Water, Development, and Environment in Cuba; A First Look

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I. Introduction

This paper presents a preliminary look at the relationship between water, development strategies, and ecological issues in revolutionary Cuba. Using an integrated water management perspective that aims to minimize the environmental and economic disruptions associated with improper water usage, it examines Cuba's endowment of water resources and selected policies regarding their use, giving explicit attention to the degree to which the Cuban government has recognized the extent and significance of water-related development/environment interactions. The paper is our first attempt to look at these important issues and is part of broader research we are undertaking on the relationship between natural resources, economic development, and environmental quality in revolutionary Cuba. Many of the water problems we discuss antedate the revolution and were a source of concern by the 1950s. Our tentative conclusion, however, is that over the last three decades Cuba's development strategies have aggravated many of these water-related problems and created others.

The paper begins with an overview of the hydrological cycle and how natural and human interventions can disrupt its natural operation, including a brief discussion of how the integrated water management concept provides a framework that can be used to minimize the potential environmental damage that could arise from the improper use of this natural resource. Next, the paper assesses the determinants of water availability in Cuba. This is followed by a discussion of selected agricultural and water policies instituted by the Cuban authorities, and an evaluation of their environmental and economic consequences.

II. The Hydrological Cycle and Integrated Water management

Munasinghe (1992:34-40) provides a useful summary of how the natural hydrological process is affected by human intervention. Two premises underlie his analysis. One is that the satisfaction of man's water needs demands that the natural environment be altered. The second is that once water is used, it must be returned to the natural ecosystem. How water is returned to the environment has important consequences. It could contribute to the lasting use of water and other renewable resources, or the degradation of the natural resource base. Mishandling water supplies can also have detrimental consequences for a myriad human activities.

The hydrological cycle encompasses "a number of atmospheric, surface, and underground sub-cycles of different magnitude where water moves from and between the air, the vegetation, the soil, the solid rock, and the rivers, lakes and seas" (Munasinghe, 1992:35). The cycle is interactive, with every phase affected by the others. Precipitation rates are partly determined by evapotranspiration, or the process whereby water is returned to the atmosphere. Evapotranspiration depends on the vegetation's capacity to retain water; the ability of water to infiltrate different types of soils; the effect that the capillary action of the soil has on evaporation; and the amount of water that plants transpire through their leaves.

Water that filtrates underground accumulates and may result in a water table that rises to the surface as the amount of water percolating downwards increases. When water deposits are large in porous rock, an aquifer is created. Water moves within the aquifers depending on the permeability of the rock and other factors. Lakes, springs and rivers are formed in places where the water table meets the land surface. The way in which water flows and how it is stored depends on geographical and morphological features, including the surface vegetation and other landscape cover.

There are many points at which humans can intervene in the hydrological cycle. The care with which these interventions are managed, and the efforts made to ensure the renewability and preservation of water resources, to a great extent determines the long-term viability of the intervention, and the sustainability of the economic uses of water and other natural resources. Policies that permit the short-term exploitation of water resources at social, economic and/or environmental costs are ill-advised. These policies could bring about long-term, or even irreversible, environmental damage.

The objective of integrated water resource management is to minimize the environmental and economic disruptions associated with improper water usage. It depends on the careful calibration of selected policy instruments that balance national development objectives, the preservation of the resource, and competing demands and interactions among different water users. It involves the careful study of the hydrological system and how it is affected by man-made disruptions. Integrated water resource management is concerned with the promotion of freshwater sustainability by a careful assessment of the interplay between water supply and demand (Munasinghe, 1992:28-30).

III. Determinants of Water Availability and Quality in Cuba

As a sub-tropical nation, Cuba receives an abundant amount of rainfall. Cuba's mean annual precipitation, according to long-term observations, amounts to 1,410 millimeters (Egorov and Luege, 1967:15). The abundant rainfall only partially translates into a steady supply of freshwater, however. Major seasonal and cyclical rainfall fluctuations and the country's geographic features give way to periods of overabundance of water followed by periods of water shortage. The frequency and intensity of hurricanes has a major bearing on seasonal and secular fluctuations in rainfall.

With marked wet and dry seasons, the monthly rainfall ratio (the ratio of the wettest to the driest month recorded in millimeters of precipitation) may be as low as 8:1 (Table 1). In some years, the monthly rainfall ratio may be as high as 15:1, and in extreme cases (as in 1989), higher than 20:1. On average, rainfall between November and April, the dry season months, ranges between 32-99 mm per month, while during the rainy season it fluctuates between 200-260 mm (Egorov and Luege, 1967:15).

Annual rainfall fluctuations are equally substantial, with the volume of rainwater varying from year to year by as much as 30 to 40 percent (Table 2). During the 1970s and 1980s, the annual average amount of rainfall was about 1330 and 1160 mm, respectively. Whereas in 1980 Cuba's mean precipitation was 1,434 mm, in 1981 it dropped to 1005 mm (70 percent of 1980 volume) and to 937 mm in 1986 (65 percent of 1980 volume).

Regional fluctuations in mean precipitation are notable as well. Mean annual rainfall ranges from 3,000 mm in the mountainous region of Northeast Cuba, to under 600 mm in the semi-desert Southeastern coastal region found between the Sierra Maestra mountain range and the Caribbean sea. As a general rule, rainfall tends to be relatively more abundant in the Western and Central plain regions than in the Eastern plains, and most abundant of all in the mountain ranges.

Cuba's elongated and narrow shape, insular character, and extensive coastline (2,306 miles or 3,735 kilometers) accentuate the cycles of water overabundance and water scarcity. Most rivers flow from the center of the country to either the Northern or Southern coasts, and rainwater reaches the seas within at most a few hours (Report of Cuba, 1976:59). Watersheds are geographically limited, with a majority of rivers having a short course. The mean length of all major Cuban rivers is only 58 miles (93 kilometers). The Cauto river, the country's longest and most voluminous, has a length of 228 miles (370 kilometers), the Sagua la Grande and Zaza about 100 miles, and all other rivers run for less than 100 miles (Table 3). Due to the short course of the rivers, and the rapidity with which rainfall reaches the sea, much rainfall cannot be captured by aquifers. Comparable problems have been reported in Indonesia, a country that shares many of Cuba's geographical features. For example, Java's watersheds are described as extremely shallow, with most of its rivers less than 50 kilometers long. These characteristics, together with deforestation and rural development, are responsible for rapid runoff and increased river flow variability (World Bank, 1990:79).

Eighty percent of the total flow of Cuban rivers occurs during the rainy season (Osterling, 1985:67). In the dry season, many of the rivers and hundreds of streams experience a complete loss of water flow. In some parts of the country, the nature of the soils contributes to rapid runoff due to their limited permeability. On the other hand, in low-lying coastal areas, often at or below sea level, flooding is a persistent problem. In many parts of the country, flooding is a serious concern during periods of intense rain and the hurricane season.

Two other factors contribute to rapid rainwater loss: high temperatures and prevailing wind patterns. A high evapotranspiration rate is associated with the country's tropical climate. The mean annual temperature is 25.5 degrees centigrade (Osterling, 1985:69). Monthly mean temperatures only fluctuate within a narrow band (from 22.5 degrees centigrade in the coldest month, January, to 27.8 degrees centigrade in the hottest month, August). Mean annual evaporation experimentally measured from a free water surface amounts to 1,995 mm, ranging from over 2,000 mm in the rainy season to about a 1,000 mm in the dry season (Report on Cuba, 1976:47; González and Gagua, 1979:29). The pattern of persistent winds prevailing in most of Cuba further contributes to high evaporation rates. Less is known about evapotranspiration rates, but some of the highest are believed to occur in the Cauto river watershed due to the combined effects of high temperatures and persistent winds. These high water losses promote the salinization of the soil by drawing to the surface underground waters that leave behind mineral deposits as they evaporate into the atmosphere (Egorov and Luege, 1967:15).

A major man-made contributor to rainwater loss is the extensive deforestation to which Cuba has been subjected since colonial times. Tropical soils' capacity to retain water is impaired when the natural forest cover is lost. Forests also contribute to the reduction of evapotranspiration rates. One of the most direct consequences of deforestation is an intensification of the runoff rate, with a consequent detrimental impact on soil conservation. Whereas in 1812, 90 percent of Cuba was forested, by 1975 this percent had declined to 18 percent (Instituto Cubano de Geodesia y Cartografía, 1978:40). By the mid-1970s, forested areas were mostly confined to the least inaccessible and inhospitable mountainous and swampy coastal regions. The last three decades have seen considerable reforestation efforts, but how much has been accomplished is open to debate (Espino, 1993:331).

The abundant annual rainfall contributes to the replenishment of the country's aquifers. However, water capacity in Cuba's aquifers varies greatly as does the quality of their waters (Academia de Ciencias de Cuba/Academia de Ciencias de la URSS, 1970:13-13 and 22-23). Geographically, the country's richest aquifers are concentrated in two regions. The first includes the aquifers running throughout much of the carsick soils (suelos cársicos de fisura) of Western Cuba, from Pinar del Río province to much of Matanzas province (except for the Zapata swamp), and into Northern Villa Clara province. The second is located in the concentration of carsick soils extending through most of Sancti Spíritus and Ciego de Avila provinces, and parts of Camagüey and Las Tunas provinces. Carsick soils are found in more than 60 percent of Cuba's land surface (Dos requisitos, 1982:79).

Water-rich, carsick aquifers can easily become contaminated. This is especially so in aquifers lacking surface areas capable of containing the filtration of pollutants (González Báez and Jiménez Hechevarría, 1988a:6). Contaminants spread swiftly in carsick aquifers since they allow a rapid displacement of underground waters (González Báez and Jiménez Hechevarría, 1988b:24). This feature of carsick soils is a serious problem in Cuba, since many of the country's principal aquifers are located in carsick soils along coastal areas, prone to be infiltrated by salt water.

The regions most poorly endowed with underground water resources are Pinar del Río province in Western-most Cuba; Ciego de Avila province and the bulk of Sancti Spíritus province in Central Cuba; and the Eastern-most provinces of Granma, Holguín, Santiago de Cuba and Guantánamo. Cuba's mountain ranges are primarily located in these regions with relatively poor endowment of underground water; the country's geographical pattern of alternating mountain ranges and plains contributes to the replenishment of the aquifers in the plains, since they receive part of the rainwater flow from the precipitation in the mountain regions (Egorov and Luege, 1967:14).

There is enormous variation in the mineral content of Cuba's underground waters. Waters are classified according to their mineral content expressed in grams per liter of water (Egorov and Luege, 1967:9). Waters with one gram or less of minerals per liter of water are adequate for all human and agricultural uses; those with mineral content up to 3 grams per liter may also be used for human consumption, in the absence of water with lower mineral content and for watering livestock; those with mineral content 3-10 grams per liter are not suitable for human consumption, though they may be used for livestock; waters with mineral content 10-50 grams per liter or even higher are unfit for human (other than for medicinal purposes) or agricultural use. In Cuba, the supply of water with low mineral content is deemed to be abundant in the carsick aquifers, but less so in regions with clay soils or soils with limited permeability.

The same is true for coastal regions. In coastal regions of Southwestern Cuba, the Zapata swamp, and the Northern coasts of Sancti Spíritus and Ciego de Avila provinces, the aquifers' mineral content tends to be high. In some of these regions, deposits of low-mineral content water suitable for human and agricultural use are found above stores of marine water (Egorov and Luege, 1967:9). This makes the danger of excessive salinization of coastal region aquifers high, a danger made more immediate by flood-prone soils that are often at or below sea level. The aquifers in the Cauto river watershed area, with a limited capacity to hold underground water stores, already have a heavy mineral load.

From an international perspective, Cuba's renewable water resources of 3.34 thousand cubic meters per capita in 1975 were about half the world average of 7.69 thousand cubic meters per capita and well below the average for North and Central America (16.26 thousand cubic meters) and South America (34.96 thousand cubic meters). Cuba's relatively limited freshwater availability per capita is similar to that of other major Caribbean islands (2.79 in the Dominican Republic; 1.69 in Haiti, and 3.29 in Jamaica) (World Resources Institute, 1992:328).

Where Cuba differed from the other large Caribbean island-nations, at least up to the mid-1970s, was with respect to the rate at which freshwater resources were withdrawn. In Cuba, as in most island-nations not receiving freshwater flows from neighboring countries, annual withdrawal of freshwater resources is calculated as a percentage using as a base internal renewable resources, exclusive of evaporative losses (World Resources Institute, 1992:334). In 1975, Cuba was withdrawing an estimated 23 percent of its freshwater resources annually (8.10 cubic kilometers), as compared to 15 percent in the Dominican Republic (in 1987), 4 percent in Jamaica (1975), and less than one percent in Haiti (1987). Only water-poor Barbados (in 1962) withdrew water at a higher rate than Cuba, 51 percent. The per capita volume of water withdrawal in Cuba in 1975 (868 cubic meters) was nearly twice as high as that of the Dominican Republic (453 cubic meters), and from five to twenty times as high as in the other island nations (46 and 157 cubic meters in Haiti and Jamaica, respectively). At the time, 89 percent of the freshwater withdrawn in Cuba was dedicated to agricultural uses, 9 percent for domestic use, and the balance to industrial use. In 1990, the annual water withdrawal had increased to 12.7 cubic kilometers, or to 1,200 cubic meters per capita, with 74 percent of the water being used for agriculture, 12 percent for domestic use, and 14 percent for industrial use (Espino, 1993:332). By 1982 it was already apparent that important economic regions of the country such as the provinces of Havana, Ciudad Habana, and Ciego de Avila were at or about a point at which water demand exceeded the supply. In three rice cultivation regions in the provinces of Pinar del Río, Camagüey, and Granma, underground water demand was already excessive

(Administración, 1982:35).

IV. Water Resources Management in Cuba

Active involvement in the management of water resources by Cuba's revolutionary government began in 1962 with the creation of the Institute of Hydraulic Resources (Instituto Nacional de Recursos Hidraúlicos, INRH) (Administración, 1988:31). The management of water resources went into high gear in the late 1960s and early 1970s with the implementation of an ambitious agricultural development program aimed at increasing output of sugar cane and other water-intensive agricultural products (MacEwan, 1981:98-99), and the supply of water for human and industrial use. In 1977, Cuba established an Institute of Hydroeconomy (Instituto de Hidroeconomía), within the Ministry of Construction, to coordinate the development and administration of water projects involving other government agencies, such as the Ministry of the Sugar Industry, the Ministry of Agriculture, and Local Organs of People's Power (with regard to household consumption of water).

Central Planning and Water Pricing Issues

Cuba's seemingly inexhaustible demand for water is, in part, the result of its system of central planning. Under a central planning system, resources are allocated on the basis of a central physical plan rather than on their price (cost). That is, central planners determine a priori the volume of water that will be required to meet demand (from agriculture, household use, industrial plants, etc.) and command other branches of the economy to provide the required volumes, without explicitly taking into account the cost of obtaining and delivering the water to the user. The central planning system is also largely oblivious to environmental externalities. State enterprises are not held accountable for environmental cost or handle them through soft budget constraints cushioned by the central government (Dávalos, 1984a, 1984b, 1984c, and 1984d).

At least through the early 1980s, water was a free commodity in Cuba (Report of Cuba, 1976:56). Writing in 1982, the President of the Institute of Hydroeconomy (Dorticós, 1982: 13 and 18) argued for the institution during the 1981-85 five-year plan of a system that would set a price for water, and charge state enterprises that used water for what they consumed. Such a system would promote conservation and more efficient use of the resource. He further argued for the ability of water providers and users to enter into contractual relationships, subject to the commercial code and the national system of commercial arbitration, to ensure that users actually paid for the water they consumed.

The five-year plan for the period 1981-85 (Lineamientos, 1981:73) had as an objective the "adoption of measures to attain and guarantee the more rational use and conservation of water resources, whether surface or underground," but there is no evidence that a water pricing system was introduced during this period. The plan for the period 1986-90 (Lineamientos, 1986:50) was even more cryptic than its predecessor on water pricing, calling instead for "preserving and controlling the quality of surface and underground waters, achieving their rational use, and increasing their conservation and recycling (reutilización)."

Water Demand and Supply Issues

As mentioned above, in the late 1960s and early 1970s, Cuba embarked on an ambitious irrigation program that has relied heavily on: 1) developing a network of water storage areas through a major dam reservoir construction program; and 2) increasing the extraction rate of underground water. The water storage areas were also designed for the artificial recharge of aquifers since there was concern about the high rates at which water was being withdrawn from underground stores. The irrigation strategy was intended to increase production of the country's export mainstay --sugar cane-- and also to boost the cultivation of other products, prominently among them citrus and rice. The planned major expansions in the output of these three crops, all prodigious users of fresh water, could only be sustained with additional water supplies, particularly during the dry season.[2]

Expanding the agricultural land surface under irrigation was a development priority during the 1970s, but even more so during the 1980s. According to a source, by 1985, 220,182 caballerías (2.95 million hectares) were irrigated (exclusive of land planted with rice), more than a quarter of Cuba's agricultural land (Analizan la situación, 1985:3). In relation to 1983, the amount of land irrigated in 1985 was 40 percent higher. If true, this would constitute a remarkable achievement in just two years.[3] Expanding the irrigated area demanded the investment of hundreds of millions of pesos in equipment, machinery and wells. The 1986-90 Cuba-USSR cooperation agreement alone assigned 40 million rubles for the expansion of the national irrigation system.

Since the 1970s, the demand for water has mushroomed with the growth of the country's system of urban aqueducts; an estimated 74.1 percent of dwellings had access to running water in 1980 compared to 54.5 percent in 1953 (Rodríguez and Carriazo Moreno, 1987:141). Also taxing water resources were the establishment or expansion of mining operations (e.g., nickel) and industrial plants (e.g., cement) that are heavy water users and contaminate the environment. These development initiatives have further strained Cuba's freshwater resource availability with potential long-term economic and ecological consequences.

To satisfy the increasing demand for water, an extensive dam construction program has been implemented. Increasing water availability in man-made reservoirs was consistent with the mobilization of resources to meet production targets and minimize water shortages during the dry season. The dam construction strategy was also consistent with Fidel Castro's personalistic style of government and the weight of his views in the country's development policies. The role of Castro in the country's water development policies --as in so many other national issues-- should not be underestimated, since in 1962 he asked "that not a single drop of water be lost, that not a drop of water reach the sea...that not a single stream or river not be dammed" (El paisaje, 1982:52). Damming Cuba's rivers and mobilizing the country's water resources became a national priority. Castro's wishes began to be translated into reality with the initiation in 1962 of an extensive Soviet water-related technical assistance program (with heavy Bulgarian input). In the fifteen year period between 1976 and 1990, it was projected that Cuba would invest between 10.4 and 16.8 billion pesos in hydraulic works (Report of Cuba, 1976:57). By 1992, Cuba had 200 dams and close to 800 microdams (COMARNA, 1992:16).

Whether or not the current water freshwater withdrawal rate is higher than the 23 percent reported in 1975 cannot be determined with exactitude, but it would seem that the withdrawal rate must have declined as a result of the increase in the amount of water being held in artificial reservoirs. The dam and water reservoir construction program increased the stored water capacity from 48 million cubic meters in 1959 to 7,000 million cubic meters in 1987, or by a factor of nearly 150 (Editorial, 1988). This enormous gross gain in reservoir capacity, however, would have to be evaluated against the potential decline in the volume of water being held in aquifers, despite reported artificial recharge efforts. Underground water losses could be anticipated as a result of the diversion of surface and underground water sources from aquifers to man-made reservoirs, and also from the contamination of freshwater aquifers by sea water. To this may be added further underground water losses associated with the increasing extraction of aquifer stores for irrigation and other uses.

V. Environmental Impact: A Preliminary Assessment

The Cuban technical literature suggests that there is increasing concern in the country about the adverse environmental consequences of damming the country's rivers. A major worry is that the low volume of freshwater flowing below the dams alters nature's ecological balance by drastically reducing the water's oxygen level and the amount of freshwater reaching the coasts. Equally troublesome are sea water intrusions made possible by reduced freshwater flows. In some cases, sea waters may even reach the dams' walls. As a result, the rivers' beds and adjacent fields have become contaminated by salts (Tapanes, 1981:39).

Historically, water had been extracted from some of Cuba's major aquifers at a higher rate than they were recharged, but in recent years the pace of water extraction appears to have intensified. Reports of salt water intrusions along coastal areas suggest the overexploitation of underground fresh water stores (World Bank, 1992:47). Surface waters diverted into man-made reservoirs can interfere with the natural recharge of aquifers. High evaporation rates from tropical region reservoirs can have adverse environmental impacts by increasing the concentration of minerals in irrigation water. If proper drainage and flushing practices are not followed, the high mineral content of irrigation waters and their rapid evaporation while flowing through irrigation canals and in the fields can contribute to soil salinization. Some of these issues are examined below.

Contamination of Surface Waters

Surface waters have been contaminated by industrial wastes and by the chemical runoff associated with the use of increasing amounts (before drying up of imports during the Special Period) of chemical pesticides and herbicides. There is ample evidence of dumping of industrial wastes in rivers and bays (see, for example, Dávalos, 1984a, 1984b, 1984c, 1984d; Emprende, 1985). González Báez and Jiménez Hechevarría (1988b:18-24) have pointed out to sugar mills as the main source of pollutants, although untreated urban sewage, industrial pollutants, and agricultural chemical inputs are also to blame. Seventy percent of the gross weight of the sugar cane processed in the mills is water, and another 15 percent is bagasse (Varela Pérez, 1976). The contamination of Havana harbor has received the most attention (United Nations, 1985), but many other Cuban harbors are equally polluted (Schlachter, 1990; Solares, 1993:16).

The amount of chemicals used in agriculture was projected in 1976 to increase from one million tons to between 8 and 12 million tons by 1990-2000 (Report of Cuba, 1976:54). Such chemical contamination decreases the usefulness of water for human and agricultural uses. The World Bank's (1992:47) global review of environmental issues in development concluded that "it is often more important to prevent contamination of groundwater than of surface water. Aquifers do not have the self-cleansing capacity of rivers and, once polluted, are difficult and costly to clean."

The reduction in water volume carried by many rivers, particularly during the dry season, is having adverse environmental consequences. In Cuban rivers with no or little runoff during the dry season, "sewage volume can surpass several times the stream flow" (Report of Cuba, 1976:54). The diversion of surface waters for irrigation and other uses is implicated in the increased pollution of many of Cuba's rivers. The resultant reduction in water flow aggravates the contamination of the rivers, an old problem in Cuba, since the rivers lose part of their capacity to carry away or dilute contaminants. For decades, sewage and industrial contaminants from urban areas and the sugar cane waste products generated by sugar mills in rural areas were directly discharged into rivers and streams. This problem is reported to have affected numerous rivers, including the Almendares (Emprende ciudad, 1985; Gumá, 1989), Luyanó (Gómez, 1985), and Quibú (Hernández Pardo, 1975). Surface pollution eventually reaches underground water stores.

Similar problems are reported in other parts of the country as the number and capacity of water reservoirs has increased, river flows have declined, and the discharge of organic material and other pollutants increased. Reduced water flow also contributes to a higher sedimentation rate in rivers. In Cuba, the danger of contaminating underground waters is high since the carsick aquifers found in much of the country facilitate the flow of large amounts of subterranean waters (La contaminación, 1975).

Contamination and Losses of Underground Waters

By 1976, Cuba was already reporting that the country's major environmental problem was the intrusion of salt waters along coastal areas (Report of Cuba, 1976:58). A 1980 report (Shayakubov and Morales, 1980:10-11) remarks that the scope of this problem was alarming. All along Cuba's southern coast, the inland intrusion of salt water reached between 2 and 15 kilometers. Official sources attribute this environmental damage is attributed to the indiscriminate use of underground water for irrigation prior to the revolution. This is not a convincing argument, however, since prior to the revolution, irrigation was relatively sparingly used in Cuba. Whereas in 1958, 160,000 hectares were being irrigated, by 1982 land under irrigation had increased to 900,000 hectares, or by a factor of six (Riego, 1982:63).

The diversion of rainwater into reservoirs and a high rate of extraction of underground freshwater is associated with the salinization of aquifers along the coastline. The best documented case concerns the aquifers bordering the low-lying coastal region of Havana province (Salazar, 1991). This aquifer supplies water to some of Cuba's richest agricultural regions (e.g., Güira de Melena) and the city of Havana, contributing 200 million cubic meters per annum of water for human and agricultural uses.

In 1985, an underground dyke (Dique Sur) of approximately 100 kilometers in length, running from Majana in the West to Batabanó in the East, with a width of seven meters and a depth of between two to four meters, began to be built. Its objective is to arrest the inland infiltration of saltwater--and prevent freshwater losses to the seas--by impeding water flows in either direction, thus contributing to the replenishment of the aquifer with freshwater. The design of the dyke includes drainage canals to facilitate the flow of excess surface water during the rainy season. It is claimed that by 1991 the Dique Sur had helped reduce the freshwater runoff by 90 percent, and the level of salinization in the aquifer declined from 4.44 grams per liter in 1982 to one gram per liter in 1991, making the water suitable for human consumption. This claim seems to be an exaggeration considering that contamination of underground water resources is very difficult to reverse.

The location of this aquifer and its history suggest that the salt water intrusions may have resulted from three main causes: (1) the diversion of groundwater that normally would replenish aquifers to reservoirs; (2) the continued excessive drawing of aquifer waters to serve the needs of the city of Havana; and (3) the increasing use of aquifer water for irrigation. Between 1970 and 1988, 16 reservoirs, with a total capacity of 458 million cubic meters of water, were built in Havana province (Comité Estatal de Estadísticas, 1989: 175). In the neighboring province of Pinar del Río, during the same time period (1969-89), 21 dams with a total storage capacity of 832 million cubic meters were constructed. Some of these reservoirs were to provide water to urban populations, but mostly were built to irrigate crops with high water consumption, such as sugar cane, citrus, and rice.

In recent years, in an attempt to increase the country's self-sufficiency in rice, one of Cuba's main food staples, large-scale cultivation of this very water-intensive crop with a fairly high tolerance to salty waters has been expanded (Colina and Peláez, 1976). While under the right circumstances rice cultivation may contribute to the desalinization of the soil, this crop could well aggravate the problem if proper agricultural practices are not followed, or if poor quality waters are used for irrigation (Martín Alonso, 1976; Sotolongo and Abreu, 1992:165-166). In the last twenty years, citrus cultivation, also a water intensive process (Bianchi Ross, 1985:24), has also increased phenomenally, with many of the country's citrus plantations being located along the Southern coast of Central and Western Cuba. The very large water needs of these crops and the network of reservoirs that was built must have reduced the amount of water flowing to the aquifers of Pinar del Río and Havana provinces.

Since the potential for increasing the capacity of reservoirs in these two provinces, but particularly in the province of Havana whose landscape is dominated by plains, is limited, the water needs of sugar cane, citrus, and rice had to be served with irrigation water drawn or diverted from aquifers. This agricultural development strategy is consistent with the Soviet agricultural practices adopted in Cuba that relied heavily on the use of chemical inputs, irrigation, and mechanization, and was extended even to sugar cane, a crop that in pre-revolutionary Cuba only exceptionally was subjected to large scale irrigation.

Last but by no means least, excessive water pumping from the aquifers serving the province of Ciudad Habana and urban agglomerations in Havana province are certain to have contributed to the salinization of underground waters. Between 1954 and 1964, the water table surrounding the basins of the Ariguanabo and Almendares rivers dropped between six and eight meters (Egorov and Luege, 1967:24). In 1967, the Ariguanabo watershed supplied water to the towns of Bauta, Corralillo, Bejucal and San Antonio de los Baños. The water consumption of these towns at the time was 55 million cubic meters a year. In addition, a textile plant in the region used 5 million cubic meters, irrigation 30 million cubic meters, and other agricultural uses 1.5 million cubic meters, for a total of 99 million cubic meters. Yet, the replenishment capacity of underground waters in the Ariguanabo watershed was of only 77 million cubic meters annually (Egorov and Luege, 1967:51).

At the time, the Almendares watershed, the main water source for greater Havana, was experiencing an annual deficit of 46 million cubic meters: whereas 221 million cubic meters were extracted, the aquifer received only 175 million cubic meters annually (Egorov and Luege, 1967:54). The conclusion of the hydrologists conducting the study was that were extraction rates to remain at those levels, the inevitable result would be a continuous drop in the water table and/or the eventual exhaustion of underground water stores. As we have pointed out, the diversion of surface waters to irrigation and other uses, population growth, and the absence of measures to reverse the deterioration of water resources, could only have resulted in a significant aggravation of the water supply situation in Western Cuba. In this context, the Southern Dyke may be seen as an expensive effort to arrest the decline of the rich carsick aquifer running from Pinar del Río to Matanzas province.

Contamination and Deterioration of Coastal Regions

With a lower volume of water, and the continuous discharge of organic matter into rivers and other water bodies, oxygen levels in the water are depleted, the flow of rivers is disrupted, less and more polluted freshwater reach important estuary coastal breeding grounds, and the highest density of contaminants reaching the seas has a damaging influence in coral reefs. Aquatic and other life forms suffer as a consequence (Sáenz, 1990; World Bank, 1992:49-50). As in most of the Caribbean, riverine estuaries, coastal lagoons and mangroves have been damaged by upriver human interventions. Barrio Menéndez (1990) reports that as a result of a persistent drought during the late 1980s and the diversion of water to reservoirs, the amount of freshwater reaching Cuba's coastal lagoons--economically important since they serve as hatcheries for shrimp and other species--has declined by 2,243 million cubic meters annually. As a result, many of these lagoons have dried out or are in the process of doing so. In the thirty years from 1960 to 1990, 9,800 hectares of coastal lagoons were damaged. Revealingly, 61 percent of the damage occurred between 1971 and 1985, the period of accelerated reservoir construction. Barrio Menéndez also reports that draught and the diversion of surface waters has also had an adverse effect on mangroves, and has reduced the flow of organic substances reaching coastal areas. Organic material reaching the coastal lagoons are an important food source for juvenile shrimp (Rehabilitan, 1991).

Water diversion to reservoirs is likely to also be implicated in the virtual destruction of the oyster bed and a major decline in the fish catch in the Casilda coastal region of Southern Santa Clara province (Dávalos, 1984a, 1984b, 1984c, 1984d). The artificial oyster bed was at the mouth of the Agabama-Manatí river, a river that in 1984 received 50,000 cubic meters of industrial residues from the Pulpa Cuba paper plant, and also from the FNTA (old Trinidad) sugar mill. The Pulpa Cuba plant, in operation since 1959, was a source of contaminants of the Agabama-Manatí river for many years, but the environmental damage to the Casilda coast did not become alarming until the 1970s. Between 1960 and 1972, in Santa Clara province, four dams with a combined capacity of 780 million cubic meters were completed. The loss of marine life may have resulted from a reduced flow of highly contaminated water completely depleted of oxygen. By 1989, four other dams were under construction in this province (Comité Estatal de Estadísticas, 1989: 175 and 177).

Soil Salinization and Drainage Problems

High evaporation rates from man-made reservoirs and irrigation ditches is contributing to the salinization of Cuba's soils. This problem is aggravated by poor irrigation practices. The World Bank (1992:57) reports that in many regions of the developing world "salinization and waterlogging ... are eating away at the productivity of irrigation investment." It notes further that "the problem is substantially greater in tropical developing countries, where soils, rainfall, and agricultural practices are more conducive to erosion and where many reports have found rates of soil loss well above the natural rate of soil formation" (56).

Significant expanses of Cuba's agricultural lands have been degraded by mineral deposits. It is estimated that one million hectares, or about 14 percent of the country's agricultural surface (6.7 million hectares) have excessive salt deposits (Estudio, 1991). Of these, about 600,000 hectares with light to modest salinization levels could be reclaimed with appropriate techniques and the use of salt-tolerant crops. Badly salinized soils could be improved if treated with organic and mineral compounds. The Cuban regions with the highest salt concentrations are in Guantánamo and the Cauto valley. The salinization of these regions partly responds to man-made causes, but mostly to natural features. Waterlogging associated with the flooding from rapid rainwater runoff, the relative impermeability of the soils, and inadequate drainage are important determinants of salinization in these regions (Exhorta el partido, 1985).

The ambitious irrigation plans were not accompanied by the required complementary drainage facilities to prevent the soils from accumulating excess waters. This was an old problem. In 1979, it had already been reported that drainage facilities were sorely lacking in flood-prone areas, and that frequently irrigation canals were activated before adequate drainage measures were in place (Peñalver, 1979).

About a third of the national territory is affected by an overabundance of water, whether permanently or temporarily. Approximately 1.8 million hectares have drainage problems, or 27 percent of Cuba's total agricultural land. Without proper drainage, salinization of the soil occurs. In the absence of drainage water, the minerals deposited by irrigation remain in the soil as the water is absorbed or evaporates. In 1979, however, Cuba had very limited experience in drainage.

The 1981-85 plan called for a national census of drainage areas; developing a taxonomy of these soils; basic research on the country's aquifers; studies of salt-resistant plants; technical evaluations of the economic potential of soils that could be protected against flooding; and studies about the proper maintenance of drainage facilities.

Even if it had been possible to acquire the basic drainage knowhow anticipated under the 1981-85 plan, it is highly unlikely that much could have been accomplished in the way of constructing a drainage infrastructure during the 1986-90 quinquennium. With the end of the Soviet subsidies and the Special Period, it is safe to assume that most drainage facility work came to a halt. Overall, however, it is difficult to judge the consequences of these developments for the preservation of Cuba's soils, but it is likely that the extraordinary expansion of irrigation in the absence of adequate drainage facilities may have contributed to the further salinization of the country's soils.

VI. Conclusions

Among the tentative conclusions that can be reached from the analysis presented here is that the water policies pursued by the revolutionary authorities have intensified environmental stress in Cuba. Whereas many problems associated with management of water resources were already in evidence by the 1950s (e.g., too rapid extraction of underground waters in the Havana region), the efforts of the last thirty years to expand the urban water supply and increase irrigation may be jeopardizing the sustainability of some of Cuba's main water sources.

The extent to which the authorities have been sensitive to the environmental consequences of these policies is difficult to judge. Despite continued rhetorical attention to environmental conservation, the central planning system is likely to have led in Cuba, as in other socialist countries, to environmental abuse (Feshbach and Friendly, 1992). The most worrisome environmental consequences of the water policies of the revolutionary government appear to be associated with an extensive dam construction program and its implications for the recharge of aquifers and the degradation of coastal areas. Both the mineral load in many of Cuba's aquifers and soil salinization seem to be on the rise.

Some of the reported water-related problems were aggravated by Cuba's relatively limited rainfall during the 1980s. The heavy rains of 1992-93 may have eased the water bottlenecks. An important question yet to be addressed is if the widespread flooding reported during the 1993 "storm of the century" was not partly caused by the disruption of natural river flows. Another important issue is assessing the impact of the Special Period on the national irrigation plan specifically, and more generally, on the country's overall environmental situation. Due to fuel shortages, the use of fuel-driven pumps to draw irrigation water from aquifers must have been curtailed. This and the absence of other inputs is implicated in Cuba's recent poor agricultural performance.

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Table 1

Average Rainfall in Wettest and Driest Months

(in millimeters)

Year	Wettest Month	Driest Month	Ratio of Wettest to Driest Month
1975	197	14	14.1
1976	280	29	9.7
1977	315	21	15.0
1978	201	29	6.9
1979	319	27	11.8
1980	186	20	9.3
1981	168	16	10.5
1982	200	16	12.5
1983	193	43	4.5
1984	202	12	16.8
1985	168	24	7.0
1986	196	17	11.5
1987	237	31	7.6
1988	281	16	17.6

1989 169 8 21.1

Source: Comité Estatal (1989):30-31 and earlier issues.

Table 2

Average Annual Rainfall

(in millimeters)

Year	Average Rainfall	Rainfall Index*
1965	1075	76.2
1966	1591	112.8

1967	1216	86.2
1968	1565	111.0
1969	1839	130.4
1970	1228	87.1
1971	1277	90.6
1972	1611	114.3
1973	1249	88.6
1974	1126	79.9
1975	1105	78.4
1976	1310	92.9
1977	1361	96.5
1978	1539	109.1
1979	1490	105.7
1980	1434	101.7
1981	1005	71.3
1982	1142	81.0
1983	1328	94.2
1984	1015	72.0
1985	1106	78.4
1986	937	66.5
1987	1176	83.4
1988	1361	96.5
1989	1158	82.1

* Long-term average of 1410 mm per annum=100

Source: Comité Estatal (1989) and earlier issues.

Table 3

Length of Principal Rivers, by Province

(in kilometers)

Province, River	Length
Pinar del Río	
Cuyaguateje	112
Hondo	107
San Diego	88
Camagüey	
San Pedro	124
Las Yeguas	117
Saramaguacán	92
La Habana	
Mayabeque	55
Las Tunas	
Jobabo	96
Chaparra	86
Yarigua	62
Ciudad de la Habana	
Almendares	47
Holguín	

Mayarí	106
Sagua de Tánamo	73
Nipe	54
Matanzas	
La Palma	71
San Juan	64
Canímar	46
Granma	
Cauto	370
Bayamo	89
Cautillo	68
Villa Clara	
Sagua la Grande	163
Sagua la Chica	81
Santiago de Cuba	
Contramaestre	91
Baconao	62
Cienfuegos	
Hanábana	93
Arimao	84
Caunao	82
Sancti Spiritus	
Zaza	155
Jatibonico del Sur	119
Agabama or Manati	105
Guantanamo	
Toa	100
Guantanamo	98
Jobabo	95
isla de la Juventud	
Las Nuevas	31
Del Medio	22
Las Casas	17
Ciego de Avila	
Caonao	133

Source: Comité Estatal, 1989, p. 22.

Footnotes

Water, Development, and Environment in Cuba; A First Look

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1 This paper presents only the personal views of the authors. We are grateful to José Alvarez and Arturo Pino for their very useful comments on an earlier draft.

2 To illustrate the relationship between irrigation and yields, Cuban technicians have estimated that non-irrigated citrus plantations yield about six metric tons of fruit per hectare, while irrigated lands have potential yields of over 40 tons (Riego, 1982:61).

3 The irrigation data, as many other Cuban statistics, must be used cautiously. According to other irrigation figures reviewed here, the land surface under irrigation is far less than the 2.95 million hectares claimed in this source. The *1989 Anuario Estadístico* (p. 215) indicates that the total amount of land irrigated in the state sector reached 896 thousand hectares, an estimate consistent with the 900,000 hectares used by other sources consulted for this paper.