Study on the water availability in Iran, using the international water indicators

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Abstract
The climate of Iran is one of great extremes due to its geographic location and varied topography. The summer is extremely hot with temperatures in the interior rising possibly higher than anywhere else in the world; certainly over 55°C has been recorded. Annual rainfall ranges from less than 50 mm in the deserts to more than 1600 mm on the Caspian Plain. The average annual rainfall is 251 mm and approximately 90% of the country is arid or semiarid. Overall, about two-thirds of the country receives less than 250 mm of rainfall per year.
In the last century (since, 1900) the population of Iran has increased about six-fold. The population growth rate, which was less than 0.6 percent in the beginning of this period, reached the rate of 3.19 percent in the decade from 1976 – 1986. Fortunately; it has considerably decreased once again in the last decade. The major changes in population growth rate, resulting from reduction of mortality and increase of natural growth rate, occurred in the 1960s and afterward. In the period from 1961-2000, the urban population increased by about 31.7 million and the rural population increased by 11 million. In 1956, there were only three cities with a population over 250,000 in Iran, while in 2000 the number of cities with a population of over one million reached seven.
The direct impact of population growth on the water resources management of the country was an increased need for potable water in population centers. Indirect impacts were increased demand for agricultural products, development of irrigated lands, and the need for job opportunities and more income, especially in the agricultural sector.
This paper reviews and assesses water resources situation and water scarcity indicators in Iran based on the international indicators. The most widely used indicator, the Falkenmark indicator, is popular because it is easy to apply and understand but it does not help to explain the true nature of water scarcity. The International Water Management Institute model (IWMI model), The Water Resources Vulnerability Index and the Water Poverty Index (WPI) are the other international indicators that are evaluated for the water resources situation and availability of water in Iran.
Key words: water deficit indicators, Falkenmark, water poverty index, water availability, Iran.

Introduction
Decades ago, water was viewed as a non-limited natural resource because it was renewed every year in the course of the seasons. Man progressively appropriated this resource and used it with few restrictions. Developments in controlling and diverting surface waters, exploring groundwater, and in using the resources for a variety of purposes have been undertaken without sufficient care being given to conserving the natural resource, avoiding wastes and misuse, and preserving the quality of the resource. Thus, nowadays, water is becoming scarce not only in arid and drought prone areas, but also in regions

where rainfall is relatively abundant. Scarcity is now viewed under the perspective of the quantities available for economic and social uses, as well as in relation to water requirements for natural and man-made ecosystems. The concept of scarcity also embraces the quality of water because degraded water resources are unavailable or at best only marginally available for use in human and natural systems.

Water scarcity is among the main problems to be faced by many societies and the World in the XXI century. Water scarcity is commonly defined as a situation where water availability in a country or in a region is below 1000 m^3 per person per year. However, many regions in the World experience much more severe scarcity, living with less than 500 m^3 per person per year, which could be considered severe water scarcity. The threshold of 2000 m^3 per person per year is considered to indicate that a region is water stressed since under these conditions populations face very large problems when a drought occurs or when man-made shortages are created. However, the concept of water availability based on indicators driven from the renewable water resources divided by the total population should be taken with great care. This simple indicator may not be very meaningful in situations where countries make high use of desalination, of non-renewable groundwater resources and of wastewater re-use to compensate for their scarcity of renewable water. This may also be true for countries where irrigation water requirements are not large.

Water scarcity causes enormous problems for the populations and societies. The available water is not sufficient for the production of food and for alleviating hunger and poverty in these regions, where quite often the population growth is larger than the capability for sustainable use of the natural resources. The lack of water does not allow industrial, urban and tourism development to proceed without restrictions on water uses and allocation policies for other user sectors, particularly agriculture.

Poverty associated with water scarcity generates migratory fluxes of populations within countries or to other countries where people hope to have a better life, but where they may not be well received. Last, but not least, water for nature has become a low or very low priority in water stressed zones. Preserving natural ecosystems is often considered a superfluous use of water compared with other uses that directly relate to healthy human life, such as domestic and urban uses, or that may lead to the alleviation of poverty and hunger, such as uses in industry, energy and food production. However, the understanding that natural ecosystems, namely the respective genetic resources, are useful for society is growing, and an effort to protect reserve areas is already developing, even in water scarce regions.

Figure 1 presents the delimitation of arid and semi-arid regions of the world as defined by the Map of the World Distribution of Arid Zones (UNESCO, 1979). This delineation is primarily based on a bio-climatic aridity index, the P/ETP ratio (where P is the mean value of annual precipitation, and ETP is the mean annual potential evapotranspiration). The three zones are the “hyper-arid” zone ($P/ETP < 0.03$), the “arid” zone ($0.03<P/ETP<0.20$) and the “semi-arid” zone ($0.20<P/ETP<0.50$). In addition to these criteria, temperature is taken into account based on the mean temperature of the coldest and the hottest month of the year. Consideration is also given to the rainfall regimes (dry summers, dry winters) and to the position of the rainfall period in relation to seasonal temperatures.

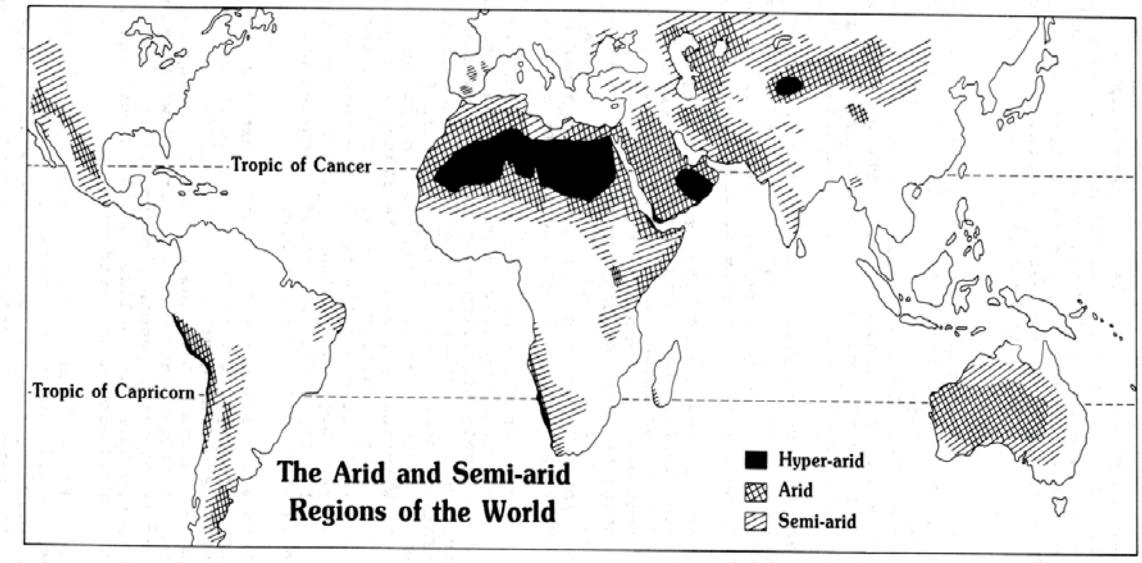

Figure 1 the arid and semi-arid regions of the world (Hufschmidt and Kindler, 1991).

Renewable Water Resources of Iran

The state of water resources in Iran is summarized as follows. The main source of water is precipitation, which normally amounts to 251 mm or 413 billion cubic meters (bcm) annually. This precipitation depth is less than one-third of worldwide average precipitation (831mm) and about one-third of the average
precipitation in Asia (732mm). About 30 percent of the precipitation is in the form of snow, and the rest is rain and other forms of precipitation. While 1 percent of the world population lives in Iran, our share of renewable freshwater is only 0.36 percent. Of the 413 bcm of annual precipitation, 296 bcm are lost as evapotranspiration, 92 bcm runs as surface flows, and 25 bcm infiltrates into groundwater resources. Annually, about 13 bcm of water flows into Iran from neighboring countries. So, total renewable water resources are 130 bcm annually. From these sources, about 88.5 bcm is withdrawn, of which 82.5 bcm (93.2 percent) goes to agriculture, 4.5 bcm (5.1 percent) is for drinking, and 1.5 bcm (1.7 percent) is allocated for industry, mines, and miscellaneous uses. While the world uses 45 percent of its freshwater resources, Iran uses about 66 percent.

Precipitation in Iran does not have spatial and temporal uniformity. Part of the country receives less than 50 mm, while the northern part receives more than 850 mm of rain annually (Figure 1). More than 50 percent of the rain falls in winter, and less than 18 percent falls in summer. From the middle of the spring, river and stream discharges start to decrease, and groundwater is the only water source for summer and fall seasons. Statistics show that in 1996 and 2000 about 59.41 and 61.2 bcm, respectively, were withdrawn from the aquifers. Non-uniform temporal distribution of precipitation causes droughts in the years when most annual rainfall occurs in a short time and runs off quickly.

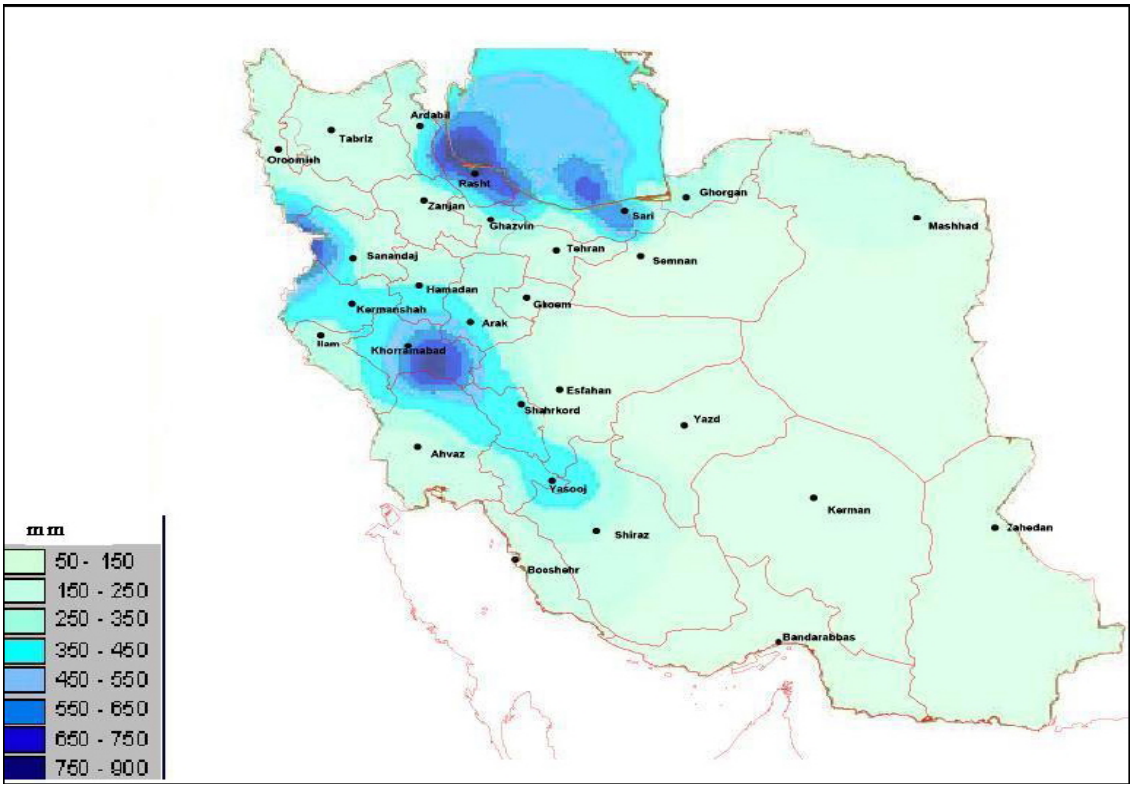

Figure 2 Precipitation Map of Iran (1999)

On the basis of studies performed by United Nations (UN) experts, the per capita water resources of Iran are projected to be about 726-860 m3 in 2025, compared with 2,200 m3 in 1990. Overpopulation in an arid and semiarid country causes diverse problems, including increased demand for scarce water and intensified competition between different sectors (agriculture, human consumption, and industry). Overpopulation in Iran will contribute to the country reaching a state of water crisis before the year 2025. Unplanned and irregular expansion of the main and satellite cities in the past 100 years has increased the population six-fold and contributed to water shortage problems. In the last 40 years, the population of Iran has increased by 45 million people, 30 million of whom have been added in the last 20 years. The water crisis and water scarcity will intensify in the future.

Water balance of many countries is in desperate straits, since aquifers are exploited severely, water is diverted from the agricultural sector to drinking and industrial supplies, and demand for more food and better diets is increasing. So, water is scarce, and as the studies of the International Water Management Institute (IWMI) show, it will get scarcer.

Table 1 shows the volume of precipitation as well as the renewable water resources (precipitation minus evapotranspiration) over the six main basins of Iran. Taking into account the water entering the country from across national borders, the total renewable water amounts to around 130 billion cubic meters (bcm)

(Jamab Consulting Engineers). Water consumption across Iran in 1994 is estimated to have been 87 bcm, and it is projected to increase to about 116 bcm in 2021 (Jamab Consulting Engineers).

Regarding the uneven distribution of both precipitation and population across Iran, the per capita volume of renewable water will vary from place to place.
Figure 3 shows the per capita volume of renewable water over six areas in Iran according to the National Comprehensive Water Studies carried out in 1994. Based on the present population of the country, the annual average per capita volume of renewable water is estimated to be around 2,000 m3, and it is estimated to decrease to below 1,000 m3 by 2025. Thus, it may be predicted that within the next two decades, most parts of Iran will be facing chronic water shortage.

Table 1 average annual precipitation in the 6 major basins in Iran

Basin No.	Basin name	Total area (km^2)	As % of total area	Rainfall (mm/year)	Precipitation volume (mm^3/year)	NPV* (mm^3/year)
1	Caspian Sea	173730	10.5	484	84190	22937
2	Lake Orumie	51866	3.1	430	22300	6730
3	Persian Gulf and Gulf of Oman	419802	25.5	386	153820	57197
4	Central Plateau	851126	51.6	150	127510	26492
5	Lake Hamoun	107369	6.5	125	13480	1546
6	Sarakhs	44170	2.7	268	11860	2130
Sum		1 648 000	100	251	413860	117000
Across Borders						13000
Total						130000

* NPV = Net Precipitation Volume= Precipitation Volume - Evapotranspiration

All these basins, except the Persian Gulf and Gulf of Oman, are interior basins. There are several large rivers, the only navigable one of which is Karun, the others being too steep and irregular. The Karun River, with a total length of 890 km, flows in the south-west of the country to the ArvandRud, which is formed by the Euphrates and the Tigris after their confluence. The few streams that empty into the Central Plateau dissipate into the saline marshes. All streams are seasonable and variable. Spring floods do enormous damage, while there is little water flow in summer when most streams disappear. Water is however stored naturally underground, finding its outlet in subterranean water canals (qanats) and springs. It can also be tapped by wells.

In the period from 1961-2000, the urban population increased by about 31.7 million and the rural population increased by 11 million. In 1956, there were only three cities with a population over 250,000 in Iran, while in 2000 the number of cities with a population of over one million reached seven. The direct impact of population growth on the water resources management of the country was an increased need for potable water in population centers. Indirect impacts were increased demand for agricultural products, development of irrigated lands, and the need for job opportunities and more income, especially in the agricultural sector.

The main source of water resources throughout the country is annual precipitation. According to studies carried out for formulation of the Water Comprehensive Plan, the main characteristics of annual precipitation and its conversion to water resources are as follows:

• Average annual precipitation	417 bcm
• Average annual evaporation & transpiration	299 bcm
• Surface currents	92 bcm
• Direct seepage to alluvial aquifers	25 bcm

According to the above figures:

- About 72 percent of precipitation is not accessible due to evaporation and transpiration,
- About 22 percent of precipitation flows as surface water resources,
- About 6 percent of precipitation within the borders of the country is used for direct recharge of alluvial aquifers.

Consequently, about 117 bcm of water is directly and potentially accessible by people through precipitation (internal renewable resources) each year. In addition to water resources gained through precipitation within the limits of the country, about 13 bcm of surface flow enters the country across its borders. When this flow is combined with the surface flow with internal origins, the total figure of surface water resources of the country increases to about 105 bcm. Of this amount, about 13 percent (13 bcm) is used for recharge of alluvial aquifers. Accordingly, annually about 130 bcm of water is accessible for people through precipitation and inflow currents across borders (total renewable resources). In addition to naturally processed water resources, about 29 bcm of exploited and consumed water from surface and groundwater resources appears again as exploitable surface water or penetrates to alluvial aquifers as reservoirs. Correspondingly, the total water resources of the country, including such water exchange processes, increase to about 159 bcm. Out of this, 82 percent (130 bcm) are renewable sources, and 18 percent (29 bcm) are return waters that are discharged into surface and groundwater resources and are included in the calculation of total water resources. As annual changes in quantity and quality of consumption patterns take place, this section of water resources also changes quantitatively and qualitatively.

Annual per capita water in Iran

Population growth in Iran is high. The highest recorded rate of 3.9 percent occurred in 1986. But a remarkable achievement of Iran in applying family planning programs during the years of 1986-1996 contributed to a lower rate of population growth of 1.45 percent in that decade (Ghazi, 2002). The latest census figures showed the population of Iran to be 60 million in 1996. Today, it is estimated that the population of the country may be more than 65 million. It is also expected that the population may double by 2021 (Plan and Budget Organization, 1999). Rapid population growth in the last two decades has changed the relative composition of the rural and urban populations. While the ratio of rural to urban population was 40/60 before the revolution, it is now reversed. By 2010 some 80 percent of the total population may live in urban areas and especially in big cities like Tehran, Mashhad, and Isfahan. Most of the water resources that sometime ago were used for agriculture are now used to supply drinking water to these cities. Altogether, population growth, urban and industrial growth, and agricultural development in Iran have created a condition of water stress. This situation is beyond a water shortage or crisis and aggregates the serious scientific, technical, ecological, economic, and social issues surrounding water for now and the years to come (Ghazi, 2002).

The increasing water demand has caused an alarming decrease in per capita renewable water available. The annual per capita water as a general index of the water resources status used to be about 7,000 m3 in 1956 when the population was only 19 million. At present, with a population that has grown to about 65 million, the index is estimated to be about 2,000 m3. With the increasing trend in population growth, it is predicted to sink further, to below 1,000 m3 in the year 2025. These figures clearly show that our future generations are to face a serious water shortage during the coming decades. Pollution of water resources due to human activities makes this situation even worse.

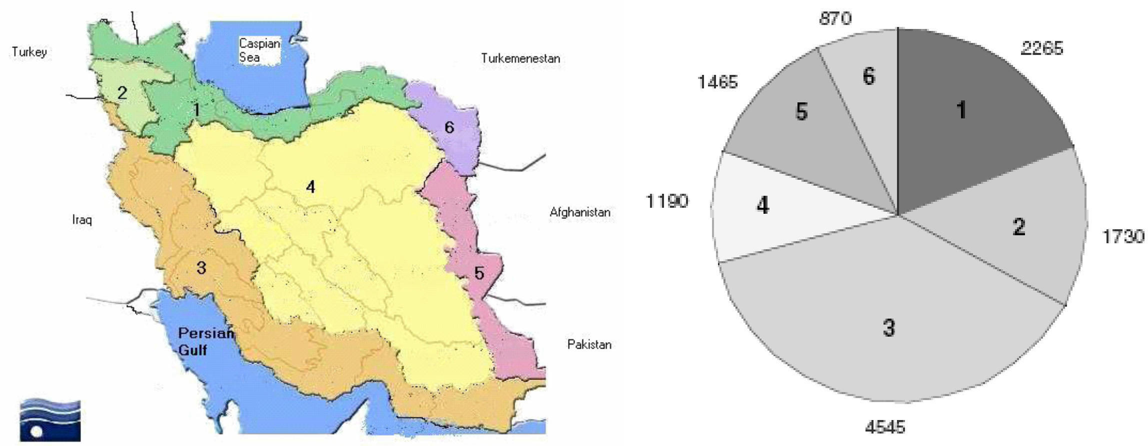

Figure 3 Per capita water resources in six main basins of Iran (m3/year in 1994).

Figure 3 represents the uneven distribution of water in proportion to population distribution across the country. Besides the uneven distribution of population, the distribution of agricultural, industrial, and urban activities makes uneven water distribution even more important. In fact, it can be claimed that it is not only the case that water has a higher value added in certain areas as compared to others, but that the demand for water is also far higher than its supply. There are many other underlying management causes for existing water shortages such as overexploitation of groundwater resources, pollution of surface and ground water resources, low water use efficiencies in agricultural, urban, and industrial sectors, and low water productivity in agriculture as common phenomena in the country.

- One hundred cities out of the 700 cities and towns in the country with a population of more than 20 million are confronted with water shortage; more than 20 million head of livestock have been slaughtered or lost; 3,731 springs, 2,500 Qanats, and thousands of water wells have dried up. About 200,000 tribal people have lost their only revenue.
- The agricultural sector, which makes up 27 percent of gross national product (GNP), has suffered damage causing GNP to decrease by about 6 percent. The value of 6 million tons of agricultural products is about 8,000 BR.
- Other than vast mining of groundwater resources, with overdraft of 6 bcm per year, 40 percent of the forest land has been converted to other uses in the past 40 years, and forest area has decreased from 21.5 million ha to 12.5 million ha.
- Soil erosion has increased from 10 tons/ha/year in the last decade to more than 30 tons/ha/year, and the total soil loss is about 4 billion tons/year.
- Total surface flows and groundwater recharge of Khorasan Province was 7.5 bcm in 2001, which is 43 percent less than a normal year. Precipitation and river discharge have declined about 40 percent and 90 percent, respectively.

STATUS OF GROUNDWATER RESOURCES

Groundwater is one of the most important water resources of Iran. One of the best methods of supplying water is digging Qanats, a practice with a long tradition in Iran. Researchers have considered Qanats to be an innovation developed by Iranians about three thousand years ago. A Qanat initially consists of a well dug in a mountainside to reach the groundwater stored there. An underground tunnel is then dug from this point, directing the water to the village. Along the way to the village, some access wells are also dug at certain intervals, to provide access for later repairs and cleaning of the tunnel. Some of the main wells of the Qanats systems in eastern Iran are more than 400 meters in depth, deep enough to hide the Eiffel tower. Their tunnels are longer than the equator. A great amount of water in Iran is supplied by Qanats whose total length is estimated to be 160,000 kilometers. Unfortunately, most of the Qanats have become dry due to exploitation of groundwater by pumps and wells.

Groundwater balance shows that there is a difference of 4.8 bcm between recharge of groundwater resources (56.5 bcm) and discharges from them (61.3 bcm). The effect of this unbalance is evident in most of the valleys. Land subsidence, salt intrusion, and lowering of the water table are among the most prominent effects. The average drawdown of the water table in 168 valleys of the country, from which 73 percent of all withdrawals occur, is more than 1 meter per year. In some of the eastern provinces, more than half of the groundwater storage has been depleted.

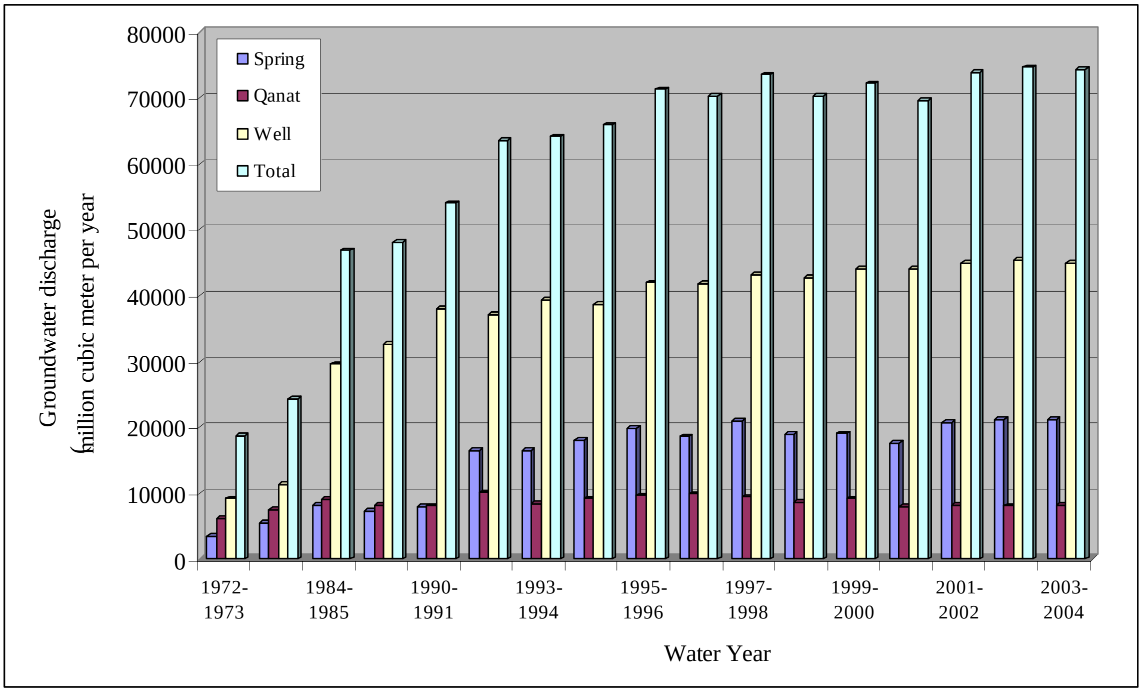

Figure 4 increasing trend of groundwater discharge during years 1972 to 2004 in Iran

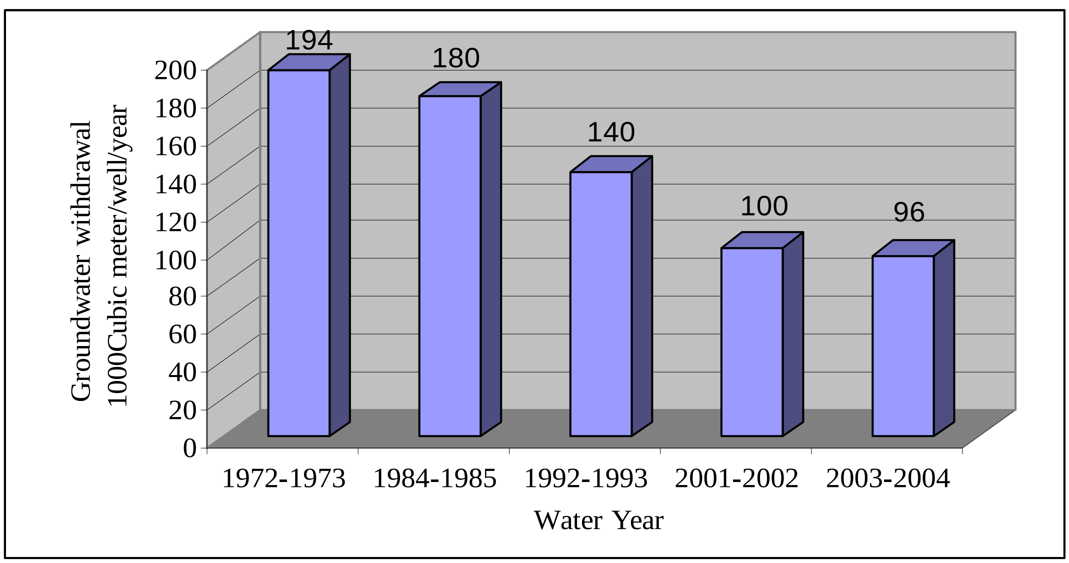

Figure 5 decreasing trend of underground surface water table and consequently the wells output during the years 1972 to 2005 in Iran

In the northeast Iran, Chenaran Plain—a fertile agricultural region to the east of Mashad, one of Iran's largest and fastest-growing cities—is fast losing its water supply. Wells drawing from the water table below the plain are used for irrigation and to supply water to Mashad. The latest official estimate shows the water table falling by 8 meters in 2001 as the demand for water far outstrips the recharge rate of aquifers.

Falling water tables in parts of eastern Iran have caused many wells to go dry. Some villages have been evacuated because there is no longer any accessible water. Iran is one of the first countries to face the prospect of water refugees—people displaced by the depletion of water supplies.

International water stress indicators

Falkenmark Water Stress Index, International water management institute index (IWMI), The Water Resources Vulnerability Index are the main international water crisis indicators. All indices, however well established are not without problems. The consumer price index (CPI), established in the late nineteenth century, is based on the prices of a representative basket of goods. However, this basket of goods changes over time as new products come onto the market and other products disappear. The importance of individual items in the basket may change over time both because of changing consumption habits with rising income, and because of changes in relative prices. These problems are partly overcome by regular changes of base year and changes in the weights given to each item in the basket. However, although an imperfect representation of price changes in the long run, the single number CPI is widely used to deflate nominal Gross Domestic Product (GDP) in order to estimate real output growth over time, the traditional way of judging a country's rate of development.

Using GDP as a measure of levels of development and rates of growth of real GDP as a measure of progress was considered to be an unsatisfactory way to compare levels of development because it said nothing about the quality of that development. Increases in output might not necessarily mean that there were improvements in health or education or that the benefits of increased output were spread throughout the population. The search for more representative indicators led to the development of the Human Development Index (HDI).

The HDI is an average of three separate indicators: life expectancy at birth, educational attainment and GDP per capita at purchasing power parity (PPP) values. The educational attainment index comprises an index of adult literacy and of primary, secondary and tertiary educational enrolment in which adult literacy is given a two-thirds weighting and school enrolment one-third. The life expectancy index is constructed by taking the ratio of the differences between the actual value for the country concerned and a fixed minimum (25 years), and a fixed maximum (85 years) and the fixed minimum. So a country with a life expectancy of 50 years would have an index of (50-25)/(85-25) = 0.417, while one with a life expectancy of 70 years would have an index of 0.75. Measures of educational attainment are straight percentages. The PPP measure of GDP per capita is adjusted by using log values in order to reduce the effect of very high incomes which are not necessary to attain a reasonable standard of living. The individual indices which make up the HDI are also published, so that it is possible to see what is driving any changes which take place.

Falkenmark water stress index

When describing water availability in a country, the Falkenmark Water Stress Indicator, which was developed by the Swedish water expert Falkenmark in 1989, is one of the most commonly used indicators. Originally, the indicator based on the estimation that a flow unit of one million cubic metres of water can support 2,000 people in a society with

a high level of development, using Israel as a reference by calculating the total annual renewable water resources per capita. Water availability of more than 1,700m³/capita/year is defined as the threshold above which water shortage occurs only irregularly or locally. Below this level, water scarcity arises in different levels of severity. Below 1,700m³/capita/year water stress appears regularly, below 1,000m³/capita/year water scarcity is a limitation to economic development and human health and well-being, and below 500m³/capita/year water availability is a main constraint to life.
Despite its global acceptance, this indicator has numerous shortcomings. First of all, only the renewable surface and groundwater flows in a country are considered. Moreover, the water availability per person is calculated as an average with regard to both the temporal and the spatial scale and thereby neglects water shortages in dry seasons or in certain regions within a country.
Furthermore, it does not take the water quality into account at all nor does it give information about a country's ability to use the resources. Even if a country has sufficient water according to the Falkenmark indicator, these water resources possibly cannot be used because of pollution or insufficient access to them. Values of water availability and water demand for selected countries are depicted in the figure below.
According to Falkenmark water stress index, the availability of water in Iran is 1850 m^3 /capita /per year which close to water crisis.

Figure 6 water scarcity in 2030 based on the Falkenmark indicator. (Source, Wallace 2000).

The Water Resources Vulnerability Index
Others have focused on a more accurate assessment of the demand for water than taking fixed requirements per person as a proxy, on a national scale, and related that to the national, annual renewable water supply and national, annual demand for water. A major effort over several decades by a large team of researchers in the State Hydrological Institute in St. Petersburg, Russia, led by Professor Igor Shiklomanov, is

behind most published global analyses of water demand and availability in the last 15 years. An early publication on this group's supply–demand analysis (Shiklomanov, 1991) compared national annual water availability with assessments of national water demand in the agricultural, industrial and domestic sectors. In a global water assessment for the United Nations Commission on Sustainable Development, Raskin et al. (1997) use Shiklomanov's basic data on water resource availability, but replace water demand with water withdrawals (intended as a more objective assessment of “use” than the more subjective “demand”), and present scarcity as the *total annual withdrawals as a percent of available water resources*, in what is referred to as a Water Resources Vulnerability Index. Water withdrawals are defined as the amount of water taken out of rivers, streams or groundwater aquifers to satisfy human needs for water. They suggest that a country is water scarce if annual withdrawals are between 20 and 40% of annual supply, and severely water scarce if this figure exceeds 40%. At the present, annual withdrawals of renewable water resources of Iran is 68 percent that shows severely water scare situation, according to this indicator.

Water poverty index

The idea of a WPI is to combine measures of water availability and access with measures of people’s capacity to access water. People can be ‘water poor’ in the sense of not having sufficient water for their basic needs because it is not available. They may have to walk a long way to get it or even if they have access to water nearby, supplies may be limited for various reasons. People can also be ‘water poor’ because they are ‘income poor’; although water is available, they cannot afford to pay for it.

It is this kind of water poverty that the WPI constructed here is trying to capture alongside the more traditional definition of this condition. There is a strong link between ‘water poverty’, and ‘income poverty’ (Sullivan, 2002). A lack of adequate and reliable water supplies leads to low levels of output and health. Even where water supply is adequate and reliable, people’s income may be too low to pay the user costs of clean water and drive them to use inadequate and unreliable sources of water supply. The underlying conceptual framework of the index therefore needs to encompass water availability, access to water, capacity for sustaining access, the use of water and the environmental factors which impact on water quality and the ecology which water sustains. Availability of water means the water resources, both surface and groundwater which can be drawn upon by communities and countries. Access means not simply safe water for drinking and cooking, but water for irrigating crops or for non-agricultural use. Capacity in the sense of income to allow purchase of improved water, and education and health which interact with income and indicate a capacity to lobby for and manage a water supply. Use means domestic, agricultural and non-agricultural use. Environmental factors which are likely to impact on regulation will affect capacity. This conceptual framework was developed as a consensus of opinion from a range of physical and social scientists, water practitioners, researchers and other stakeholders in order to ensure that all the relevant issues were included in the index.

Using a methodology comparable to that of the Human Development Index, we have constructed an index which measures countries’ position relatively to each other in the provision of water. In order to do this, we construct an index consisting of five major components, each with several sub-components. Corresponding to the conceptual framework discussed above, the main components are: Resources, Access, Capacity, Use and Environment.

WPI = R + A + C + U + E

The basic calculation, except where indicated below, is based on the following formula: (xi – $x$min)/ ($x$max – $x$min), where xi, $x$max and $x$min are the original values for country i, the highest value country, and the lowest value country respectively. The indices therefore show a country's relative position and for any one indicator this lies between 0 and 1. The maximum and minimum values are usually adjusted so as to avoid values of more than 1. Any remaining values above 1 or below zero are fixed at 1 and 0, respectively. Within each of the five components, sub-component indices are averaged to get the component index. Each of the five component indices is multiplied by 20 and then added together to get the final index score for the WPI, which is in the range 0 to 100.

Table 2: Structure of Index and Data Used

WPI Component	Data Used
Resources	• internal Freshwater Flows • external Inflows • population
Access	• % population with access to clean water • % population with access to sanitation • % population with access to irrigation adjusted by per capita water resources
Capacity	• ppp per capita income • under-five mortality rates • education enrolment rates • Gini coefficients of income distribution
Use	• domestic water use in litres per day • share of water use by industry and agriculture adjusted by the sector's share of GDP
Environment	indices of: • water quality • water stress (pollution) • environmental regulation and management • informational capacity • biodiversity based on threatened species

Table 3 The Water Poverty Index and Sub-Indices Compared with the Falkenmark and the Human Development Index in some selected countries

Country	Resources	Access	Capacity	Use	Environment	Water Poverty	HDI	Falkenmark
Iran	6	8	13.9	15.5	19	64	0.71	1850
Austria	10.1	13.4	18.8	14.2	15.7	72.2	0.92	8500
Turkey	7.8	9.5	13.1	13.1	9.5	53.1	0.26	3000
Saudi Arabia	0.2	14.9	16.1	20.0	6.8	58.0	0.75	100

Challenges of water resources management

Renewable water resources of the country are estimated to be about 130 bcm. Because of rapid population growth, per capita water resources have steadily decreased and will continue to decrease in the future. Geographic distribution of water resources of the country has not been consistent with geographic distribution of population, especially in the last two decades. The transition from an agricultural economy and renewal of agricultural structure is not yet complete. Land ownership and agricultural activities are still going through transition, and agricultural development still happens mainly through expansion of irrigated lands.

In spite of previous endeavors, it is necessary to strengthen the following aspects of water resources management:

- Policy formulation,
- Laws, regulations, criteria, and standards,
- Organizational improvement (coordination, cooperation, different specialization, and decision making processes),
- Water allocation system,
- Personnel planning and management,
- Financial and economic management,
- Information systems and data banks, and
- Technological research and development.

The present system of water resources management in Iran began to evolve about 70 years ago under certain historical and social conditions. The general progression of this evolution can be summarized as follows:

In the last century (since 1900) the population of the country has increased about six-fold. The population growth rate, which was less than 0.6 percent in the beginning of this period, reached the rate of 3.19 percent in the decade from 1976-1986. Fortunately, it has considerably decreased once again in the last decade. The major changes in population growth rate, resulting from reduction of mortality and increase of natural growth rate, occurred in the 1960s and afterward. Part of the population growth of the last decade has been due to immigration of Afghan refugees. Between 1960 and 1996, about 37 million people (about 60 percent of the existing population) were added to the country's population. In the period from 1961-2000, the urban population increased by about 31.7 million and the rural population increased by 11 million. In 1956, there were only three cities with a population over 250,000 in Iran, while in 2000 the number of cities with a population of over one million reached seven.

The impacts of rapid urbanization included an increased domestic use of water, especially for hygienic purposes, and the emergence of new water needs due to the expansion of cities and improvements in living standards. Under such conditions, new responsibilities have been created for water resources management, of which the most important are the increased importance of protecting population centers against drought and flood, and the ever increasing importance of water treatment to provide hygienic water, as well as collection and sound disposal of wastewater and drainage water.

The existing system of management and exploitation of water resources of Iran has been shaped by the events of the 1960s. Conditions and events since then have increased the importance of national management of water in macroeconomic planning of the country.

The increased need for national planning and expansion of water resources management will continue into the future.

References

Alcamo, J, T Henrichs and T Rosch (2000). World Water in 2025: Global Modeling and Scenario Analysis, in: Rijsberman, World Water Scenarios Analyses, (World Water Council, Marseille).

Alizadeh, Amin and Abbas Keshavarz, Status of Agricultural Water Use in Iran, Water Conservation, Reuse, and Recycling: Proceedings of an Iranian-American Workshop, 2005. Committee on U.S-Iranian Workshop on Water Conservation, Reuse, and Recycling, Office for Central Europe and Eurasia Development, Security, and Cooperation, National Research Council.

Ardakanian, Reza, Overview of Water Management in Iran, Water Conservation, Reuse, and Recycling: Proceedings of an Iranian-American Workshop, 2005. Committee on U.S-Iranian Workshop on Water Conservation, Reuse, and Recycling, Office for Central Europe and Eurasia Development, Security, and Cooperation, National Research Council.

Iranian Water Resources Management Company, 2002. Water Resources Management and sustainable development.

Ghazi, I. 2002. Water resources management and planning in Iran. Report to the University of Isfahan.

IWMI (2000). World Water Supply and Demand in 2025. In: FR Rijsberman, ed. World Water Scenario Analyses. (World Water Council, Marseille).

Lawrence, P., Meigh, J.R., Sullivan, C.A. (2003). The Water Poverty Index: An international comparison. Keele Economic Research Papers 2003/18 and Center for Ecology and hydrology (CEH), Wallingford.

Pereira, Luis S. Ian Cordery, Iovos Iacovides, Coping with water scarcity, International Hydrological Program, IHP-VI, Technical Documents in Hydrology, No. 58, UNESCO, Paris, 2002.

Raskin, P, P Gleick, P Kirshen, G Pontius and K Strzepek (1997). Water Futures: Assessment of longrange patterns and prospects. (Stockholm Environment Institute, Stockholm).

Rijsberman Frank R., 2006. Water scarcity: Fact or fiction? Agricultural Water Management No.80 , pages 5–22

Sullivan, C (2002). Calculating a Water Poverty Index, World Development, 30(7): 1195- 1210.

Shiklomanov, IA (1998). World Water Resources: An Appraisal for the 21st Century. IHP Report. (UNESCO, Paris).

Shiklomanov, IA (1991). The World’s water resources. In: Proc. Int. Symp. To Commemorate 25 Years of the IHP. Pp. 93-126. (UNESCO/IHP, Paris).

Shiklomanov, IA (1998). World Water Resources: An Appraisal for the 21st Century. IHP Report. (UNESCO, Paris).

Wallace, JS (2000). Increasing agricultural water efficiency to meet future food production. Agriculture, Ecosystems and Environment. 82:105-119.