Impact analysis of Climate Change on Water Resources: A case study of Iran and Vietnam

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Abstract— **Climate change refers to a period piece, ten years or longer in climate average state and deviation in which both occur significant change together in the sense of the statistics (Yang, 2011). Water plays a vital role in maintaining the balance in climate. Water covers nearly three-quarters of Earth. It is continuously moving above, on and below Earth's surface, cycling among ice, liquid water and vapor. This cycling of water shapes the climate by delivering rain and snow, and it supports life on Earth. Water and climate are deeply interconnected, and as the climate changes so does the distribution and cycling of Earth's water. As more greenhouse gases are emitted into the atmosphere, heat that would normally be radiated into space is trapped within the Earth's atmosphere, causing the Earth's temperature to increase. This research will cover various aspects of climate change such as: definition, impacts, vulnerabilities and adaptation with cases of developing countries like Iran & Vietnam.**

Index Terms— **Climate Change, Water Resources, Bio-diversity, Ecosystem, Temperature**

CLIMATE CHANGE

Climate change have wide-ranging effects on the environment, and on socio-economic and related sectors, including water resources, agriculture and food security, human health, terrestrial ecosystems and biodiversity and coastal zones. Changes in rainfall pattern are likely to lead to severe water shortages and/or flooding. Melting of glaciers can cause flooding and soil erosion. Rising temperatures will cause shifts in crop growing seasons which affects food security and changes in the distribution of disease vectors putting more people at risk from diseases such as malaria and dengue fever. Temperature increases will potentially severely increase rates of extinction for many habitats and species (up to 30 per cent with a 2° C rise in temperature). Particularly affected will be coral reefs, boreal forests, and Mediterranean & mountain habitats. Increasing sea levels mean greater risk of storm surge, inundation and wave damage to coastlines, particularly in Small Island States and countries with low lying deltas. A rise in extreme events will have effects on health and lives as well as associated environmental and economic impacts.

"During the Earth's history, the climate has changed many times and has included ice ages and periods of warmth. Before the Industrial Revolution, natural factors such as volcanic eruptions, changes in the Earth's orbit, and the amount of energy released from the sun were the primary factors affecting the Earth's climate. However, beginning late in the 18th century, human activities associated with the Industrial Revolution and burning fossil fuels began changing the composition of the atmosphere." (O'Keefe, Thomas C; Elliot, Scott R; Naiman, Robert J;, 1998)

What Is Causing Climate Change?

The global carbon cycle involves billions of tons of carbon in the form of CO2 (Fig.). Carbon dioxide is absorbed by oceans and living biomass and is emitted to the atmosphere annually through natural processes. When in equilibrium, carbon movement among these various reservoirs is roughly balanced. The concentration of CO2in the atmosphere has increased from a preindustrial value of about 280 parts per million (ppm) to 379 ppm in 2005 (IPCC, 2007d).

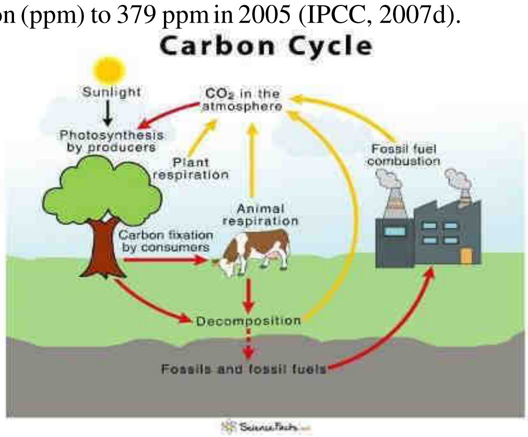

Figure 1 Carbon Cycle

Most scenarios of future emissions of CO2 involve increases of CO2. In 2004, 26.9 billion metric tons of CO2 were emitted, and 33.9 billion metric tons are projected to be emitted in 2015. By 2030, 42.9 metric tons of CO2 are projected to be emitted.

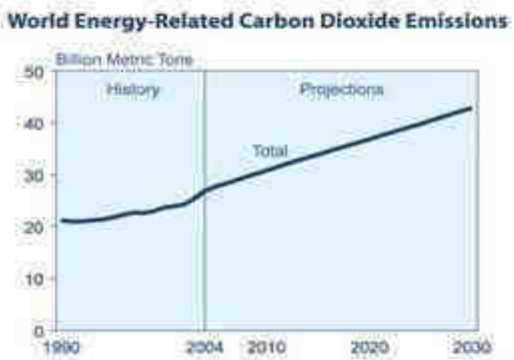

Figure 2 Carbon Emission Data

Impacts of Climate change on Water resources

The water resources and the hydrologic cycle is a very important link of climate change. The effect of climate change on water resources is because of the water and water quality changes that caused by climate factors (mainly includes rainfall and temperature changes).And it is achieved by the changes of the various water cycle links. Climate change will change the world of the present situation of the hydrologic cycle, and cause the redistribution of water resources in time and space. It also will have a direct effect on the evaporation, runoff and the soil humidity and so on. The redistribution and changes of water resources in space will cause the human society and ecology change a lot. At the same time, the water resources system changes will affect the local climate, and will exacerbate climate change in a certain extent. (Yang, 2011)

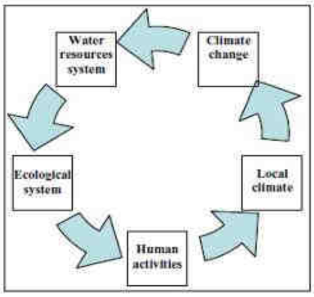

Figure 3 Cycle diagram of climate change affects

Several hydrological variables and characteristics of the water resources systems may be affected by global climate change.

Figure 4 Climate Change Impact on Hydrology

The Effect on Water Resources

An increase in the air temperature will cause water temperatures to increase as well. As water temperatures increase, water pollution problems will increase, and many aquatic habitats will be negatively affected (Figure).

Figure 5 Effects of increased temperature on water resources

For example, increases in water temperatures are expected to result in the following:

1) Lower levels of dissolved oxygen due to the inverse relationship that exists between dissolved oxygen and temperature. As the temperature of the water increases, dissolved oxygen levels decrease.

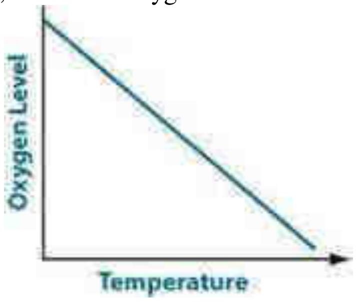

Figure 6 Relationship between Increase in temperature and dissolved oxygen

2) Increases in pathogens, nutrients and invasive species.
3) Increases in concentrations of some pollutants such as ammonia and Pentachlorophenol due to their chemical response to warmer temperatures.
4) Increase in algal blooms.

Figure 7 Formation of Algi in water resources

5) Loss of aquatic species whose survival and breeding are temperature dependent.
6) Change in the abundance and spatial distribution of coastal and marine species and decline in populations of some species.
7) Increased rates of evapotranspiration from water bodies, resulting in shrinking of some water bodies such as the Great Lakes.

A brief reference to these variables and characteristics

Temperature

Impacts of global climate change on temperature are perhaps the most obvious ones and are particularly important because temperature is a driver of many other hydrological variables.

Precipitation

Together with temperature, precipitation is the second hydrological variable considered in the global climate models to express the impact of global climate changes.

Evapotranspiration

An increase of temperature normally leads to an increase of potential evapotranspiration, although actual evapotranspiration is conditioned by the amount of water available in the soil and plants. Transpiration of water by plants is affected by a number of variables, including stomata behaviour and concentration of CO2 in the atmosphere.

Soil Moisture
Temperature, precipitation and evapotranspiration directly affect soil moisture. But the strongest influence is normally due to precipitation. Soil moisture changes influence strongly crop growth and water needs for irrigation.

Run off
Runoff is clearly affected by the above mentioned hydrological variables and, in particular, by precipitation. However future runoff is also conditioned by several other climatic factors and human influences, such as stream flow diversions and regulation or interaction between surface and groundwater, which makes difficult to predict future runoff.

Groundwater
Changes in the magnitude and seasonal distribution of precipitation will cause changes in the patterns of seasonal aquifer recharge with consequences for the groundwater stocks and flows and for the quality of groundwater. The interaction between surface water and groundwater is also expected to be modified.

Floods and Droughts
In parallel with the impact of climate change on the average values of hydrological variables, the impact on extreme phenomena, such as floods and droughts, is also relevant. Several studies indicate a tendency for an intensification of climate variability in situations of climate change and offer, for some regions, apparently paradoxical scenarios of increase in both floods and droughts.

Figure 8 Condition of Drought

Water Quality
Climate change may affect the quality of water bodies as a consequence of changes in runoff, changes in the pattern of transport of agricultural, industrial or domestic pollutants or modification of the assimilation capacity of pollution by the water bodies related to changes in water temperature.

Aquatic-Ecosystems
Climate change may affect aquatic ecosystems in many different ways as the health of ecosystems depends of many climate-sensitive factors, including temperature, water quantity and quality, and timing of water availability. These impacts may be particularly serious in lakes and reservoirs, where important changes in the dynamics of these water bodies may lead to alterations of nutrient exchanges or to invasions of exotic species

Water Demand
The changes in temperature associated to global climate change will not only have an impact on water availability but, also, on water demand. This impact will tend to be particularly relevant in the case of water use for agriculture, as a result from changes of evapotranspiration and soil moisture, but may also be significant in the cases of industrial and domestic uses.

Sea Level Rise
The temperature increase associated to global climate change will cause a rise of the sea level as a consequence of thermal expansion of the ocean waters and melting of glaciers and polar ice. This will have negative impacts on water resources, causing saline intrusion in coastal aquifers and affecting coastal and estuarine ecosystems. (Cunha, Proenca, Nascimento, & Ribeiro, 2007)

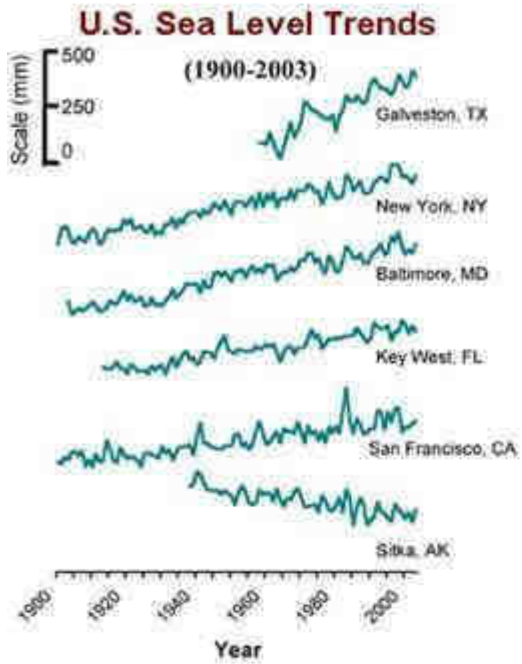

Figure 9 Sea Level changes

Case Study Iran
Iran is located between 25 ° and 40° north latitude and 44° –63° east longitude and has a total area of 1,648,000 km2 (Figure 1). The altitude varies from -40 m to 5670 m, which has a pronounced influence on the diversity of the climate. Iran as a whole is a semiarid country. The per capita freshwater availability for the country was estimated to be around 2000m3 per capita yr-¹ in the year 2000 by Yang et al., who also predicted that it may go below 1500 m3 per capita yr-1 by 2030 due to the population growth.

However, Iran has a broad spectrum of climatic conditions across regions with significant rainfall variability (averages of 2000 mm yr-1 in the northern and western provinces, and 120 mm yr- 1 in the central and eastern parts of the country) and temperature variability (extremes of -20ºC in the southwest to 50ºC along the Persian Gulf).

Climate change is expected to have different impacts on rainfall and temperature patterns across regions and consequently on the spatial and temporal distributions of the various components of water resources.

The Hydrologic Simulator (SWAT)

Spatial parameterization of the SWAT model is performed by dividing a watershed into sub basins based on topography, soil, land use, and slope. The resulting units, referred to as hydrologic response units (HRUs), are used as the basis of the water balance calculation. Water, sediment, and nutrient transformations and losses are determined for each HRU, aggregated at the sub basin level, and then routed to the associated reach and catchment outlet through the channel network. SWAT represents the local water balance through four storage volumes: snow, soil profile (0–2 m), shallow aquifer (2–20 m), and deep aquifer (>20 m). The soil water balance equation is the basis of hydrological modelling. The simulated processes include surface runoff, infiltration, evaporation, plant water uptake, lateral flow, and percolation to shallow and deep aquifers. Surface runoff is estimated by a modified Soil Conservation Service curve number equation using the daily precipitation data based on soil hydrologic group, land use and land cover characteristics, and antecedent soil moisture.

The main effects of climate change related to water resources are rising temperatures, shifts in precipitation patterns, snow cover, and increasing the likelihood of floods and droughts. Climate change may significantly change the seasonal variation in river-flow changes. Higher temperatures will push the snow line upwards in mountainous regions which reduces precipitation and causes a higher winter runoff. Moreover, earlier spring melts will lead to a shift in peak flow levels. As a result of the declining snow cover and decreasing glaciers, there will be less water to compensate for the low flow rates in summer. Listed below are the summary of the results:

Climate Data

Annual rainfall of the country would follow the trend of minimum rainfall obtained from simulated outputs which is 43.36% of the long-term historical time series (dry period which may last from 5 to 8 years). Furthermore there is a shift of 1 month in the distribution of rainfall for long rainy seasons and analysis of data indicates snow melting process at least 1 month earlier.

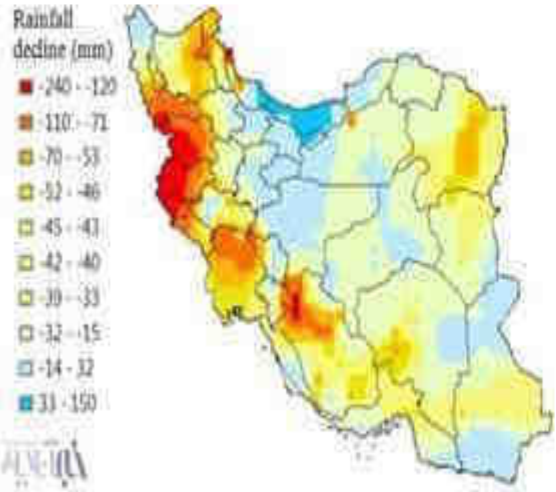

Figure 10 Average rainfall variation (mm) from 1977 to 2012

There has been an increment of temperature by 1.1 °C from 1977 to 2012. Furthermore, it has been found that temperature may increase by 2–3 °C in most parts of the Alborz region by 2050.

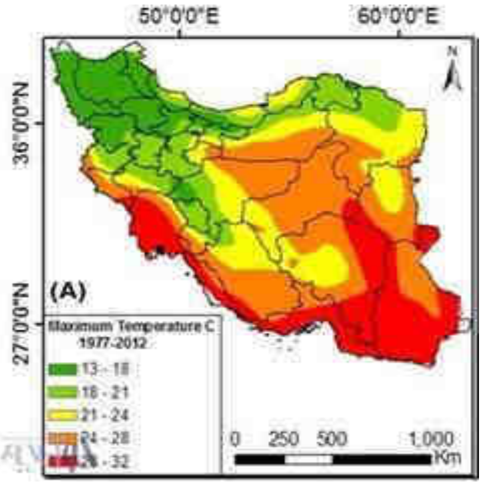

Figure 11 Average maximum temperature from 1977–2012

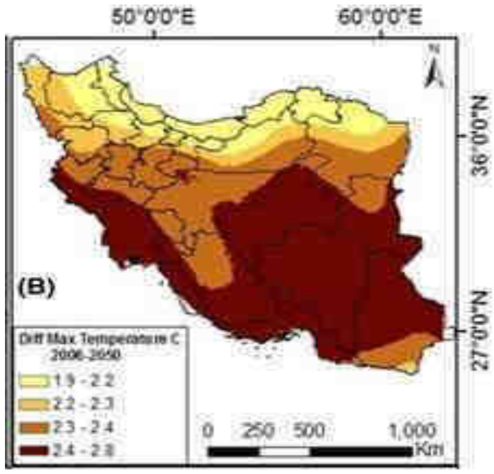

Figure 12 Prediction of Max. Temperature 2006-2050

It has been found that temperature may increase by 2–3 °C in most parts of the Alborz region by 2050. If there is an increment of temperature by 2 °C and the total precipitation throughout the country (413 bcm) kept constant, the potential evaporation will increase by 6.7%, which comes to be 26.00 bcm and equivalent to capacity of existing reservoirs.

Climate Analysis

Analysis of data indicates that theannual runoff has undergone significant changes with more runoff in winter and less in spring by shifting parts of the spring-melt runoff to an earlier peak in winter which may be due to climate change phenomena.

Caspian Sea level has been dropped nearly by 1.5 meters. The current Caspian Sea level is only about 1 m above the historic low level (− 28.50 m) reached in the late 1970s

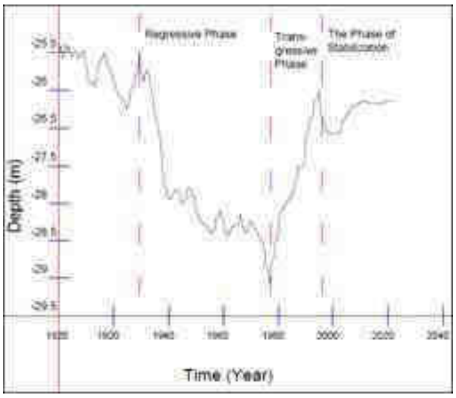

Figure 13 Caspian Sea level Change

Vietnam

Vietnam has experienced climate change, such as rising air temperatures and variableprecipitation. From 1958 to 2007, the average annual temperature increased by 0.5–0.7WC. Annual precipitation decreased in Northern Vietnam but increased in Southern Vietnam, and for the entire country, rainfall has decreased on average by 2% over the past 50 years (1958– 2007). These changes have significantly affected the availability of water resources in Vietnam. The Srepok river basin, a sub-basin in the Lower Mekong was selected as the study area. Within Vietnam, its basin area is 18,000 km2 and is distributed among four provinces: Gia Lai, DakLak, DakNong and Lam Dong (Figure).

Figure 14 Location of the Srepok watershed

Climate Data

The watershed has two seasons: dry and rainy. The annual rainfall of the basin is 2,112 mm, and average daily maximum and minimum temperatures are 28.7WC and 19.8WC respectively. In the Srepok watershed, the forest covers about 9,720 km2 of the watershed area and agricultural land about 5,060 km2. Currently, there are many critical issues for water resource management in the basin. So far, few studies have quantified the potential impacts of climate change on hydrology in the Srepok watershed. However, comprehending climate change impacts on hydrological conditions is essential to enable more efficient water resources development and to make suitable adaptation plans in this region. The overall objective of such studies is to investigate changes in streamflow and hydrological processes resulting from climatic variation in the Srepok watershed, which is located in the DakLak and DakNong provinces, Vietnam. (Huyen, Le, Minh, & Liem, 2017)

The specific objectives are:

1) To set up, calibrate and validate the SWAT model in terms of streamflow;
2) To simulate responses of streamflow and hydrological components under climate change scenarios.

Climate change trend in Srepok watershed

The simulated climate change data show that not only does the maximum daily average temperature increase but also the minimum daily average temperature increases in the period from 2011 to 2069 in both scenarios A1B and A2 compared to base scenario

Scenario A1B (medium emissions scenario) has the maximum daily average temperature as 29.0WC which increases by 0.3WC from 2011 to 2039. The minimum daily average temperature, which is 20.6WC, increases by 0.8WC. In the period between 2040 and 2069, the maximum and minimum daily average temperatures are nearly 30.3WC and 21.9WC, increases of 1.6WC and 2WC respectively. For scenario A2 (high emission scenario), it is not difficult to realize the increase of the daily average temperature in the two periods. From 2011 to 2039, the maximum and minimum daily average temperatures increase by 2.8WC and 2.3WC respectively. (Huyen, Le, Minh, & Liem, 2017)

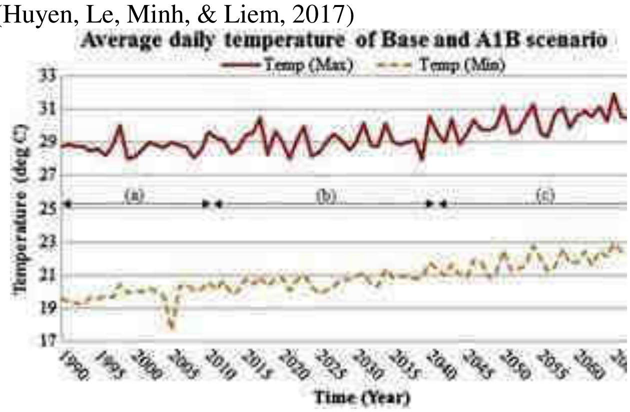

Figure 15 Change of daily temperature in (a) period 1990– 2010 of base scenario; (b) period 2011–2039 and (c) period 2040–2069 of A1B scenario.

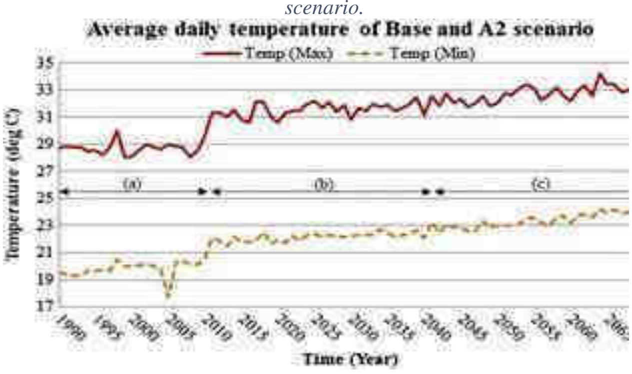

Figure 16 Change of daily temperature in (a) period 1990– 2010 of base scenario; (b) period 2011–2039 and (c) period 2040–2069 of A2 scenario

CONCLUSION

Climate change is expected to make worse current pressures on water resources resulting from including urbanization, population growth, economic factors and land use changes.

On a regional scale, mountain snow packs, glaciers and small ice caps play a crucial role in freshwater availability. Mass losses from glaciers and reduction in snow cover, reported in recent times, which is further projected to accelerate throughout the 21st century, impacting the reduction of availability of fresh water, hydropower potential, and changing seasonality of flows in regions supplied by melt water from major mountain ranges, where more than one-sixth of the world population currently lives.

Runoff is projected with high confidence to increase by 10 to 40% by mid-century at higher latitudes and in some wet tropical areas, including populous areas in East and South-East Asia due to increase in rainfall and lower rates of evapotranspiration. Also, it is projected to decrease by 10 to 30% over some dry regions at mid-latitudes and dry tropics, due to decrease in rainfall and higher rates of evapotranspiration.

There is also high confidence in the projection that many semi- arid areas will suffer a reduction in water resources due to climate change. Drought-affected areas are projected to increase in extent, with the potential for adverse impacts on multiple sectors, including agriculture, water supply, energy production and health. Regionally, large increase in irrigation water demand is projected as a result of climate change.

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