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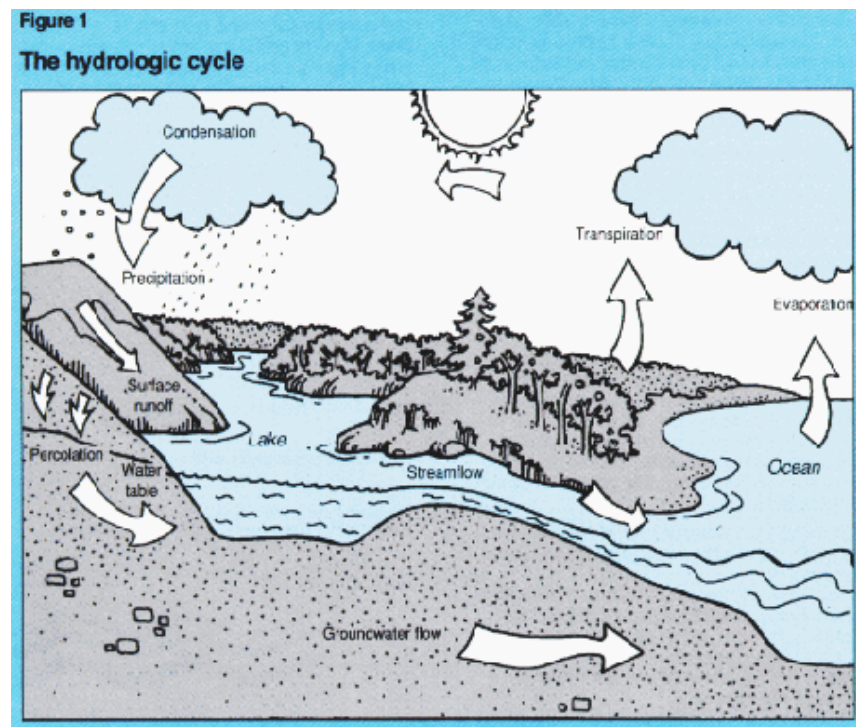
7. WATER SCARCITY

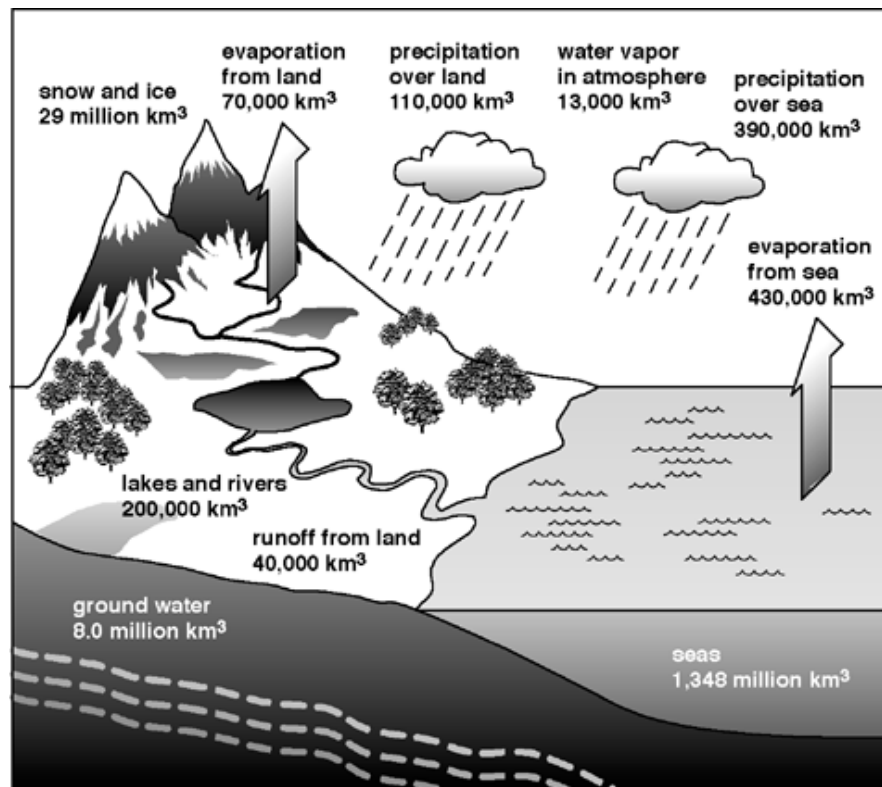
7.1. AROUND CONCEPTS AND DIMENSIONS

7.1.1. DEFINITIONS OF KEY WATER TERMS AND CONCEPTS [B.8.3.]

Hydrologic cycle (also called the water cycle): the cycle by which water evaporates from oceans and other bodies of water, accumulates as water vapor in clouds, and returns to oceans and other bodies of water as rain and snow, or as runoff from this precipitation or as groundwater. See Figures 7.1.

Figures 7.1.





Runoff: water originating as rain or snow that runs off the land in streams, eventually reaching oceans, inland seas or aquifers unless it evaporates first.

Aquifer: a layer or section of earth or rock that contains groundwater.

Groundwater: any water naturally stored underground in aquifers, or that flows through and saturates soil and rock, supplying springs and wells.

Water withdrawal (Freshwater withdrawal) : removal of water from any natural source or reservoir -such as a lake, stream or aquifer- for human use. Not counting evaporative losses from storage basins. It is also included water from non renewable groundwater sources, river flows from other countries, etc. If not consumed, the water may later be returned to the same or another natural reservoir.

Water consumption (Water use): use of water that allows its evaporation or makes it unfit for any subsequent use.

Renewable water (Internal renewable freshwater): water continuously renewed within reasonable time spans by the hydrologic cycle, such as that in streams, reservoirs or other sources that refill from precipitation or runoff. This

refers to the average annual flow of rivers and recharge of groundwater generated from endogenous precipitation. These annual averages also disguise large seasonal, interannual, and long term variations. The renewability of a water source depends both on its natural rate of recharge and the rate at which the water is withdrawn for human ends. To the extent water is withdrawn faster than its source is recharged, it cannot be considered renewable.

Non-renewable water: water in aquifers and other natural reservoirs that are not recharged, or are recharged so slowly that significant withdrawals will cause depletion.

Water scarcity (First definition or approach): used in reference to countries by water engineers and in this report, condition in which the annual availability of internal renewable fresh water is 1,000 cubic meters or less per person.

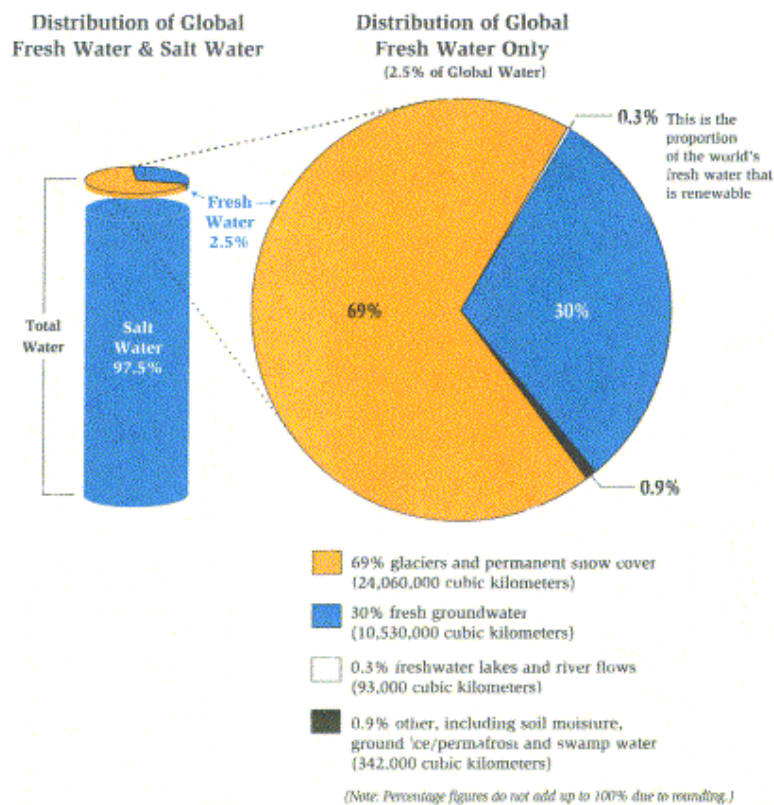
Water stress (First definition or approach): condition in which the annual availability of internal renewable fresh water is less than 1,667 and greater than 1,000 cubic meters per person in the population.

7.1.2. THE EARTH'S WATER

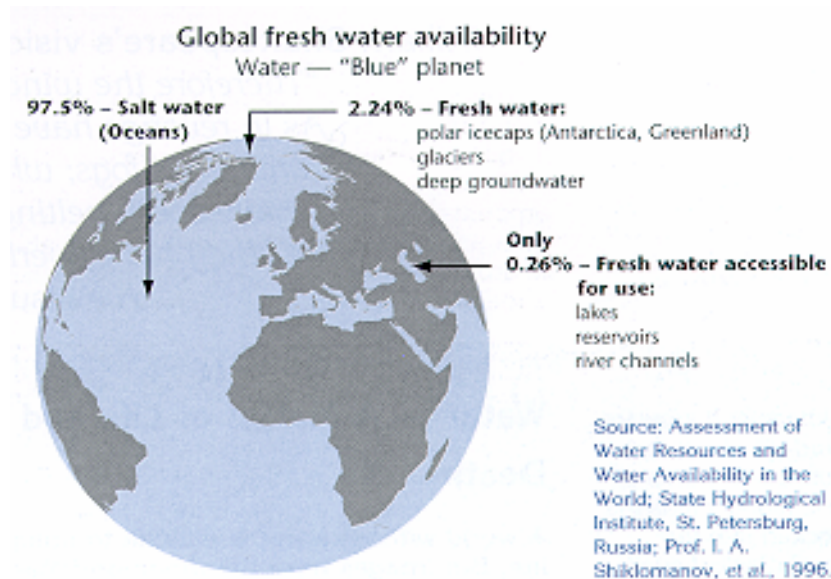
Total water on earth: 1.4 billion cubic kilometers (335 million cubic miles), enough to cover the United States to a depth of 150 kilometers (93 miles).

Understanding the limits of renewable fresh water supply requires an appreciation of how little of the planet's 1.4 billion cubic kilometers of water actually fits into that category. Only 2.5 percent is fresh -fit for drinking, growing crops and most industrial uses. Moreover, 69 percent of that is locked in polar ice caps and mountain glaciers or stored in underground aquifers too deep to tap under current and foreseeable technology [B.8.]. See Figures 7.2.

Figures 7.2.



Source: Igor Shiklomanov, "World Fresh Water Resources" in Peter H. Gleick, ed., *Water in Crisis: A Guide to the World's Fresh Water Resources*, 1993



In calculating how much fresh water is available for human use, what counts is not the sum total of global fresh water supplies, but the rate at which fresh water resources are renewed or replenished by the global hydrologic cycle. Powered by the sun, this cycle each year deposits about 113,000 cubic kilometers of water on the world's continents and islands as rain and snow. Of that, about 72,000 cubic kilometers evaporates back into the atmosphere. That leaves 41,000 cubic kilometers a year to replenish aquifers or to return by river or other runoff to the oceans. And a substantial proportion of this amount is needed to sustain natural ecosystems -in and around rivers, wetlands and coastal waters- and the millions of living species they contain.

Total internal renewable water falling on continents and islands each year: 41,000 cubic kilometers (10,000 cubic miles), enough to cover the United States to a depth of 4.4 meters (15 feet).

So, powered by the sun, the global hydrologic cycle each year deposits about 113,000 cubic kilometers of water on the world's continents and islands as rain and snow. Of that, about 72,000 cubic kilometers evaporates back into the atmosphere. That leaves 41,000 cubic kilometers a year to replenish aquifers or to return by river or other runoff to the oceans. Moreover, not all of this 41,000 cubic kilometers can be captured for human use. About 28,000 of this is available in the form of surface runoff and the amount of this is usable depends on how much water can be captured by dams and reservoirs. The other 14,000 or so is in the form of stable underground flow, which is the result of water that infiltrates the soils. Approximately 5,000 cubic kilometers of this underground water is located in areas that are not inhabited. (In other

words, more than half flows unused to the sea in floodwaters and as much as an eighth falls in areas too far from human habitation to be captured for use). Some water experts suggest that the practical upper limit of the world's available renewable fresh water lies between 9,000 and 14,000 cubic kilometers per year depending on how much can be captured by dams and how much can be used or transported from the uninhabited areas. Probably we can consider that, at maximum, 3,500 cubic kilometers of water can be captured and stored by dams and reservoirs. So, finally, we can estimate that 12,500 cubic kilometers is the maximum quantity of water that we can imagine to use in the future.

7.1.3. THE EARTH'S WATER AND THE POPULATION

Of all the planet's renewable resources, fresh water may be the most unforgiving.

Difficult to purify, expensive to transport and impossible to substitute, water is essential to food production, to economic development and to life itself. Its importance to human health and well-being was underlined in mid-1993 when the United Nations' new Commission on Sustainable Development made improvement of water quality as one of the first priorities for technology transfers from wealthy countries to poorer ones.

Only when taps run dry, as happened for a time in 1993 in places as far apart as Des Moines, Iowa, and Sarajevo, that those who live in the industrialized world realized how critical access to water is to all aspects of life. In less prosperous countries millions of people, most of them women, need no such reminder. They walk miles each day to find the water they need and carry it home.

Yet water availability has not received the attention it deserves in global discussions of the sustainable use of natural resources. It has been examined even less in the context of population growth. On a planet whose surface is more than two thirds covered by water, the illusion of abundance has clouded the reality that renewable fresh water is an increasingly scarce commodity.

While the world's oceans may seem unbounded, the amount of fresh water actually available to people is finite -and a mere fraction of the water visible from outer space. Over the long term, the water humanity can count on for use year after year is the planet's renewable supply. That is the water that falls from the sky, seeps into the ground or collects in rivers and lakes, and flows back to the sea, from which it was first drawn up by the sun. **To be used sustainably, water cannot be withdrawn from reservoirs and other sources faster than it is replenished through this natural hydrologic cycle.**

Our capacity for capturing and storing fresh water has expanded throughout history, and we are learning how to use it more efficiently. But no technology can significantly expand the basic resource. The use of desalination may suggest the world's oceans are potentially inexhaustible sources of fresh water, but the process of extracting salt from seawater remains expensive and dependent on polluting and non-renewable fossil fuels. **The reality is that there is essentially no more fresh water on the planet today than there was 2,000 years ago when the**

earth's human population was less than three percent its current size of near 6 billion people.

The finite nature of renewable fresh water makes it a critical natural resource to examine in the context of population growth. Few other resources so essential to daily life are bounded by such fixed limits on supply -limits that in dozens of countries are already constraining efforts to improve health and living standards. As population grows, the average amount of renewable fresh water available to each person declines. Hydrologists and other water experts agree that when certain ratios of human numbers to renewable fresh water supplies are exceeded, water stress and outright scarcity are all but inevitable.

In recent decades these ratios have been approached or exceeded in more than two dozen countries. And the projected population growth of the next few decades could push yet another two dozen countries and hundreds of millions more people over the brink of water shortage. Moreover, predicted changes in global climate could redistribute or reduce water supplies and intensify storms, adding to the challenge of managing water supply.

Acute water shortages already have required extraordinary measures in some countries. When thousands of refugees from Djibouti, the most water-scarce country in the world, crossed into Ethiopia in the summer of 1993, the Red Cross had to send tankers up to 300 miles to find water for them. During severe droughts in western India, the government brings drinking water to some rural areas by railway.

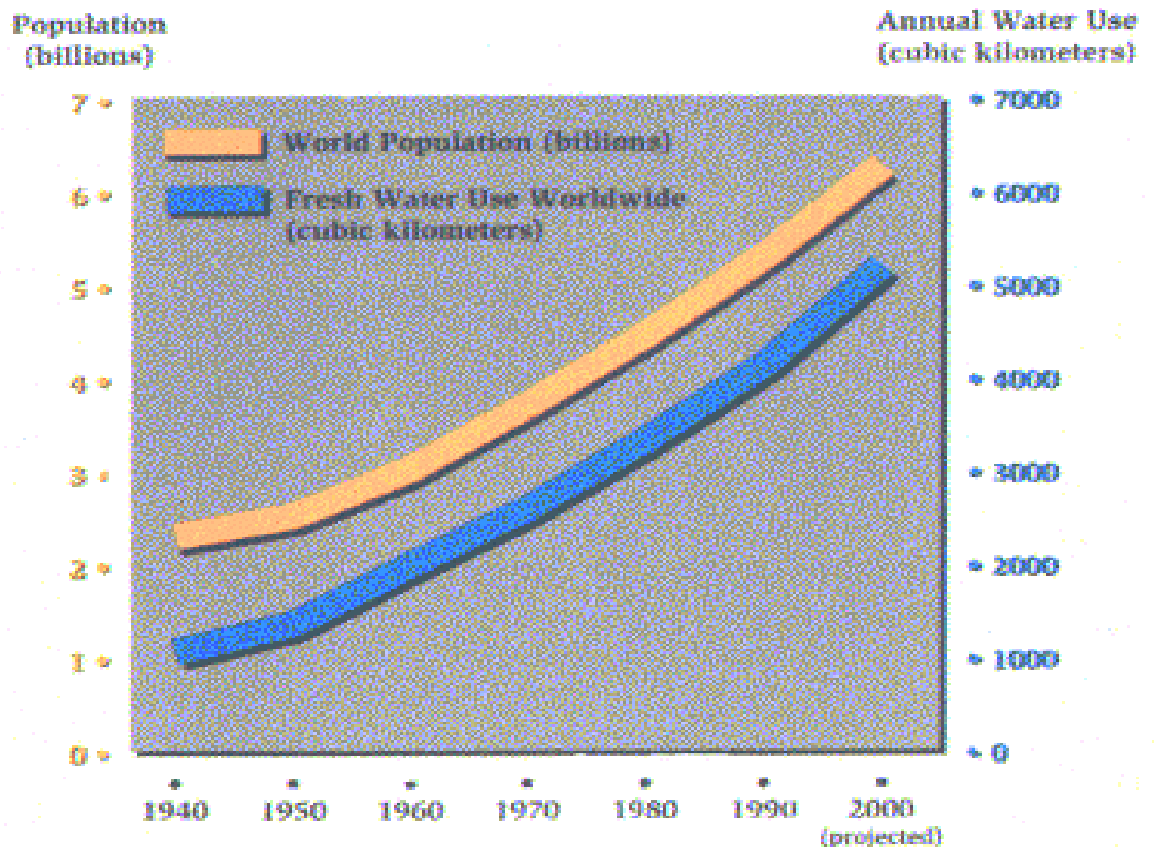
Life is tied to water as it is tied to air and food. And food is tied to water since plant growth depends on its flow from roots to foliage. Throughout history, secure access to water has been essential to social and economic development and the stability of cultures and civilizations. Since ancient times agriculture has depended on fortuitous combinations of good soils and predictable water supplies, and dependable sources of abundant water played a prominent role in the industrialization of Europe and North America. **Even if less developed nations pursue new development paths that avoid the errors of the past, it is difficult to imagine how sustainable development will proceed if renewable fresh water is in short supply.**

Efforts to encourage water conservation face special challenges not encountered with other natural resources. In much of the world, water is not controlled by market mechanisms because it is either free for the taking or unmetered. Nor is water a global resource that can be traded like petroleum or given in aid like food

or medicine. Whether people waste water in one river basin is irrelevant to those who live in another. People need sources of clean water close to home.

Meanwhile between 1940 and 1990, world population was more than doubled -reiterated cited before-, from 2.3 billion to 5.3 billion human beings, simultaneously, per capita use of water was also doubled, from about 400 to 800 cubic meters per person per year [B.8.2.] . The practical result of these two trends was that global use of water increased by more than four times in that half century. Given the finite nature of the earth's fresh water resources, such a quadrupling of world water use probably cannot occur again. In many of the regions where population is growing most rapidly, the needed water is simply unavailable. See Figure 7.3..

Figure 7.3.



7.1.4. WATER AVAILABILITY IMBALANCES

Although water remains abundant in many countries, in others the continual subdivision of renewable water resources among more people is leading to unsustainable uses of water or substantial declines in water availability and quality. This is especially true in Africa and the Middle East, but over time the ratio of people to renewable water supply is likely to become a concern in parts of Asia and Latin America, and possibly even in Europe.

The critical limits, of course, are not at the global level but at regional, national and local levels. In measuring a country's water resources, hydrologists refer to endogenous, or internal, and exogenous, or external, resources. Internal supply refers to the precipitation that falls on national territory, minus that portion lost through evaporation. External water supply is that which flows into a country from rivers and aquifers originating in other countries -and is vulnerable to the restrictions of those countries.

While most of the renewable water will be available for a country's use under ideal conditions, many countries can only mobilize -capture for use- a proportion of their potential water resources, depending on the suitability of their land for water storage in reservoirs and the extent and condition of their infrastructure. **Some developing countries can currently mobilize only 20 percent of their potential water resources [B.8.5].**

Throughout most of human history, the world's fresh water reserves were more than adequate to serve human needs while maintaining the integrity and biological diversity of the earth's ecosystems. But as populations have grown, fresh water has become increasingly less available where and when it is needed.

Fresh water availability is dictated in large part by climate, and particularly by the timing and location of precipitation and by "evaporative demand," a measure of how much moisture the atmosphere can absorb that is chiefly determined by average temperature. **Some arid countries in the Middle East and North Africa have such low precipitation and high evaporation that only a small amount of fresh water can be captured for human use.** Rainfall in many desert areas amounts to a few millimeters a year -and all of that may fall within a few days. By contrast, nations such as Sweden or Iceland, where precipitation is high and evaporative demand low, enjoy abundant water resources.

Water availability can vary tremendously from season to season, causing distinct wet and dry seasons in well -watered regions. Bangladesh is inundated with

rainfall during its two-to-three-month monsoon season, but lacks rainfall for much of the rest of the year. **Water availability also varies from year to year, making even semi-arid regions vulnerable to a succession of dry years, such as the drought that gripped 20 sub-Saharan African nations from 1981 to 1984.** To be useful, moreover, fresh water supplies must be close to the populations that need them.

Socioeconomic factors greatly influence access to water. Developing countries may lack the capital and technology to tap potential water resources. Within a country powerful industrial or agricultural interests may claim a disproportionate share of water resources. People with the least status and wealth often suffer disproportionately when supplies are limited.

Access is further complicated by conflicts arising over rights to water in river and lake basins shared by two or more countries, and to water in aquifers that cross international borders. Access to water is one of the critical negotiating issues for Israel and its Arab neighbors, who together have among the highest ratios of population to renewable water in the world. **Areas of real or potential water conflict also include the valleys of the Nile, the Tigris and Euphrates, and the Indus, Ganges and Brahmaputra rivers.**

Among the greatest single influence on fresh water availability, however, is the number of people competing for the resource. Higher population size and standards of living boost demand for finite quantities of water and intensify competition and tension among users. Since much of the world's urbanization, industrialization and irrigation is characterized by unsustainable patterns of fresh water use, the situation threatens to grow worse.

7.1.5. HUMAN USES OF WATER

Worldwide, agriculture is the single biggest drain on water supplies, accounting for about 69 percent of all use. About 23 percent of water withdrawals go to meet the demands of industry and energy, and just 8 percent to domestic or household use. Patterns of use vary greatly from country to country, depending on levels of economic development, climate and population size. **Africans, for instance, devote 88 percent of the water they use to agriculture, mostly irrigation,** while highly-industrialized Europeans allow more than half of their water to industry and hydroelectric energy production.

Although much of the world's farming still relies on the renewable water that falls on crops from the sky, irrigation largely explains agriculture's thirst. And the watering of crops has grown in tandem with rising world population. (Livestock production is an agricultural activity, but its use of water is minor compared to irrigation.) **In 1990, 250 million hectares of land were under irrigation worldwide, supplying a third of the world's harvested crops, and agriculture was the primary use for water in two out of three countries.** Sandra Postel, from the Worldwatch Institute, in her 1999 last book, **Pillar of Sand: Can the Irrigation Miracle Last?**, said that "some 40 percent of the world's food comes from irrigated cropland, meanwhile only the 16 percent of the agricultural land is irrigated".

Agricultural water use is particularly high in arid areas such as the Middle East, North Africa and the southwestern United States, where rainfall is minimal and evaporation so high that crops must be irrigated most of the year. Afghanistan, and Sudan apply an estimated 99 percent of all the water they use to agriculture.

The area of irrigated land worldwide nearly doubled in the first half of this century to meet the needs of a growing population that was developing economically and consuming more food per capita. **Land under irrigation was more than doubled again between 1950 and 1990. Only in recent years has the growth of irrigation slowed, reflecting the challenge of finding new sites for dams and reservoirs and of squeezing more water out of already overpumped aquifers.** In California and the southwestern United States water is becoming so valuable that farmers are selling their land--and the accompanying water rights--to ballooning metropolitan areas with huge demand. **A few countries, such as Malta and Botswana, have opted to rely on imported food in part to save water. This reduces the need for irrigation water, but at the risk of limiting options if imported food becomes expensive.**

Domestic water use--including drinking, food preparation, washing, cleaning, gardens and service industries such as restaurants and laundromats--accounts for only a small portion of total use in most countries. The amount of water people apply to household purposes tends to increase with rising standards of living, and variations in domestic water use are substantial. In the United States, each individual typically uses more than 700 liters each day for domestic tasks. In Senegal, the average individual uses just one twentieth of that -29 liters -to meet household needs. Domestic needs account for a greater share of overall use in countries, rich or poor, that have little agriculture or industry. In both Kuwait and Zambia, nearly two out of every three liters of water are used in households.

Industry, a category that includes energy production, uses water for cooling, processing, cleaning and removing industrial wastes. Nuclear and fossil-fueled power plants are the single largest industrial users, applying staggering amounts of water to the job of cooling. While most of the water used for industrial purposes is returned to the water cycle, it is often contaminated by chemicals and heavy metals, or its temperature is increased to the detriment of water ecosystems. Industrial use varies from less than 5 percent of withdrawals in dozens of developing countries to as much as 85 percent in Belgium and Finland. Only in Europe, where reliance on irrigation is relatively low, does industrial water use equal the sum of water applied to agriculture and domestic uses. The proportion of water used for industrial purposes is often seen as an indicator of economic development.

7.2. POPULATION AND WATER STRESS AND SCARCITY

Malin Falkenmark, a widely respected Swedish hydrologist, pioneered the concept of a "water stress index", based on an approximate minimum level of water required per capita to maintain an adequate quality of life in a moderately developed country in an arid zone. Falkenmark began with the calculation that 100 liters per day (36.5 cubic meters per year) is a rough minimum per capita requirement for basic household needs to maintain good health. The experience even of water-efficient and moderately developed countries shows that roughly five to 20 times this amount tends to be needed to satisfy the requirements of agriculture, industry and energy production, she found. Based upon these findings, Falkenmark suggests specific thresholds of water stress and water scarcity [B.8.4].

A country whose renewable fresh water availability, on an annual per capita basis, exceeds about 1,700 cubic meters will suffer only occasional or local water problems. Below this threshold countries begin to experience periodic or regular *water stress*. When fresh water availability falls below 1,000 cubic meters per person per year, countries will begin to experience chronic *water scarcity*, in which the lack of water begins to hamper economic development and human health and well-being. When renewable fresh water supplies fall below 500 cubic meters per person, countries will begin to experience *absolute scarcity*. We have mentioned about this as the first definition or approach.

These levels should be considered rough benchmarks, not precise thresholds. The exact level at which water stress sets in varies from region to region, a function of climate, level of economic development and other factors. Water stress can also be eased by comprehensive programs of water conservation and more efficient technologies. But the basic concept of scarcity thresholds provides a useful tool for considering how changes in population can affect per capita water supply, and hence abundance on country-wide scales.

The 1,000 cubic meter benchmark has been accepted as a general indicator of water scarcity by World Bank and other analysts. Gleick, of the Pacific Institute for Studies in Development, Environment and Security, has called it the "approximate minimum necessary for an adequate quality of life in a moderately developed country." Israel, a relatively prosperous country, is commonly cited for surviving on much less -461 cubic meters of fresh water per person (although Israel also depends on some non-renewable groundwater). But even countries with high water availability may experience problems because of regional

disparities or very high water demand. Acknowledging such discrepancies, however, hydrologists and water use experts find 1,000 cubic meters serves as a useful benchmark for water scarcity around the world. Falkenmark's higher stress benchmark of about 1,700 cubic meters per capita per year is a "warning light "to nations whose populations continue to grow. In time, in the absence of conditions that lead to population stabilization, most water-stressed nations will fall into the scarcity category.

The impact of population growth on water availability can be analyzed by comparing current data on each country's renewable water supply (including river inflow from other countries) with data on past, present and projected population size. The World Resources Institute publishes country-by-country data on water availability and use. These data were recently updated and revised by Gleick [B.8.7.] in collaboration with Population Action International. We have reiterate that The United Nations periodically publishes projections of future population growth and size for most countries. The water scarcity index makes clear that water is, or is likely to become, a major constraint on development for more than a third of the countries studied, on four of the five major continents. See, concretely, next subsection.

7.2.1. WATER-SCARCE COUNTRIES

Quantities of renewable fresh water have qualified 20 nations in 1990 as water-scarce, 15 of them with rapidly growing populations. By 2025, between 10 and 15 nations will be added to this category. Between 1990 and 2025 the number of people living in countries in which renewable water is a scarce resource will rise from 131 million to somewhere between 817 million under the UN's low projection of population growth and 1.079 billion under the high projection. In this case, the difference between the high and low projections -262 million- is precisely twice the number of people living in water-scarce countries in 1990.

For several countries varying population scenarios could mark the difference between potentially manageable water stress and outright water scarcity in 2025.

Figure 7.4. (see also Figure 7. 8.)

Table 1: Countries experiencing water scarcity in 1955, 1990 and 2025 (projected), based on availability of less than 1,000 cubic meters of renewable water per person per year

Water-scare countries in 1955	Countries added to scarcity category by 1990	Countries added to scarcity category by 2025 under all UN population growth projections	Countries added to scarcity category by 2025 only if they follow UN medium or high projections*
Malta	Qatar	Libya	Cyprus
Djibouti	Saudi Arabia	Oman	Zimbabwe
Barbados	United Arab Emirates	Moroco	Tanzania
Singapore	Yemen	Egypt	Peru
Bahrain	Israel	Comoros	
Kuwait	Tunisia	South Africa	
Jordan	Cape Verde	Syria	
	Kenya	Iran	
	Burundi	Ethiopia	
	Algeria	Haiti	
	Rwanda		
	Malawi		
	Somalia		

A dozen or more African nations also are struggling to balance declining per-capita water supplies with the demands of rapidly rising populations. Of 20 African countries that have faced food emergencies in recent years, half are either already stressed by water shortage or are projected to fall into the

stress category by 2025. Lacking the financial resources and technology to improve management of scarce water or gain access to more renewable supplies, these countries are in desperate need of improvement in the development and management of renewable fresh water resources. They include war torn Somalia as well as Algeria, Kenya, Malawi and Rwanda.

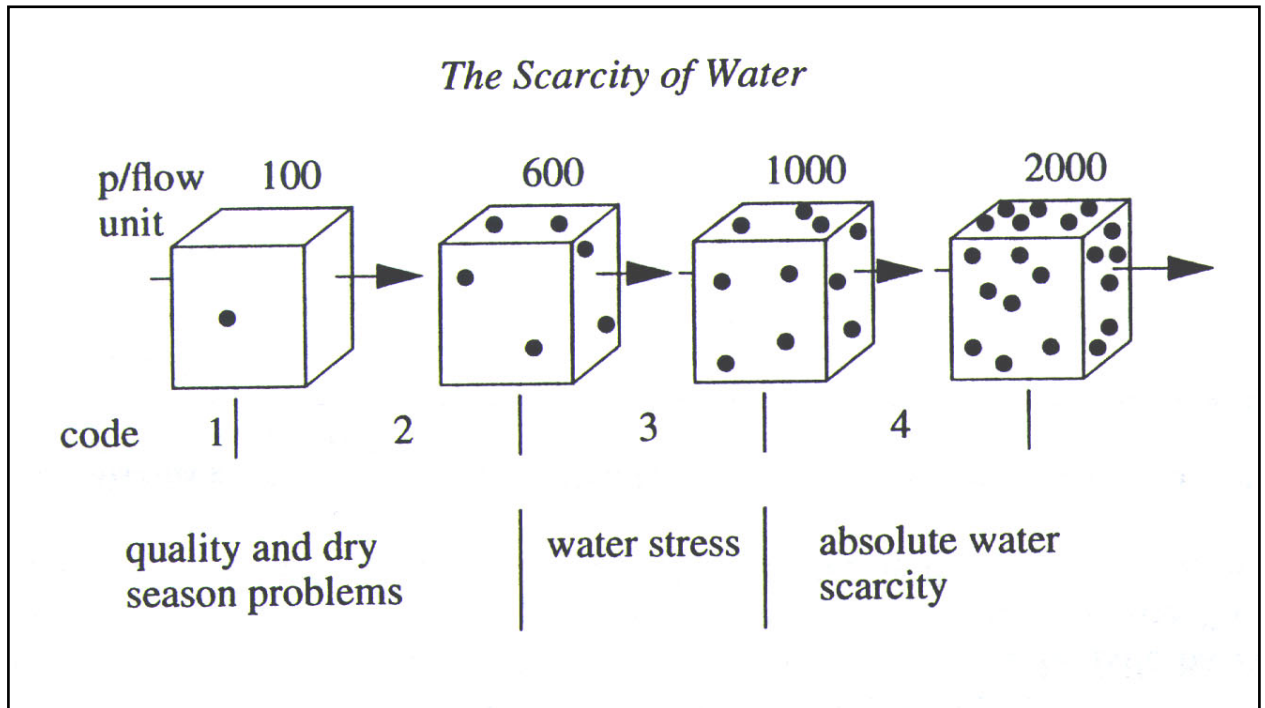
7.3. A COMPLEMENTARY POINT OF VIEW AROUND THE STRESS AND SCARCITY INDEX'S

How do we measure the scarcity level? **Again Malin Falkenmark [B.8.6.] introduced a second approach or definition to the concept of water scarcity index.** This is an index that indicates the relation between water availability for a particular region and the number of people that can be supported in a sustainable way. This takes into account food security, household use, and industrial supply. A flow unit of water is defined as equal to 1 million cubic meters per year. See Figure 7.5.. Thus, the scarcity index is expressed in terms of the number of people in one flow unit. In many industrialized countries this index usually ranges between 100 - 500 people per flow unit. Based on practices in moderate climate zone, a region is considered to experience water stress if the number of people that are dependent on the available of water is more than 500 people / flow unit. If this number exceeds 1,000 people / flow unit, then the region is already in the scarcity level. In terms of how much water is available per person, the above numbers can be expressed as 1,700 cubic meters and 1,000 cubic meters per person, respectively. Thus, a region that has less than 1,700 cubic meters of water available per person is said to be water-stressed. The present water barrier is said to be 2,000 people / flow unit. If a region passes this barrier, then extensive recycling, use of non-traditional source of water, and other means for increasing water supply has to be considered to meet the demands. Israel has already passed this barrier. They have been able to maintain balance on supply and demand simply because they implement a flexible and efficient water management. The various projects that are implemented such as drip irrigation and water-transfer from the Sea of Galilee, are very expensive.

Most countries in Africa, which is the driest and yet has the highest growth in population, are likely to pass the water barrier in the near future. Such water management is simply not feasible to be implemented, at least in the coming decade. This limitation, plus the tendency of political objective to become self-sufficient in food production will make the water problem in Africa more severe coming in to the next millenium.

The concept of water barrier draws many reactions by hydrologist and engineers. Despite of the pro and contra, the scarcity index nonetheless provides us a measure for comparison between one region and another. This indicator is used in the analysis for this purpose.

Figure 7.5.



According to this, we will talk about **the first water scarcity index** when we use the concepts of section 7.2., and we will talk about **the second water scarcity index** when we use this section 7.3. approach.

7.4. THE CASE STUDY REGION AND THE FIRST AND SECOND WATER SCARCITY INDEX'S

First of all we need to look at carefully the data of the internal renewable freshwater resources in the countries of our case study region; see Figure 7.6. (data is in accordance to the main sources of our study, [B.8.]):

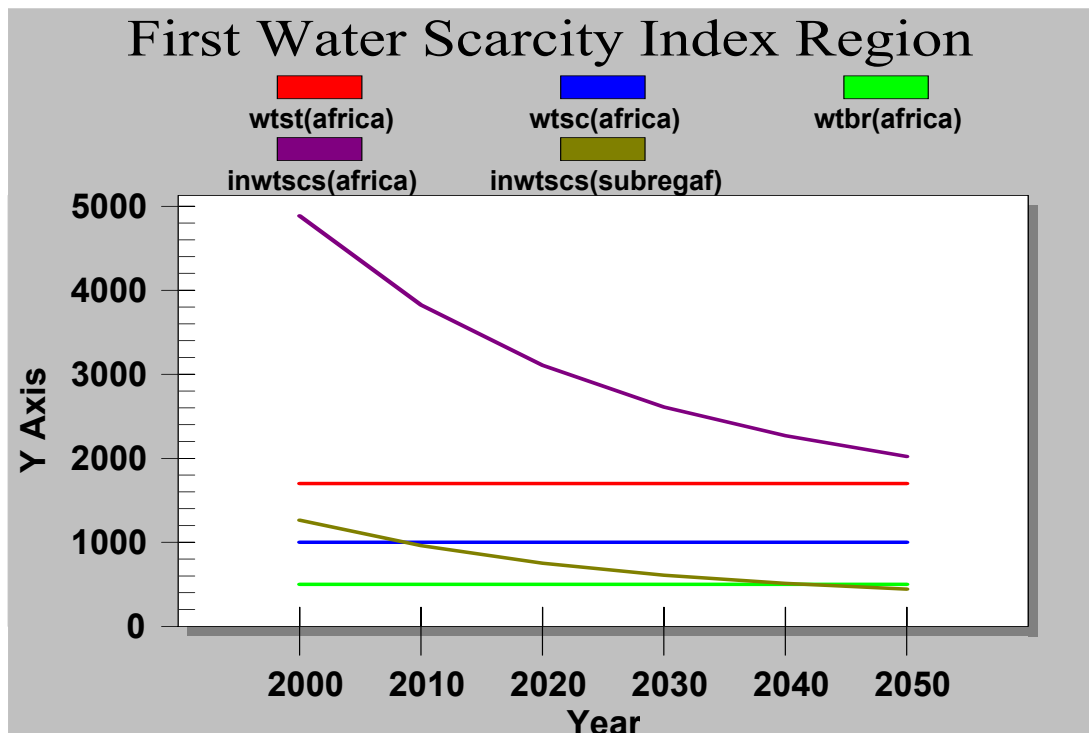
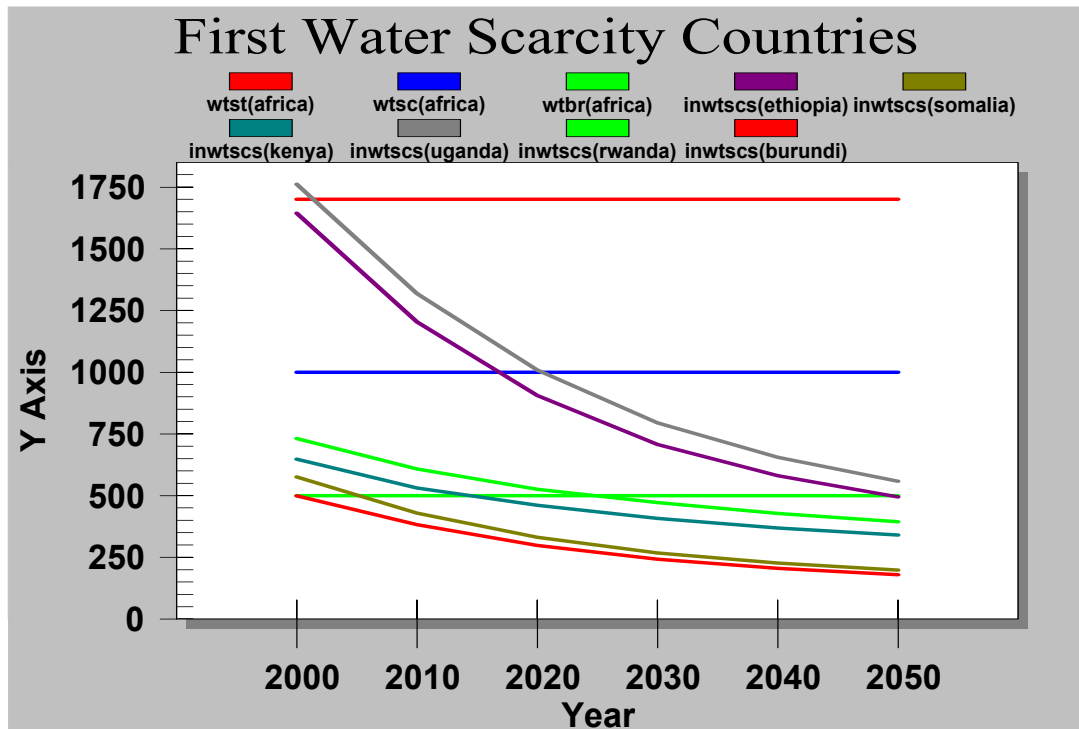
Figure 7.6.

	WTRNRS(Km ³)
WORLD	41022
AFRICA	3996
ETHIOPIA	110
SOMALIA	6
KENYA	20.2
UGANDA	39
RWANDA	6.3
BURUNDI	3.6
REGION	185.1

And then, using again GLOBESIGHT, in agreement with the data of population and hydrology experts, and as we did and commented in chapter 5 for the population, we can have a country-to-country approach to the situation and forecasting projections -taken into account the population standard projections- in water problematique in our case study region.

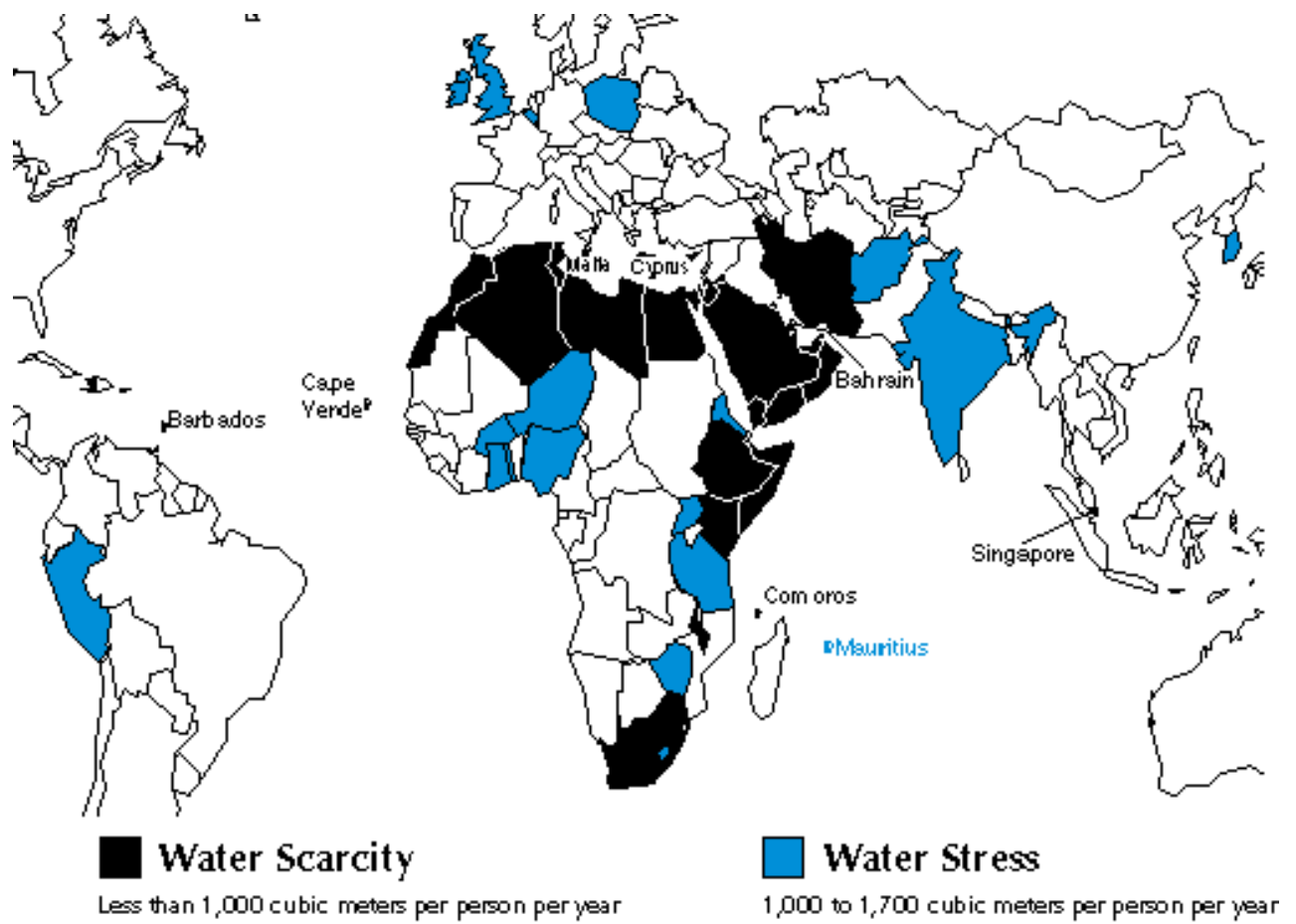
Again, and it is clear after all the comments that we have done until this point in our study and now especially in this chapter, we are facing one of the most water problematique aggregate regions in the world. This is strongly related, we mentioned this before, with the carrying capacity problematique.

Figures 7.7. : First Water Scarcity Index



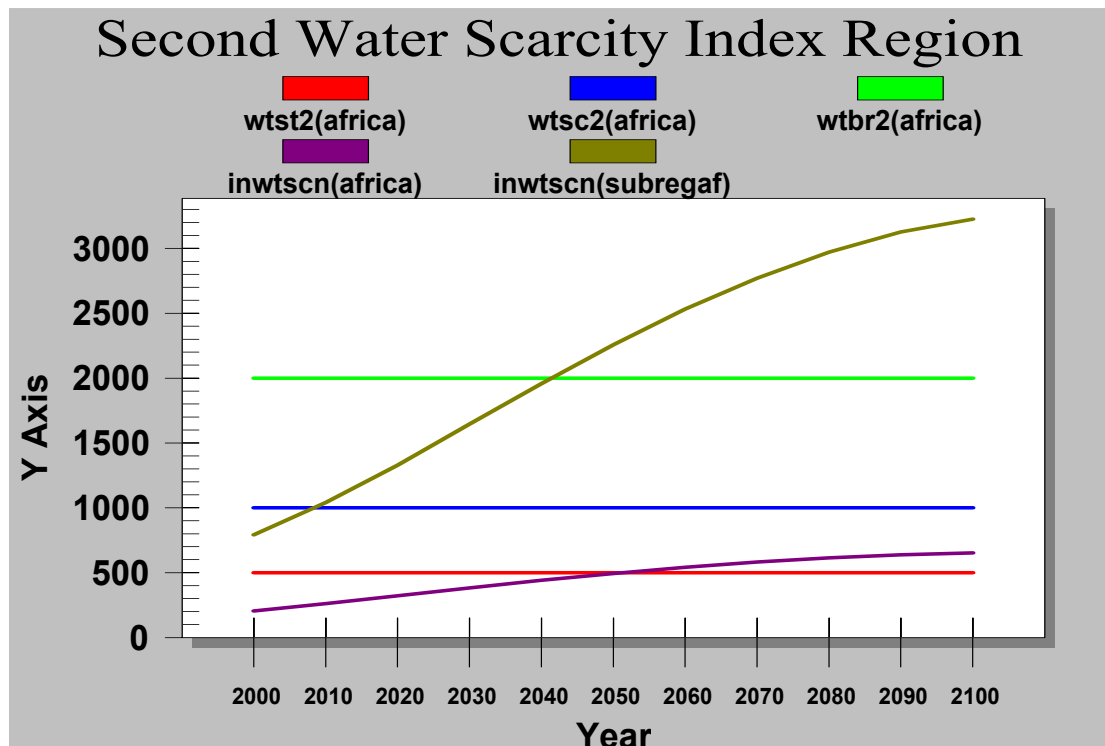
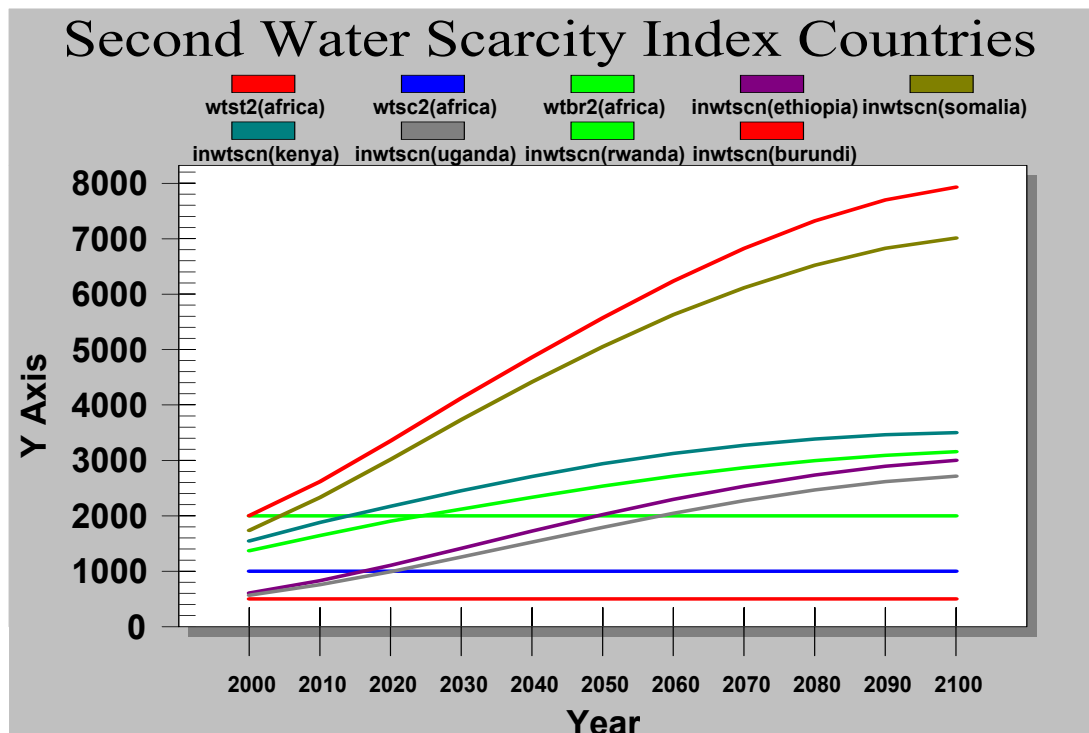
Totally consistent with the following Figure 7.8., 2025 projection represented in the map form,:

Figure 7.8.



Source: Gardner-Outlaw & Engelman 1997 (69) and Table 1

Figures 7.9.: Second Water Scarcity Index



As an especially significant last comment to these projections, we want to add here the following Figure 7.10., from a document that is being made available by the Population Information Network (POPIN), Gopher of the United Nations Population Division, Department for Economic and Social Information and Policy Analysis, in collaboration with the Population Program Service, Sustainable Development Department, United Nations Food and Agriculture Organization: POPULATION AND WATER RESOURCES (Population and the environment: a review of issues and concepts for population program staff I) September 1994:

Figure 7.10.

Countries of Africa classified by level of water competition (stress, scarcity and barrier) and level of agricultural intensification needed in 2025 for self-sufficiency, in agreement of the FAO/IIASA/UN report

	Technology for self-sufficiency:			
	Low level	Intermed. level	High level enough	High level not enough
Competition (P/FU):				
100-600	Angola Chad Cote-d'Iv. Zaire Zambia	Botswana Ghana Mali Sudan	Mauritania Namibia Niger Senegal	
Water stress (600-1000)		Benin Burkina F. Gambia Mozambique	Ethiopia Uganda	
Water scarcity (1000-2000)		Tanzania Togo Zimbabwe	Nigeria	Algeria Egypt Lesotho Libya Morocco Somalia
Water barrier (> 2000)		Malawi		Burundi Kenya Rwanda Tunisia

7.5. SOME TRENDS IN WATER RENEWABLE AND WITHDRAWAL AVAILABILITY AND USE

In general, on the continental level we can assume that the renewable freshwater solely depends on precipitation that falls on that continent since there are no water transported between each continent. The availability of the renewable and withdrawal water on a country level is more difficult to determine. This is because generally a country receives its water supply not only from the precipitation that falls on it (referred to as endogenous water) but also inflow from neighboring countries or upstream countries if they are in the same river basin (referred to as exogenous water). The amount of this inflow water depends on activities of upstream countries, i.e. how much water is withdrawn and returned to the rivers. Thus, the water that is available for a country like Egypt, which almost exclusively comes from the Nile, depends on how much water is withdrawn by Ethiopia, Sudan, and other upstream countries in the Nile river basin. If for development purposes these upstream countries are increasing their withdrawals, then Egypt will face water shortage. Unlike the case in the continent level where water available for each continent can be treated separately, water availability in countries that are located in the same river basin are thus not independent. This imposes a significant problem in determining water availabilities on a country level.

Nonetheless, information on renewable freshwater for most countries is available in a report by Gardner-Outlaw and Engelman [B.8.3.]. Another important source of data is from the publications World Resources Institute or, more recent [B.8.7.]. Note that the data for each country is optimistic, meaning real withdrawal by upstream countries is ignored. It is optimistic also in the sense that no distinction is made on stable and unstable runoff (flood), or on accessible and inaccessible water (e.g. inaccessible underground rivers). Although this simplification is not accurate, nonetheless this gives us an upper limit of what is available.

In the same source the information about current water withdrawal is also available.

The world used as much as 1,360 cubic kilometers of water in 1950. In next Figure 7.11., first we can see that it has increased threefold to 3720 cubic kilometers in 1990 -this is mainly due to the doubling of world population during this time period and increasing use of water per capita-. Second, we can see also the main forecasting on water withdrawal in 2025 by hydrology experts [B.8.7.].

Figure 7.11.

Year	Water withdrawal	Water consumption	Consumption rate
1950	1360	894	0.66
1970	2590	1540	0.63
1990	3720	2120	0.57
2000	3940	2206	0.56
2025	5000		

Here, water consumption is total water consumed through evapotranspiration process (irretrievable loss). For example, through the leaks in water distribution systems which then evaporates or transpired through plants. This loss of water accounts for about 60% of total water withdrawal. As we can see from the figure, this number has decreased simply because of increasing efficiency in distribution of water and other means of capturing the evaporated water.

On the continent level, Asia, which has more than 50% of world population, naturally leads in total water withdrawal (see Figure 7.12.). In terms of withdrawal per capita, Europe has had the highest growth for the past 40 years. This is mainly because of growth in industry. Figure 7.13. shows current, 1995, withdrawal per capita in all 6 continents.

Figure 7.12.

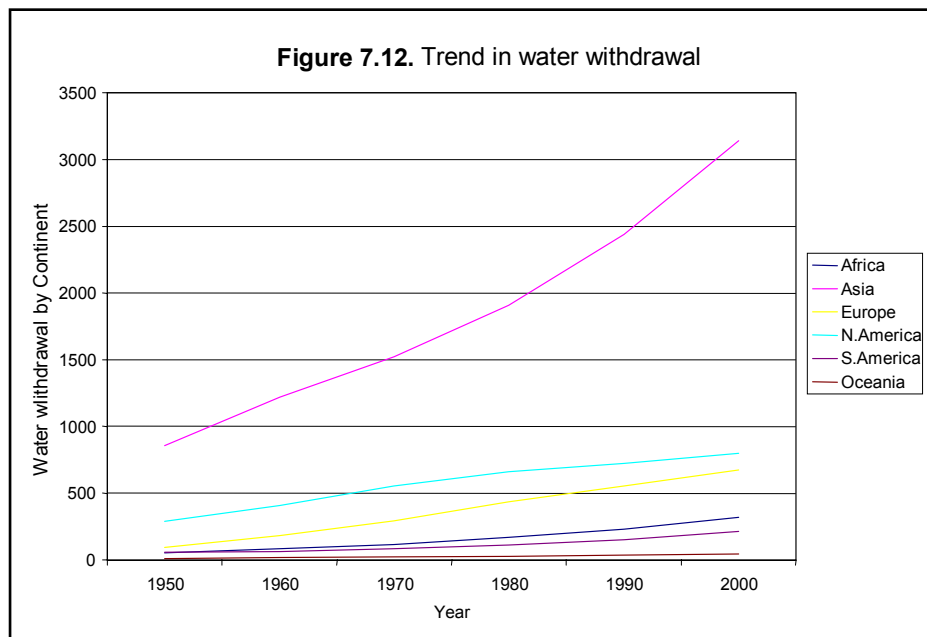
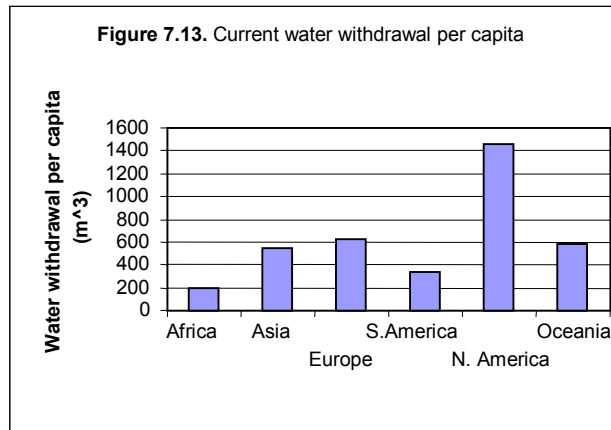
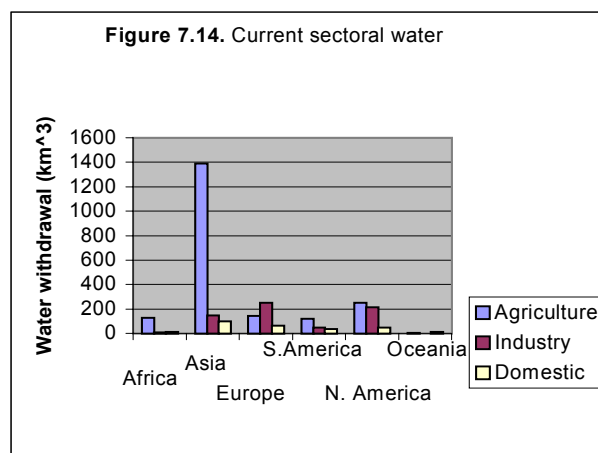


Figure 7.13.



Water is mainly used in three different sectors: agriculture, industry and domestic. Worldwide, agriculture takes about 68% of total withdrawal, followed by industry with 23% and domestic 9%. This distribution is more likely applicable to developing countries than developed countries where agriculture is still the primary sector of the economy (industrial water withdrawal in many developed countries accounts for more than 40%). More than 80% of water that is lost is due to evapotranspiration (consumed water) comes from agriculture. This is mainly because of traditional methods in distributing the water to the fields, primarily by gravitational system, which is very inefficient. Current water withdrawal for the three sectors in different continents as shown in Figure 7.14, indicates that Asian agriculture requires huge amount of water.

Figure 7.14.



7.5.1. WATER USE IN AGRICULTURE

Water is needed for agriculture to feed a growing population. Because of the variability of water available throughout the year, dams and reservoirs are built to capture the excess water during the wet season in order to have a more stable supply during the dry season. This is particularly important for some crops, which depend on irrigation to have a regular water supply. Although only 15% of total cultivated lands are irrigated, they contribute about 50% of crop production, making it clear that we depend extensively on irrigation for food production. Irrigation projects boomed during the 60's and 70's and started to slow down because of their high costs and the environmental damages. These environmental damages take the form of inundation by a reservoir behind a dam, displacing people, providing barrier for migration of fish, drowning forests, etc. Extensive use of fertilizers always follow irrigation contributing to decreased water quality.

Water requirement for irrigation varies among different regions because of differences in climate, land fertility, and water management. **In arid region such as Africa, we need as much as 25,000 cubic meters to irrigate 1 hectare of land**, where in northern Europe we need only as much as 5,000 cubic meters [B.8.13.]. **This fact together with the high population growth in Africa already put some countries in that region in a situation where water scarcity has become a major obstacle in development.**

Water demand for agriculture in the future will depend on changes in irrigation systems, primarily in technology to water the fields such as drip irrigation, surge irrigation, tailwater recycling systems, etc. Although the role of agriculture will decrease because of the estimated growth in industry and domestic services, the demand for water in agriculture will still be increasing due to expansion of irrigated land.

7.5.2. WATER USE FOR DOMESTIC PURPOSES

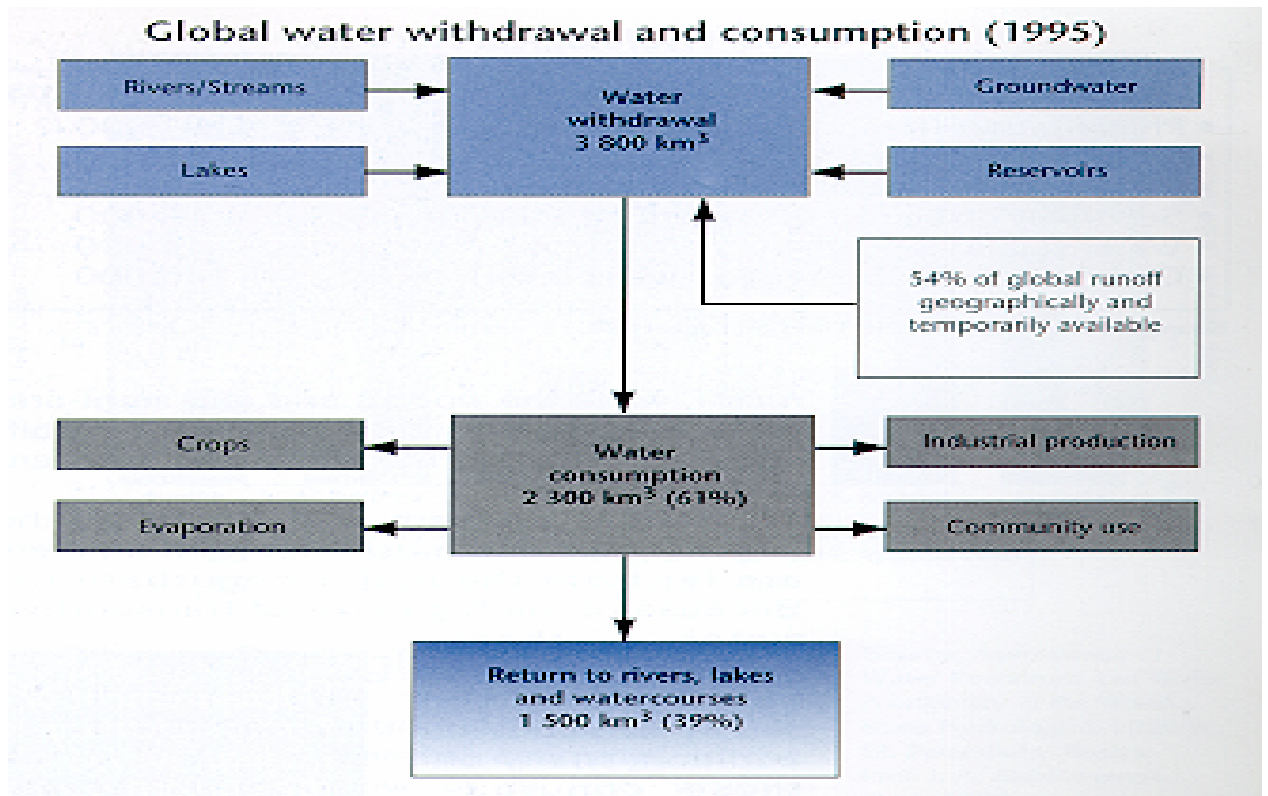
We use water for drinking, washing, sanitation, and other daily activities. Water supply in urban areas and cities is also used to clean the streets, watering the garden, and by other public services. Thus, as urban areas and their population grow in size, water demand also increases. This demand ranges from 300 - 600 liters/day per capita in many large cities with modern water facilities, to 10 - 40 liters/day per capita in regions where water scarcity occurs. At the UNESCO Conference on Water, June 3 - 6, 1998, Paris, France, 300 scientists from around the world adopted a resolution, asking every country (developing and developed) to assure a domestic consumption of 50 liters/day per capita as a minimum and equating this with human rights.

Water lost through evaporation is mainly due to the leaks in distribution systems. Better construction of water distribution systems in the near future will reduce the loss and thus the same amount of water withdrawn is able to support more people. It has been estimated in some urban centers in developing countries as much as 40% is lost through leakage and pilferage. Water withdrawal per capita is expected to increase in many countries, especially in region where demand for domestic purposes is given priority due to increasing levels of scarcity.

7.6. ANOTHER DIFFERENT POINT OF VIEW ABOUT THE CONCEPT OF WATER STRESS AND SCARCITY, STRONGLY RELATED WITH THE SUSTAINABLE DEVELOPMENT IDEAS AND/OR THE CAPABILITY POINT OF VIEW

From previous sections it should be absolutely clear that, in essence and in the world point of view, we have, on average, 41000 cubic Kilometers of renewable freshwater per year, with a maximum of 12500 cubic Kilometers (~30% of 41000) of future water withdrawal. In the year 2025 perspective, around 5000 cubic Kilometers (~10% of 41000) of water withdrawal, will correspond to a water consumption of less than 60% of this. See Figure 7.15. [B.8.17.].

Figure 7.15.



So other measure of scarcity level is also available. The approach that is used is somewhat different. Instead of dealing with absolute number dynamically related only with the population evolution, this index is expressed in terms of the ratio of water withdrawal to renewable water resources. Within the natural limits (probably the 30% of 41000 cubic Kilometers) we can try to use also or may be mainly in developing countries, as much water as possible. In other words, to

improve the withdrawal of water and the efficiency in the transport and distribution of it, it is obviously a general sustainable way to proceed, basically if we can use this for food-security, for example.

In other words, if we take into account the renewable freshwater, we also should have taken into account that we can use different ratios or different possibilities amount of withdrawal water -inside the proper limits-.

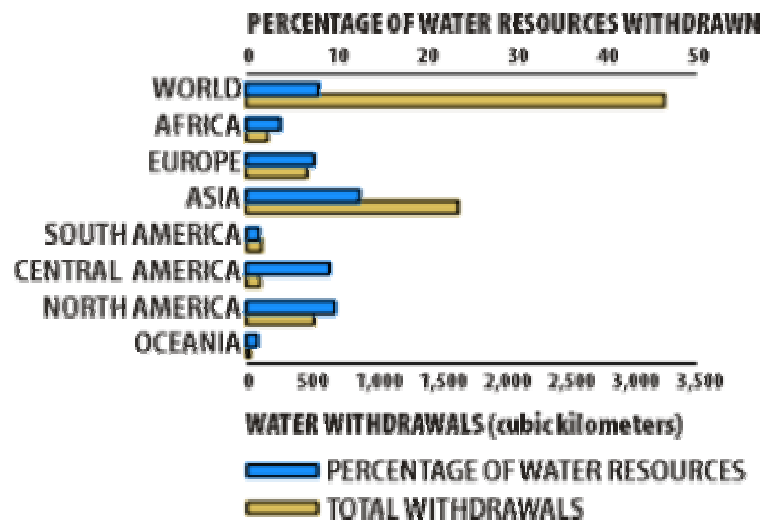
And independent of the index that relates total renewable water resources and population, we can also define another index that relates the utilization of water withdrawal with total renewable water resources. In fact, this index can give us more information about the relative capability to use the water, than the index on absolute level of scarcity.

Below is the actual definition of the index, quoted directly from different sources, i.e., [B.8.17.],:

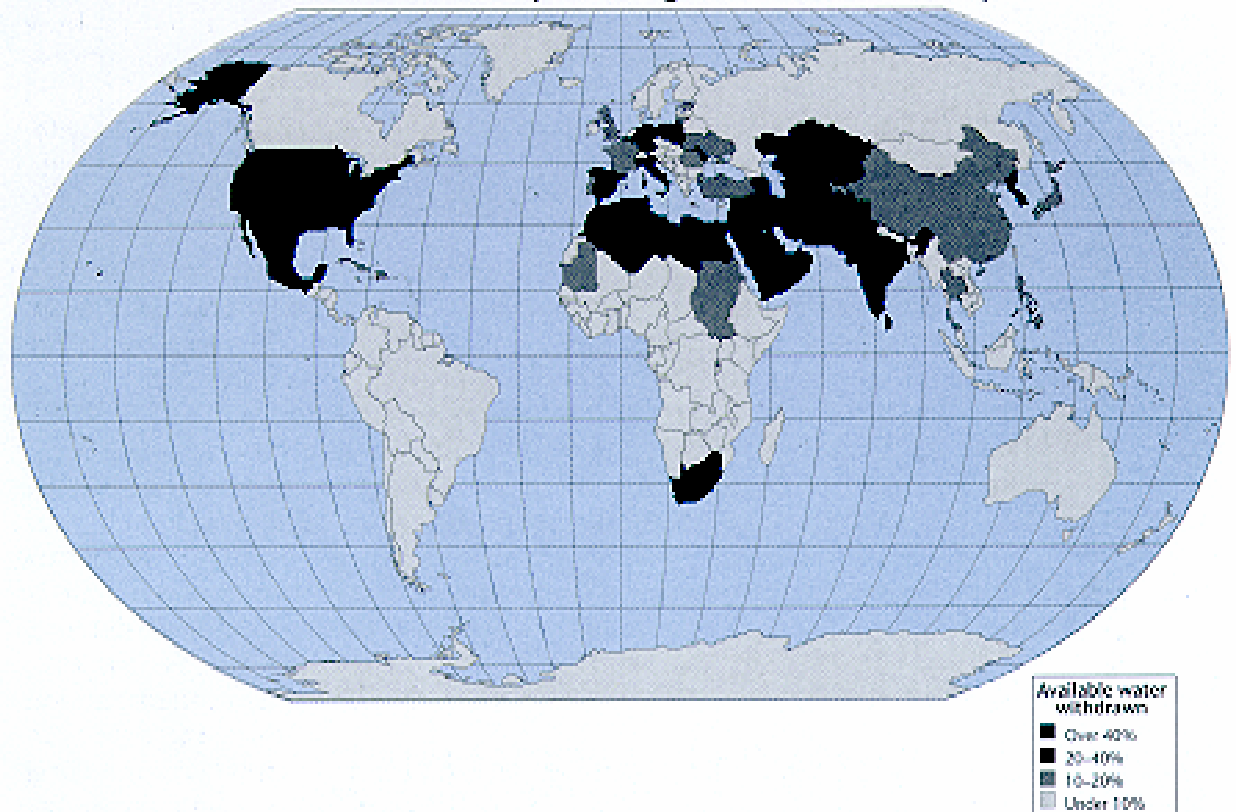
1. **Low water stress:** if a certain region or country uses less than 10% of its renewable water resources, then in general there is no problem of scarcity.
2. **Moderate water stress:** if a region or country uses 10 – 20% of its renewable water resources, then the problem of shortage is rising. Water management has to deal with reducing demand and increasing supply.
3. **Medium to high water stress:** if a region or country uses 20 – 40% of its renewable water resources, then scarcity becomes apparent. Water management needs to focus on patterns of use that ensure sustainability and the protection of ecosystems.
4. **High water stress:** if a region or country uses more than 40% of its renewable water resources, then the region is experiencing scarcity. Current pattern of use is unlikely sustainable and economic development can be limited by the scarcity problem.

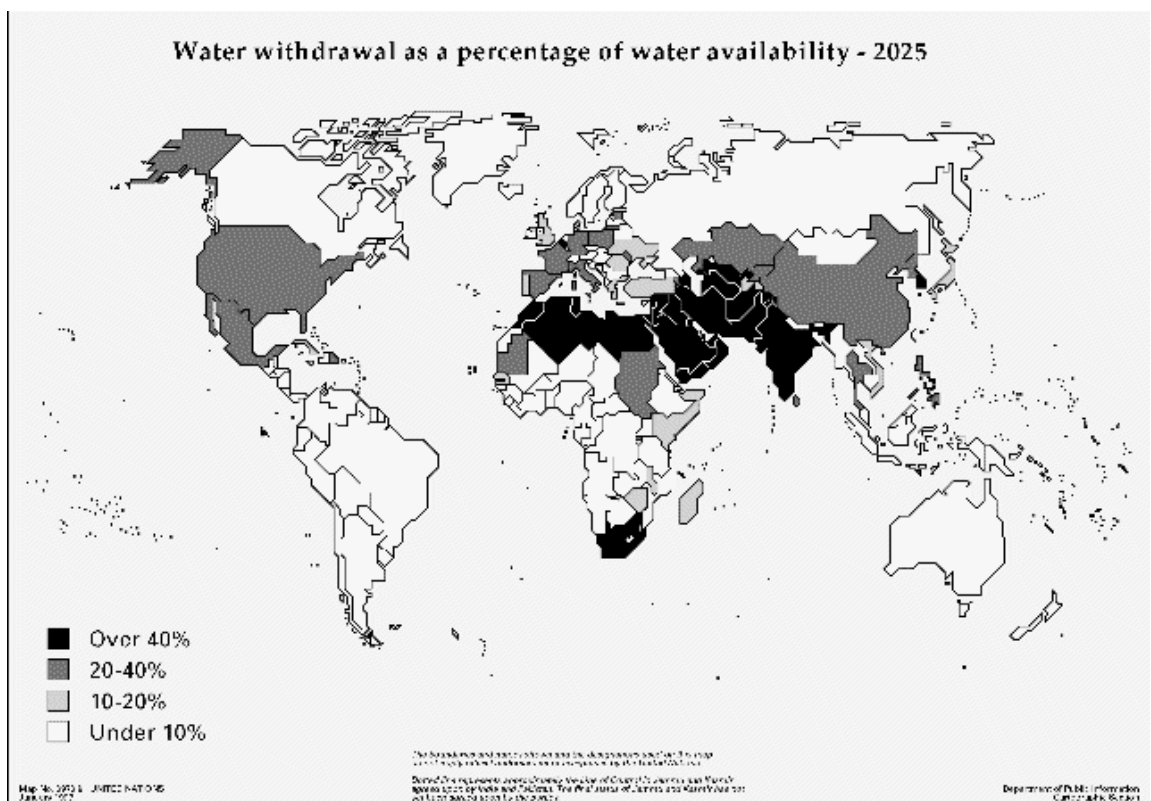
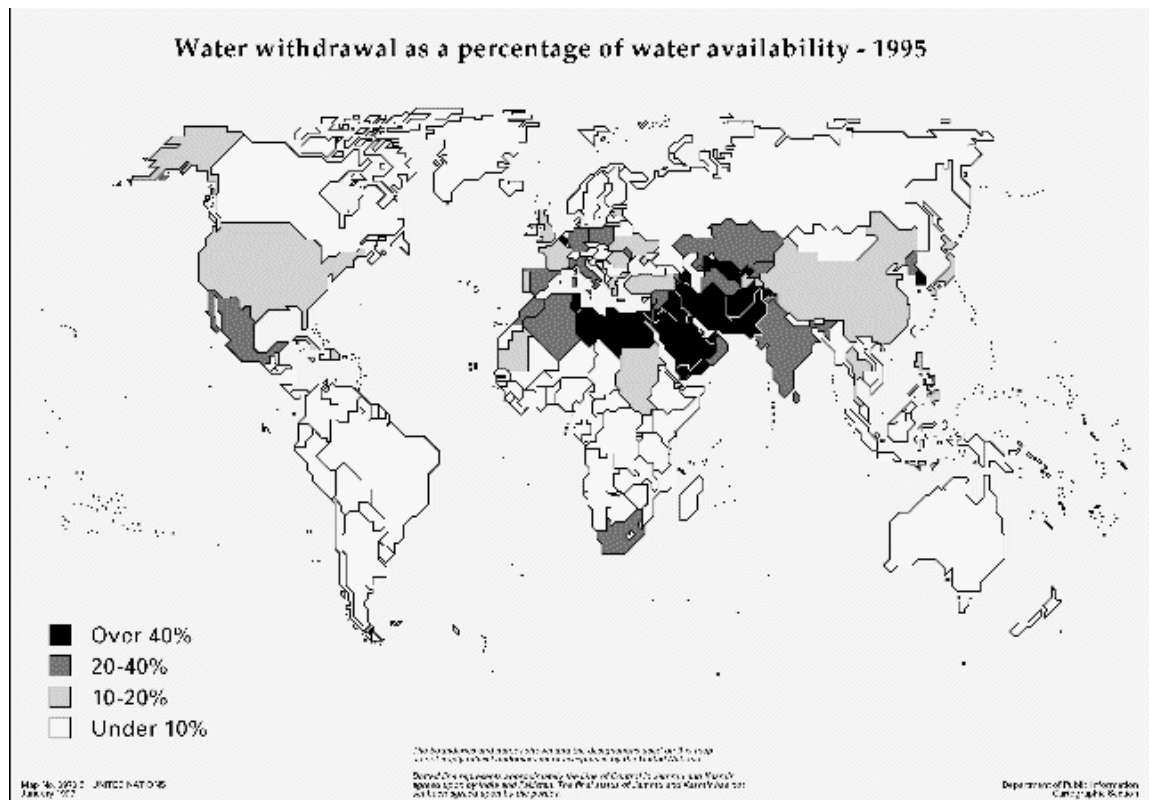
Related with this new third index are the following Figures 7.16:

Figures 7.16.



Water withdrawal as a percentage of water availability (1995)





7.7. THE CAPABILITY AND SUSTAINABLE INDEX'S OF WATER SCARCITY OF OUR CASE STUDY REGION; A POSSIBLE MORE OPTIMISTIC FUTURE PERSPECTIVE

Now we need to look at again, carefully, the data of our case study region on both, internal renewable water and water withdrawal.

And the application of the four stress levels according to these data is shown in Figure 7.17..

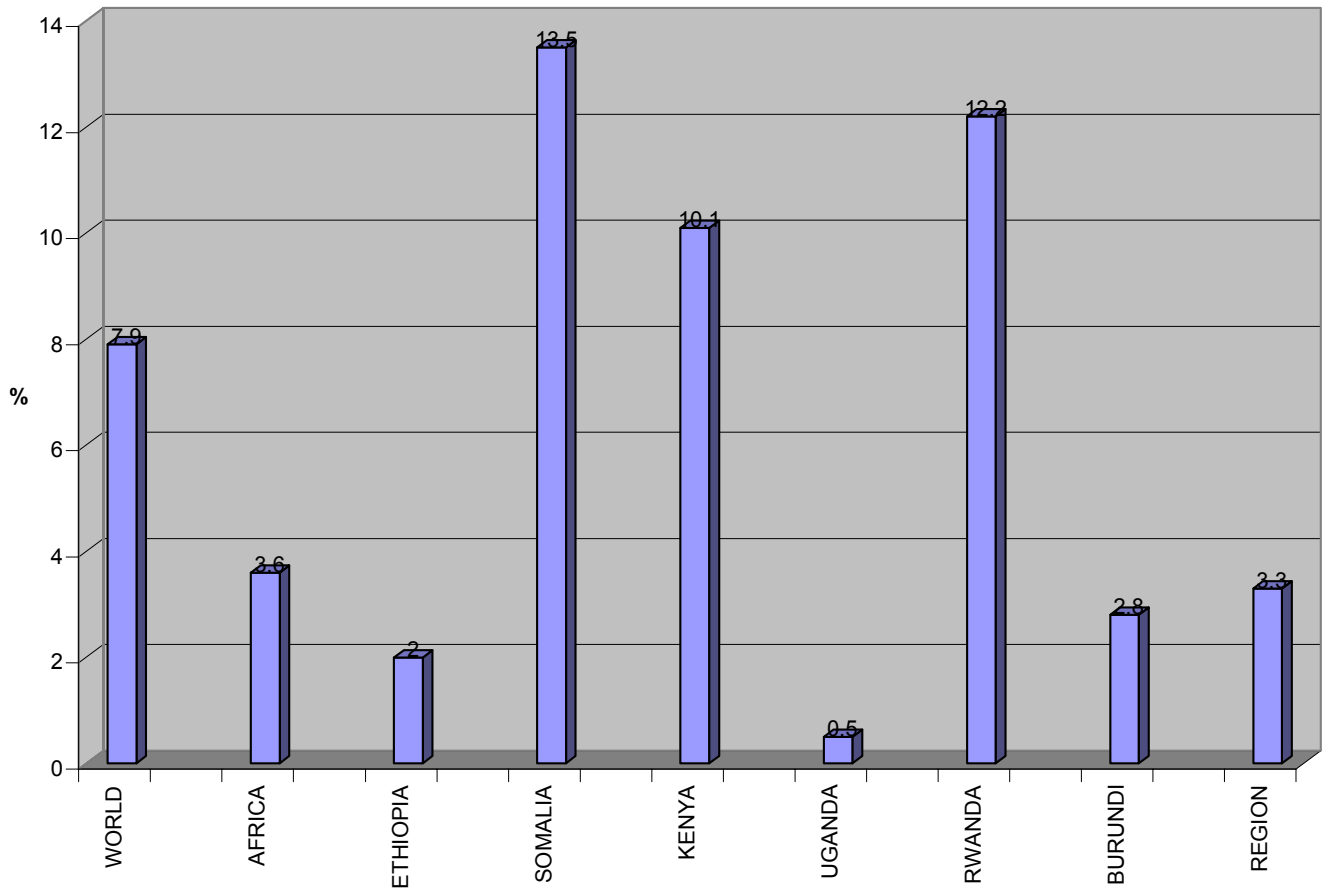
Figure 7.17.

	WTRNRS (Km ³)	WTWDT (Km ³)	WTD/WTNRS (%)	10% (Km ³)	20% (Km ³)	30% (Km ³)
WORLD	41022	3240	7.9	4102.2	8204.4	12306.6
AFRICA	3996	145.14	3.6	399.6	799.2	1198.8
ETHIOPIA	110	2.21	2	11	22	33
SOMALIA	6	0.81	13,5	0.6	1.2	1.8
KENYA	20.2	2.05	10.1	2.02	4.04	6.06
UGANDA	39	0.2	0,5	3.9	7.8	11.7
RWANDA	6.3	0.77	12.2	0.63	1.26	1.89
BURUNDI	3.6	0.1	2.8	0.36	0.72	1.08
REGION	185.1	6.14	3,3	18.5	37	55.5

And we can represent the fourth column as this capability and sustainable index's of water scarcity, or **the third water scarcity index**. If we remember the table of the figure 7.11., we can conclude, obviously, than the dynamical variation on time on this index has been really slow. So we will represent only the1995 index in the Figure 7.18.

Figure 7.18.

Third Water Scarcity Index (withdrawal/renewable)



It is useful to compare the order of the countries of our case study region in agreement with our first or second index and with this third index. The order is from the less scarcity to the most and is shown in Figure 7.19..

In conclusion although it is true that Burundi, from the point of view of the renewable freshwater per capita, is the worst country, from the point of view of the withdrawal possibilities it has the potential to improve a lot. Another significant example is in the case of Kenya and Somalia which are in the bottom position from the two point of views, but both also have possibilities to improve their water withdrawal potential.

Figure 7.19.

First or Second	Third
Africa	Uganda
Uganda	Ethiopia
Ethiopia	Burundi
Case Study Region	Case Study Region
Rwanda	Africa
Kenya	Kenya
Somalia	Rwanda
Burundi	Somalia

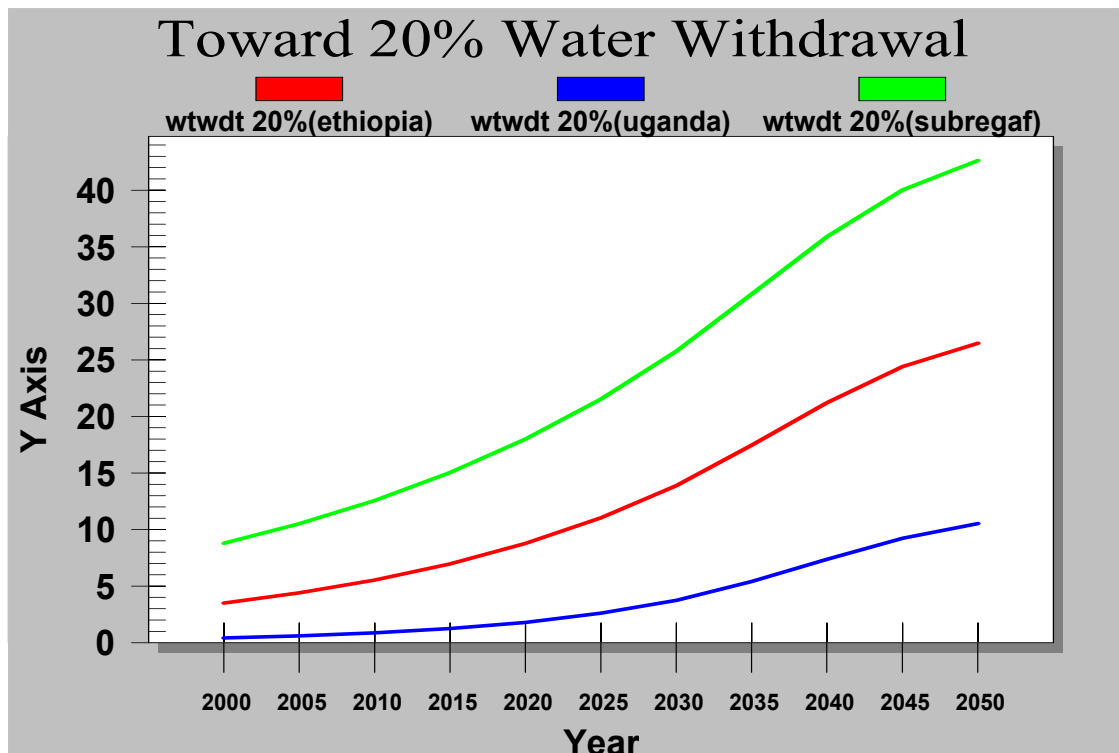
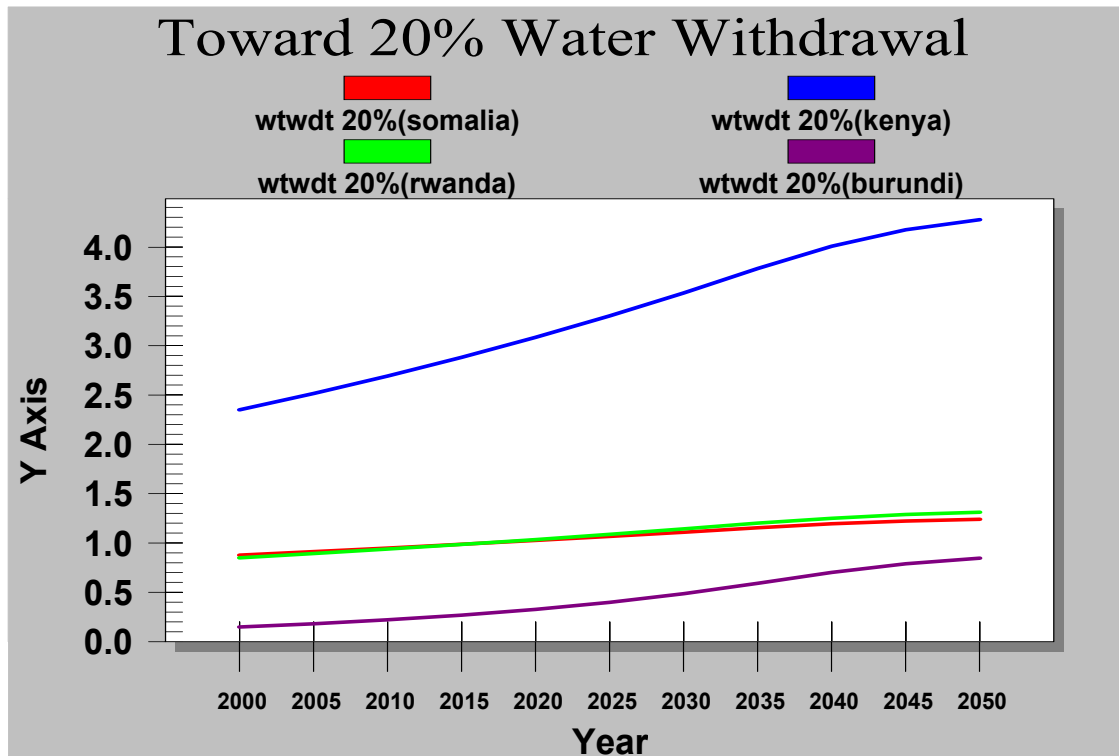
7.7.1. A DYNAMICAL APPROACH TO THE IMPROVE WATER WITHDRAWAL IN THE COUNTRIES OF OUR CASE STUDY REGION

According to the last ideas we can do the following assessments:

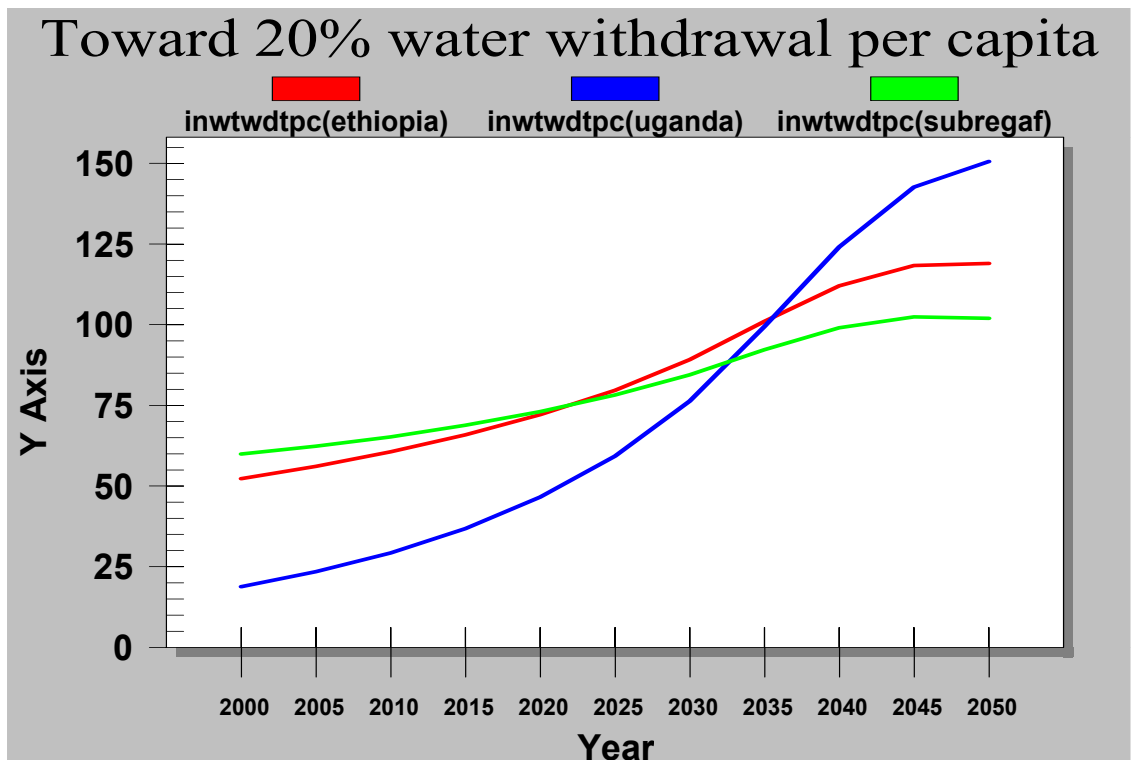
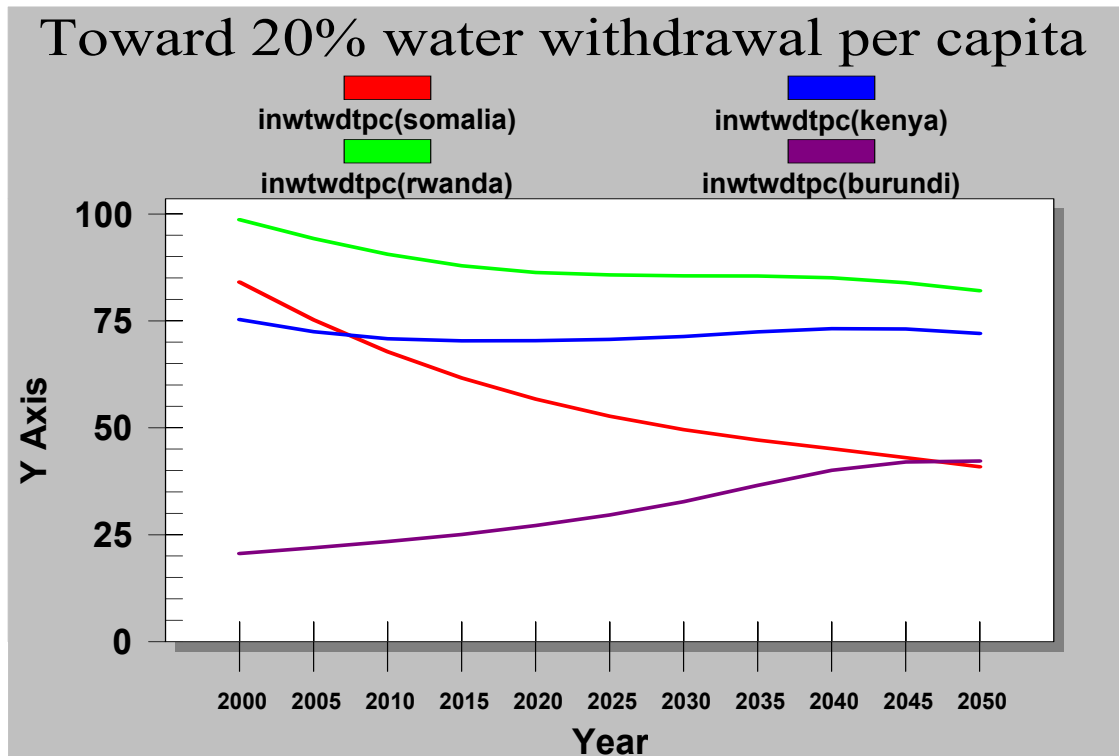
- 1) At the level of world and especially at the level of Africa we are far from the diverse potentials that we have presented. This amount can not be considered proportionally distributed around the world. Africa, and especially our case study region, is a very problematic area in this issue. But in spite of this we can consider different possible future scenarios, because although it is true that we are in the scarcity area, there are many more potential capacities to use the natural renewable water resources even though this is a semiarid or arid area. At least it is clearly a big challenge for them.
 - 2) Probably, as cited before directly from WB, the future scenarios are expensive, because of the necessary investments in infrastructures. But, how much does it cost for the actual and future human life there?
 - 3) Inside of sustainable capabilities we shall decide on some kind of combinations between population policies, water policies, land policies, etc.. It is quite sure that one of the most feasible and efficient policies (not necessarily from an economical point of view) will be the water option.
- 4) Using the model described below (which is formally identical to population and carrying capacity 1st level model), we have computed constant evolution rates like in the carrying capacity dynamical scenarios, but using scenario multipliers in order to reproduce a gradual saturation trends in achieving **the goals of 10, 20 or 30% of water withdrawal with respect to renewable freshwater. The following results are shown and will be used properly in the following sections of this work. They represent the dynamical actions that we can do in order to really use more water from their own natural resources.** Figures 7.20. show the scenarios with the 20% as the goal in 2050.

And in the last Figures 7.21. we can see that, except Somalia and Rwanda (the bottom countries from the point of view of our “third index”), with this policy to improve the water withdrawal we can, at least maintain (Kenya and Burundi) or indeed to increase significantly (Ethiopia and Uganda) the water withdrawal per capita over our future time period.

Figures 7.20.



Figures 7.21.



7.7.2. OUR WATER FIRST LEVEL MODEL

Figure 7.22.

```

/*****
*
* WATER RESOURCES, AVAILABILITY AND CAPABILITY MODEL
*
* from population 1st level model
*
*****/

/* Compute FIRST water scarcity index (water in cubic Kilometers) */

for (r=0; r<reg; r++) {
    inwtscs[r] = 1000*wtrsrn[r]/pops[r];
}

/* Compute FIRST water scarcity index for X region */

inwtscs[9] = 1000*wtrsrn[9]/pops_agg;

/* Compute SECOND water scarcity index */

for (r=0; r<reg; r++) {
    inwtscn[r] = 1000.*pops[r]/wtrsrn[r];
}

inwtscn[9] = 1000.*pops_agg/wtrsrn[9];

/* Compute THIRD water scarcity index */

for (r=0; r<reg; r++){
    inwtwtac[r] = 100.*wtwtac[r]/wtrsrn[r];
}

inwtwtac[9] = 100.*wtwtac[9]/wtrsrn[9];

/* Compute capability evolution of water withdrawal */

if (year > firstYear)
{
for (r=0; r<reg; r++) {
    rwtwdt[r] = swtwdt[r]*(1.+ rwtwdt[r]*rwtwdtm[r]/100.);
}
}

```

```
/* Compute per capita index water withdrawal total */  
  
if (year > firstYear)  
{  
  for (r=0; r<reg; r++) {  
    inwtwdtpc[r]= 1000*wtwdt[r]/pops[r];  
  }  
  
  inwtwdtpc[9]= 1000*wtwdt[9]/pops_agg;  
}  
  
for (r=0; r<reg; r++) {  
  /* Backup water withdrawal total */  
  swtwdt[r]=wtwdt[r];  
}
```