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Climate Change and Water Resources Management in Iran

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ABSTRACT

Climate change is projected to result, on average, in earlier snowmelt and reduced summer flows, patterns that are not well represented in the historical observations used for planning and reliability analyses by water utilities. We extend ongoing efforts in the Iran basins, to characterize differences between historic and future stream flow and the ability of the region's water supply systems to meet future demands. We use future stream flow simulations for the 2030s, 2050s, and 2070s from the climate simulations archived by Report of the Intergovernmental Panel on Climate Change (IPCC). We use ensembles of stream flow predictions produced by GCM forced with multiple downscaled ensembles from the IPCC climate models as inputs to reservoir system models for the Iran water supply systems. How these shifts impact water management depends on the specifics of the reservoir system and their operating objectives, site-specific variations in the influence that reductions in snowmelt have on reservoir inflows, and the adaptive capacity of each system. Without adaptations, average seasonal drawdown of reservoir storage is projected to increase in all of the systems throughout the 21st century.

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INTRODUCTION

Water scarcity is expected to become an ever-increasing problem in the future, for various reasons. First, the distribution of precipitation in space and time is very uneven, leading to tremendous temporal variability in water resources worldwide [9]. For example, the Atacama Desert in Chile, the driest place on earth, receives imperceptible annual quantities of rainfall each year. On the other hand, Mawsynram, Assam, India receives over 450 inches annually. If all the freshwater on the planet were divided equally among the global population, there would be 5,000 to 6,000 m3 of water available for everyone, every year [10]. Second, the rate of evaporation varies a great deal, depending on temperature and relative humidity, which impacts the amount of water available to replenish groundwater supplies. The combination of shorter duration but more intense rainfall (meaning more runoff and less infiltration) combined with increased evapotranspiration (the sum of evaporation and plant transpiration from the earth's land surface to atmosphere) and increased irrigation is expected to lead to groundwater depletion [7]. Thus, a region that experiences higher annual precipitation and more runoff increases the likelihood for flooding.Furthermore, in areas that are already vulnerable due to their limited groundwater storage availability, this cycle intensifies with increased warming and diminishing water supplies. In water stressed regions, variability of precipitation patterns is likely to further reduce groundwater recharge ability. Water availability is likely to be further exacerbated by poor management, elevated water tables, overuse from increasing populations, and an increase in water demand primarily from increased agricultural production. A recent global analysis of variations in the Palmer Drought Severity Index (PDSI) indicated that the area of land characterized as very dry has more than doubled since the 1970s, while the area of land characterized as very wet has slightly declined during the same time period. In certain susceptible regions, increased temperatures have already resulted in diminished water availability. Precipitations in both western Africa and southern Asia have decreased by 7.5% between 1900 and 2005 [2]. Most of the major deserts in the world including the Namib, Kalahari, Australian, Thar, Arabian, Patagonian and North Saharan are likely to experience decreased amounts of precipitation and runoff with increased warming. In addition, both semiarid and arid areas are expected to experience a decrease and seasonal shift in flow patterns. If increased

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temperatures cause an intensification of the water cycle there will be more extreme variations in weather events, as droughts will become prolonged and floods will increase in force [6]. Water supplies can also be affected by warmer winter temperatures that cause a decrease in the volume of snowpack. The result is diminished water resources during the summer months. This water supply is particularly important at the midlatitudes and in mountainous regions that depend upon glacial runoff to replenish river systems and groundwater supplies. Consequently, these areas will become increasingly susceptible to water shortages with time, because increased temperatures will initially result in a rapid rise in glacial meltwater during the summer months, followed by a decrease in melt as the size of glaciers continue to shrink. This reduction in glacial runoff water is projected to affect approximately one-sixth of the world's population. A reduction of glacial runoff has already been observed in the Andes, whereby the usual trend of glacial replenishment during winter months has been insufficient. This is due to increased temperatures, which have caused the glaciers to retreat. It is likely that Andean communities such as El Alto in Bolivia have already observed a reduction in glacial runoff due to the scattered distribution of smaller sized glaciers, which further reduces the potential for runoff. In these areas, approximately one-third of the drinking water is dependent upon these supplies, and the recurrent trend of increased melt with diminished replenishment provides a dismal projection for water reserves if this same pattern continues [5]. Freshwater bodies have a limited capacity to process the pollution stemming from expanding urban, industrial and agricultural uses. Water quality degradation can be a major source of water scarcity.Although the IPCC projects that an increase in average temperatures of several degrees as a result of climate change will lead to an increase in average global precipitation over the course of the 21st century, this amount does not necessarily relate to an increase in the amount of potable water available. A decline in water quality can result from the increase in runoff and precipitation- and while the water will carry higher levels of nutrients, it will also contain more pathogens and pollutants. These contaminants were originally stored in the groundwater reserves but the increase in precipitation will flush them out in the discharged water. Similarly, when drought conditions persist and groundwater reserves are depleted, the residual water that remains is often of inferior quality. This is a result of the leakage of saline or contaminated water from the land surface, the confining layers, or the adjacent water bodies that have highly concentrated quantities of contaminants. This occurs because decreased precipitation and runoff results in a concentration of pollution in the water, which leads to an increased load of microbes in waterways and drinking-water reservoirs.One of the most significant sources of water degradation results from an increase in water temperature. The increase in water temperatures can lead to a bloom in microbial populations, which can have a negative impact on human health. Additionally, the rise in water temperature can adversely affect different inhabitants of the ecosystem due to a species' sensitivity to temperature. The health of a body of water, such as a river, is dependent upon its ability to effectively self-purify through biodegradation, which is hindered when there is a reduced amount of dissolved oxygen. This occurs when water warms and its ability to hold oxygen decreases. Consequently, when precipitation events do occur, the contaminants are flushed into waterways and drinking reservoirs, leading to significant health implications. For coastal populations, water quality is likely to be affected by increased quantities of salt in water supplies. This will result from a rise in sea levels, which will increase salt concentrations in groundwater and estuaries.

MATERIALS AND METHODS

Iran is located between 25°and 40°north latitude and 44° and 63°east longitude and has a total area of 1,648,000 km2. The altitude varies from40 m to 5670 m, which has a pronounced influence on the diversity of the climate. Iran as a whole is a semi arid country. However, Iran has a broad spectrum of climatic conditions across regions with significant rainfall variability (averages of 2000 mm/year in the northern provinces, and 100 mm/year in the central and eastern parts of the country) and temperature variability. 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. We extend ongoing efforts in the Iran basins, to characterize differences between historic and future stream flow and the ability of the region's water supply systems to meet future demands. We use future stream flow simulations for the 2030s, 2050s, and 2070s from the climate simulations archived by Report of the Intergovernmental Panel on Climate Change (IPCC). We use ensembles of stream flow predictions produced by GCM forced with multiple downscaled ensembles from the IPCC climate models as inputs to reservoir system models for the Iran water supply systems. How these shifts impact water management depends on the specifics of the reservoir system and their operating objectives, site-specific variations in the influence that reductions in snowmelt have on reservoir inflows, and the adaptive capacity of each system. Without adaptations, average seasonal drawdown of reservoir storage is projected to increase in all of the systems throughout the 21st century. Developmental objective is to prepare water managers and users for changing climatic conditions (especially reduced flows) through provision of technical data, planning, and improved allocation, capacity building and awareness-raising. The overall goal is to mainstream climate change into Integrated Water Resources Management in the Iran Basins, so that it may support the equitable provision of freshwater for the environment and for livelihoods for current and future generations. Iran Basins must begin to incorporate climate change preparation at all levels into its planning and management. Technical information on the social and economic effects of rivers flow scenarios under changing climatic conditions must be collected and used to inform the water allocation process. Institutional linkages must be established between water-dependent sectors and also with the National Climate Change Committee.

RESULTS AND DISCUSSION

The Objective of the proposed project intervention is to: Prepare water managers and users for changing climatic conditions (especially reduced flows) through provision of technical data, planning, and improved allocation, capacity building and awareness-raising. Within this overall purpose, project outcomes and activities will focus on three technical areas:

- Understanding current and future climatic vulnerability (in the broadest sense of the term): and developing and using such information for more equitable water allocation in a changing hydrological regime;
- Negotiated outcomes to minimize future climatic vulnerability and future climatic risk: Continuing dialogues to ensure sustainable water resources management;
- Incorporating climate change adaptation in the water sector: national linkages and lessons learned. Lessons learned will come from experiences of all three outcomes.

The approach advocated in this paper to plan for the climate impacts on local water resources for Bredasdorp includes establishing the following four key components: Future water use and demand, Future projected climate change, Future climate impacts on water resources and Future water resource management strategies.

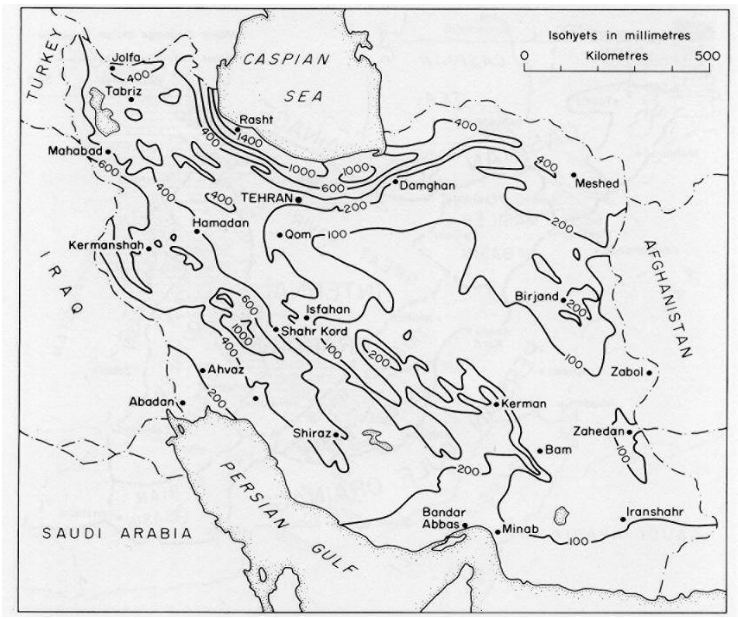

Fig. 1: Precipitation Distribution and isohyets lines (IRAN).

Rainfall in Iran is highly seasonal, with a rainy season between October and March, leaving the land parched for the remainder of the year. Immense seasonal variations in flow characterize Iran's rivers. For example, the Karun River in Khuzestan carries water during periods of maximum flow that is ten times the amount borne in dry periods. In numerous localities, there may be no precipitation until sudden storms, accompanied by heavy rains, dump almost the entire year's rainfall in a few days. Water shortages are compounded by the unequal distribution of water. Near the Caspian Sea, rainfall averages about 1,280 mm per year, but in the Central Plateau and in the lowlands to the south it seldom exceeds 100 mm.

Table 1: Annual Water Resources in Bilion Cubic Meters (IRAN).

Sector	Bilion Cubic Meters
Avarage Annual Precipitation	400 BCM
Renewable Water Resources	140 BCM
Avarage Annual Evapotranspiration	270 BCM
Surface Current 92 BCM	
Seepage to Alluvial Aquifers	38 BCM

Return Water From Consumption 29 BCM

Table 2: Water Distribution Prediction in Diverse Sectors (IRAN).

Years / Sector	2030s	2050s	2070s
Municipal	7%	9%	10%
Industrial	6%	8%	9%
Agricultural	87%	83%	81%

Table 3: Predict of Temperature and Precipitation by GCM model (IRAN).

Years / Sector	2030s	2050s	2070s
Temperature	+0.8 (C)	+1.4 (C)	+1.9 (C)
Precipitation	-3%	-5%	-7%

Iran is a dry country, and only 10 percent of the country receives enough rainfall to meet its needs. The remainder of the country is heavily reliant on groundwater, with around 50 percent of Iran's water being supplied by aquifers. Population growth, combined with economic development and a boom in industry and farming, has caused a huge increase in demand for water in Iran. But the slow-filling aquifers have not been able to keep up. Most of the aquifers have recharge times of thousands of years. Between 1970 and 2000 the water table in the region sunk by 50 feet (15 meters), and satellite radar observations reveal land subsidence rates of up to 20 inches (50 centimeters) a year in some places.

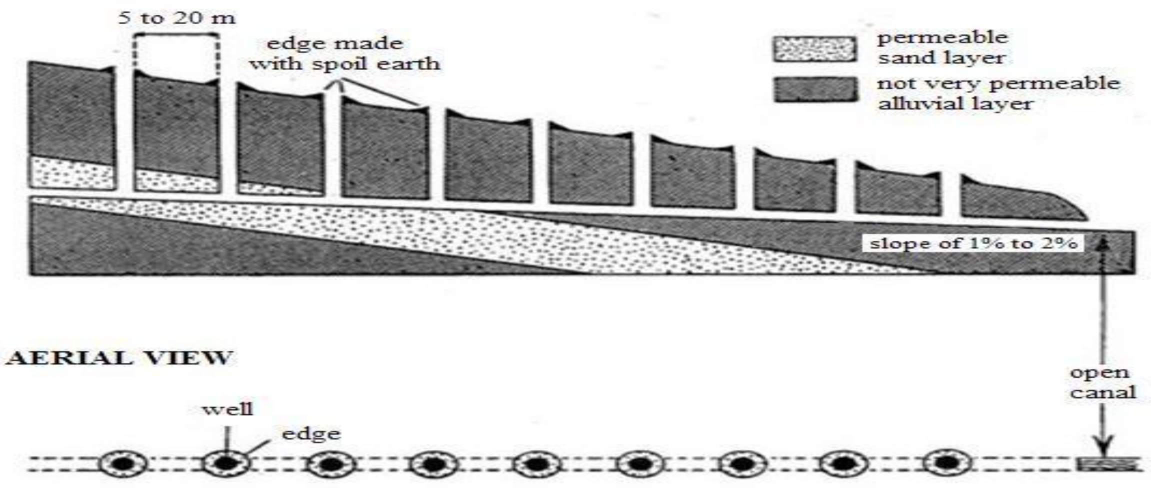

Fig. 2: Qanat’s System Profile and Aerial View.

Iran’s interest is exploiting groundwater goes back more than 2,500 years when the "Qanat " system was developed which is still widely used today. It comprises a system of tunnels excavated into the hillside and as it intercepts the groundwater table, water flows out under gravity. The value of the qanat is directly related to the quality, volume, and regularity of the water flow. Much of the population of Iran and other arid countries in middle east historically depended upon the water from qanats; the areas of population corresponded closely to the areas where qanats are possible. Although a qanat was expensive to construct, its long-term value to the community, and thereby to the group that invested in building and maintaining it, was substantial.

Key changes to the hydrological cycle (associated with an increased concentration of greenhouse gases in the atmosphere and the resulting changes in climate) include:

- Changes in the seasonal distribution and amount of precipitation.
- Changes in the balance between snow and rain.
- Increased evaporation and transpiration and a reduction in soil moisture.
- Changes in vegetation cover resulting from changes in temperature and precipitation.
- Consequent changes in management of land resources.
- Accelerated melting glacial ice.
- Increased coastal inundation and wetland loss from sea level rise.
- Effects of CO2 on plant physiology, leading to reduced transpiration and increased water use efficiency

While some areas will likely experience a decrease in precipitation, others (such as the tropics and high latitudes) are expected to see increasing amounts of precipitation. More precipitation will increase a region's susceptibility to a variety of factors, including:

- Flooding
- Rate of soil erosion
- Mass movement of land
- Soil moisture availability

In addition, warming accelerates the rate of surface drying, leaving less water moving in near-surface layers of soil. Less soil moisture leads to reduced downward movement of water and so less replenishment of groundwater supplies. In locations where both precipitation and soil moisture decrease, land surface drying is magnified, and areas are left increasingly susceptible to reduced water supplies.

Untreated industrial wastewater and domestic sewage generated in many Iranian cities, are polluting rivers, streams and groundwater. Particularly, the contamination of groundwater from the inadequate handling of domestic sewage is quite common in smaller cities and towns. Industrial waste treatment has become an urgent issue in Iran as many new and unlicensed industries have started operating. Untreated industrial wastes carrying grease, oil, explosives, highly odorous substances, are being disposed on land, which pollutes groundwater and surface water. Iranian industries, such as chemicals, pharmaceuticals, soap, sugar and distilleries, textiles, still mills, fertilisers, are contributing to this pollution. Several additional sources of pollution are contaminating water supplies. Cracked pipes and leaky joints in underground distribution systems allow contaminants in surrounding substances to enter the water supply system. The discharge of oily wastes from ships and tankers using oil as fuel often, but not always, leads to beach pollution. In addition, water travelling through lands contaminated by chemicals, non-chemicals, bacterias, silt, etc. or passing through peaty lands possessing brown colour, spreads the contamination to new regions. Recycling and reclamation, two new concepts in Iran, should be strongly promoted to increase available water supplies, and break the population-water paradox. Dams must be constructed to increase water storage capacity and prevent water shortages. Irrigation systems, water management and water distribution networks should be improved, and effective pricing must be implemented to control water consumption.

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