

**THE CHALLENGES OF WATER RESOURCES AVAILABILITY AND
DEVELOPMENT IN HUAI RIVER BASIN, CHINA****ABSTRACT**

The impact of climate change was examined on the processes for water uses in domestic, production and eco-water consumption, which is central to the allocation and conservation of water resources in the ecological system and socio-economy in arid Northeast of China. The population growth requires adequate supply of water especially during glacier ice- melt, anomalous rainfall, water pollution and reservoir dwindle. Our focus on the relationships between natural factors and social factors, as well as effect of different scales of water use for socio-economic expansion and ecosystem water demand. It incorporates the factors of water ecology-economy and water social economy into a large intricate system with respect to the interactive relationship between socio-economic and eco-environmental systems. Again, it empirically measures changing water resource susceptibility under several climate and human activities which develop coherent water resource allocation thresholds to deliver sustainable growth of ecosystems and the socio-economic system in the China's northeast region. The paper recommends measurable adjustments to present regime of water utilization in regards to impeding and inevitable changes in climatic and human actions around the Huai River Basin (HRB) tributaries. In effect, outcomes of the research will assist in mitigating imminent water scarcities and shortages for both economic and social development of the study area.

Keywords: Water Resource, Availability, Challenges, River Basin, Scarcity, Allocation

INTRODUCTION

Huai River Basin is a preponderantly evolving area in China. The number of industries serviced by the Huai River Basin (HRB) is continuously on the increase including paper making factories, production of coal chemical, textiles and food processing. One major industry having unprecedented growth on the basis of the basin is agriculture, which has been used to produce rice, wheat, soya beans, and cotton. The basin spreads its tributaries to four main cities including Luohe, Zhengzhou, Zhoukou and Bengbu which share several infrastructural lands such as sluices, dams and other water project constructions; (Ma, 2006; Yang et al., 2012).

At the heart of the Huai River Basin is droughts controls system which is made up of over 5000 sluices and 57000 reservoirs (Zhang, Liang, & Shao, 2010). Obviously, Huai

River Basin facing several issues common to infrastructure similar to it around the world. Apart from using certain tributaries as source of water supply for populace; it is the site for disposal of wastes from agricultural, domestic and industrial activities. The basin is highly susceptible to pollution from chemical, metal and organic substances. Agricultural practices cause pollution due to chemical wastes washed-off from fertilized land. Similarly, organic and metal wastes are generated by industries around the basin. In addition, most of the cities surrounding the basin whose huge piles of untreated sewage are dumped or eventually washed-off into it (Goudie, 2006).

In 2009, sewage of over 8.6 billion m³ was discharged into the Huai River whose 78 % capacity was short of chemical oxygen demand (COD) and ammonia nitrogen (NH₃-N) required combinations in drinking water (Huai River Commission, 2009). As expected, the uncontrolled pollution in the river is a serious concern. According to studies conducted by (Huang, et al., 2004); (Wang B. Y., Zhang, Hu, & Wang, 2006); (Hu, Wang, Deng, & Li, 2008); (Zhang, Liang, & Shao, 2010), an estimated 200 or more severe water pollution happened throughout the Huai river basin channels (Huang, et al., 2004); (Wang B. Y., Zhang, Hu, & Wang, 2006); (Hu, Wang, Deng, & Li, 2008). There is presence of organic pollution prevailed in Huai River especially in tributaries such as Jialu River (Zhang, Tang, Song, & Li, 2009) and the Jiangsu (Ma, Wang, & Wang, 2005); (Wang, Yu, Huang, Hu, & Wang, 2009); (Wang B. Y., Zhang, Hu, & Wang, 2006). Nevertheless, much is not done in terms of the effects of hydrochemistry caused by human actions on the Huai River. In another study, (Zhang, et al., 2011) investigated the Huai River's ion chemistry control mechanisms; but, no mention was made to specific statistics for dry season situation. Consequently, a sampling campaign was embarked upon in the middle of 2009 which is dry season in order to identify the hydrochemistry in the upper reaches of Bengbu Sluice in Huai River Basin.

There is ever increasing rate of human advancements giving rise to intense changes universally both in climatic conditions and forms of land-use in catchments. In general, the effects of these changes on environment and ecological advancement are receiving extensive attention (Vorosmarty, Green, Salisbury, & Lammers, 2000); (Li, Liu, Zhang, & Zheng, 2009); (Ma, Xu, Luo, Aggarwal, & Li, 2009); (Yang, et al., 2010). On a

67 catchment scale, the effects of these processes of hydrology including infiltration,
68 groundwater recharge, and runoff continue to adversely take tolls in the sense of balance
69 of water resources' demand, supply and quality of water; thereby causing imbalances in
70 environment, ecosystems, and economy. The direct consequences of land use change are
71 rate of flood incidences (Brath, Montanari, & Moretti, 2006), base-flow (Wang B. Y.,
72 Zhang, Hu, & Wang, 2006) and annual mean discharge (Costa, Botta, & Cardille, 2003),
73 whereas the variability of climate can alter the peak-flows, flow routing time, and volume
74 (Prowse, 2006). In future, an effective planning, management and water resources
75 development requires an adequate knowledge of the influences of climate variability and
76 land use forms on hydrological processes.

77 One approach of estimating the effect of management on water, chemical yields of
78 agriculture, and sediment is Soil and Water Assessment Tool (SWAT) which is a
79 physically based, basin-scale, spatially distributed, and continuous-time method operating
80 on basis of a daily time step whose goal is to estimate the influence of management on
81 agricultural chemical yields, sediment, and water in watersheds.

82 The problem of water cycle and distribution in areas bounded by Huai River Basin are
83 common features in local and regional scales. In this arid Northeast region, water
84 resources are a key factor restricting socio-economic development and affecting
85 ecological security, and plays a significant function in attaining sustainable socio-
86 economic development in the imminent (Chen Y. , Li, Li, & Li, 2016). Major factors
87 attributing to these are the land use, land cover and climate change; unprecedented
88 increases in the annual temperature trend while annual rainfall is relative stable over the
89 period of time. These climatic conditions however are among the major issues affecting
90 the present-day human communities in the Northeast China environs. Thus considering
91 the above facts, the present review aims to provide a detailed information on the climatic
92 conditions and human factor on water resource cycle of Huai River Basin. The
93 information will be useful for the ascertaining the degree of variation in water resource
94 availability and development caused by human and climatic condition.

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HUAI RIVER BASIN DESCRIPTION

The Huai River Basin stretches from 30_550N to 34_560N and 111_550E to 117_300E, which encompasses the upper reaches of Bengbu Sluice, including the Ying River, Guo River, Shi River, Feng River, Pi River, and the mainstream of the Huai River. The Huai River originates from the Tongbai Mountain in Henan Province, flows easterly through southern Henan, northern Hubei, northern Anhui, and northern Jiangsu, finally into the Yangtze River at Jiangdu, Yangzhou.

Elevation of the study area ranges from about 23 m to 2,153 m. Variations in elevation are indicative of different land-use patterns and climatological changes. Over 50 % of the study area is cultivated land. The chief enterprises include textiles, chemical pesticides, food processing, alcoholic beverages and wine in Bozhou, Fuyang, and Bengbu. The major urban areas are the metropolitan areas of Zhoukou, Fuyang on the Ying River, Bozhou on the Guo River, and Bengbu on the Huai River (NBS Survey Office in Anhui 2010). The climate throughout the study area varies from northern semi-tropics to sub-humid with warm, moist summers, cool and dry winters. Average temperature ranges from 11.8—16 °C while the temperature could reaches up to 28 °C in summer. The mean annual precipitation was 600–1,400 mm per year and most of the precipitation falls in the form of rain during the four-month period from June through September (Wang et al. 2001). Monthly variations in the water discharge of the Huai River main channel show an appreciable seasonal variability with low discharges in the dry season (October–May) and high values in the wet season (June–September).

WATER RESOURCE CHALLENGES IN HUAI RIVER BASIN

Three parameters for measuring water quality including NH₃-N, industrial wastewater discharge, and COD used in the west region of the river basin showed greater discharges when compared to the eastern region, and pollutant discharges in nearby Nansi Lake were at a high level than other regions. Obviously, there were regional discrepancies in values of industrial output, COD discharges, NH₃-N, industrial wastewater. The regions having huge industrial wastewater discharges were centrally situated. Regions in east revealed

lesser and stable quantities of industrial wastewater discharges as against those in the west.

Conversely, entire industrial output was considerably greater, while industrial pollutants discharges were lower in the Luozhuang District and Zoucheng. In 2010, the association between industrial output values and discharges of industrial wastewater was examined using a correlation analysis at the county level and a significant correlation (0.614 and 0.312) was observed between the quantities of industrial wastewater, industrial output value and industrial COD discharges (s, 0.614 and 0.312 correlation indices respectively) as depicted in Table 1 (Guoyong et al., 2015).

Table 1 Correlation between pollution load and industrial output in Huai River Basin and Shandong Region.

	Industrial output value	Wastewater	Industrial COD	Industrial NH ₃ -N
Industrial output value	1	0.614**	0.312*	0.233
Wastewater discharge	0.614**	1	0.813**	0.592*
Industrial COD	0.312*	0.813**	1	0.755**
Industrial NH ₃ -N	0.233	0.592**	0.755**	1

*Correlation is significant at the 0.05 level; **Correlation is significant at the 0.01 level

The construction materials are considered as high-energy-consumption/low-output/high pollution industries; textiles, electric power, and petrochemical are considered as high-energy-consumption/high-output value/high-pollution industries; and the medical manufacturing and mechanical sectors are low-energy-consumption/high-output value/low-pollution industries. The food processing industry contributed 11.4 % of economic production, and 23.55% and 26.05 % of COD and NH₃-N discharges respectively. Again, it was found that no significant correlation existed between the quantity of industrial NH₃-N discharge and value of industrial output. The Gross Domestic Product (GDP) per capita of the Huai River Basin with in Shandong Province (HRBSP) and the four cities situated nearby (Heze, Zaozhuang, Jining and Linyi) is

expressed as the economic factor, and the industrial wastewater discharge is expressed as the industrial load factor.

The Gross Domestic Production (GDP) of the four prefecture-level cities improved suddenly at 18.2 % per annum, which indicates the speediness of economic growth, particularly in the Heze city that has the fragile economic grounds in Province of Shandong. At the beginning stages of economic growth, industrial water pollution treatment investment could be negligible.

During early stages of industrialization, the primary industries were trailed by secondary industries. Results of industrialization led to a greater percentage of secondary industries as against primary and tertiary industries. The decline of primary industries by less than 20 % was matched with the corresponding secondary industries though surpasses tertiary industries, which was known as mid-stage of industrialization process. Whereas primary industries drop to nearly 10 % which led to a number of secondary industries reaching its highest while the supremacy of tertiary over secondary industries gave rise to the emergence of the post-industrial phase (Kuznets, 1986); (Li, Wei, Wang, & Zeng, 2015).

In 2010, it was estimated that the GDP of the HRBSP was put at 810.14 billion Yuan. The primary, secondary, and tertiary sectors contributed 11.32%, 50.23%, and 38.46 % of the industrial arrangement in the study area, with respect to industrial outputs valued at 100.71, 430.77, and 278.66 billion Yuan.

HUAI RIVER BASIN SOCIO-ECONOMIC DEVELOPMENT

There are several perspectives for the seemingly speedy and sluggish pace of growth in Huai River Basin. These include:

POPULATION DENSITY

In the socioeconomic development standpoint, the large-scale agricultural growth in the Huaibei plain started in the Jin and Wei empires over one thousand years past. During the period, grain production was predominant alongside mass migratory type of settlement. A

great amount of people died in the natural disasters and turmoil of wars by end of
 Dougjin Dynasty in 316–420 AD. Land reclamation became popular due large-scale
 migration and large mortality numbers happened then again because of the regimes
 instability during the Tang and Sui dynasties. Similarly, the growth of Huaibei plain
 during the Song, Yuan, Ming and Qing dynasties stretched out from the upstream to the
 middle region steadily occasion by massive people migration. Certain scholars attributed
 that population grew abruptly in the Qing Dynasty between 1616–1911 in the four
 provinces of Shandong, Henan, Jiangsu, and Anhui. In particular, the Anhui and Jiangsu
 population enlarged by 16.7 times more (that is, 3.45 million to 82 million); the
 Shandong population increased by 18.9 times more (that is, 1.76 million to 33.2 million);
 and the Henan figure even enlarged by 26 times more through the years 1851 and 1661.

Also, the rising population caused a disorderly growth in the plain of Huaibei. The
 construction of water conservancy projects on the Huai River enabled conversion of
 several lands mass prone to flood discharge to farmland, which later formed a situation
 where people and water competed for landscape. In the socioeconomic consideration, the
 history of wars and growth of immigrant population in the Huai River Basin has altered
 considerably with rapid population increases next to the Qing Dynasty. The increase in
 population and economic advancement created the contention for water, which brought
 about the lakes development chaos.

In 2007, a total population of Huai River was estimated as 170 million, which is nearly
 13% countrywide. In addition, the urban population estimate was 56.57 million,
 contributing 9% of total urban population China, and rate of urbanization of 33.3%. The
 average population density in the Basin was 631 people/km², 4.5 times higher than the
 national average figures, which makes it topmost in seven other river basins in China. In
 Huai River Basin, the GDP reached 2.2 trillion Yuan, with GDP per capita of 13.2
 thousand Yuan. The total cultivated land in the basin area was 190 million mu, which is
 about 11.7% nationwide. Though, rate of land per capita was 1.12 mu (about 0.075 ha),
 lesser than the national average estimates. Also, the total grain output was 94.9 million
 tons, which is 17.4% of the national output figures.

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213 **PHYSICAL AND GEOGRAPHY**

214 The current population in the Huai River beach area and flood plain is higher than in the
 215 1950s and 1960s. The fixed assets have improved significantly in terms of regional
 216 economic development. Once a flood occurs, its property damage will be serious.
 217 The recurrent natural flooding damages have constrained the regional economic growth.
 218 Consequently, the strength of local economy weakens, and the capability to manage
 219 disasters and production restoration after a disaster is short. Thus, socio-economic
 220 progress needs includes:

221

222 *(a) Economic development:* The speedy socioeconomic expansion in the Basin, the
 223 economy is expected to further grow, which will impact on its water demand especially
 224 in agricultural production, the industrial, urban and rural population. Socioeconomic
 225 progress in the Basin will accelerate the expansion pace of water conservancy projects,
 226 water infrastructure improvement, increases in the water conservancy projects capacity,
 227 reinforcement of support capability of water resources in order to attain coordinated
 228 growth. More so, there is increasing need to strengthen the integrated management of
 229 water, which include water project optimal operation, allocation of water resources,
 230 enhancing water use efficiency, water consumption reduction, and the environment
 231 protection.

232

233 *(b) People's livelihood improvement:* Water conservancy expansion and people's
 234 livelihood enhancement are interwoven. The protection of life and property is related
 235 directly to flood control measures; whereas mental and physical health is linked to
 236 drinking water safety, and improvement of water environment impacts on social harmony
 237 in which people live and work in peace and prosperity. There is opportunity for
 238 upgrading in the existing flood control and disaster mitigation system of the Huai River.
 239 In fact, wide portions are prone to the menace of flooding as well as several issues
 240 including water shortage, water pollution, inadequacy of water supply facilities, and
 241 safety of drinking water. In many areas, soil and water resources are overexploited,
 242 resulting in damages to the water ecological environment of varying proportions.

243

244 *(c) Equally accessible basic public amenities:* Natural situations and the socioeconomic
 245 growth level differ widely throughout the Huai River Basin giving rise to lopsided water
 246 conservancy growth, low capability and level of public service in this direction. To
 247 achieve a stable growth and bridge the development shortfall a coordinated and
 248 comprehensive expansion of the river basin water resources, enhance public amenity
 249 capability in water conservancy, encourage building of backbone and vital river
 250 harnessing ventures, reinforce the expansion of the river basin water resources, and speed
 251 up schemes to connect the low-lying portions, small and medium rivers. There is need to
 252 focus consideration on the development of rural water management, the capability
 253 upgrading to combat flood disasters, and advance water situations for rural economic and
 254 agriculture growth.

255

256 *(d) Food security:* In China, the Huai River Basin is provides most of breadbasket, which
 257 is a vital part in ensuring the nation's food security. Consequently, there is a necessity to
 258 increase construction and management of rural water conservancy structure for protection
 259 of cultivated land areas and control of flood, increase capacity for available irrigation
 260 zones, improve water-saving irrigation system, steadily develop the effective irrigation
 261 zones, expansion the irrigation coverage and management reinforcement.

262 **CLIMATIC CONDITIONS**

263 The arid Northeast region has exceptionally different features of water resource
 264 formation and conversion, spatio-temporal distribution and water cycle process, which
 265 are illustrative of those found in arid regions throughout the world. Oases and deserts in
 266 flat plains are short of water even with several sources of water and land. Oases and
 267 desert ecosystems are severely impacted by hydrological practices. The magnitude of
 268 oases is influenced by the quantity of runoffs such as glaciers, melting snow and
 269 precipitation. These sources are relatively sensitive to variations in hydrological practices
 270 and water conditions. Recently, studies have revealed that prospecting climate variations
 271 may lead to bigger disparity between spatial distribution of productivity and water
 272 resources, which may increase struggle over water for economic and ecological purposes

(Chen, Li, & Fan, Progress and Prospects of Climate Change Impacts on Hydrology in the Arid Region of Northwest China, 2015).

According to the Fourth Assessment Report of the IPCC, one main obvious consequences of climate change is water cycles variations and matching changes to the coefficient of runoff (IPCC, 2007). Specifically, the arid northwest zone's land surface patterns and climate have been impacted by diverse characteristics of the water cycle. Water resources are multifaceted, and there is substantial elasticity in water resources and runoff. Whenever, there is slight variation in temperature and precipitation triggered by changes in climatic conditions; there is a substantial fluctuations in runoff leading to a major effect on eco-hydrological practices in arid zones. Fluctuations to water cycles of mountainous regions triggered by the effect of climate change further exacerbate the water system instability. Consequently, the reaction of water resources and future trends, watershed surface water and groundwater water cycle processes and mechanisms in arid regions due to climate change have attracted global efforts.

GLACIER MELT WATER CHANGING TRENDS

The glacial melt inflection point, time of occurrence, the procedure and strength of its impacts on water resources in the arid northwest zone are a key hot spot in the debate on future water resource developments in the endorheic drainage basins of the region. Mountain precipitation and glacial melt-water are the core sources of majority of the northwest region rivers. Nonetheless, glaciers are tremendously subtle to change in climate, which further impact on water resources due to direct the influence on quantity of river runoff from snow reserves, and headwater glacial ice (Ma, Fan, Zhang, & Su, 2014). Global warming continues to affect precipitation and temperatures in the 20th Century; the mainstream of the glaciers throughout the world have moved back considerably, notably the fast retreat happening in the past two decades (Wang, Zhang, & Li, 2011).

Interestingly, this magnitude of change was totally unanticipated and tough to expound and forecast with available models. In Northwest China, Water resources are sourced from snowmelt and mountain precipitation, which are predominantly subtle to global

climate variation as well as a substantial insecurity. Water formation in mountainous areas is realized from glacial meltwater and high mountain snow, low mountain bedrock fissure water, and mid-mountain forest precipitation (Chen Y. , Li, Li, & Li, 2016). But, climate variation results uncertainty in terms of the growth prospect and reduction of mountain glaciers and snow cover, and spatio-temporal variations in precipitation, which implies the ambiguity of future water resource trends under climate situation The rise in temperature and the global climate variations implies that glacial melt-water increases, runoff from rivers linked to melt-water will obviously increase. However, the huge quantity of small glaciers situated at lower elevation will increase abruptly.

FLOODING AND DISASTERS

By 1949, a number of management actions for a disaster alleviation and flood control system were set up in the Huai River, which was considered as a milestone in this regard. The water storage capability in the upper part of the river was reinforced to cover an area of 27, 000 km² in control of a large-scale reservoir. The flood discharge ability upgraded considerably to 7000 m³/s from 2000 m³/s in the upper reaches; and to 7000–13000 m³/s from 5000–7000 m³/s in the middle reaches flanked by Wangjiaba and Hongze lake; and to 18270 m³/s from 8000 m³/s in the lower reaches.

The strength of the flood discharge system of Yishusi River system into the sea was upgraded to 14200m³/s from 1000 m³/s previously. The flood control standard is 10 years' frequency for the upstream of the Huai River, and 100 years' frequency for important flood control and protection areas and important cities. The standard for flood control has been elevated to 50 years' frequency for important flood control and protection areas in the middle and lower reaches of the Yishusi River. The flood control standard is elevated to frequency of 20 years for key trans-provincial tributaries in Huaibei with an exception of the Hongru River, which is frequency of 10 years. In addition, the conditions of flood-release for low-lying land hitherto susceptible to waterlogging were enhanced, and the river drainage standard of key drainage river ways has stretched to a 3-year return period.

The appreciation and the requirements for controlling flood are directly linked to socioeconomic growth, which continues to vary proportionately. Presently, the development of the Huai River has reached appreciable height when put side-by-side with local socioeconomic growth, but, there is need to enhance its flood control system. In fact, there is a stretch to achieving the requirements of socioeconomic progress. Obviously, the impact of this can be felt in inadequate ability to store floodwater, lower flood-control standard in upper reaches, congested flood discharge in the middle reaches, poor flood discharge outlet, and small discharge ability in the Hongze Lake for low and medium water level.

In order to adapt to the varying flood control requirements, additional upgrading is needed for the Huai River disaster mitigation and flood control project system: :

- a) To build 10 large-scale reservoirs such as the Chushandian Reservoir.
- b) To reinforce reservoirs and sluices in dangerous state, and upgrade flood-discharge capacity in the upper reaches.
- c) To enforce complete control of the Huai River by adjusting the mainstream flood-discharge areas, raise flood channels for medium-scale floods, and combine flood discharge capacity in the middle reaches;
- d) To harness the river way to supply water into the Yangtze River, and strengthening the levees of the Hongze Lake, building the 2nd phase water project to access water into the sea by building the Sanheyue big sluice.
- e) To improve and consolidate the flood control in the basin's lakes and its backbone river flood control engineering system.
- f) To expand the flood discharge capacity through diversion water to the south from the east in the Yishusi river system using existing scheme.
- g) To build flood storage and retention zone, and standardized levees.
- h) To connect main tributaries such as the Shaying River, the Hongru River, and small and medium rivers step-by-step.
- i) To undertake activities such as dewatering, storing, interception.
- j) To harness waterlogged low-lying zone using sensible low-lying land subareas.

- k) To reinforce the building of seawalls and city-wide flood control in order to increase the flood control and disaster mitigation scheme.

INSECURITY OF MAIN STORAGE ZONE OF THE BASIN

The flood-storage zone in the Huai River and the beach areas are contribute vitally in the discharge, storage of floodwater and flood control safety guarantee. In 2010, a staggering 1.45 million people reside in floodwater storing and beach areas in the mainstream, while approximately 930,000 people are under this direct threat. The consequence is in the inability protect lives of people and property. Also, it disrupts the regular flood and the flood control of whole basin. In fresh development plan for the Huai River, there are measures in place for flood-storage modification and the resettlements of people living in the regions of floodwater storage and mainstream beach areas.

The immigration in the beach areas and the floodwater storage districts in the mainstream can be achieved peacefully through government's guidance, all-inclusive planning and steady execution to assist the residents in dangerous zones to transfer to safer zones, which charts the path to the disaster mitigations. Although flood plains are typically dangerous places for flood but also a fertile land which is good for agriculture. Therefore resettlement could not be a good solution.

INDUSTRIAL ACTIVITIES

In practice, water is the topmost critical resource for the sustainable growth of societies as well as for the basic support of all human and natural arrangements (Ni, Wu, Wu, Lu, & Chris, 2012). Naturally, water bodies possess distinctive geographical features in which river basins are a hydrogeological component. A basin is a whole drainage structure, whereby diverse water forms are cycled within the basin by means of continuous movement and mutual transformation (Sun, Zhong, Zhang, Liu, & Hua, 2007). But, the rate of human activity such as urbanization, industrialization, and the expansion of megacities, quantities of waste products and pollutants increases are discharged directly into waterways which have contaminated several groundwater aquifers (Abu-Zeid, 1998); (Biswas, 1991). Integrated water resource management of

watersheds makes a single unit arrangement significant for synchronizing the growth of environmental safeguards and economic resources.

(Mays, 2007); (Mays, Groundwater Resources Sustainability: Past, Present, and Future, 2013) describe sustainability of water resource as the capability to utilize water in appropriate quantities and quality from the domestic to the universal measure to meet the ecosystems and humans demands for the contemporary and the future to support life. It means the protection of humans from the harms caused by natural and human disasters which impact life sustenance. In this kind of management setup, there is a need to thoroughly comprehend the composite interactions between water use, land use and ecological quality, particularly from the perspective effects interconnected to human activities capable of triggering the ecosystems degradation (Cai, 2008).

In China, speedy growth of economic activities has open up fresh issues for managers of water resource, due to the increasing water demands and inadequacy of resources obtainable, combined with stark water pollution and different water-associated ecological trepidations (Liu & Speed, 2009). Consequently, China undertook a great deal of effort to stimulate continuous economic process, modify structure of industrial development, and advance organized reform at the same time (Zhang, Liu, Zhang, & Tan, 2014). Socioeconomic progress is a topmost and fundamental influencer on water quality of river basin, and the regional model of expansion, particularly in trends of economic progress and estimation of water pollution lasting cycle.

The Huai River Basin is situated between the Yellow River and the Yangtze River, which forms a geographical boundary between china's northern and southern regions (Zhao, Liu, Xia, Zhang, Yu, & Eamus, 2012). From the inception of 1980s, industrialization and urbanization of the Huai River Basin in Shandong Province (HRBSP) section have improved speedily, exacting great pressure on the region's water resources. After the 1990s, the structure of industrial setup of the HRBSP was developed with emphasis on industry fields such as chemical fertilizers, papermaking, tanning, and winemaking (Shi Y. , 1999) (Shi, 1999). Recently, the study area's secondary industries are very efficient

as well as China's gross domestic product (GDP) biggest contributors. The river basin's main area lies round the Eastern Route of the South-to-North Water Diversion Project, which requires the rigorous water quality Grade III standard. The HRBSP's water pollution control scheme is evolving, which makes main dual goals of spring-cleaning diverse water bodies in the basin and the river ecosystem restoration far from being attained.

To attain improvements in water quality and industrial progress, the need to understand the connection between water quality and industrial progress cannot be overstated. Studies have shown that the consequence of economic advancements is emission levels increases, but there are prospect of reducing emissions through structural and technological modifications (de Bruyn, van den Bergh, & Opschoor, 1998). The twelve industrial sectors enlisted by the National Economical Industry Classification (GB/T4754-2002) were mostly secondary industries category. The water pollution loads (COD, NH_3^+) and industrial output values of these industrial sectors were acquired from the General Survey Database of Pollution Sources for Province of Shandong, which served as the basis for describing industrial pollutant loads by end of 2010. The pollution survey considered other industrial sectors such as agriculture, and domestic pollution sources. In addition, it took into account centralized pollution treatment facilities and pollution generation or discharge facilities. In particular, the industrial pollution sources survey take in the basic registration data of companies; production parameters; raw material consumption; conditions of facilities susceptible to pollution; statistics on the emission, control, discharge, and widespread exploitation of several kinds of pollutants; and the setup and operation of different pollution avoidance and control facilities as shown in Table 2 (Global Environmental Institute (GEI), 2008).

455 Table 2. Huai River Basin's GDP per capita and industrial wastewater discharge at
456 Shandong Province (Zhang, Liang, & Shao, 2010)

Year	GDP (billion Yuan)	Population (million)	GDP per capita (Yuan)	Discharge amount of Industrial wastewater (million ton)
2001	174.75	30.09	5807.58	327.70
2002	197.53	30.3	6519.14	280.94
2003	234.54	30.48	7694.88	308.61
2004	293.79	30.63	9591.58	300.81
2005	355.79	30.77	11562.89	310.27
2006	415.73	31.12	13358.93	340.69
2007	500.50	31.40	15939.49	406.31
2008	598.98	31.66	18919.14	422.11
2009	654.27	31.99	20452.33	398.16
2010	753.18	32.65	23065.17	476.95

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458 From Table 2, there is seemingly growing trends in GDP, population, GDP per capita,
459 and industrial wastewater discharges over the period of 2001 – 2010. This implies the
460 presence of worsening situation of water pollution in the Sandong Province region of
461 Huai River Basin, which is expected to increase beyond the study period.

462

463 **LANDFORMS AND MOUNTAINS**

464 According to (Chen Y. , Li, Li, & Li, 2016), the China's arid northwest zone is regarded
465 as location of high mountains and large basins. The effect of these prominent physical
466 features is great due to activities of plateau uplift, the East Asian monsoon, and westerly
467 circulation. The outcome is creation of a special climate system consisting three key
468 geographical entities such as oasis, mountains and deserts. This produces material
469 migration and processes of energy conversion largely water-driven. The arid northwest
470 zone is entirely massive, with composite regional topography and various ecosystems
471 such as the Altay, Lofty Tianshan, the Gobi Desert Kunlun and Qilian mountain ranges.

472 Unlike, the special arid northwest region is different from low-latitude subtropical arid
473 zones because its location is in the moderately humid latitudes, giving rise to its unique
474 and composite climate structure. Studies have revealed that nearly 50 years on, the oases,
475 mountains, and deserts of Northwest China continues to witness diverse climatic changes.
476 Obviously, this is evident in the variations and in the speed of temperature changes,

precipitation and instability in the timings of climatic (Li, Chen, & Shen, Analysis of Changing Pan Evaporation in the Arid Region of Northwest China, 2013). In the same vain, there are substantial regional variances in climate change within the same ecosystem. In particular references to the high barriers formed by the terrain, the northern and southern slopes of the Tianshan Mountains continue to experience changes in climate conditions (Wang *et al.*, 2015).

Again, the northwest zone is susceptible to the negative effects of human activities and global warming, which lead to instability in climate system and exceptionally profound to changes in worldwide climatic conditions. In the past 5 decades, the climate of Earth has warmed up with matching increases in temperatures around the arid northwest zone by twice or thrice rate, more than the global average figures. China's average levels of precipitation fell sharply, the precipitation variability enlarged with a matching rise in precipitation in northwest zones. These special changes in climate conditions are closely related to rise and fall in the Western Pacific Subtropical High, Siberian High, Qinghai-Tibet Plateau Circulation, North American Subtropical High, Circulation and other atmospheric pressure structures (Li *et al.*, 2012; Chen *et al.*, 2014a; Li *et al.*, 2016a).

RELATED STUDIES

(Zhang, Xia, & Hong, 2012), addressed the change of the river-lake relationship in the Huai River and its causes due to environmental change and human activities. A preliminary analysis is made from three aspects: (i) the natural geographical change particularly captured by the Yellow River, (ii) water conservancy project construction, and (iii) socioeconomic development in the Huai River Basin. Key problems of changes in this river-lake relationship and the Huai River flood control are tackled, involving flood control and disaster alleviation ability of the Basin, engineering and non-engineering measurements applied to flood control and disaster mitigation, and water governance for adaptive management. Research shows that the Huai River is a rather complex one due to its complex geography with a hybrid wet and dry climate zoon, and higher population density. With the alternation of the river-lake relationship and socioeconomic development in the region, new problems keep arising, imposing new

requirements on its sustainable water management. Thus, understanding the Huai River is a long and gradually improving process. Its future planning should keep absorbing new achievements of science and technology development, employing new technologies and methods, and gradually deepening our understanding of its fundamental principles. Water governance and adaptive water management will be new challenges and opportunities for the Basin in its river system change and flood control (Zhang, Xia, & Hong, 2012).

(Guoyong, QiuHong, & Scott, 2015) undertook a bias corrected daily climate projections from five global circulation models (GCMs) under the RCP8.5 emission scenarios were fed into a calibrated Variable Infiltration Capacity (VIC) hydrologic model to project future hydrological changes in China. The standardized precipitation index (SPI), standardized runoff index (SRI) and standardized soil moisture index (SSWI) were used to assess the climate change impact on droughts from meteorological, agricultural, and hydrologic perspectives. Changes in drought severity, duration, and frequency suggest that meteorological, hydrological and agricultural droughts will become more severe, prolonged, and frequent for 2020–2049 relative to 1971–2000, except for parts of northern and northeastern China.

(Zhang, Liang, & Shao, 2010), noted that despite rapid economic growth and industrialization in the Huai River Basin within Shandong Province, water quality improved during 2005–2010 under state-controlled monitoring. The industrial structure theory, environmental Kuznets curve, and statistical analyses were used to examine correlations between economic development and industrial water pollutant loads. The beverage, textile, paper, and food processing industries are major polluters, and structural pollution deters simultaneous industrialization and water resource management. This paper proposes policy actions and indicates that constant adjustments to the industrial structure are important for promoting coordinated growth of industry and water environmental protection.

(Xiao, Zhang, Singh, & Chen, 2016), revealed that the Huai River basin is one of the major supplier of agricultural products in China. Droughts have critical impacts on agricultural development hence good knowledge on drought phenomena is of great importance in the planning and management of agricultural activities in the Huai River basin. With the copula functions to model the persistence property of drought, the probabilistic seasonal drought forecasting models have been built in the Huai River basin. Results indicated that the uncertainty related to the predicted seasonal drought is larger when more severe droughts occurred in the previous seasons, and the severe drought which occurs in summer and autumn will be more likely to be persistent in the next season while the severe drought in winter and spring will be more likely to be recovered in the subsequent season.

The Huai River basin is densely populated and is also the principle cropping area in China hence, extreme droughts will have considerable impacts on the availability of water resources and agricultural produce. Previous study provides theoretical references for the planning of crop cultivation and also for human mitigation to drought-induced losses in the Huai River basin, China (Xiao, Zhang, Singh, & Chen, 2016).

The unique landscape of Northwest China increases the complexity and uncertainty of the climate system. Climate change and water resource issues are global problems of common concern to the international community, and are the major bottlenecks affecting the eco-environment and sustainable socio-economic development in the arid region of Northwest China (Chen, Li, Li, & Li, 2016). Among the problems include; the impact of climate change on the formation, conversion and future trends of water resources in the region; bi-directional coupling of high-resolution regional climate models and water cycle models of arid region land surface patterns; and the impact of climate change and human activities on water resources of the arid northwest region. Through consideration and discussion of the above, however further specific areas of research on pressing issues related to climate change and water resources in Northwest China would establish a solid scientific basis for significantly enhancing our ability to respond to climate change and water shortages (Chen, Li, Li, & Li, 2016).

569

570 Water resources play a principal role in supporting environment and climate change will
571 challenge the current water resources management practices and threaten water security
572 through acceleration of the hydrological cycle (Wang & Zhang, 2015), Historical
573 variation of recorded runoff on main streams and influence of climate change on water
574 resources in the Huang-huai-hai area (Yellow River, Hai River, and the Huai River) were
575 analyzed with statistical methods and a hydrological simulation approach. Results
576 indicate that the recorded runoff showed a significant decreasing trend during past 50
577 years for the Hai River and the middle and lower reaches of the Yellow River, with
578 insignificant change occurring in the Huai River basin and the upstream of the Yellow
579 River basin. Temperature was projected to steadily rise in the next 30-50 years while
580 precipitation was expected to increase slightly. Water resources in 2021-2050 under the
581 three scenarios of RCP2.6, RCP4.5, and RCP8.5 were estimated to change 1.3%, 1.0%
582 and 2.3% relative to the reference period of 1961 and 1990, respectively. The water
583 shortage for the Huanghuai-Hai area might be aggravated due to climate change. It is
584 therefore of significance to enhance water saving construction, utilize non-traditional
585 water sources, and speed up water conservancy project planning and implementation for
586 adaptation to climate change.

587

588 Climate change has already strained the water security of China, especially for north
589 China. Under climate warming, recorded discharges from the Huang-huai-hai area have
590 declined significantly in the Hai River, and the middle and lower reaches of the Yellow
591 River.. Climate change will likely enhance water shortages for the Yellow River basin
592 and aggravate flood issues for the Huai River basin. The Hai River basin will probably
593 undergo additional climate-induced flooding issues, although there still been much
594 uncertainty in the current projections of water resources. The effective adaptation
595 measures and strategies to climate change are to reduce the vulnerability of water
596 resources and mitigate the conflicts between water supply and demand. Joint efforts from
597 the central government as well as local people are essential for better coping with climate
598 change (Wang & Zhang, 2015)..

599

Despite rapid economic growth and industrialization in the Huai River Basin within Shandong Province, water quality improved during 2005–2010 under state-controlled monitoring (Li, Wei, Wang, & Zeng, 2015). The industrial structure theory, environmental Kuznets curve, and statistical analyses were used to examine correlations between economic development and industrial water pollutant loads. The beverage, textile, paper, and food processing industries are major polluters, and structural pollution deters simultaneous industrialization and water resource management. Constant adjustments to the industrial structure are important for promoting coordinated growth of industry and water environmental protection. Measurements of water quality played a vital role in the construction of water conservation projects and socioeconomic development. The water quality in most rivers has shown gradual improvement because of efforts made by local governments (Li, Wei, Wang, & Zeng, 2015).

Correlation appeared to exist on the economic development of most cities with environmental costs to water resources. Industrial wastewater discharges increased as industrial output increased, and some cities showed much higher industrial wastewater discharges despite having minimal industrial output. Due to regional variations in industrial output values and industrial pollution loads, the four prefecture-level cities showed differently shaped EKC, and effective control of industrial pollutant loads did not necessarily rely on economic growth. At the macro-level, the coal, papermaking, and food processing industries were the competitive industries with high-energy consumption and high-pollution generation. Industrial growth was based on extremely high resource consumption, and the structural pollution of the industries remained significant, increasing pressure to improve water quality. The importance of industrial composition and structure should be emphasized for the sustainable development of the HRBSP. Based on these findings, a series of policy recommendations are outlined to balance industrial development with water resource protection (Li, Wei, Wang, & Zeng, 2015).

(Shi, Ma, Hou, & Li, 2013)) investigated the how Land use/land cover and climate change can significantly alter water cycle at local and regional scales. Xixian Watershed, an important agricultural area in the upper reach of the Huaihe River, has undergone a

dramatic change of cultivation style, and consequently substantial land use change, during the past three decades. A marked increase in temperature was also observed. To better support decision making and policy analysis relevant to land management under climate change, it is important to separate and quantify the effect of each factor on water availability. We used the Soil and Water Assessment Tool (SWAT), a physically based distributed hydrologic model; to assess the impact of Land use and climate changes separately (Shi, Ma, Hou, & Li, 2013).

The SWAT model was calibrated and validated for monthly stream flow. Nash-Sutcliffe efficiency (NSE), percentage bias (PBIAS), and coefficient of determination (R²) were 0.90, 6.3 % and 0.91 for calibration period and 0.91, 6.9 %, and 0.911 for validation period, respectively. To assess the separate effect of land use and climate change, we simulated stream flow under four scenarios with different combinations of two period climate data and land use maps. The joint effect of land use and climate change increased surface flow, evapotranspiration, and stream flow. Climate variability increased the surface water and stream-flow and decreased actual evapotranspiration; and land use change played a counteractive role. Climate variability played a dominant role in this watershed. The differentiated impacts of land-use/climate variability on hydrological processes revealed that the unapparent change in stream-flow is implicitly because the effects of climate variability on hydrological processes were offset by the effects of land use change (Shi, Ma, Hou, & Li, 2013).

HUAI RIVER BASIN WATER RESOURCES CONSERVATION

In recent years, a number of drought disasters and flooding on a large scale are common occurrence annually due to the distinctive natural landscapes of the HRB. Certain water resource conservation schemes have been introduced including structural and non-structural approaches.

STRUCTURAL APPROACH

Approximately 5700 reservoirs have been built with an overall loading capacity of 30 billion m^3 , in which 38 are big reservoirs offering a overall loading capacity of 20 billion m^3 as well as a 62 billion m^3 flood control capacity. In addition, over 17 flood detention zones and big lakes for mitigating flood incidences have been erected with installation capacity of 35.9 billion m^3 full loading, and a 26.3 billion m^3 capacity for flood storage. Several other artificial channels have been erected to cover a vast landmass of 2,100 km. Various kinds of dikes were created having a length of 50,000 km, and a key dike length of 11,000 km. Discharge capacity for River channel has been considerably supported, in effect, the upper mainstream channel discharge capacity increased to $7000\text{m}^3/\text{s}$ from $2000\text{m}^3/\text{s}$. Similarly, the middle mainstream channel discharge capacity improved from $5000\text{m}^3/\text{s}$ - $7000\text{m}^3/\text{s}$ initially and later to $13000\text{m}^3/\text{s}$. More so, the middle mainstream channel discharge capacity was boosted to $18270\text{m}^3/\text{s}$ from $8000\text{m}^3/\text{s}$. Recently, the mainstream in the upstream flood control standard is review after a 10-year period, while flood control standards of major flood protection zone, main cities in the lower and middle reaches were upgraded to a 100-year period of review. In the case of major tributaries, flood control standards reviews were modified from a 20-year to a 50-year period.

NON-STRUCTURAL APPROACH

To this point, non-structural measures of flood prevention regulation command system jointly form system mechanism for flood prevention and disaster reduction:

a) The flood monitoring scheme

Flood forecasting and hydrological data are the foundation for effective mitigating flood throughout rainy time of year. In 2014 alone, over 329 hydrological stations, 220 gauge stations and 2,488 rain gauges, 1,489 water quality monitoring stations, 324 moisture stations and 3,024 ground water monitoring stations make up a vast the hydrological network and flooding monitoring scheme were installed across the Huaihe River Basin. In addition to these stations, 1,250 of them were dedicated for the purpose of reporting and delivering hydrological data at different flood season. There are regular time interval

hydrological elements created as specified requirement for river flood prediction system (Huaihe River Commission (HRC), 2014); (Wang, Chiu, & Yang, 2016).

(b) Transmission of information

In practice, the country's telecommunication systems are used for transmitting hydrological information. There are provisions of special transmission lines for remotely situated reporting stations without telecommunication system coverage. More so, government's regulation of telecommunication industry has enacted guidelines to support high priority transmission of the hydrological information at the flood period. In case of special rivers, river reaches and water projects of high interest short wave radio stations were installed in order to improve the transmission of information. More importantly, the tasks of data collection, processing, storage, retrieval and dissemination have been computerized for the real time forecasts of flood activities.

(c) Flood forecasting and warning

The Flood Fighting and Drought Defying Headquarters (FFDDHS) is responsible for flood forecasting and warning tasks carried out at diverse levels such as the river basin commissions, the central government, the provinces/municipalities/autonomous regions and prefectures. Whenever the critical condition is attained (such as surpassing specified water level), the FFDDHS issue warning through various media (TV, radio, and newspapers) to concerned parties, government's agencies and the general public. The flood mitigation systems are equipped earlier before the commencement of the flood periods; with proper reviews of the preparedness during FFDDHS annual meeting of stakeholders cutting across different levels. There are special flood forecasting systems installed for completed and uncompleted large reservoirs for purpose of flood monitoring operations. Also, an approximately 1,000 hydrological stations are involved for river flood forecast operation on request basis only. In the early 1950s, a model was proposed using the traditional methods in flood routing and runoff yield analysis. One of such model was developed by Chinese scholars known as Xinanjiang Model which enjoys widespread usage in many big river basins. Recently, more advanced flood forecasting system based application of computers have emerged with real time tuning to produce

high accuracy in the detection of flood events (Jiang, Xia, Wang, & Zhao, 2009); (Li, Bao, Xue, Hu, & Fang, 2008); (Ma, Fan, Zhang, & Su, 2014). Nowadays, an integrated system of flood monitoring, flood dispatching and flood control discussion, forecasting and warning which comprises weather prediction, flood monitoring and forecasting has been developed in the Huai River Basin which thereby support flood controls around river basin areas. Nevertheless, there is need for work to be carried out on flood risk management such as probability flood forecasting system, reservoirs and hydro-junction flood risk dispatching models (Wang, Chiu, & Yang, 2016).

d) Setting up of the drought-causing climate threshold

The Standardized Precipitation Index (SPI) is a technique for designating the drought degree in a quantitative manner. This is useful for indicating the intensity of drought and duration of drought in several regions (Yan, Wang, & Wu, 2010). Habitually, the Huai River Basin experiences the negative effects of unexpected heavy drought-flood change of events (Cheng, Xu, & Luo, 2012). The SPI approach used to analyse the yearly precipitation of the Huai River Basin for the period (1959 – 2008). The outcomes revealed that the SPI values for 1966, 1978, 1988 and 2001 exceeded -1.5 scales. Also, the value of SPI designated 1966 an extreme year of drought, while the remaining 3 years recorded heavy drought.

The process of calculating SPI value is straightforward, and provides precision for drought events analysis (Yuan & Zhou, 2004). The defect of this approach is limitation to a monthly scale; which makes it unsuitable for analysing extreme rainfall in a short time frame as well as matching flooding happenings (Naresh & Murthy, 2009); (Cheng, Xu, & Luo, 2012). Interestingly, the actual drought years are the same to those provided by the SPI curve without actual flood happenings for the same period of time. The drought causing climate threshold is calculated using the daily precipitation in 1959, 1992, 1994 and 1999. Based on the threshold, drought related disasters are broken down into five grades: normal, light drought, drought, heavy drought and extreme drought. The disaster-causing climate threshold calculations are capable of designating the flood and drought happenings of diverse time scales in an accurate manner; it can be effectual in

meeting the analysis demand of majority flood and drought happenings. The threshold can be applied in other regions of similar circumstances (Gao & Jianqing, 2015).

The authors measured the drought-causing threshold of the other four drought years: 1966, 1978, 1988 and 2001, then made a spatial distribution map of the drought causing threshold of year after year. In the four maps, the middle-upper reaches of the Huai River Basin experienced a heavy drought area and extreme drought area in 1966. The southern part of the middle lower reaches in 1978 was an extreme drought area. In 1988, the junction area of Henan, Shandong, Jiangsu and Anhui Provinces was a heavy drought area, whereas Peixian, Shanxian, Feixian, Jinxiang and Pingyi experienced extreme drought related disasters. In 2001, the south of the Huai River Basin witnessed a heavy drought, while central Anhui and eastern Henan were extreme category (Naresh & Murthy, 2009). and the results illustrated by four maps basically consistent with the actual scenarios (Gao & Jianqing, 2015).

e) Water resource allocation

The evaluation of the climate change impact on the processes and intensity of future water use for manufacturing, domestic and eco-water consumption is a main challenge in deciding the most effective water allocation approach in compound water-ecology-social economy scheme of the arid northwest zone (Chen Y. N., 2014). The impact of global warming and population size explosion continue to trigger increasing demand for water in manufacturing, living and eco-environment purposes. Temperatures upsurge and rising precipitation in mountainous zones are leading to glaciers melt adding to the runoff from rivers. Melt water from the mountains are produced by ice and snow melt water which predicted to remain at relatively high level for a particular time period. But, retreats from glaciers water reserves diminish speedily and tend to a point of inflection, the available surface water resources from smaller glacial rivers drop or rise sharply because of irregular variability of rainfall.

Greater water pollution problems can be influenced by upper degrees of temperatures (Mimikou, Blatas, & Varanaou, 2000); (Patz, 2001). The water pollution is capable of

exacerbating pressures on water resource, and further escalating the struggle for water-ecology-social economy of the arid northwest zone. The social and ecological landscape pattern in the northwest region is influenced by the spatio-temporal spreading of water resources. Whereas, the spatio-temporal spreading of water volumes provides functional zoning, and spatial configuration of socio-economic system and ecosystems. In the last 5 decades, economic expansion activities have considerably enlarged the artificial oases areas in the northwest region. Furthermore, a trend for socio-economic efforts to move to the rivers' middle- and upper-reaches continue to hold sway, which has given rise to downstream lakes shrinkages and speedy deterioration in desert riparian forest ecosystems (Li, Chen, & Yuan, 2015); (Li, Chen, & Li, 2016).

Water-ecology-social economy problems associated with development of water resources in the China's arid Northwest region are mostly caused by social and natural factors. Though, past studies revealed presence of disconnect between natural factors and social factors impacts on water resource expansion. There is no consideration on diverse scales of water demand for socio-economic growth and ecosystem. Again, there is no literature supporting the relationship between water resource socio-economic service roles and ecosystem service roles in arid areas (Chen Y. , Li, Li, & Li, 2016).

CAUSAL FACTORS EFFECTS ON WATER RESOURCES

Sodium Adsorption Ratio (SAR) is used to estimate and assess the suitability of water provided by River Basins considered for the purpose of supporting irrigation farming. SAR combined EC to determine the hazard in respect to magnesium and calcium concentrations as given by Equation 1: (Richard, 1954; Yang, Song, Zhang, Yuan, Ma and Dongmei, 2012)

$$SAR = \frac{m_{Na^+}}{\sqrt{(m_{Ca^{2+}} + m_{Mg^{2+}})}} \quad 1$$

Where,

m_i depicts the ion concentration (in mmol/L)

811 The amount of concentration in soluble salts in irrigation water (EC) can be classified as
812 salinity zone:

813 Low = 250 $\mu\text{S}/\text{cm}$,

814 Medium = 250 –750 $\mu\text{S}/\text{cm}$,

815 High = 750 –2,250 $\mu\text{S}/\text{cm}$, and

816 Very high = 2,250 –5,000 $\mu\text{S}/\text{cm}$.

817

818 In irrigation water quality, the percentage of sodium is estimated by Equation 2 (Wilcox,
819 1995):

$$\%Na^+ = \frac{Na^+}{Ca^{2+} + Mg^{2+} + K^+ Na^+} \quad 2$$

820

821 Units are meq/L.

822

823 Mann-Kendall rank test is a non-parametric distribution-free method suitable for
824 detecting changes trends runoff series with least assumption for data series (Shi, Ma,
825 Hou, & Li, 2013). It can be estimated by Equation 3:

$$k = \sum_{i=1}^{n-1} \sum_{j=i+1}^n \text{sgn}(x_i - x_j) \quad 3$$

826 where,

827 x_i and x_j are the sequential data values of annual runoff, and

828 n is the length of the data set.

$$\text{sgn}(x_i - x_j) = \begin{cases} 0 & \text{if } x_i - x_j > 0 \\ 1 & \text{if } x_i - x_j < 0 \end{cases} \quad 4$$

829 U is the Mann-Kendall rank test index (M-K value). Under the NULL hypothesis of no
830 trend, the value of n increases which can be represented comparable to standard normal
831 distribution as given by Equation 5:

$$U = \frac{\tau}{[\text{var}(\tau)]^{1/2}} \quad 5$$

832

$$\tau = \frac{4k}{n(n-1)} - 1 \quad 6$$

$$var(\tau) = \frac{2(2n + 5)}{9n(n - 1)}$$

7

When the calculated value of M-K is positive or negative; then the trend is an upward or downward correspondingly. The null hypothesis is rejected at the significance level of α if $|U| \geq U_{\alpha/2}$, where $U_{\alpha/2}$ is the critical value of the standard normal distribution with a prospect surpassing $\alpha/2$. If $|U| < U_{\alpha/2}$, the null hypothesis is accepted representing insignificant trend. The value of $U_{\alpha/2} = 1.96$ is obtained for the significant level $\alpha = 5\%$.

The Variable Infiltration Capacity (VIC) model is used to measure the prospective effect of climate condition variations on water resources of the study area (Liang, Lettenmaier, & Wood, 1994); (Lohmann, Raschke, & Nijssen, 1998); (Liang & Xie, A New Surface Runoff Parameterization with Subgrid-Scale Soil Heterogeneity for Land Surface Model, 2001). The VIC model breaks down a study area into several compartments, and the soil column of each component into three layers. In most situations, the topmost two layers can be combined into one layer in order to represent the dynamic response of soil to rainfall happenings.

The seasonal soil moisture behaviour is characterized by the soil lower layer. The base flow and surface flow are used to calculate the total runoffs. Surface flow consist saturation excess flow and infiltration excess flow created in the two top layers. The soil storage capacity distribution curve and infiltration capacity curve were used to illustrate soil properties heterogeneity. The B exponents' power functions are shown as double curves while, ARNO technique depicts lowest layer where base flow happens (Mao, Wu, He, Lu, Xu, & Lin, 2016). Again, the soil moisture vertical measure is achieved with the Richard's one-dimensional equation (Wang & Zhang, 2015).

To estimate effect of climate on the River Basin in terms of a physical quantity, the amount of soil wetness or dryness available is used. In the long run, soil moisture anomaly may illustrate random precipitation on the land surface, which determines growth of crops and the progress of drought events (Wang G. O., *et al.*, 2012). In effect,

soil moisture is important for agricultural drought and drought monitoring expressed by Equation 8: (Wu, Lu, & Lin, 2011)

$$SMAPI = \frac{z - \bar{z}}{\bar{z}} \times 100\% \quad 8$$

Where,

z is the soil moisture content (mm) daily simulated,

$\bar{z}$ is the multiyear average of soil moisture content (mm).

The classification of drought levels with SMAPI makes use of frequency distribution.

The threshold of -5% and lower indicates a severe drought situation around the study area.

(Huang, Wang, Chen, & Liu, 2016) investigate the relationship between metrological factors and daily normalized difference vegetation index (NDVI) given by Equation 9:

$$r_{ab} = \frac{\sum_{i=1}^n (a_i - \bar{a})(b_i - \bar{b})}{\sqrt{\sum_{i=1}^n (a_i - \bar{a})^2 \sum_{i=1}^n (b_i - \bar{b})^2}} \quad 9$$

Where,

r_{ab} is the correlation coefficient between a and b ,

a is the meteorological factors

b is NDVI values if distinct grades of winter crop growth.

The significance level ($P < 0.05$) is used for hypothesis testing

The various variables and their representations in the study are presented in Table 3.

887

888 Table 3. Description of causal factors and assigned variables for the study

Variables	Definitions
Water Resource (WR)	Quality of water supplied per population
Climatic conditions:	
Rainfall (RAIN)	Rainfall
Precipitation (PREC)	Precipitation
Flood level (FLO)	Flood level
Temperature (TEMP)	Temperature
Humidity (HUM)	Humidity
River level (River)	River level
Human activities:	
Road (RD)	Construction of access roads
Drainage (DR)	Drainage channels blockade
Water supply (WS)	Water supply requirements
Population (POP)	Size of population
Electricity (ELEC)	Electricity dams on the rivers
Housing (HOU)	Private Housing
Waste disposal (WD)	Waste disposal in rivers and basins
Pollution source (POLL)	Pollution material generation
Industrial (INDUS)	Industrial activities
Land-use:	
Rice farming (RICE)	Rice plantation
Agriculture (AGRIC)	Agriculture purpose
Irrigation (IRRIG)	Irrigation farming
Forestry (FROST)	Forest conservation
Residential (RESID)	Residential area

889

890 STATISTICAL ANALYSES OF DATA

891 Data obtained was subjected to statistical analyses using IBM SPSS (Version 24.0, IBM
892 Corp., and Chicago, IL, USA). The data was tested for fitness to a normal distribution by
893 the Shapiro-Wilk test, and was shown to conform to normality. Thereafter, the data was
894 subjected to ANOVA and Turkey LSD pairwise comparison to test for significant
895 difference between the different treatments and weeks of treatments. Statistical
896 significant difference was determined at confidence level of 95% ($\alpha = 0.05$). The

897 quality of water supply is impacted by a number of factors expressed in regression
898 equation below:

$$\text{Log}Y = a + \text{log}b_1 x_1 + \text{log}b_2 x_2 + \dots + \text{log}b_n x_n + e$$

899 Where,

900 Y is the dependent variable or water quality index

901 a is the intercept

902 b is the slope

903 x is the dependent variables or factor influencing water quality development

904 e is the error term permissible

905 n is the range of factors considered by the study

906

907 CONCLUSION

908 Global response to climate change and the actions required to mitigate its effects upon
909 most components of the natural ecosystems and human activity. Huai river being a home
910 to morethan 200 million people with vast agricultural undertaken driven by sustained
911 rapid growth of agricultural and industrial activities is facing.The present-day human
912 society of the Northeast China arid region, an area susceptible to evolving global climate
913 change, relies on mountain precipitation and glacial melt water as the basic water source
914 system. At present, there is higher insecurity concerning water resources, the customary
915 rules guiding the water cycle changes, and demand in eco-water. Socio-economic
916 development increases water demand largely due to increase in human population which
917 continues to sway the water resource availability and deepening scarcity. Furthermore,
918 Northeast China's Huai River Basin is the cause of a number of chief international rivers,
919 and uncertainty of water resources occasioned by climate change continues to raise
920 tensions among Central Asian nations. Reginal discrepancies in industrial out put showed
921 greater discharge of industrial waste in the northwest compared to the eastern region.
922 Direct consequences of land use changes in Huai river affect flood incidences, base flow,
923 annual mean discharge, variability of climate, flow routing time and flow value while
924 population density, climatic conditions, geographical distribution, glacier melt ice,
925 flooding, insecurity of main storage zone of the basin, land forms, maintenance and
926 industrial activities pose a challenge on water distribution towards sustainable water
927 management. Naturally, alternation of wet and dry climate zones couple with cumulative
928 increase in population density and socio-economic activity can pose new requirements on
929 water management strategy. Therefore an effective planning management and water
930 resources development requires an adequate knowledge of climate variability and land
931 use forms on hydrological processes. Intense investigation on hydrochemistry as affected
932 by pollution due to human activity is worthy. Future planning should incorporate
933 absorbing new technology and Deeping understanding of water governance and
934 management system however constant state-control monitoring could improve the water
935 quality in the Huai basin and beyond.

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