P: ISSN No. 0976-8602 RNI No.UPENG/2012/42622 VOL.-7, ISSUE-2, April-2018

E: ISSN No. 2349-9443 Asian Resonance

Ramifications of Climate Change on Water Resources- Comments on Importance

Poonam Khare
Assistant Professor,
Deptt.of Geology,
J. V. Jain College,
Saharanpur, U. P.
India

Pramendra Dev
Professor & Head (Ex),
Deptt.of Geology,
School of Studies in Earth Science, Vikram University,
Ujjain. M.P.
India

Abstract

The present paper highlights comments on the implications of climate change on water resources. The climatic factors affect the water resources and their relationships are mutually dependent. The observations have revealed that climate change results into significant impact on the water resources all around the world because of the close relations between the climate and hydrologic cycle. The changes in precipitation and drought pattern occur due to Latitudinal variations such as the decrease in precipitation between 10^0 S and 30^0 N. Subtropical regions are more stressed on water resources but tropics and high latitudes are expected to experience increasing amount of precipitation. Due to this, number of problems have arisen on high latitudes, such as flooding, rate of erosion, mass movement of land and soil moisture availability. The rainfall is one of the most important factors of climate that governs the excess or deficiency of water resources. The rainfall is the only source of water recharge and the excess or scarcity of rainfall both cause adverse and beneficial implications on the water resources. Another climatic factor is temperature, which affects the evapo-transpiration. It is the priority need of the day to combat with the implications of climate change by the implementation of a scheme for the a forestation, construction of artificial recharge structures and proper management of water resources by avoiding the wastage of water. A strategy has been suggested for the mitigation of the implications generated by the climate changes on water resources.

Keywords: Ramification, Climate Change, Climate Factor, Water Resource, Rainfall, Present Status,

Introduction

Water is one of the most vital natural resources that performs as the elixir of life. The present increasing trend of the human population, industrialization, agriculture/irrigation, energy and sports sectors, is generating enormous pressure on the water resources resulting into scarcity of water supply, even causing a drought situation in several parts of the globe. It is well recognized fact that about 71 % of planet earth is covered by water as ocean and 29 % is occupied by the land. It has been estimated that approximately, 97.5 % of all water on the Earth is salt water, and only 2.5 % is the fresh water. 70 % of the fresh water is frozen in the ice caps of Antarctica and Greenland, and most of the rest water is present as soil moisture, or lies in deep underground aquifers as the ground water (0..67 %). Only 1 % of the world's fresh water is available for the human uses. Ground water is the only substitute for inadequate surface water supply. It has been observed that major aquifers of the world are facing the problem of water levels depletion because of increasing demand of water supply by the users of water including the agriculture, industries, household, recreational and environmental activities. It has been estimated that 70 % of world-wide water is used for the irrigation.

Water is the primary medium through which climate change influences the ecosystem of Earth, livelihood and well being of society. The relationship between water and climate is noteworthy. Climate change is a phenomenon and its effects have been increasingly evident world wide. The Intergovernmental Panel on Climate Change (IPCC, 1997) estimated that the global mean surface temperature has increased 0.6 ± 0.2 ^oC since 1861, and predicted an increase of 2 to 4^o C, over the next 100 years. Climate change results into significant impact on the water resources around the world because of the close connections between the climate and hydrologic cycle. Changes in temperature and other forms of precipitation have important implications on climate change. The changes in precipitation and drought pattern occur due to Latitudinal variations such as decrease in precipitation between 10^0 S and 30^0 N. Subtropical regions are more stressed on water resources but tropics and high latitudes are expected to experience increasing amount of precipitation. Due to this, number of problems has arisen on high latitudes, such as flooding, rate of erosion, mass movement of land and soil moisture availability. Intergovernmental Panel on Climate Change (IPCC, 2007) has defined climate as "the average weather in terms of the mean and its variability over a certain time-span and a certain area", and a statistically significant variation of the mean states of the climate or of its variability lasting for decades or longer is referred to as the climate change.

Objective of the Study

Ths prime objective of present paper is to discuss the implications of climate change on water resources. It is based on a review of simulation of changes of surface and ground water resources and their impacts on water quality. The formulation of mitigation strategy to control the implications of climate change has been suggested

Methodology

The present paper is basically focused on research regarding scientific knowledge of Climate changes on hydrological cycle, water resources and their implications on environment, The informations given in this paper have been collected from published literature on climate and water resources.

Review of Literature

The previous studies on climate change with hydrological studies, have generally investigated the impacts of climate change on water resources in different areas. The scientific understanding of an aquifer's response to climate change has been studied in several locations within the past decade. Some of the recent studies on impacts of climate change on water resources have been discussed in this paper.

Bouraoui *et al*. (1999) presented a general approach to evaluate the effect of potential climate changes on ground water resources. A general methodology has been proposed to disaggregate results of large-scale models and thus to make information directly usable by hydrologic models. This method was applied to a CO_2 - doubling scenario through the development of a local weather generator, although many uncertainties are not yet assessed about the results of climate models. The important hydrological variables namely rainfall and potential evapo-transpiration are generated which are then used by coupling with a physically based hydrological model for the estimation of effects of climate changes on the ground water recharge and soil moisture in the root zone.

Ghosh Bobba (2002) analysed the effects of human activities and sea-level changes on the spatial and temporal behaviour of the coupled mechanism of salt-water and freshwater flow through the Godavari Delta of India. The density driven salt-water intrusion process was simulated with the use of a SUTRA (Saturated-Unsaturated Transport) model. The physical parameters, initial heads, and boundary conditions of the delta were defined on the basis of available field data, and an areal, steady-state ground water model was constructed to calibrate the observed head values corresponding to the initial development phase of the aquifer. Initial heads and boundary conditions determined from the areal calibration were used to evaluate steady-state, hydraulic heads. Consequently, the initial position of the hydraulic head distribution was calibrated under steady-state conditions. The changes of initial hydraulic distribution, under discharge and recharge conditions, were determined, and predicted the present-day position of the interface. The present-day distribution of hydraulic head was estimated via a 20 year simulation. The results indicate that a considerable advance in sea water intrusion can be expected in the coastal aquifer if current rates of ground water exploitation continue and an important part of the fresh water from the river is channelled from the reservoir for domestic, irrigation, and industrial purposes

Dai *et. al* (2004) discussed about the Palmer Drought Severity Index (PDSI). It indicates that the area of land characterised as very dry, has more than doubled since 1970 and wet land simultaneously declined and in some region increased temperature reduced water availability.

Huntington (2005) elaborated that the increase in temperature causes an intensification of the water cycle, there will be more extreme weather events as droughts will become prolonged, and floods will increase in force.

Nearing, *et at* (2005) have considered that Global warming accelerates the less water movement inside the soil due to this less ground water replenishment occurs.

Intergovernmental Panel on Climate Change (IPCC 2007) highlighted the changes in precipitation and drought patterns. The changes indicate that increase of precipitation is likely in subtropics, especially along the pole ward edge. Latitudinal variation affects the distribution of water resources.

Kang *et al*, (2009) published a review of literature on the evaluation of climate change impacts on the crop productivity using climate, water, and crop yield models. It has been remarked that the study of existing climate change models with higher spatial resolution nay be used in future climate projections. The stochastic projections of more than one climate are essential for giving insights into model uncertainties and to expand risk management plan. These authors remarked that "the climate change impacts on soil water balance will lead to changes of soil evaporation and plant transpiration, consequently, the crop growth period may shorten in the future impacting on water productivity". The results of modelling demonstrate that with the increase in precipitation the crop yield also increases. In other words, the crop yield is more sensitive to precipitation than the temperature, and If the availability of water is reduced in the future, soils will be of high water…

Khan (2010) remarked that the "Climate change refers to variation in the earth's global climate or in regional climate over time". Climate change has been defined as weather averaged over a long period of time. In the countries like Nepal, which has lots of biodiversity directly affected by climate change and has a massive disaster with its consequences? Glaciers are one of the effects of climate changes on water resources, which are thinning and retreating throughout much of the region. Khan suggested that there are some of the reasons behind the rainfall pattern, lack of water resources, lakes are drying and reducing in water levels of the rivers and streams.

Geriesh, *et. al*. (2015) have recognized the evidences of implications of climatic changes on the ground water flow regime and geochemistry at the Nile Delta on the basis of environmental isotope analyses in conjunction with the hydro-geochemical investigations and tentative reviewing of the paleoclimatic sea level changes. Following the footprints of ground water flow history, These authors, have observed that environmental isotope analyses in conjunction with the hydrogeochemical investigations and cautious reviewing of the paleoclimatic sea level changes. Hence, the present-day ground water flow regime could be affected by the latest Holocene phase of climate changes during which no significant dramatic sea level changes were recorded. After the time period of the Mediterranean humid phase, 8000-5500 BP, the sea level started to rise steeply from –15 m to the present-day level. Under this rising rate, the sea water invaded most of the northern delta sprint and several 10ths of kilometres inland via the mouths of the ancient Nile branches. During these arid conditions, deterioration of the Pleistocene, unconfined aquifer could take place. This finding matches a famine and economic instabilities during the arid periods and flourishing and economic stabilities during the humid pluvial periods along the history of ancient Egyptian civilization. In accordance to the latest active sea level rise stage, in conjunction with the delta subsidence, a contagious groundwater level rise with a current order of 3 cm/year is taking place leading to form numerous lake-like lagoons, water logging and soil salinization along the coastal plain and eastern low lands. The Nile Delta is expected to incident of severe soil salinization and gradual merging under the ground water logging and sea water transgression, along the eastern coastal zone, which suffers a high subsidence rate of about 5 mm/year. These authors remarked that as compared to earlier studies, their findings illustrate that "the present ground water composition and salinity in the Nile Delta aquifers cannot be attributed to a recent seawater intrusion. The physico-chemical processes that explain this composition are combination of salt dissolution (mainly from Holocene fluvio-marine aquifer), flushing by recent Nile water, ion exchange and evaporation"

Ning *et a*l. (2015) analyzed recent changes in water resources and grassland in the Hulun Lake region, which is a semi-arid region in northeastern China, using monthly GRACE and Tropical Rainfall Measuring Mission (TRMM) data. Results indicate decreasing trends in overall water storage and precipitation between 2002 and 2007, followed by increasing trends during the period from 2007 to 2012. Water storage trends are mainly correlated to precipitation and temperature patterns. As a result, a large proportion of grassland recovered to its normal state in 2008–2012, and only a small proportion of grassland (16.5% of the study area) is classified as degraded. The authors remarked that degraded grassland areas in the region, are more vulnerable to climate variability and require protective strategies to prevent further degradation.

Buma *et al*. (2016) observed changes in hydrological conditions of Lake Chad basin based on the total water storage (TWS) derived from GRACE, lake levels taken from satellite altimetry, water fluxes and soil moisture obtained from the Global Land Data Assimilation System (GLDAS). The authors have observed a similar pattern between TWS and lake level changes and subsurface water volume changes. The derived values for subsurface water volume changes are originated to be consistent with ground water outputs calculated from the Water GAP Global Hydrology Model (WGHM). By utilizing recently developed remote sensing datasets, this study provides an alternative means of generating information for the management of water resources in the Lake Chad basin.

Wang *et al*. (2016) investigated the impact that climate change has on the duration of flood seasons in the Fenhe River, China, from 1957 to 2014, based on daily precipitation data from 14 meteorological stations in the basin and an analysis of the variations in the onset and retreat dates of yearly flood seasons. The results exhibit that the observed duration of the flood season has been extended since 1975. In particular, the onset of flood has advanced 15 days, although the retreat date is relatively stable. Based on these results, the authors have recommended corresponding measures to adapt to the flood season variations

Stagge, and Moglen, (2017) discussed that the "Water Resource adaptation to climate and demand change in the Potomac River." These workers have elaborated the relative effects of climate change on water resources. The study exhibits that how water resources could be managed in the area of Washington D C, to adapt to the climate change, and future demand increases. The study has been conducted by measuring the projected changes in drought vulnerability for the period (2010 to 2039), intermediate (2040 - 2069) and distant future (2070 - 2099) under climate and demand changes. Adaptation strategies were developed and discussed. Optimized reservoir management policies were compared using six distinct objectives, ranging from reservoir storage to environmental and recreational benefits. Simulations of future conditions show water stress increasing with time.

Status of Surface Water in India

The nature has blessed India by the exceptional affluence of many rivers. 12 are classified as major rivers, having a total catchments area of 252.8 mha and total discharge as 1570.98 bcu.m. Rest 48 are classified as the medium rivers. The total area of basin catchments is 24.9 mha and total annual discharge is 1869 km^3. Most of these rivers are perennial rivers though few are seasonal. Average water yield per unit area of the Himalayan river system, indicates the importance of snow and glacier melt contribution from high mountains.

The contributions of rainfall are greater in the eastern region, while the snow and glacier melt contributions are more important in the western and central Himalayan region. Apart from the monsoon rains, contribution from snow and glacial melt are playing a significant role on the water resources and development of the country. Global warming and its impact on the hydrological events have posed an additional threat to the Himalayan region. of India..

The extreme precipitation events have geomorphologic significance in the Himalayas, causing the prevalent landslides. The response of hydrological systems, erosion processes and sedimentation in Himalayan region can alter significantly due to climate change. Himalayan glacier provides snow and the glacial melt water, which keep the Himalayan Rivers perennial. The most useful facet of glacial runoff is the fact that glaciers release more water in a drought year and less water in a flood year and thus ensure water supply even during the lean years. The snow line and glacial boundaries are sensitive to changes in climatic environments. Almost 67 % of glaciers in the Himalayan mountain ranges have retreated in the past decade. Gangotri glacier is retreating about 28 m per year. A warming is likely to increase the melting more rapidly than the accumulation.

On an average, 10 mha area is actually affected by floods every year in India, out of which about half is crop land. It has been assessed that the area liable to floods is 40 mha, which is nearly one eighth of the country's area. 99 districts spreading over 14 states (Andhra Pradesh, Gujarat, Maharashtra, and Rajasthan) have been identified by Central Water Commission as drought prone areas in the country.

Status of Ground Water in India

India accounts for 2.45 % of land area and 16 % of the world population, whereas only 4 % of fresh water resources of the world are available in India, of which 38.5 % is ground water. India utilized around 220 – 230 billion m^3 year-^{1}, over twice that the USA. India is now the biggest user of ground water for agriculture in the world. Ground water irrigation structures are now around 27 million, with every fourth rural household having one irrigation structure (Shah 2009). The per capita water availability is continuously declining since 1951.

Ground water is a principal source of drinking water in the rural areas. In India, about 85 % of the rural water supply is dependent on ground water. India has a potential of 45.22 Mha-m/year of replenishable ground water. In India, Central Ground Water Board is the national body and other Sates Ground Water Departments are engaged in the exploration, exploitation, development and management of ground water resource. Present trend of extraction and recharge of ground water is generating pressure on ground water levels resulting in water crisis in several parts of the country. Ground water levels in Gujarat, Haryana, Punjab, Rajasthan and Tamil Nadu have revealed a critical decline. Ground water decline has been registered in 289 districts of India. The water levels in Ahmedabad are declining at a rate of 4 – 5 m every year and in some parts of Delhi a lowering of 10 m has been noticed (Singh and Kumar 2010). Due to melting of the Himalayan glaciers, the Indo-Gangetic Plains will experience increased water discharge up to 2030, but will face gradual reductions, thereafter. Sea-water intrusion has been observed in several coastal states of India, such as the Tamil Nadu, Pondicherry and Gujarat (Saurashtra), which is not only engulfing the land but also the ground water reservoirs. India is highly sensitive to climate change in terms of its effects on water supply for irrigation needs.

Implication of Climate Change on- Hydrological Cycle and Sub-surface water Zones

Ground water is directly affected by changes in the rate of precipitation and evapo- transpiration. The response of ground water to climate change may be less as compared to surface water; however, it is still a matter of concern because ground water is one of the largest available resources of fresh water and potable water on the Earth. It is estimated that approximately 30 % of global fresh water is present in the form of ground water. Generally, ground water occurs in zone of aeration and zone of saturation. The effects of climate change on both the zones have been discussed.

Soil water zone is important as it supports vegetation and all bio-geochemical reactions. Climate change has an adverse effect on this zone. Higher temperature leads to higher evapo- transpiration rates, resulting in less moisture content in this zone. Little or no moisture in the soil leads the penetration of solar radiation into the deeper soils and increased dryness in soils, resulting in rigorous droughts. The high precipitation in wet climate change scenario, it will increase surface run-off and in promoting rapid soil erosion. Less infiltration, high evapo-transpiration and high run-off will have a great impact on the water availability in this zone that will affect the entire plant and animal kingdom, because of change in evapo - transpiration pattern in this zone and the rainfall pattern will also be affected. The transpiration process, which holds 80 to 90 % of overall evapo-transpiration on the Earth will demonstrate various changes depending on the regional vegetation.

Changes in vadose zone due to climate change can be computed by studying the variations in major cations, anions, trace elements and isotopes from the pore water. Due to increase in surface temperature, ground water temperature will increase. The change in temperature will affect pore water chemistry, residence time and volume of water in matrix and fractures, and thus the composition of the water.

Ground water in the saturated zone is important as it is less polluted and has no effects of evapo-transpiration. The sensitivity of this zone depends on the depth of the water table, shallow aquifers are more vulnerable to climate change than deeper aquifers. This zone responds to climate change by showing changes in its amount, quality and flow of water depending on the trends of precipitation, evapo-transpiration, recharge and discharge. It is generally observed that climate change has less effect on this zone in comparison to human activities on ground water exploitation, such as excessive pumping, reduction in recharge rate and contamination.

Confined and unconfined aquifers exhibit alterations in some of their properties during climate change. It has been noticed that severe dry periods can alter the properties of aquifers such as transmissivity and storativity. During dry periods, the conductive channels such as fractures and fissures may become desiderated and the pressure pulse of water within the aquifer will be transmitted slowly, whereas during the wet season, fractures acquire fully saturated and transmit pressure pulse rapidly. Thus, the changes in recharge patterns will affect the specific storage of an aquifer. In case of extreme aridity, their vulnerability becomes higher if the potentiometer surface falls below the upper confining beds and results in converting confined aquifers to unconfined aquifers.

Effects of Climate Change on Recharge and Discharge

The changes in recharge patterns will affect discharge patterns, which will have a direct impact on ground water supplies and on surface water availability. In a cold or wet and cold–wet scenario, the relationship is directly proportional, i.e. high temperature results in high precipitation and high recharge. In case of dry scenario, the temperature and precipitation are inversely related to each other, as high temperature will result in less rainfall. Hence, the effects in case of dry scenario will be severe, implying that the aquifers of semiarid and arid regions are more vulnerable to climate change. Changes in recharge patterns will also change the quality of water by affecting geochemical reactions and movement of water in the vadose zone. Different types of aquifers (unconfined and confined aquifers) will be recharged differently.

Under wet climate scenarios, run-off is considered as a most sensitive component and the combined effect of increased precipitation and high discharge will increase the risk of flooding. Under dry climate scenarios, recharge will be the most sensitive component as evapo-transpiration will increase, while both recharge and discharge will decrease in all seasons, resulting in decline in ground water level. Increased discharge from melting of glaciers in the Himalayas will increase the risk of flooding in the catchments areas affecting major parts of North India, Pakistan and Bangladesh. Due to changes in discharge, the quality of ground water will be adversely affected, since during high discharge all the pollutants will be mobilized and may reach ground water level. In the case of a dry climate scenario, generally the water level will fall and this will affect the needs of the people and may result in increased use of energy to extract water. The increase in ground water pumping and loss of ground water storage from aquifers resulted in land subsidence in many Asian cities such as Osaka and Bangkok. In future, the increase in discharge and decrease in recharge will make land subsidence as a elevated problem.

Effects of Climate Change on Ground Water Quality

The ground water quality relates to the physical, chemical and biological properties of the aquifers, which are controlled by climatic fluctuations, changes in the recharge rate and the ground water temperature in the vadose zone affects its pore water chemistry, contaminant transport and residence time, affecting the quality of water. Under a climate change, the following events can deteriorate the ground water quality. During the wet climate, increased infiltration can mobilize large pore-water, chloride and nitrate reservoirs in the vadose zone of arid and semi-arid regions. Increase in recharge leads to the dissolution of carbonates; increase in “Ca” content, may increase the hardness of ground water. During a dry climate, the increase in total dissolved solids may deteriorate the ground water quality by increased concentration of salt contents.

Mitigation Strategy for the Implication of Climate Change

The linkage between climate change mitigation measures and water is a reciprocal one. Mitigation measures can influence water resources and their management, and it is important to recognize this when developing and evaluating mitigation options. On the other hand, water management policies and measures can have an influence on the green house gas (GHG) emissions. The following suggestions are being recorded for the mitigation of implications due to climate change.

Behavioural and Structural Adaptations

The judicious use of water is recommended, using buckets and mug instead of showers for bathing, and use of recycled water for agriculture. Structural adaptation implies building infrastructure or techniques that can minimize the risk of climate change on ground water and increase storage capacity of aquifers. Implementations of rain water harvesting, artificial recharge of aquifers, and constructions of sub-surface dams, reservoirs and check dams, and others. Defining ground water risk zones and climate change mapping. Spatiotemporal effect of climate change on aquifers should be assessed and based on this risk assessment of each aquifer should be rated. The actions and policies should be designed accordingly. Climate change mapping on different resources will give better results and answers about the vulnerability and risks involved.

Promoting Aforestation or Reforestation

Trees are the sinks for CO_2 on the Earth, and to minimize the effect of global warming, Aforestation is the best method for reducing of the deforestation. Land-use development planning should emphasize on planting more trees and increasing recharge area.

Geosequestration

Large amounts of CO_2 added to the atmosphere due to intensive land clearing, burning of fossil fuel like oil and coal these anthropogenic activities producing green house gases. Carbon cycle is insufficient to maintain the balance, annual carbon emissions from the use of fossil fuels. U S A accounts for 1.6 giga tons, whereas the natural annual uptake is only about 0.5 giga tons, i.e. 1.1 giga tons per year remains in the atmosphere. This extra CO_2 is responsible for global warming, which can be trapped in forests, grasslands, oceans and in the sedimentary formations such as coals, this sequestration processes is also beset with many environmental issues and concerns. Storage of carbon dioxide is envisaged either in deep underground geological formations or in the form of mineral carbonates, the process is known as Geosequestration. Carbon dioxide deep inside the earth can be dissolved over salty non drinking water or react chemically with surrounding rock producing several carbonate minerals. Deep ocean storage is not currently considered feasible due to the associated effect of ocean acidification. Geological formations are currently considered the most promising sequestration sites.

Managed Aquifers Recharge schemes (MAR)

Many different technologies and principles exist for the managed recharge of ground water, from the local scale capture of surface water runoff into derelict wells to restore ground water levels, to large scale engineered infiltration galleries with recycled waste water. All serve the same purpose of increasing the availability of ground water and securing access in times or seasons of water shortages. Water can be stocked in the upper aquifer layers and thus the energy needed to pump it up again is limited. Depending on the amount needed, cheap solar energy pumps or wind pumps can be used.

In poor arid rural areas, the local population can build small earth dams for surface water retention and infiltration. Surface water will be treated while percolating through the soil horizons; a natural effect, which is for free. However clogging may occur and therefore, the infiltration basin has to be cleaned during the dry season. The substrate can be used as a valuable fertilizer when free of contaminated substances.

Conclusion

The climate change is sensitive to the precipitation, evaporation and transpiration that directly affects the surface water as compared to ground water and its impact on the hydrological system has posed pressure to mountainous region of the Indian subcontinent. The processes of erosion and sedimentation in Himalayan region can alter drastically s pattern affected by evapo-transpiration phenomena.

Climate change indirectly effects the ground water system. Higher temperature leads to higher evapo-transpiration in soil water zone, which results in less moisture content in this zone. Due to presence of less moisture, solar radiation penetrates into deeper soils and increased dryness in soils, which results into droughts.

Climate change also affects vadose zone. The variation in cations and anions, trace elements and isotopes from pore pressure, affect pore water chemistry. The ground water in saturated zone, is less polluted and has no effects of evapo-transpiration. The climatic fluctuations and anthropogenic activities, affect the water quality of an aquifer.

Mitigation strategy for combating the implications due to the climate change includes the following options:

1. The judicious use of water is recommended, using buckets and mug for bathing, and application of recycled water for agriculture. Structural construction techniques that can minimize the risk of climate change on ground water and increase aquifer storage capacity. .
2. Carbon dioxide capture and storage (CCS) are promising options in the direction of alleviation of the climate change implications.
3. Managed Aquifer Recharge Scheme (MAR) is a vast adoptive measure to reduce the vulnerability due to climate change and hydrological changeability.
4. Land-use development planning should lay emphasis on planting more trees and increasing recharge area. Promoting aforestation for minimizing the consequences of global warming
5. Ecosystems must be protected because they serve as water catchment areas and natural infiltration basins. Gallery forests play an important role for the river flora and fauna. Furthermore, erosion is very limited when gallery forest are well developed and dense.

Rerferences

Bouraoui, F., Vachaud, G., Li, L. Z. X., Le Treut, H,, Chen, T. (1999), Evaluation of the impact of climate changes on water storage and groundwater recharge at the watershed scale, Climate Dynamics, vol. 15, p. 153-161

Buma, W.G.; Lee, S.I.; Seo, J.Y (2015). Hydrological Evaluation of Lake Chad Basin using Space Borne and Causes, and Implications. Water, vol. 7, p. 5849–5875.

Dai, A., Trenberth, K., and Qian, T. 2004. A Global Dataset of Palmer Drought Severity Index for 1870-2002: Relationship with Soil Moisture and Effects of Surface Warming. Journal of Hydrometeorology. vol. 5. p. 1117- 1130.

Geriesh M. H,, Balke K. D, El-Rayes A. E, and Mansour, B. (2015). Implications of climate *change on the ground water flow regime and geochemistry of the Nile Delta, Egypt. Journal Coastal Conservation vol.9, no. 4, p.:589-608.*

Ghosh Bobba, A. (2002), Numerical modelling of salt-water intrusion due to human activities and sea-level change in the Godavari Delta, India, Hydrological Sciences Journal, vol. 47, no. S, p. 67-80.

Huntington, T. G. (2005). Evidence for Intensification of the Global Water Cycle: Review and Synthesis. Journal of Hydrology. vol. 319, p. 83-95

Intergovernmental Panel on Climate Change IPCC (1997), The regional impact of climate change: an assessment of vulnerability: A Special Report of IPCC working group II, Watson, R. T., Zinyowera, M. C., Moss, R. H., Dokken.

Intergovernmental Panel on Climate Change (IPCC (2007), Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge, UK and New York, NY, USA, 966 p.

Kang Y.,Khan, S., and Ma, Z. (2009). Climate change impacts on crop yield, crop water productivity and food security- A review. Progress in Natural Science. vol. 19, no. 12., p. 1065 - 1074.

Khan, S. A. (2010). Global Warming and Climate Change. RVS Books, New Delhi.

Nearing, M.A., Jetten, V., Baffaut, C., Cerdan, O., Couturier, A., Hernandez, M., Le Ning, S.; Ishidaira, H.; Udmale, P.; Ichikawa, Y. (2016). Remote Sensing Based Analysis of Recent Variations in Water Resources and Vegetation of a Semi-Arid Region. Water 2015, 7, 6039–6055.n the Duration and Division of Flood Season in the Fenhe River Basin, China. Water 2016, vol. 8, p. 105.

Shah. T (2009) Climate change and groundwater India's opportunities for mitigation and adaptation. Environ Res Lett.J. vol. 4, no. 3:5005, 13 p.

Singh, R. D. and Kumar, C. P. (2010), Impact of climate change on groundwater resources,; www.angelfire.com/nh/cpkumar/ publiation.

Stagge,J.H and Moglen, G. .I. (2017) "Water Resource adaptation to climate and demand change in the Potomac River " Journal hydrologic Engineering vol. 22, no. 11, p. 04017050.

Wang, H. J.; Xiao,W..H.;Wang, J. H. ;Wang, Y. C.; Huang, Y.; Hou, B..D.; Lu, C.(.2016). The Impact of Climate Change on the duration and division of flood season in thr Fenhe River Basin, China Article Published in Water MDPI.