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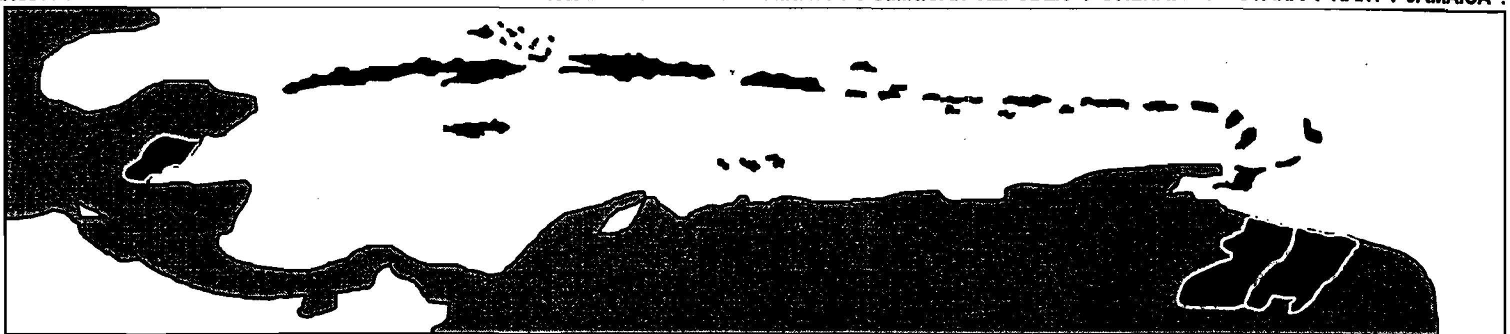

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# SURVEY OF POTENTIALLY NEW TECHNOLOGIES THAT WILL IMPACT ON CARIBBEAN DEVELOPMENT

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Subregional Headquarters for the Caribbean

CARIBBEAN DEVELOPMENT AND COOPERATION COMMITTEE

## Table of contents

## SURVEY OF POTENTIALLY NEW TECHNOLOGIES THAT WILL IMPACT ON CARIBBEAN DEVELOPMENT

## PART I: INTRODUCTION

The pace of development in information technology, biotechnology and environmentally clean technologies require constant monitoring of new developments so as to avoid investment in and applications of technologies that do not have long-term utility, especially given the limited resources in the subregion. At the same time, present development of these technologies may require minor adaptations to be effectively applied in the subregion. One example is the research work in genetically modified organisms (GMOs) that can have implications for food security, nutrition, environment preservation and a redirecting of research and development priorities.

### Summary

#### Agriculture

Biotechnology, irrigation, non-conventional energy sources and integrated pest management. While biotechnology covers many tools and techniques commonplace in agriculture and food production, it is the area of GMOs that are of concern to persons in both developed and developing countries at this time. Caribbean economies do not have the resources to invest in biotechnology research, so it is recommended that countries strive for increased technical collaboration and cooperation with countries that have the capabilities, especially countries such as Brazil, China, Egypt, India and South Africa. While high cost technologies and research associated with these technologies may not be an option for Caribbean countries, other technologies to increase agricultural production may be utilised and further developed, including irrigation technologies, use of non-conventional energy sources within the sector and integrated pest management, the other areas which are explored in the survey.

#### Natural resource management

Because the management of natural resources is the frontline of the struggle for more sustainable and equitable development, all our actions ultimately have consequences on the quality and quantity of natural resources on the planet. Environmental degradation is one of the first indications of unsustainable social and economic systems. There is one generally held view that non-renewable resources - minerals and petroleum - are unlikely to be depleted because as their costs rise, substitutes will be found, recycling will increase or new sources may become accessible. The fact remains, though, that the extraction of these resources places a heavy toll on natural and social systems.

Indicators show, however, that renewable resources - water, forests, topsoil, fisheries - are under extreme pressure under current practices and their productivity is in decline. These resources are the basis for life on this planet, and their exploitation constitutes the primary source of livelihoods for most of the world's population. As human population doubles and as we seek to improve the welfare of the three billion people who live on less than $2 a day, pressure on these resources will only increase.

Escaping this trap will require great ingenuity and cooperation across nations and cultures. Failure to manage these resources sustainably and equitably is in many cases already leading to conflict and disaster. Resolution of this challenge will be the key to sustainability.

**Water**

Competing demands are outstripping supply in many parts of the world, constraining development and laying the seeds for social tension and conflict. Water is vital to survival and is a key input to agriculture, industry and the maintenance of natural systems. Yet rainfall, rivers, lakes and groundwater aquifers are not always located where water demand arises. Moreover, industrial, municipal and agricultural pollution are decreasing the quality of available water sources, as is continued clearing of forests and draining of wetlands.

The survey therefore addresses the issue of Integrated Water Resources Management (IWRM), as well as the various technologies that may be put to use in the Caribbean, given the patterns of rainfall in the subregion. Also addressed in the survey is the issue of sanitation, even though there may not seem to be a sanitation crisis in the majority of Caribbean countries. There is still, however, a need to find sustainable alternatives to conventional approaches, some of which have been identified.

**Fisheries management**

An ecosystem approach to fisheries resources management is highlighted as opposed to the traditional approach which considers the target species as independent, self-sustaining populations.

**Forestry resource management**

Constraints to the sustainable use of forest resources are common to all Small Island Developing States (SIDS) regardless of the geographic, biological, social, cultural and economic characteristics. Some of these constraints and the possible solutions have been identified in the survey.

**Energy**

Solar energy and more specifically new technologies in solar energy systems have been highlighted as an alternate source of energy for the Caribbean. Included as information to solar energy use is an introduction to the concept of environmental design or green buildings.

While the technologies outlined herein can by no means be described as comprehensive, it provides some insight as to the options available for the use of technological innovation in sustainable development in the areas that are crucial to the subregion's development. In the Small Island Developing States Programme of Action (SIDS POA), particular attention was given to such areas as freshwater, marine resources, land resources and agriculture and science and technology as areas that were crucial to development of small islands. The technologies mentioned here address these issues and how they can help the development process and at the same time help to preserve the fragile ecosystems of Caribbean States.

## PART II: SURVEY

### Agriculture

#### Biotechnology

Biotechnology can be broadly defined as *"using living organisms or their products for commercial purposes"*. As such, biotechnology has been practiced by human society since the beginning of recorded history in such activities as baking bread, brewing alcoholic beverages, or breeding food crops or domestic animals. A narrower and more specific definition of biotechnology is *"the commercial application of living organisms or their products, which involves the deliberate manipulation of their DNA molecules"*. The Convention on Biological Diversity (CBD) defines biotechnology as: *"any technological application that uses biological systems, living organisms, or derivatives thereof, to make or modify products or processes for specific use"*. Interpreted in this broad sense, the definition of biotechnology covers many of the tools and techniques that are commonplace in agriculture and food production. Interpreted in a narrow sense, which considers only the new DNA techniques, molecular biology and reproductive technological applications, the definition covers a range of different technologies such as gene manipulation and gene transfer, DNA typing and cloning of plants and animals.

In the Caribbean, most of the work in agricultural biotechnology has concentrated on tissue culture to provide clean planting materials. However, biotechnology can also be used to help farmers produce more by developing new crop varieties that are drought-tolerant, resistant to insects and weeds and able to capture nitrogen from the air. Biotechnology can also be used to improve the nutrient content in the edible portion of plants.

In order to make informed choices, consumers have a right to know the contents of their food. Questions about safety must be addressed for people in both developed and developing countries. It is therefore recommended that developing countries invest in strengthening bio-safety testing and developing agricultural biotechnology suitable for their needs and their environments. In addition, research collaboration, both within and among countries, is essential if economies of scale are to be realized. Currently, biotechnology research in the developing world is taking place in only a few countries such as Brazil, China, Egypt, India and South Africa. It may be necessary for Caribbean countries to strive for increased technical collaboration and cooperation with these countries, rather than enter into agreements with the few private corporations that focus on the agricultural sectors of industrial countries, and which expect the highest rate of return on their investment.

**Irrigation**

Irrigation may very simply be defined as supplying dry land with water. More specifically, irrigation is the application of water (or wastewater) to land areas to supply the water (and sometimes nutrient) needs of plants. Techniques for irrigating include furrow irrigation, sprinkler irrigation, trickle (or drip) irrigation, and flooding.[1] Irrigation may be also defined as the controlled application of water for cultural purposes through man-made systems to supply water requirements not satisfied by rainfall.[2]

The World Vision of Water for Food and Rural Development (Hofwegen and Svendsen, 2000) showed that by 2025 the world population would increase by 2 billion inhabitants to a total of approximately 8 billion people. The water requirement critical to livelihood, including food production, is 1700 m3/capita. This water is not available for everybody. Nearly one third of the world's population will live in regions that will experience severe water scarcity. Recent assessments by the Food and Agriculture Organization (FAO) of the United Nations put the world's area of potentially suitable cropland at some 3200 million ha (FAO, 1996). Agriculture in areas with artificial water management (irrigation and drainage) contributes to about 50% of present food and fiber production (FAO 1998). To improve the productivity (in terms of crop yield per m3 water consumed) water resources need to be more alertly managed.

Given the above scenario, the importance of irrigation cannot be over-emphasized. New tools are continuously being developed to facilitate integrated water resources management. Managers have to be able to assess to what extent targets are met and evaluate their strategy. This management process requires an advanced quantitative approach and a well-thought data acquisition system. The use of satellite images to support land and water management is beginning to be put into place. The success of remote sensing (RS) applications in land and water management is limited, and far behind the successes of RS applications in weather and climate studies.

Because accurate, timely and cost-effective information for the planning and monitoring of drainage systems are badly needed, it is recommended that a review of the possible contribution of advanced space information technologies in irrigated and drained agriculture be done. Remote sensing in irrigation and drainage-related studies can be broadly grouped into three different categories: (a) monitoring of irrigation and drainage processes across larger areas; (b) identification of local crop classes, salinity hazards and crop yield; and (c) surveying field layout, plot boundaries and legislative aspects.

Specific to the Caribbean, it has been shown that agricultural output can be increased with irrigation. However, both the cost factor and microclimate changes must be monitored in order to not lose the benefits of increased water in the micro-environment. The above points are

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[1] www.agriculturelaw.com/links/dictionaryg-l.htm

[2] Houk, 1951

aids to more efficient management of the water supplies and applicable on a large scale. At the comparatively smaller level as exists in the subregion, there are no "new" technologies, but rather innovative adaptations of the traditional methods of irrigation suitable for small holders. For example, four years ago in 2000, an *Innovative Irrigation Ideas and Technologies for Smallholders* contest was launched in November during the annual Convention and Trade Show of the Irrigation Association (IA). Supported by the World Bank's Rural Development Department, the objectives of the technology contest were: (a) to raise public awareness of the need for innovation in irrigation technologies for poor small holders in developing countries; (b) to encourage individuals, the irrigation supply industries, and research institutes to develop irrigation technologies that were appropriate and affordable for small holders; and (c) to identify new technologies that the World Bank and others in the development community could promote. The contest was launched as a pilot effort to stimulate development of irrigation technology for agricultural smallholders. The following systems were adjudged winners:

*Tote-a-Way - a Small Farm Irrigation System - A complete sprinkler irrigation system that utilizes durable lay-flat flexible pipe and fits in a plastic tote box that can be easily carried from one field to another. It operates at 10 to 13 meters of pressure head at the pump and provides high long-term water-use efficiency of 80%. The system is available in various sizes to cover from 250 to 2500 square meters and costs $ 25 to $250 ex-works USA.*

*South African "KIT" Treadle Pump - A low cost, quality treadle (suction/pressure) pump in kit form. It is fabricated from "off the shelf" plastic pipe and fittings that are locally available. The performance of the pump is competitive but it is lower in cost compared to treadle pumps. It is easy to operate and requires less energy than many treadle pumps because it utilizes simple low friction- loss valves.*

*Stone Hammer Modified Sludge Drilling - Two low-cost manual drilling techniques for developing shallow tube-wells in areas with hard subsurface strata.*

*Dream Drip Kits Irrigation Innovation for Small-scale Farmers - Development and marketing of low-head (0.8- meter) drip irrigation kits that are assembled from components that are easily locally manufactured. The systems addresses the limitations farmers have identified in other drip kits: e.g. a double screen filter and a silt trap, the header connector is provided with removable end plugs for flushing small sediments, and a gate valve for regulating the flow of water.*

*Pitcher (or Pot) Irrigation - Development of pitcher (sometimes referred to as pot) irrigation utilizing locally manufactured unglazed 5 to 8 liter capacity clay pitchers. The researchers have thoroughly researched the techniques for manufacturing the pitchers, installing them and the garden farming methods to take best advantage of the technology. The technology is completely indigenous, cost effective, technical feasible, and economically viable. Furthermore, pitcher irrigation provides a means for obtaining maximum production of fruit trees and vegetables from very limited water supplies and from saline water supplies.*

The winning entries were based on the innovativeness and superiority of the technologies compared to conventional technologies available on the market, as well as their potential for improving irrigation performance for small holders. The contest emphasized the need to identify new and useful technologies to provide the benefits of irrigation or improved irrigation performance to small holders. The technologies, however, must be promoted and adapted to be of significant benefit.

Cooperative efforts will be necessary to enable small holders to realize the potential benefits of these new and innovative technologies involving: (a) financial assistance of donors and other international institutions; (b) marketing and technical assistance of such non-government organizations; (c) promotional and educational support of local governmental services; and (d) collaboration with various local manufacturing and business communities to enhance access to appropriate technologies.

**Pumps powered by non-conventional energy sources**

Pumping facilities are required wherever water is stored at or below ground level. Conventionally powered pumps, such as diesel and electric pumps, require readily available sources of fossil fuels or electricity. In countries where access to conventional energy is limited by cost or sources of supply, pumps powered by non-conventional energy systems may provide an alternative. Different types of pumps have been tested with mechanisms fabricated from local materials, using limited fabrication skills and available energy sources. They include:

- *Hydraulic Pumps - The hydraulic pump or water wheel is driven by the energy of the moving water in a river. The circular movement of the wheel is transmitted via a 1 in. diameter shaft, fitted with an offset arm, to the piston of a small pump.*

- *Hydraulic Ram Pumps - The hydraulic ram is a simple pump, in universal use, driven by the energy produced by differences in hydrostatic pressure, which activates a valve and raises the water. A ram can pump approximately one tenth of the received water volume to a height ten times greater than the intake.*

- *Rope Pumps - The rope pump consists of a loop of nylon rope with rubber gaskets attached to it. The gaskets slip through the interior of a PVC pipe 1 in. in diameter. The rope pump is operated manually by rotating a wheel, which pulls the rope through the pipe. The effort necessary to turn the handle depends on the length of the pipe and the depth of the water. The length of a pipe 1 in. in diameter can range from 1 m to 12 m.*

- *Windmill Pumps - The windmill pump is operated by making use of wind energy. The energy generated by the wind moves a rotor which translates to the vertical movement of a piston in the pump. Water is then drawn up through the internal pipe, reaching heights of up to 7 m, depending on the tower size. Windmill-powered pumps can lift water to a height of 20 m. The pump capacity is a function of wind speed and the suction elevation. At wind speeds of 4 m/s, pump capacities range between 0.5* *and 1.5 Vs over suction heights of 20 m and 5 m, respectively. For the same suction heights but twice the wind speed, the capacities range between 3.2 and 4.0 l/s.*

- *Photovoltaic-Powered Pumps - In spite of the abundance of solar radiation in the tropics photovoltaic solar energy has not been used as much as expected. Solar panels and a photovoltaic-powered pump system are used to raise the water to a reserve water storage tank. The pumping system consists of a submersible electric pump directly connected to a photovoltaic cell system and operated continuously whenever there is enough sunshine.*

Operation of most of these non-conventional systems is relatively simple, although most require additional labor. Some of the pumps, like the hand and rope pumps, require constant attention to keep them operating efficiently. Most of the pumps require the use of anti-corrosive paints to protect the exposed metal parts, and frequent oiling (twice a month) of the parts of the pump where friction between different parts can be expected. However, it is important to avoid the use of heavy-metal-based (e.g., lead paints) and to avoid contaminating the insides of the pumps with hydrocarbon residues, especially if the water is to be used for human consumption. Such contamination can lead to chronic public health problems.

Irrigation technology is one area in which community groups can play a significant role, especially since few governments have participated in the application of non-conventional energy sources to the pumping of water. Most pumping systems using such sources have been developed by local communities in cooperation with non-governmental organizations (NGOs) and financed by external agencies. Likewise, whenever system operators have needed technical and financial assistance (for example, to replace a pump), NGOs generally have provided the necessary technical assistance and financial support. Governments need to provide more leadership in these areas to facilitate additional funding and technical assistance.

**Integrated pest management**

Integrated Pest and Disease Management (IPM) is defined as *"the control of pests by employing all methods consistent with economic, ecological and toxicological requirements while giving priority to natural limiting factors and economic thresholds" (Brader, L. 1974).* There are many definitions of IPM, but, however defined, IPM has certain key features. IPM programmes must give effective pest and disease control if they are to be accepted and adopted. Success is achieved by selecting from the full range of control techniques that are available. An essential ingredient is pest and disease monitoring. Adopting IPM programmes can provide the additional benefit of produce with nil or minimal pesticide residues. It can also be claimed that IPM programmes are not only good for people but are also good for the environment because they are sustainable. These attributes make IPM technology a unique and valuable option for growers. The range of IPM methods includes:

(a) Biological control - using natural enemies of pests and pathogens;

(b) Plant resistance - choosing cultivars that are resistant or tolerant to pests or pathogens;

(c) Plant nutrition;

(d) Cultural techniques such as plant training, time of planting, grazing management etc.;

(e) Using sex pheromones to disrupt mating of pests;

(f) Manipulating the environment to reduce disease incidence;

(g) Selective pesticides, e.g. insect growth regulators and *Bacillus thuringiens;*

(h) Broad spectrum insecticides - these are sometimes still needed;

(i) Selective spray application;

(j) Inter cropping and crop rotation to reduce the incidence of pathogen infection.

IPM costs can be more or less than conventional pest and disease control depending both on the crop and the individual grower's previous costs that may have been above or below the industry average. All IPM programmes offer advantages that cannot always be quantified but derive from using fewer toxic pesticides which helps to promote environmental integrity. Changes to IPM programmes may be made because of new opportunities such as a new natural enemy of a pest or disease; new, more selective control techniques; new information about a pest or disease; withdrawal of key pesticides or arrival of a new pest or disease. For this reason, active research programmes are necessary and local funding should supplement international efforts in research and development.

**Natural resource management**

**Water**

***Integrated Water Resources Management (IWRM)***

IWRM promotes the coordinated development and management of water, land and related resources in order to maximise economic and social welfare in an equitable manner, without compromising the sustainability of vital ecosystems. Because water is a multisector resource the management, research and development of water resources are especially significant to the economic and social development of SIDS in the Caribbean. The importance of freshwater resources, in regard to health; the demand for water in connection with agricultural productivity through improved irrigation systems; the growing need for water supplies in the tourism sector, industrial development and sports and recreation facilities therefore cannot be over-emphasized. These demands were explicitly recognised in the 1994 SIDS POA which identified water resources as one of the 14 priority areas. Drawing on the recommendations of the SIDS POA and other initiatives, a regional seminar on IWRM was held in Trinidad and Tobago in 1997 to assess progress made and to promote IWRM in the Caribbean. Several recommendations were made, two of which were the development of a common understanding among the cross-sectoral team members of the water resources management challenges of the subregion and the sharing of relevant water resources management practices. The formation of a Caribbean Water Partnership (CWP) was one of the significant outcomes of the recommendations made. The CWP will therefore establish a framework for collaboration in IWRM within the context of a network of institutions, agencies and stakeholders that will promote IWRM; assist in technology transfer; best practice replication; institutional strengthening; information dissemination and sharing; public awareness programmes and policy formulation.

***Rain water harvesting***

The application of an appropriate rainwater harvesting technology can make possible the utilization of rainwater as a valuable and, in many cases, necessary water resource. Rainwater harvesting has been practiced for more than 4,000 years, and, in most developing countries, is becoming essential owing to the temporal and spatial variability of rainfall. Rainwater harvesting is necessary in areas having significant rainfall but lacking any kind of conventional, centralized government supply system, and also in areas where good quality fresh surface water or groundwater is lacking.

Annual rainfall ranging from less than 500 to more than 1 500 mm can be found in most of the Caribbean. Very frequently most of the rain falls during a few months of the year, with little or no precipitation during the remaining months. For more than three centuries, rooftop catchments and cistern storage have been the basis of domestic water supply on many small islands in the Caribbean. Although the use of rooftop catchment systems has declined in some countries, it is estimated that more than 500 000 people in the Caribbean islands depend at least in part on such supplies.

A rainwater harvesting system consists of three basic elements: a collection area, a conveyance system, and storage facilities. The collection area in most cases is the roof of a house or a building. The effective roof area and the material used in constructing the roof influence the efficiency of collection and the water quality. A conveyance system usually consists of gutters or pipes that deliver rainwater falling on the rooftop to cisterns or other storage vessels. Both drainpipes and roof surfaces should be constructed of chemically inert materials such as wood, plastic, aluminum, or fiberglass, in order to avoid adverse effects on water quality. The water ultimately is stored in a storage tank or cistern, which should also be constructed of an inert material. Reinforced concrete, fiberglass, or stainless steel are suitable materials. Storage tanks may be constructed as part of the building, or may be built as a separate unit located some distance away from the building.

Rainwater harvesting systems require few skills and little supervision to operate. Major concerns are the prevention of contamination of the tank during construction and while it is being replenished during a rainfall. Contamination of the water supply as a result of contact with certain materials can be avoided by the use of proper materials during construction of the system.

***Effectiveness of the Technology***

Rainfall harvesting technology has proved to be very effective throughout most of the Caribbean islands, where cisterns are the principal source of water for residences. Cisterns are capable of providing a sufficient supply for most domestic applications. The use of rainwater is very effective in lessening the demand on the public water supply system in the smaller Caribbean islands. It also provides a convenient buffer in times of emergency or shortfall in the public water supply.

***Further development***

There is a need for the water quality aspects of rainwater harvesting to be better addressed. This might come about through:

(a) Development of first-flush bypass devices that are more effective and easier to maintain and operate than those currently available;

(b) Greater involvement of the public health department in the monitoring of water quality;

(c) Monitoring the quality of construction at the time of building;

(d) Provision of assistance from governmental sources to ensure that the appropriate-sized cisterns are built;

(e) Promotion of rainwater harvesting as an alternative to both government- and private-sector-supplied water, with emphasis on the savings to be achieved on water bills;

(f) Provision of assistance to the public in sizing, locating, and selecting materials and constructing cisterns and storage tanks, and development of a standardized plumbing and monitoring code;

(g) Development of new materials to lower the cost of storage;

(h) Preparation of guidance materials (including sizing requirements) for inclusion of rainwater harvesting in a multi-sourced water resources management environment.

***Water re-use***

Artificial recharge of aquifers

The use of artificial recharge to store surplus surface water underground can be expected to increase as growing populations demand more water, and as the number of good dam sites still available for construction decreases. For example, artificial recharge may be used to store treated sewage effluent and excess storm water runoff for later use. Groundwater recharge may also be used to mitigate or control saltwater intrusion into coastal aquifers. However, in order to accomplish the uses without deleterious environmental consequences, the optimum combination of treatment methodologies before recharge and after recovery from the aquifer must be identified. It will also be necessary to consider the sustainability of soil-aquifer treatment and health effects of water reuse when using treated wastewater as the recharge medium.

The main purpose of artificial aquifer recharge technology is to store excess water for later use, while improving water quality (decreasing the salinity level) by recharging the aquifer with better water. There are several artificial recharge techniques in use in the Caribbean, including infiltration basins and canals, water traps, cutwaters, surface runoff drainage wells, septic-tank-effluent disposal wells, and diversion of excess flows from irrigation canals into sinkholes.

### Operation and maintenance

Infiltration basins and canals require minimal maintenance, consisting mostly of avoiding excessive sedimentation in the basins and canals and preventing erosion of canal banks. A bulldozer is often used in the infiltration basins to remove accumulated sediments and to rehabilitate the system. Water traps require maintenance during the first few years of operation, until the natural vegetation grows again in the area. Intense rainfalls may damage or destroy the traps and they will have to be rebuilt. Maintenance of cutwaters is similar to that required in infiltration basins. Runoff from areas with unpaved streets can carry large loads of sediment, which may be deposited in cutwaters and will need to be removed during dry periods.

### Suitability

In areas where groundwater is an important component of the water supply and rainfall variability does not allow for a sufficient level of aquifer recharge by natural means, these technologies provide for the artificial enhancement of the natural recharge. Storage of surface runoff in underground aquifers in arid and semi-arid areas has the advantage of minimizing evaporative losses. However, use of these technologies requires an appropriate geological structure. In areas underlain by igneous rock, the natural fracture lines can be expanded by injection of water under pressure and infusion of a sand slurry into the gaps thus created. Given the cost of this latter measure, however, use of natural limestone or sandstone formations, such as are common in the Caribbean islands, is preferred and most cost-effective.

### Disadvantages

In the absence of financial incentives, laws, or other regulations to encourage landowners to maintain drainage wells adequately, the wells may fall into disrepair and ultimately become sources of groundwater contamination. There is also a potential for contamination of the groundwater from injected surface water runoff, especially from agricultural fields and roads surfaces. In most cases, the surface water runoff is not pre-treated before injection.

Further development

Potential improvements in artificial recharge technologies include:

(a) Improvements in the design of pre-injection silt chambers, grease traps, and oil interceptors to reduce the amount of contaminants entering drainage wells;

(b) Improvements in the design of injection wells to eliminate the use of "sucks";

(c) Evaluation of groundwater contamination potentials from various sources of artificial recharge, and the adoption of techniques to reduce the associated impacts or risks;

(d) Improvements in the design of water traps to increase groundwater recharge efficiency;

(e) A better understanding of the causes and consequences of bacterial and viral contamination of aquifer systems, and the means of minimizing and mitigating such risks.

*Wastewater treatment technologies*

Relatively simple wastewater treatment technologies can be designed to provide low cost sanitation and environmental protection while providing additional benefits from the reuse of water. These technologies use natural aquatic and terrestrial systems and are already in use in a number of locations throughout the Caribbean. These systems may be classified into three principal types. Mechanical treatment systems, which use natural processes within a constructed environment, tend to be used when suitable lands are unavailable for the implementation of natural system technologies. Aquatic systems are represented by lagoons; facultative, aerated, and hydrograph controlled release (HCR) lagoons are variations of this technology. Further, the lagoon-based treatment systems can be supplemented by additional pre- or post-treatments using constructed wetlands, aquacultural production systems, and/or sand filtration. They are used to treat a variety of wastewaters and function under a wide range of weather conditions. Terrestrial systems make use of the nutrients contained in wastewaters; plant growth and soil adsorption convert biologically available nutrients into less-available forms of biomass, which is then harvested for a variety of uses, including methane gas production, alcohol production, or cattle feed supplements.

*Mechanical treatment technologies*

Mechanical systems utilize a combination of physical, biological, and chemical processes to achieve the treatment objectives. Using essentially natural processes within an artificial environment, mechanical treatment technologies use a series of tanks, along with pumps, blowers, screens, grinders, and other mechanical components, to treat wastewaters. The flow of wastewater in the system is controlled by various types of instrumentation. Sequencing batch reactors (SBR), oxidation ditches, and extended aeration systems are all variations of the activated-sludge process, which is a suspended-growth system. The trickling filter solids contact process (TF-SCP), in contrast, is an attached-growth system. These treatment systems are effective where land is at a premium.

### *Aquatic treatment technologies*

Facultative lagoons are the most common form of aquatic treatment-lagoon technology currently in use. The water layer near the surface is aerobic while the bottom layer, which includes sludge deposits, is anaerobic. The intermediate layer is aerobic near the top and anaerobic near the bottom, and constitutes the facultative zone. Aerated lagoons are smaller and deeper than facultative lagoons. These systems evolved from stabilization ponds when aeration devices were added to counteract odors arising from septic conditions. The aeration devices can be mechanical or diffused air systems. The chief disadvantage of lagoons is high effluent solids content, which can exceed 100 mg/l. To counteract this, HCR lagoons are a recent innovation. In this system, wastewater is discharged only during periods when the stream flow is adequate to prevent water quality degradation. When stream conditions prohibit discharge, wastewater is accumulated in a storage lagoon.

Aquaculture systems are distinguished by the type of plants grown in the wastewater holding basins. These plants are commonly water hyacinth *(Eichhornia crassipes)* or duckweed *(Lemna* spp.). These systems are basically shallow ponds covered with floating plants that detain wastewater at least one week. The main purpose of the plants in these systems is to provide a suitable habitat for bacteria which remove the vast majority of dissolved nutrients.

### *Terrestrial treatment technologies*

Terrestrial treatment systems include slow-rate overland flow, slow-rate subsurface infiltration, and rapid infiltration methods. In addition to wastewater treatment and low maintenance costs, these systems may yield additional benefits by providing water for groundwater recharge, reforestation, agriculture, and/or livestock pasturage. They depend upon physical, chemical and biological reactions on and within the soil. Slow-rate overland flow systems require vegetation, both to take up nutrients and other contaminants and to slow the passage of the effluent across the land surface to ensure maximum contact times between the effluents and the plants/soils. Slow-rate subsurface infiltration systems and rapid infiltration systems are "zero discharge" systems that rarely discharge effluents directly to streams or other surface waters. Each system has different constraints regarding soil permeability. Although slow-rate overland flow systems are the most costly of the natural systems to implement, their advantage is their positive impact on sustainable development practices. In addition to treating wastewater, they provide an economic return from the reuse of water and nutrients to produce marketable crops or other agriculture products and/or water and fodder for livestock. The water may also be used to support reforestation projects in water-poor areas. In slow-rate systems, either primary or secondary wastewater is applied at a controlled rate, either by sprinklers or by flooding of furrows, to a vegetated land surface of moderate to low permeability. The wastewater is treated as it passes through the soil by filtration, adsorption, ion exchange, precipitation, microbial action, and plant uptake. Vegetation is a critical component of the process and serves to extract nutrients, reduce erosion, and maintain soil permeability.

Overland flow systems are a land application treatment method in which treated effluents are eventually discharged to surface water. The main benefits of these systems are their low maintenance and low technical manpower requirements. Wastewater is applied intermittently across the tops of terraces constructed on soils of very low permeability and allowed to sheet-flow across the vegetated surface to the runoff collection channel. Treatment, including nitrogen removal, is achieved primarily through sedimentation, filtration, and biochemical activity as the wastewater flows across the vegetated surface of the terraced slope. Loading rates and application cycles are designed to maintain active microorganism growth in the soil. The rate and length of application are controlled to minimize the occurrence of severe anaerobic conditions, and a rest period between applications is needed. The rest period should be long enough to prevent surface ponding, yet short enough to keep the microorganisms active.

Extent of use

These treatment technologies are already widely used in the Caribbean. Combinations of some of them with wastewater reuse technologies have been tested in several countries. Colombia has extensively tested aerobic and anaerobic mechanical treatment systems. Barbados has used activated sludge plants and Curacao, Jamaica, and Saint Lucia have successfully experimented with different kinds of terrestrial and aquatic treatment systems for the treatment of wastewaters. Curaçao, Mexico, and Jamaica have used stabilization or facultative lagoons and oxidation ponds; their experience has been that aquatic treatment technologies require extensive land areas and relatively long retention times, on the order of 7 to 10 days, to adequately treat wastewater. An emerging technology, being tested in a number of different countries, is a hybrid aquatic-terrestrial treatment system that uses wastewaters for hydroponic cultivation. However, most of the applications of this hybrid technology to date have been limited to the experimental treatment of small volumes of wastewater.

Government involvement is essential in the implementation of most of the wastewater treatment technologies. The private sector, particularly the tourism industry, has successfully installed "packaged" or small-scale, self-contained sewage treatment plants at individual sites. In some cases, the installation of these plants has been combined with the reuse of the effluent for watering golf courses, lawns, and similar areas. The selection and construction of the appropriate wastewater treatment technology is generally initiated and financed, at least partially, by the government, with the subsequent operation and maintenance of the facility being a responsibility of the local community. Nevertheless, despite the large number of well-known and well-tested methods for wastewater treatment, there still exist a significant number of local communities which discharge wastewater directly into lakes, rivers, estuaries, and oceans without treatment. As a result, surface water degradation, which also affects the availability of freshwater resources, is more widespread than is desirable within this subregion.

Advantages and disadvantages

In general, the advantages of using natural biological processes relate to their "low-tech/no-tech" nature, which means that these systems are relatively easy to construct and operate, and to their low cost, which makes them attractive to communities with limited budgets. However, their simplicity and low cost may be deceptive in that the systems require frequent inspections and constant maintenance to ensure smooth operation. Concerns include hydraulic overloading, excessive plant growth, and loss of exotic plants to natural watercourses. For this reason, and also because of the land requirements for biologically-based technologies, many communities prefer mechanically-based technologies, which tend to require less land and permit better control of the operation. However, these systems generally have a high cost and require more skilled personnel to operate them.

*Wastewater re-use*

Once freshwater has been used for an economic or beneficial purpose, it is generally discarded as waste. In many countries, these wastewaters are discharged, either as untreated waste or as treated effluent, into natural watercourses, from which they are abstracted for further use after undergoing "self-purification" within the stream. Through this system of indirect reuse, wastewater may be reused up to a dozen times or more before being discharged to the sea. However, more direct reuse is also possible: the technology to reclaim wastewaters as potable or process waters is a technically feasible option for agricultural and some industrial purposes (such as for cooling water or sanitary flushing), and a largely experimental option for the supply of domestic water. Wastewater reuse for drinking raises public health, and possibly religious, concerns among consumers. The adoption of wastewater treatment and subsequent reuse as a means of supplying freshwater is also determined by economic factors.

One of the most critical steps in any reuse programme is to protect the public health, especially that of workers and consumers. To this end, it is most important to neutralize or eliminate any infectious agents or pathogenic organisms that may be present in the wastewater. For some reuse applications, such as irrigation of non-food crop plants, secondary treatment may be acceptable. For other applications, further disinfection, by such methods as chlorination or ozonation, may be necessary.

A typical example of wastewater reuse is the system at the Sam Lords Castle Hotel in Barbados. Effluent consisting of kitchen, laundry, and domestic sewage ("gray water") is collected in a sump, from which it is pumped to an aeration chamber. No primary sedimentation is provided in this system, although it is often desirable to do so. The aerated mixed liquor flows out of the aeration chamber to a clarifier for gravity separation. The effluent from the clarifier is then passed through a 16-foot-deep chlorine disinfection chamber before it is pumped to an automatic sprinkler irrigation system. The irrigated areas are divided into sixteen zones; each zone has twelve sprinklers. Some areas are also provided with a drip irrigation system. Sludge from the clarifier is pumped, without thickening, as a slurry to suckwells, where it is disposed of. Previously the sludge was pumped out and sent to the Bridgetown Sewage Treatment Plant for further treatment and additional desludging.

For health and aesthetic reasons, reuse of treated sewage effluent is presently limited to non-potable applications such as irrigation of non-food crops and provision of industrial cooling water. There are no known direct reuse schemes using treated wastewater from sewerage systems for drinking. Indeed, the only known systems of this type are experimental in nature, although in some cases treated wastewater is reused indirectly, as a source of aquifer recharge. In general, wastewater reuse is a technology that has had limited use, primarily in small-scale projects in the subregion, owing to concerns about potential public health hazards. Wastewater reuse in the Caribbean is primarily in the form of irrigation water. In Jamaica, some hotels have used wastewater treatment effluent for golf course irrigation, while the major industrial water users, the bauxite/alumina companies, engage in extensive recycling of their process waters. In Barbados, effluent from an extended aeration sewage treatment plant is used for lawn irrigation. Similar use of wastewater occurs on Curaçao.

It should be noted that international water quality guidelines for wastewater reuse have been issued by the World Health Organization (WHO). Guidelines should also be established at national level and at the local/project level, taking into account the international guidelines. Some national standards that have been developed are more stringent than the WHO guidelines. In general, however, wastewater reuse regulations should be strict enough to permit irrigation use without undue health risks, but not so strict as to prevent its use. When using treated wastewater for irrigation, for example, regulations should be written so that attention is paid to the interaction between the effluent, the soil, and the topography of the receiving area, particularly if there are aquifers nearby.

The operation and maintenance required in the implementation of this technology is related to operation and maintenance of the wastewater treatment processes, and to the chlorination and disinfection technologies used to ensure that pathogenic organisms will not present a health hazard to humans. Additional maintenance includes the periodic cleaning of the water distribution system conveying the effluent from the treatment plant to the area of reuse; periodic cleaning of pipes, pumps, and filters to avoid the deposition of solids that can reduce the distribution efficiency; and inspection of pipes to avoid clogging throughout the collection, treatment, and distribution system, which can be a potential problem. Further, it must be emphasized that, in order for a water reuse programme to be successful, stringent regulations, monitoring, and control of water quality must be exercised in order to protect both workers and the consumers.

The effectiveness of the technology, while difficult to quantify, is seen in terms of the diminished demand for potable-quality freshwater and, in the Caribbean islands, in the diminished degree of degradation of water quality in the near-shore coastal marine environment, the area where untreated and unreclaimed wastewaters were previously disposed. The analysis of beach waters in Jamaica indicates that the water quality is better near the hotels with wastewater reuse projects than in beach areas where reuse is not practiced. From an aesthetic point of view, also, the presence of lush vegetation in the areas where lawns and plants are irrigated with reclaimed wastewater is further evidence of the effectiveness of this technology.

***Desalination – Reverse Osmosis (RO) Technology***

Desalination is a separation process used to reduce the dissolved salt content of saline water to a usable level. All desalination processes involve three liquid streams: the saline feedwater (brackish water or seawater), low-salinity product water, and very saline concentrate (brine or reject water). The use of desalination overcomes the paradox faced by many small island developing States, that of having access to a practically inexhaustible supply of saline water but having no way to use it. Although some substances dissolved in water, such as calcium carbonate, can be removed by chemical treatment, other common constituents, like sodium chloride, require more technically sophisticated methods, collectively known as desalination. In the past, the difficulty and expense of removing various dissolved salts from water made saline waters an impractical source of potable water. However, starting in the 1950s, desalination began to appear to be economically practical for ordinary use, under certain circumstances. The product water of the desalination process is generally water with less than 500 mg/l dissolved solids, which is suitable for most domestic, industrial, and agricultural uses.

RO technology is used to desalinate groundwater. New membranes are being designed to operate at higher pressures (7 to 8.5 atm) and with greater efficiencies, removing 60% to 75% of the salt plus nearly all organics, viruses, bacteria, and other chemical pollutants. Industrial applications that require pure water, such as the manufacture of electronic parts, specialty foods, and pharmaceuticals, use reverse osmosis as an element of the production process, where the concentration and/or fractionating of a wet process stream is needed. Greenhouse and hydroponic farmers may also use RO to desalinate and purify irrigation water for greenhouse use. The RO product water tends to be lower in bacteria and nematodes, which also helps to control plant diseases.

In some Caribbean islands like Antigua and Barbuda, the Bahamas and the British Virgin Islands, RO technology has been used to provide public water supplies with moderate success. In Antigua and Barbuda, there are five reverse osmosis units which provide water to the Antigua Public Utilities Authority, Water Division. In addition, the major resort hotels and a bottling company have desalination plants. In the British Virgin Islands, all water used on the island of Tortola, and approximately 90% of the water used on the island of Virgin Gorda, is supplied by desalination.

Advantages and disadvantages

This technology is suitable for use in regions where seawater or brackish groundwater is readily available. The processing system is simple; the only complicating factor is finding or producing a clean supply of feedwater to minimize the need for frequent cleaning of the membrane. Systems may be assembled from prepackaged modules to produce a supply of product water ranging from a few liters per day to 750 000 l/day for brackish water, and to 400 000 l/day for seawater; the modular system allows for high mobility, making RO plants ideal for emergency water supply use. Installation costs are low and RO plants have a very high space/production capacity ratio, ranging from 25 000 to 60 000 $l/day/m^2$. There is however, a need for foreign assistance to design, construct and operate plants. Apart from this, other disadvantages include interruptions of service during stormy weather for plants that use seawater. Although there is minimal adverse impact on the environment using RO technology, the brine produced must be carefully disposed of to avoid deleterious environmental impacts. There is also a risk of bacterial contamination of the membranes; while bacteria are retained in the brine stream, bacterial growth on the membrane itself can introduce tastes and odors into the product water. RO technologies require a reliable energy source and desalination technologies have a high cost when compared to other methods, such as groundwater extraction or rainwater harvesting. RO technologies are also perceived to be expensive and complex, a perception that restricts them to high-value coastal areas and limited use in areas with saline groundwater that lack access to more conventional technologies.

The importance of water to the general well-being of man and the sustainability of the environment cannot be over-emphasized. Any measure that will result in increased availability will serve to enhance the quality of life and should be encouraged.

## Sanitation

There are at least 2.4 billion people in the world without improved sanitation, defined by the WHO as connection to a public sewer, connection to a septic system, a pour-flush latrine, a simple pit latrine or a ventilated improved pit latrine. Of the 1 billion people served by sewage systems, it is estimated that only 30% of those systems have advanced end-of-the-pipe treatment (secondary level or better) (Matsui, 2002). These figures indicate that even people with conventional sanitation solutions do not escape the sanitation crisis.

The water supply and sanitation coverage data for the year 2000 for the Caribbean and Latin America are presented on the data in the table below. The figures show that in the vast majority of countries in the region more than 75% of the people have both water supply and sanitation coverage. The countries of the Caribbean tend to have the highest reported coverage levels in the region. In only one country of the region, Haiti, is less than 50% of the population without improved water supply. Similarly, there are only two countries with less than 50% sanitation coverage, Belize and Haiti.

Even though there may not seem to be a sanitation crisis in the majority of Caribbean countries, there is still a need to find sustainable alternatives to conventional approaches for both developed and developing countries. Sanitation can no longer be a linear process where excreta is hidden in deep pits or flushed untreated downstream to other communities and ecosystems. Sustainable and ecological sanitation requires a holistic approach.

Data for 1990 and 2000 by country, area or territory.

TABLE 8.1 LATIN AMERICA AND THE CARIBBEAN: WATER SUPPLY AND SANITATION COVERAGE BY COUNTRY, AREA OR TERRITORY, 1990 AND 2000

| | Year | Total population (thousands) | Urban population (thousands) | Rural population (thousands) | % urban water supply coverage | % rural water supply coverage | % total water supply coverage | % urban sanitation coverage | % rural sanitation coverage | % total sanitation coverage |
|---|---|---|---|---|---|---|---|---|---|---|
| Anguilla | 1990 | 8 | 1 | 7 | | | | | | |
| | 2000 | 8 | 1 | 7 | 60 | 60 | 60 | 99 | 99 | 99 |
| Antigua and Barbuda | 1990 | 64 | 23 | 41 | | | | | | |
| | 2000 | 68 | 25 | 43 | 95 | 89 | 91 | 98 | 94 | 96 |
| Argentina | 1990 | 32 527 | 28 141 | 4 386 | | | | | | |
| | 2000 | 37 032 | 33 299 | 3 733 | 85 | 30 | 79 | 89 | 48 | 85 |
| Aruba | 1990 | - | - | - | | | | | | |
| | 2000 | - | - | - | | | 100 | | | |
| Bahamas | 1990 | 255 | 213 | 42 | | | | | | |
| | 2000 | 306 | 271 | 35 | 98 | 86 | 96 | 93 | 94 | 93 |
| Barbados | 1990 | 257 | 115 | 142 | 100 | 100 | 100 | 100 | 100 | 100 |
| | 2000 | 270 | 135 | 135 | 100 | 100 | 100 | 100 | 100 | 100 |
| Belize | 1990 | 187 | 89 | 98 | | | | | | |
| | 2000 | 241 | 131 | 110 | 83 | 69 | 76 | 50 | 21 | 42 |
| Bolivia | 1990 | 6 573 | 3 653 | 2 920 | 92 | 52 | 74 | 77 | 28 | 55 |
| | 2000 | 8 329 | 5 203 | 3 126 | 93 | 55 | 79 | 82 | 38 | 66 |
| Brazil | 1990 | 147 940 | 110 524 | 37 416 | 93 | 50 | 82 | 84 | 37 | 72 |
| | 2000 | 170 115 | 138 269 | 31 846 | 95 | 54 | 87 | 85 | 40 | 77 |
| British Virgin Islands | 1990 | 16 | 8 | 8 | | | | | | |
| | 2000 | 21 | 13 | 8 | 98 | 98 | 98 | 100 | 100 | 100 |
| Cayman Islands | 1990 | 26 | 26 | 0 | | | | | | |
| | 2000 | 38 | 38 | 0 | | | | | | |
| Chile | 1990 | 13 099 | 10 908 | 2 191 | 98 | 48 | 90 | 98 | 93 | 97 |
| | 2000 | 15 212 | 13 031 | 2 181 | 99 | 66 | 94 | 98 | 93 | 97 |
| Colombia | 1990 | 34 970 | 24 291 | 10 679 | 95 | 68 | 87 | 85 | 53 | 82 |
| | 2000 | 42 322 | 31 274 | 11 048 | 98 | 73 | 91 | 97 | 51 | 85 |
| Costa Rica | 1990 | 3 049 | 1 395 | 1 654 | | | | | | |
| | 2000 | 4 024 | 1 925 | 2 099 | 98 | 98 | 98 | 98 | 95 | 96 |
| Cuba | 1990 | 10 627 | 7 827 | 2 800 | | | | | | |
| | 2000 | 11 201 | 8 436 | 2 765 | 99 | 82 | 95 | 98 | 91 | 95 |
| Dominica | 1990 | 71 | 48 | 23 | | | | | | |
| | 2000 | 70 | 50 | 20 | 100 | 90 | 97 | | | |
| Dominican Republic | 1990 | 7 110 | 4 142 | 2 968 | 83 | 70 | 78 | 66 | 52 | 60 |
| | 2000 | 8 495 | 5 526 | 2 969 | 83 | 70 | 79 | 75 | 64 | 7L |

TABLE 8.1 LATIN AMERICA AND THE CARIBBEAN: WATER SUPPLY AND SANITATION COVERAGE BY COUNTRY, AREA OR TERRITORY, 1990 AND 2000 (CONT.)

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Ecuador | 1990 | 10 264 | 5 655 | 4 609 | | | | | | |
| | 2000 | 12 646 | 8 262 | 4 384 | 81 | 51 | 71 | 70 | 37 | 59 |
| El Salvador | 1990 | 5 110 | 2 242 | 2 868 | | 47 | | | | |
| | 2000 | 6 276 | 2 927 | 3 349 | 88 | 61 | 74 | 88 | 78 | 83 |
| Falkland Islands/ Islas Malvinas | 1990 | 3 | 2 | 1 | | | | | | |
| | 2000 | 2 | 2 | 0 | | | | | | |
| French Guiana | 1990 | 117 | 87 | 30 | | | | | | |
| | 2000 | 182 | 142 | 40 | 88 | 71 | 84 | 85 | 57 | 79 |
| Grenada | 1990 | 91 | 31 | 60 | | | | | | |
| | 2000 | 94 | 36 | 58 | 97 | 93 | 94 | 95 | 97 | 97 |
| Guadeloupe | 1990 | 391 | 385 | 6 | | | | | | |
| | 2000 | 455 | 454 | 1 | 94 | 94 | 94 | 61 | 61 | 61 |
| Guatemala | 1990 | 8 749 | 3 333 | 5 416 | 88 | 72 | 78 | 94 | 66 | 77 |
| | 2000 | 11 385 | 4 515 | 6 870 | 97 | 88 | 92 | 98 | 76 | 85 |
| Guyana | 1990 | 795 | 264 | 531 | | | | | | |
| | 2000 | 861 | 329 | 532 | 98 | 91 | 94 | 97 | 81 | 87 |
| Haiti | 1990 | 6 916 | 2 038 | 4 878 | 55 | 42 | 45 | 48 | 15 | 25 |
| | 2000 | 8 222 | 2 935 | 5 287 | 49 | 45 | 46 | 50 | 16 | 28 |
| Honduras | 1990 | 4 879 | 2 040 | 2 839 | 80 | 79 | 84 | 85 | | |
| | 2000 | 6 485 | 3 420 | 3 065 | 97 | 82 | 90 | 94 | 57 | 77 |
| Jamaica | 1990 | 2 369 | 1 219 | 1 150 | | | | | | |
| | 2000 | 2 583 | 1 449 | 1 131 | 81 | 59 | 71 | 99 | 85 | 84 |
| Martinique | 1990 | 360 | 326 | 34 | | | | | | |
| | 2000 | 395 | 375 | 20 | | | | | | |
| Mexico | 1990 | 83 226 | 60 305 | 22 921 | 92 | 61 | 83 | 85 | 28 | 69 |
| | 2000 | 98 881 | 73 553 | 25 328 | 94 | 63 | 86 | 87 | 32 | 73 |
| Montserrat | 1990 | 11 | 2 | 9 | 100 | 100 | 100 | 100 | 100 | 100 |
| | 2000 | 11 | 2 | 9 | 100 | 100 | 100 | 100 | 100 | 100 |
| Netherlands Antilles | 1990 | 187 | 128 | 59 | | | | | | |
| | 2000 | 217 | 153 | 64 | | | | | | |
| Nicaragua | 1990 | 3 827 | 2 031 | 1 796 | 93 | 44 | 70 | 97 | 53 | 76 |
| | 2000 | 5 074 | 2 848 | 2 226 | 95 | 59 | 79 | 95 | 68 | 84 |
| Panama | 1990 | 2 397 | 1 288 | 1 109 | | | | | | |
| | 2000 | 2 856 | 1 606 | 1 219 | 88 | 86 | 87 | 99 | 87 | 94 |
| Paraguay | 1990 | 4 218 | 2 054 | 2 164 | 80 | 47 | 63 | 92 | 87 | 89 |
| | 2000 | 5 497 | 3 077 | 2 420 | 95 | 58 | 79 | 95 | 95 | 95 |
| Peru | 1990 | 21 570 | 14 862 | 6 708 | 84 | 47 | 72 | 81 | 26 | 64 |
| | 2000 | 25 662 | 18 674 | 6 988 | 87 | 51 | 77 | 90 | 40 | 76 |
| Puerto Rico | 1990 | 3 528 | 2 516 | 1 012 | | | | | | |
| | 2000 | 3 869 | 2 910 | 959 | | | | | | |
| Saint Kitts and Nevis | 1990 | 41 | 14 | 27 | | | | | | |
| | 2000 | 38 | 13 | 25 | | | 98 | | | 96 |
| Saint Lucia | 1990 | 134 | 50 | 84 | | | | | | |
| | 2000 | 154 | 58 | 96 | | | 98 | | | |
| Saint Vincent and the Grenadines | 1990 | 106 | 43 | 63 | | | | | | |
| | 2000 | 114 | 62 | 52 | | | 93 | | | 96 |
| Suriname | 1990 | 402 | 263 | 139 | | | | | | |
| | 2000 | 418 | 310 | 108 | 94 | 96 | 95 | 100 | 34 | 83 |
| Trinidad and Tobago | 1990 | 1 216 | 840 | 376 | | | | | | |
| | 2000 | 1 295 | 959 | 336 | | | 86 | | | 88 |
| Turks and Caicos Islands | 1990 | 12 | 5 | 7 | | | | | | |
| | 2000 | 17 | 8 | 9 | 100 | 100 | 100 | 98 | 94 | 96 |
| United States Virgin Islands | 1990 | 102 | 45 | 57 | | | | | | |
| | 2000 | 93 | 43 | 50 | | | | | | |
| Uruguay | 1990 | 3 106 | 2 755 | 351 | | | | | | |
| | 2000 | 3 337 | 3 045 | 292 | 98 | 93 | 98 | 95 | 89 | 95 |
| Venezuela | 1990 | 19 502 | 16 378 | 3 124 | | | | | | |
| | 2000 | 24 170 | 21 010 | 3 160 | 88 | 58 | 84 | 75 | 69 | 74 |

Source: (30)

Source: **Global Water Supply and Sanitation Assessment 2000 Report**

### *Ecological sanitation*

Ecological sanitation provides alternative solutions with or without water, while providing containment, treatment and recycling of excreta. It can involve soil-based composting toilets in shallow reinforced pits, dry urine-diverting toilets with storage vaults, urine-diverting miniflush toilets and even high-tech vacuum systems.

### *Decentralized wastewater treatment*

With decentralized wastewater treatment is a system of small, individual or cluster type wastewater treatment facilities maintained by a local utility. The local utility provides wastewater treatment services to residents – meaning it distributes sewer service – but does not use a traditional, centralised wastewater treatment plant to serve a region. In other words, it uses decentralised wastewater treatment options. A decentralised wastewater treatment system as a distributed sewer has marked advantages over regional sewer models, especially when it comes to funding infrastructure construction. By forming cooperative arrangements, utilities and developers are creating win-win situations, which provide sewer service for landowners, ideal lot sizes for developers and infrastructure at essentially no cost to utilities. It should be noted, however, that decentralised sewer is not a good option for areas with high population density. Paradoxically, there are times when the population is too sparse to justify the cost of a distributed sewer, the minimum number of residences to justify this type of system being 20. Additionally, there are certain soil conditions, such as very dense clay or rock areas, which limit the drip feature of distributed sewer treatment systems. [3]

### *Self-contained wastewater treatment systems*

These systems may be used for the secondary treatment of wastewater, primarily for the conversion and reduction of nitrogen and phosphorus removal. It is a series of filters partitioned into several treatment compartments that can be operated under anaerobic, anoxic or aerobic conditions. Typical installations include residential clusters, malls, nursing homes, schools, supermarkets, restaurants, gas stations, golf courses, hotels and small communities.[4]

### *Biological wastewater treatment plants for individual dwellings*

Biological wastewater treatment plants are intended for individual dwellings, small hotels, motels, boarding houses, etc. The treatment process is based on modern knowledge and last discoveries in the field of hydro microbiology. Biological process develops independently without any external interference. The treatment process is of high resistance to changes in working conditions owing to the system's self-regulation and ability to adapt to concrete flow characteristics. During biofiltration, there is no excess sludge; no need for control and regulation; minimum power consumption; and a high degree of biological disinfection that makes possible reuse of treated water for watering and other purposes.

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[3] Craig Lindell. Decentralised wastewater treatment. The marketplace and infrastructure reform. CE News. March 2002.

[4] AquaPoint self contained wastewater treatment systems. www.aquapoint.com

### Land fill management

Several new technologies for landfill management applicable to the subregion include:

(a) The application of analytical technologies to waste streams for the identification of compounds of interest;

(b) Examining the benefits of composting putrifiable waste and application to agricultural land;

(c) Manure management to reduce burden of waste.

The implications of poor sanitation measures are obvious - in terms of cost to the population, given its place in the development process it is a factor that must be taken seriously if catastrophes are to be avoided.

## Fisheries management

### The ecosystem approach to capture fisheries management

In recent years there has been a growing awareness that the traditional approach to managing fisheries, which considers the target species as independent, self-sustaining populations, is insufficient. It is being recognized that sustainable use of the world's living aquatic resources can only be achieved if both the impacts of the ecosystem on the living resources and the impacts of the fishery on the ecosystem are explicitly identified and, as far as possible, understood. It is also being formally acknowledged that fishers are an integral part of the ecosystem and that both ecosystem and human well-being must be achieved.

Awareness of the essential interactions between populations and their biological, physical and chemical environment is not new. However, traditional knowledge was frequently overlooked and models focused all attention on the target resources and on the impact that fishing removals had on their dynamics. An ecosystem approach, however, requires the monitoring and assessment of all aspects of the ecosystem, a wider range of management measures, possibly more control and surveillance, and more time dedicated to interacting with a wider range of stakeholders.

Most methods and approaches to fisheries management require an assessment of fish stocks in terms of their biomass, size or age composition and survival, as well as their responses to natural and fishing mortality. Population models and their dynamics under environmental and human-induced perturbations are the principal tools. These require data on how much fish has been caught, the size, age or gender of that fish, and the growth and survival rates that it exhibits, as well as additional information on many other factors.

In order to make stock assessments relevant to site-specific fisheries management, such additional information might include data on the place and time of capture, the reproductive status and the behaviour of the fish. It is essential to know what is actually being fished from the wild population, as this affects the stock's ability to survive and, most important, to reproduce and repopulate. This is why catch and effort statistics, along with other data regarding the fish caught, are the key and essential basis for effective fisheries management.

Statistics are often also used for direct administrative management control to ensure that fishers are constrained within the set limits. Fisheries management measures often specify how much fish may be taken, by whom, by what means, when and where. Thus, total allowable catch and licence or quota allocation, fishing gear and operational controls, as well as seasonal and area closures, all require monitoring, much of which can only be achieved by the regular and systematic collection of reliable statistics on the catch and the amount of fishing effort.

Fisheries management should protect the food security and livelihoods of dependent communities and try to ensure that benefits from the surplus production of wild stocks are brought into economies in ways that are appropriate to the political, social and development environments in which they occur. Governments and industries need reliable statistics in order to understand the economic relationships within the fisheries sector and its linkages to other sectors, e.g. finance, energy supply or vessel construction. They must plan for training and investment if potential yields are greater than current yields, or for retraining and stable industry reduction if the existing capacity is greater than appropriate. Communities need catch and effort statistics if they are to achieve and ensure a fair and appropriate distribution of benefits. Policy makers need such statistics so that fishing communities can be properly represented when sectoral policies are being developed.

In addition, improving reliable statistics requires cooperation in the development and adoption of standards. Standardization of nomenclature and coding, adoption of agreed statistical methodologies and implementation of transparent information exchange methods require high levels of trans-boundary agreement so that the nature and origin of fishery statistics is understood across regions, oceans and the world.

The trend towards healthier eating makes fish and other marine products a more desirable dietary item. There are therefore compelling reasons for proper management and sustainability.

## Forestry resource management in Small Island Developing States

There is no internationally accepted definition of a small island developing State. However, small island States were given an international political identity with the establishment in 1991 of the Alliance of Small Island States (AOSIS) currently comprising 39 members (including four low-lying coastal States: Guinea-Bissau, Belize, Guyana and Suriname) and four dependent territories as observers. All the countries of the Caribbean are classified as SIDS, which vary enormously according to distinct geographic, biological, social, cultural and economic characteristics, but face similar constraints to the sustainable use of forest resources. These include: [5]

- *Limited land area and natural resources (Suriname and Guyana are notable exceptions).* This intensifies competition among alternative land use options.

[5] www.fao.org/forestry/site/4461/en

The relatively limited size of watersheds makes soil and water conservation a priority;

- *Vulnerability to environmental disasters.* With few exceptions, Caribbean SIDS are susceptible to storm surges, forest fires, landslides, extended droughts and extensive floods.[6] Since damage often occurs on a national scale, a single disaster can cripple an island's infrastructure and economy. SIDS also face the long-term threat of rising sea levels associated with global climate change;

- *High species endemism but low occurrence of individual species leads to high risk for loss of biological diversity.* The small land area makes it difficult to set aside large areas for strict protection purposes. There is a particular need to develop suitable strategies for conservation of biological diversity, including the conservation of genetic resources of a number of socio-economically important tree species which are endangered in part or all of their natural range.

- *High human population density, usually concentrated in lowland areas, increases pressure on already limited resources*;

- *Economic constraints due to relatively small scale.* This results in high costs for public administration and infrastructure; small internal markets; limited export volumes (sometimes from remote locations) which lead to high freight costs and reduced competitiveness; and difficulties in establishing competitive forest processing industries;

- *Institutional constraints.* National forest agencies have limited material, financial and human resources; forest policies are in need of updating; reliable information is unavailable on forest resources and the value of their productive and protective functions; in some countries, tenure systems result in fragmentation of ownership rights; and high levels of migration, particularly of skilled human resources;

- *Lack of integrated land use planning.* Only few SIDS have well-defined and executed land use plans;

- *Unsustainable forest management practices.* Overexploitation of commercial timber resources, inappropriate harvesting practices, forest industries running below capacity, and the use of inferior planting material due to lack of access to seed of high genetic and physiological quality.

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[6] The 1990 UN Disaster Relief Organization review of the economic impact of disasters over the past 20 years reports that of the 25 most disaster-prone countries, 13 are SIDS.

## Prospects for forest production intensification and diversification in support of improved forest security for SIDS[7]

### *Product intensification*

The short-term prospects for forest production intensification in terms of wood production in natural forests is limited in most SIDS. Although many of the larger SIDS are well endowed with forests, not all forests are accessible and harvesting of commercial species is, in many places, already undertaken at levels which are unsustainable. In many of the smaller SIDS no, or no significant, forest cover exists. In the medium to long term, increases in production from natural forests depend on the adoption of environmentally sound forest harvesting practices and the application of appropriate silvicultural practices - in many cases including enrichment planting of previously harvested areas.

An increase in wood production from plantations is possible in some of the larger SIDS. However, the competition for limited land area, at times combined with customary ownership (see above), limits the potential for large-scale plantation establishment. Lack of good soils is also a limiting factor in some SIDS (particularly those which are coral-based).

### *Diversification*

Value-added wood processing, in particular of local hardwoods, offers good prospects for diversification in SIDS that are well endowed with forests. Good prospects also exist for diversification in terms of the provision of non-wood goods and services:

- Non-wood forest products (plant products collected from the wild or cultivated in plantations or agroforestry systems and animals hunted in the wild or raised in captivity) should be promoted where a niche market exists or can be developed.

- Tourism is one of the most important income earning industries in many SIDS and interest in eco- or nature-based tourism is increasing. Whereas the forests on these islands rarely are the primary attraction for overseas visitors, they may contribute to the tourism appeal. Various islands have made special efforts to develop the tourist potential of their forest areas, among which are Dominica, Jamaica and Saint Lucia.

### *Enhancement of the indirect support to improved food security*

Conservation, enhancement and sustainable use of the forest resources are not only important for the direct benefits to improved food security, but also for the indirect benefits in terms of support to other sectors and the protective functions of forests (see above).

Special efforts may be needed in terms of reforestation of degraded areas (e.g. watersheds) and in most islands, planting in coastal areas is necessary to protect against coastal

[7] www.fao.org/forestry/site/4462/en

erosion. Protection of mangrove areas, which are highly resistant to storm damage, is particularly important in this regard.

In addition to the maintenance and enhancement of forest cover, conservation of biological diversity is of economic importance both from a productive (forestry and agriculture) point of view and in support of nature-based tourism activities.

## Energy

### Solar energy - new technologies in solar energy systems

There are a variety of technologies that have been developed to take advantage of solar energy. These include:

- Photovoltaic (solar cell) systems - producing electricity directly from sunlight;
- Concentrating solar systems - using the sun's heat to produce electricity;
- Passive solar heating and daylighting - using solar energy to heat and light buildings;
- Solar hot water - heating water with solar energy;
- Solar process heat and space heating and cooling - industrial and commercial uses of the sun's heat.

### Concentrating solar power

Many power plants today use fossil fuels as a heat source to boil water. The steam from the boiling water rotates a large turbine, which activates a generator that produces electricity. However, a new generation of power plants, with concentrating solar power systems, uses the sun as a heat source. There are three main types of concentrating solar power systems: *parabolic-trough*, *dish/engine*, and *power tower*.

Parabolic-trough systems concentrate the sun's energy through long rectangular, curved (U-shaped) mirrors. The mirrors are tilted toward the sun, focusing sunlight on a pipe that runs down the center of the trough. This heats the oil flowing through the pipe. The hot oil then is used to boil water in a conventional steam generator to produce electricity.

A dish/engine system uses a mirrored dish (similar to a very large satellite dish). The dish-shaped surface collects and concentrates the sun's heat onto a receiver, which absorbs the heat and transfers it to fluid within the engine. The heat causes the fluid to expand against a piston or turbine to produce mechanical power. The mechanical power is then used to run a generator or alternator to produce electricity.

A power tower system uses a large field of mirrors to concentrate sunlight onto the top of a tower, where a receiver sits. This heats molten salt flowing through the receiver. Then, the salt's heat is used to generate electricity through a conventional steam generator. Molten salt retains heat efficiently, so it can be stored for days before being converted into electricity. That means electricity can be produced on cloudy days or even several hours after sunset.

**Passive solar heating and daylighting**

Buildings may be designed to take advantage of this natural resource through the use of passive solar heating and daylighting. Materials that absorb and store the sun's heat can be built into the sunlit floors and walls. The floors and walls will then heat up during the day and slowly release heat at night, when the heat is needed most. This passive solar design feature is called *direct gain.*

Other passive solar heating design features include *sunspaces* and *trombe walls*. A sunspace (which is much like a greenhouse) is built and as sunlight passes through glass or other glazing, it warms the sunspace. Proper ventilation allows the heat to circulate into the building. On the other hand, a trombe wall is a very thick wall, which is painted black and made of a material that absorbs a lot of heat. A pane of glass or plastic glazing, installed a few inches in front of the wall, helps hold in the heat. The wall heats up slowly during the day. Then as it cools gradually during the night, it gives off its heat inside the building.

Many of the passive solar heating design features also provide daylighting. Daylighting is simply the use of natural sunlight to brighten up a building's interior. To lighten up rooms and upper levels, a *clerestory*— a row of windows near the peak of the roof— is often used along with an open floor plan inside that allows the light to bounce throughout the building.

In the Caribbean, too much solar heating and daylighting can be a problem, especially during the dry season or January–June. Fortunately, there are many design features that help keep passive solar buildings cool. For instance, overhangs can be designed to shade windows when the sun is high. Sunspaces can be closed off from the rest of the building and a building can be designed to use fresh-air ventilation in the summer.

**Solar water heating**

Most solar water heating systems for buildings have two main parts: a solar collector and a storage tank. The most common collector is called a *flat-plate collector*. Mounted on the roof, it consists of a thin, flat, rectangular box with a transparent cover that faces the sun. Small tubes run through the box and carry the fluid – either water or other fluid such as an antifreeze solution – to be heated. The tubes are attached to an absorber plate, which is painted black to absorb the heat. As heat builds up in the collector, it heats the fluid passing through the tubes.

The storage tank then holds the hot liquid. It can be just a modified water heater, but it is usually larger and very well-insulated. Systems that use fluids other than water usually heat the water by passing it through a coil of tubing in the tank, which is full of hot fluid.

Solar water heating systems can be either active or passive, but the most common are active systems. Active systems rely on pumps to move the liquid between the collector and the storage tank, while passive systems rely on gravity and the tendency for water to naturally circulate as it is heated.

Swimming pool systems are simpler. The pool's filter pump is used to pump the water through a solar collector, which is usually made of black plastic or rubber. And of course, the pool stores the hot water.

**Solar process heat and space heating and cooling**

Commercial and industrial buildings may use the same solar technologies— photovoltaics, passive heating, daylighting, and water heating— that are used for residential buildings. These non-residential buildings can also use solar energy technologies that would be impractical for a home. These technologies include ventilation air preheating, solar process heating and solar cooling.

Solar process heating systems are designed to provide large quantities of hot water or space heating for non-residential buildings. A typical system includes solar collectors that work along with a pump, a heat exchanger, and/or one or more large storage tanks. The two main types of solar collectors used— an *evacuated-tube collector* and a *parabolic-trough collector*— can operate at high temperatures with high efficiency. An evacuated-tube collector is a shallow box full of many glass, double-walled tubes and reflectors to heat the fluid inside the tubes. A vacuum between the two walls insulates the inner tube, holding in the heat. Parabolic troughs are long, rectangular, curved (U-shaped) mirrors tilted to focus sunlight on a tube, which runs down the center of the trough. This heats the fluid within the tube.

The heat from a solar collector can also be used to cool a building. It may seem impossible to use heat to cool a building, but it makes more sense if you just think of the solar heat as an energy source. Home air conditioner uses an energy source, electricity, to create cool air. Solar absorption coolers use a similar approach, combined with some very complex chemistry tricks, to create cool air from solar energy. Solar energy can also be used with evaporative coolers (also called "swamp coolers") to extend their usefulness to more humid climates, using another chemistry trick called *desiccant cooling.*

Open plan concepts are preferred as they stay cooler and better reflect the informal lifestyle of the Caribbean, as well as lending themselves to the creation of "inside/ outside" spaces that are at one with nature. Buildings should be timeless, built to last and adjust to the topography of the site. This allows buildings to respond to their sites rather than just "sit" on them.

As an important component of the development process, reliable and affordable energy sources can boost development at a level that is sustainable. Energy deficiency, on the other hand, can seriously hamper the development process. There is therefore ample reason for policy and programmes in the energy equation of States and the region.

**Environmental design - green buildings**

Environmental building design is design that engages environmental considerations. It is design that includes environmental criteria in the decision-making or filtering steps that lead to the completion of a design. Adjectivally, the term environmental is often thought of as an incidental issue, a public concern and an addition to marketing that adds cost but distinguishes one product over another. However, the term environmental modifies design so radically that it is almost a discipline on to its own.

To achieve environmental design it is imperative that the entire design method, approach, and discipline be overhauled. Every component, every guideline, every mark of the pen must consider the implications of the adjective environmental. As such, environmental design must be thought of as an overall approach or philosophy. Its limits go well beyond the practice of design to every aspect of society and to the personal life of every designer. It becomes a way of life, a way of thinking, a means to interact with the world.

A "green" building can be defined as any building that is sited, designed, constructed, operated and maintained for the health and well-being of the occupants, while minimizing impact on the environment. "Green building" refers to those practices that promote occupant health and comfort while minimizing negative impacts on the environment. There are different degrees of "greenness." Often, it is necessary to strike a balance among the many different, sometimes conflicting, green options based on the particular conditions of a given project. For example, proper strategy for a sustainable retrofit project may differ from that of new construction design. Green building practices offer an opportunity to create environmentally sound and resource-efficient buildings by using an integrated approach to design. Green buildings promote resource conservation by including design features which encourage energy efficiency, use of renewable energy and encourage water conservation. By promoting resource conservation, green building design creates healthy and comfortable environments, reduces operation and maintenance costs, considers environmental impacts of building construction and retrofit, and concentrates on waste minimization. In the interim, green building design addresses such issues as historical preservation and access to public transportation and other community infrastructure systems. The entire life cycle of the building and its components are considered, as well as the building's economic and environmental impact and performance. Green buildings are really resource efficient buildings and are very energy efficient, utilize construction materials wisely -- including recycled, renewable, and reused resources to the maximum extent practical -- are designed, constructed and commissioned to ensure they are healthy for their occupants, are typically more comfortable and easier to live with due to lower operating and owning costs, and are good for the planet.

The overall environmental impact of new building and community development and the choices made when we either reuse or demolish existing structures is very important to the cultural landscape of development.

**Conclusion**

The technologies identified above are by no means exhaustive, but the paper serves to demonstrate that alternatives are available and more importantly, the constant need to be aware of the existence of technologies that will contribute to sustainable development. This is especially important in the Caribbean, where a culture of technological innovation has not yet sufficiently evolved.