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Liquid Assets

How Demographic Changes and Water Management Policies Affect Freshwater Resources

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Prepared for the Compton Foundation

RAND LABOR AND POPULATION

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Summary

Demographic factors play an important role in environmental change, along with biophysical, economic, sociopolitical, technological, and cultural factors, all of which are interrelated. Recent demographic trends have sparked concern about the impact of the human population on a critical element of the natural environment—fresh water. In the last 70 years, the world's population has tripled in size (Bernstein, 2002) while going from overwhelmingly rural to a near balance of urban and rural—a change that affects both how humans use water and the amount they consume.

In the late 1980s, concern over a potential water crisis began to grow. Much of the resulting literature has taken an alarmist view. Numerous reports sensationalized the so-called water crisis without taking into account the local or regional nature of water resources and the relationship between supply and demand. A number of factors are cited to support the position that the earth is headed toward a water crisis. They include the following:

- The human population continues to grow.
- Water withdrawals are outpacing population growth.
- Per-capita water availability is declining.
- Clean, potable water is less available worldwide.

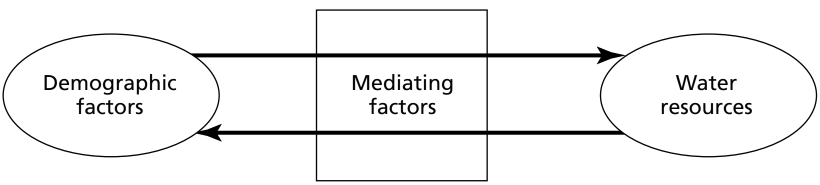
However, calculations of water resources rely on factors that are difficult to measure. It is important to consider the following:

- Water supply and demand are difficult to measure accurately.
- Water management plays an important role in the supply of and demand for water.
- Population forecasts are changeable.

Given these limitations, predictions of water scarcity may be overstated. At the same time, the risk of a water shortage remains. This risk arises not simply from population growth, but from a host of interrelated factors, including other demographic factors.

Figure S.1 illustrates the framework of analysis for this monograph. In this framework, there is not a direct, linear relationship between demographic factors and water availability, but rather there are numerous mitigating factors, such as resource management, human adaptation, and technological fixes, which mitigate the impact of change in demographic factors or water resources. The framework also illustrates the reciprocal nature of the relationship between water and demographic factors.

Figure S.1
Framework of Analysis



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This monograph integrates literature from different perspectives to explore the factors that cause and mitigate the condition of world water resources and the demographic influences on them, how they interact, and how they work together and against each other.

Freshwater Availability

About 30 percent of the earth's freshwater is found as groundwater, while only about one percent, or about 200,000 cubic kilometers (km^3), of it is easily accessible for human use in lakes, rivers, and shallow aquifers. Humans' primary source of freshwater comes from the water that runs off after precipitation.

Natural Influences on Water Availability

Water is not distributed evenly across land masses, and much of it is far from population centers. About three-quarters of annual rainfall occurs in areas where less than one-third of the world's population lives. Because precipitation is also temporally uneven, people in many regions are unable to make use of the majority of the hydrologically available freshwater supply.

Climate change affects precipitation and therefore affects the freshwater supply. Higher global and regional temperatures mean increased evapotranspiration, changes in snowfall and rainfall patterns, and changes in the intensity, severity, and timing of major storms. These changes will in turn affect the supply of and demand for water, as well as its quality in some regions of the world.

Calculating Water Availability

The quantity of water *practically* available to a population is defined by factors such as quality of water demanded, cost, environmental effects, political and legal agreements, individual wealth, and the technical ability to move water from place to place. It also depends on the quality of water demanded; for example, drinking water must be of higher quality than water for industrial or recreational uses.

The actual amount of water available to any person or group for a particular use depends not only on physical availability, but also on management and infrastructure to capture runoff and groundwater. Simple measures of water availability can hide factors such as variability of access, temporal and spatial availability, and legal and political restrictions, over- or underemphasizing existing or potential signs of stress, and misleading policymakers and water managers.

Patterns of Demand for Freshwater

Water usage is commonly analyzed according to three categories or sectors: agricultural, industrial, and domestic or municipal. Water usage in each sector varies across regions, over time, in relative quantity, and may vary seasonally.

Agriculture is generally the largest user of freshwater, accounting for about 70 percent of all annual water withdrawals worldwide, though in Europe it ranks behind industry. Most agricultural water use is for irrigation. Much of the demand for irrigation is being met in nonsustainable ways (e.g., by pumping nonrenewable groundwater supplies) and therefore may be problematic in the future. Furthermore, much of the future food production in developing countries is expected to come from irrigated land.

Industry is the second largest consumer of water, responsible for about 20 percent of annual worldwide withdrawals. Water is used in industry for cooling, cleaning, processing, generating steam power, and transportation. Because industries tend to cluster in urban areas, industrial water withdrawals are a significant component of urban water demand. There are a growing number of industries in rural areas, however, adding to rural industrial demand.

The domestic and municipal sector generally demands the smallest share of water (about 10 percent worldwide), except in countries with little agriculture or industry. Water is used in the domestic and municipal sector for purposes such as drinking, food preparation, and sanitation. The domestic sector, although less demanding in terms of volume than the other sectors in most places, warrants special attention because of its implications for health and mortality. Safe drinking water is an important public health and political concern. Poor water quality is a major causal factor in infant mortality, premature mortality, and lost productivity in many countries, especially in the developing world.

Demographic Influences on Water Resources

Demographic factors affect water consumption and the quality and health of natural ecosystems both directly and indirectly. Population growth, urbanization, and migration strongly affect the sustainability of water resources. Other factors that affect water use are indirectly linked to population—income levels, a rise in living standards, modifications to landscapes and land use, contamination of water supplies, and inefficiency of water use caused by a failure to manage demand.

Population Size and Growth

Population size is fundamentally linked to water use, and some perceive it to be the most important demographic factor affecting water resources. Although populations and individuals use resources differently, population size and changes in population size affect the magnitude of water use and can affect water quality because humans compromise the quality of water when they increase in number, migrate, and change the landscape.

The 20th century saw world population grow from 1.65 billion to 6 billion people, with almost 80 percent of that increase taking place after 1950. This rapid growth was due in part to mortality reductions, which were partly due to improvements in water quality. Population growth will continue for some time into the future. The water demands of humans will continue to affect water resources in ways we can only partially predict.

Number of Households

The number of households is increasing worldwide, and the average household size is decreasing—both factors that influence water demand. In fact, an increase in smaller households may do more environmental damage than simple population growth. The decrease in household size affects household-related economies of scale and reduces the effectiveness of investments in technical water-saving measures. Per capita, smaller households consume more water and produce more waste. More households require more housing units, increasing the materials needed for construction and contributing to urban sprawl. This damages water resources and water quality by paving over land that would otherwise help filter the water that replenishes lakes and rivers.

Urbanization

Urbanization, both by the degree and the rate of growth, can affect the levels of per capita water use, overtax water resources by concentrating demand in a small area, and overwhelm the existing infrastructure. It can also have a broader impact when freshwater resources must be transported from elsewhere.

Economic Development

A country's level of freshwater use is tied to its level of economic development, and the correlation is strong enough that water use is often used as a measure of economic development. Overall, developing countries use less water per capita than industrialized countries. Freshwater is used to run industry, grow food, generate electricity, and carry pollution and wastes, so increased industrialization is associated with increased water use per capita. Both the individual water use levels and the water used by society to support individuals and their ways of life are higher in industrialized countries.

Within countries, income level also determines the structure of freshwater demand. The poorest people in a country tend to use less water than those with high incomes. In cities, wealthier individuals are more likely to be connected to piped water supplies and waterborne sanitation systems, as well as to consume larger amounts of products that require water to produce. Rural dwellers, who are more likely to be poor, often use less water because of inaccessibility of supply and lower consumption of goods and services.

How Water Resources Influence Demographic Factors

Just as demographic factors affect water resources, water resources also affect demographic variables.

Morbidity and Mortality

Those who have less access to water and sanitation systems—whether due to scarcity or lack of infrastructure—tend also to have higher rates of disease and mortality, both because of poorer drinking water quality and because of reduced availability of water for hand washing. Countries with higher national incomes have built sewer networks and wastewater treatment facilities that have reduced the incidence of waterborne diseases. In contrast, rapidly expanding cities in much of the developing world have not been able to build such infrastructures, and they have higher rates of illness from such diseases.

Migration

Water resources often affect migration decisions. Lack of water can be a push factor in the decision to migrate away from a location. Deforestation, desertification, drought, and lack of land to cultivate can significantly influence migration from rural areas to towns. Millions of people have become refugees due to dam building, environmental deterioration, or the destruction of environmental resources that they require to live or make a living.

Water can also be a pull factor that induces people or industry to move to a region. For example, an industrial entity may choose to locate itself near water resources, and the employment opportunities it creates may influence the scale of future labor migration.

Approaches to Sustainable Water Management

Whether or not a water crisis is imminent, policymakers should explore ways to reduce the pressures on the water supply. The management of water supply and demand can make large differences in water withdrawals, and can influence the quality of water and its impact on human health. Supply management involves the location, development, and exploitation of new sources of water. Demand management involves the reduction of water use through incentives and mechanisms to promote conservation and efficiency.

Supply Management

Options for increasing water supplies include building dams and water-control structures, watershed rehabilitation, interbasin transfers, desalination, water harvesting, water reclamation and reuse, and pollution control.

Dams and water-control structures are used for energy production, flood control, and water storage. Substantial benefits may accrue from large dams, such as electric power production, irrigation, and domestic water provision. However, dams also have large environmental, social, and demographic consequences, including the submergence of forests and wildlife, greenhouse gas emissions from the decay of submerged vegetation, the impact of changed flow in the dammed river, the relocation of families, the destruction of villages and historic and cultural sites, and the risk of catastrophic failure. Currently, there are more than 41,000 large dams in the world, impounding 14 percent of the world's annual runoff.

Reforestation of degraded and unproductive land can be cost effective in the long term if all the ensuing benefits to the water supply, agricultural revenue, and pollution reduction are taken into consideration. However, the high initial cost combined with the drive to find short-term solutions make watershed rehabilitation a less appealing choice in many regions.

Small-scale irrigation systems may provide an opportunity to expand irrigation with fewer constraints than large-scale water projects. Studies have shown that small-scale irrigation systems may be as successful as large-scale irrigation projects, but their success depends on institutional, physical, and technical factors, including technology, infrastructure, and implementation.

Groundwater is a more efficient source of irrigation water than open canals because the water can be accessed when and where it is needed, reducing transportation costs. However, sustainable use of groundwater requires oversight to ensure that the amount tapped does not exceed the amount recharged through the hydrological cycle each year.

Interbasin transfers and water exports are two more methods of providing water to areas with dense populations or insufficient supplies of water. The infrastructure required for interbasin transfers (i.e., using canals or pipelines to transport water), however, is expensive and potentially environmentally harmful, both to the freshwater ecosystem from which the water is extracted and the lands over which the pipes or canals must flow. The selling of water through exports has been controversial because water is perceived as a common resource that should not be sold by private companies.

Water reallocation from one sector to another can be done via supply management, i.e., by reallocating water from the top down, or via demand management, i.e., using incentives to move water between sectors. Because water in developing countries is predominantly consumed by the agriculture sector, reallocation of even small percentages of water consumption to the domestic sector can fulfill domestic needs.

Desalination, a process of turning saltwater into fresh drinking water through the extraction of salts, is an expensive, energy-intensive process, and it produces brine that must be disposed of carefully to avoid environmental damage. For these reasons, it is currently an unappealing option for increasing the water supply, except in the most arid areas of the world.

Water harvesting, i.e., the capture and diversion of rain or floodwater, can provide environmental benefits by reducing the polluted runoff from urban areas into surface waters and can increase efficiency, productivity, and soil fertility on a local and regional basis.

Water reclamation and reuse have helped reduce water use in the industrial sector in some developed countries, and they reduce the amount of pollution released into receiving waters such as oceans, lakes, and streams. However, the practice is limited when the water contains high levels of salt or heavy metals.

Pollution control, i.e., preventing contamination from agricultural residues, soil erosion, urban runoff, industrial effluent, chemicals, excess nutrients, algae, and other pollutants, is another supply option to maintain the quality of the current supply of water. Pollution-control laws in developed countries have helped to clean up rivers, lakes, and streams, and they promote conservation and the efficient use of water. Although most countries have pollution-control laws, many developing countries lack the political will or financial resources to enforce them.

Policy Options for Demand Management

Although supply management measures like those discussed above will help to meet demand for water in the future, much of the effort to meet new demand will have to come through demand management, including conservation and comprehensive water policy reform. Management approaches such as integrated water resources management and demand management offer effective means of providing water for human use while easing the stress on the freshwater ecosystems and the ecological goods and services that they provide.

Poor governance is at the core of many water problems, especially in developing countries. Several categories of policy instruments can be used to enact demand management and improve governance of water systems, including institutional and legal change, market-based incentives, nonmarket instruments, and direct interventions.

Institutional and legal change of the atmosphere in which water is supplied and used includes water-quality matching, decentralizing supplies, and privatization of water management. Water-quality matching involves channeling pure water only to functions that require it, such as human consumption, and using lower-quality water for appropriate uses, such as irrigation and industrial processing. Decentralization allows local communities to control their own water supplies. Privatization involves private firms in the building and operation of water-management systems. Privatization is controversial because private firms are motivated by profits, and concerns about equitable access to water for the poor, the integration of environmental concerns, and the sharing of risks must be addressed before privatization becomes a widely viable option.

Market-based incentives use economic means to modify the behavior of consumers. Water pricing, the most common example of a market-based incentive, typically reduces demand, increases conservation, encourages reallocation between sectors, and increases environmental sustainability by reducing the strain on ecosystems.

Nonmarket instruments, policies that use direct, non–incentive-based laws and regulations to control water use, include quotas, licenses, pollution controls, and restrictions. Educational measures that encourage water conservation are important companions to nonmarket instruments.

Direct intervention, i.e., technological and other interventions to conserve water include, for example, leak detection and repair programs, investment in improved infrastructure, and conservation programs. Conservation can occur through measures such as efficiency standards for plumbing fixtures or changing industrial processes to use less water.

Will There Be a Global Water Crisis?

There will undoubtedly continue to be localized problems of water scarcity, and perhaps more widespread problems in some areas, depending on local physical, social, economic, and cultural conditions. However, a global water crisis can be averted. There are many options for improving water management and alternatives for meeting supply and demand, even for growing and changing populations. Attention to demographic factors is an important part of the formula for staving off water crisis indefinitely. To be successful, there must be sufficient institutional, intellectual, and administrative capacity to create solutions and to execute them.

Sustainable water development and management requires the integration of social and economic concerns with environmental concerns. This effort will be enhanced by research that focuses on as small a scale as possible, to provide data and information on methods that will help to manage water at socially relevant levels, more locally, as well as at environmentally relevant levels such as the watershed. Looking ahead, research on demographic variables that are less understood, such as the impact of the number and size of households on the environment, will help to improve the overall understanding of the relationship between demographics and water resources.