on several factors in the regional scale. The factors that need to be considered in the regional scale is population growth, land-use change, water demand, industrial growth, irrigation practice method, land cover, etc. SWAT coupling with MODFLOW helps the researcher to understand the watershed system in a better way. Climate variability, water resource management, and economic development are complicatedly linked with each other. The extent of the climate change forecast on regional scales has a limitation, but measures must be taken to anticipate, prevent, or lessen the causes of climate change and mitigate its adverse effects. Rigorous research efforts are also needed to incorporate the prominent linkages in the climate variability nexus in climate and earth system modeling.

## **Abbreviations**

IPCC- Intergovernmental Panel of Climate Change

SWAT- Soil and Water Assessment Tool



NPS – Non Point Source

GCM- Global Climate Model

RCP- Representative Concentration Pathways

SLR - Sea Level Rise

ANN- Artificial Neural Networks

ELWC - Energy, Land, Water, and Climate

SDSM - Statistical Down Scaling Model

CMIP5 - Coupled Model Intercomparison Project 5

SUTRA - Saturated-Unsaturated TRANsport

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