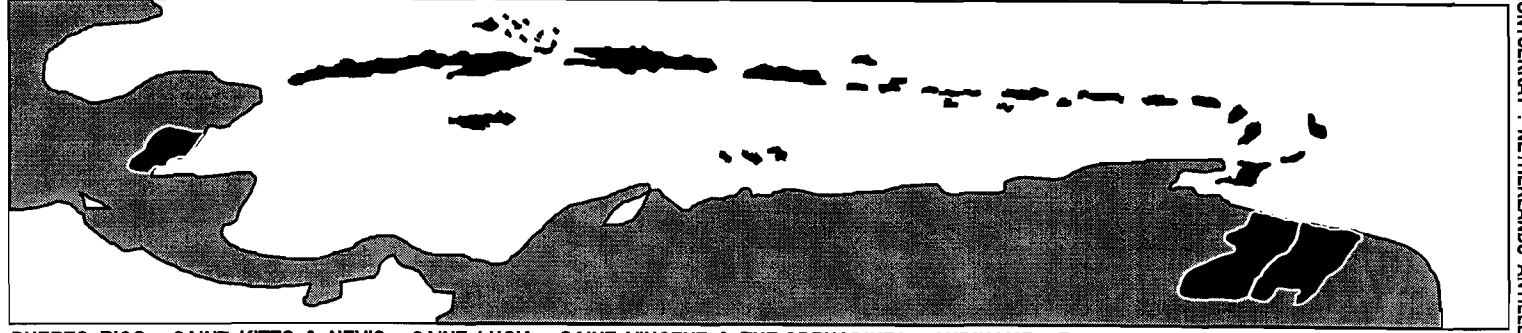




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**A PROGRAMME FOR SCIENCE AND TECHNOLOGY MANAGEMENT
IN THE CARIBBEAN — 2000**



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TABLE OF CONTENTS

NATURE AND SCOPE OF SCIENCE AND TECHNOLOGY	1
SCIENCE AND TECHNOLOGY IN THE CARIBBEAN.....	1
A VISION OF THE CARIBBEAN IN THE FUTURE.....	2
ROLE OF SCIENCE AND TECHNOLOGY IN ACHIEVING THIS VISION	2
SCIENCE AND TECHNOLOGY ISSUES FOR THE SMALL STATES AND THE CARIBBEAN	4
<i>Climate change and sea-level rise</i>	5
<i>Natural and environmental disasters</i>	7
<i>Management of wastes</i>	8
<i>Coastal and marine resources</i>	9
PROGRAMME PROPOSALS	11
<i>Fisheries biology and management</i>	12
<i>Mariculture and aquaculture</i>	15
<i>Pollution control and amelioration</i>	16
<i>Ocean energy</i>	16
<i>Freshwater resources</i>	18
<i>Land resources</i>	20
<i>Energy resources</i>	21
<i>Tourism resources</i>	22
<i>Biodiversity resources</i>	23
<i>Transport and communication</i>	24
<i>Human resource development</i>	25
<i>Information technology</i>	26
<i>Computer technology</i>	26
PRIORITY PROGRAMME FOR SCIENCE AND TECHNOLOGY MANAGEMENT IN THE CARIBBEAN--2000	27
THE NATURE OF SMALL STATES	27
<i>Preservation and management of the environment</i>	28
<i>Agriculture</i>	29
<i>Tourism</i>	30
<i>Biotechnology</i>	31
<i>Energy</i>	31
<i>Science education</i>	32
<i>Industrial and technological development</i>	33
THE ENVIRONMENT FOR THE PROMOTION OF SCIENCE AND TECHNOLOGY MANAGEMENT IN SMALL STATES	34
REGIONAL AND INTERNATIONAL COOPERATION AND THE DEVELOPMENT OF CENTRES OF EXCELLENCE	34

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Nature and scope of science and technology

Science can be defined as knowledge ascertained by observation and experiment, critically tested, systemized and codified under general principles. Technology can be considered as the use of knowledge for the production of goods and services to meet the development needs of a population. Advancement in modern technology is increasingly science-led. At the same time, by providing new modes and instruments of observation and experiment, technology contributes to the advancement of science. Thus, science and technology have a synergistic relationship, and because of this they tend to be paired as though representing a single entity, that is, "science and technology".

Science and technology has relevance, not only for productive sectors such as industry and agriculture, but also for the economic and socio-economic sectors - health, transport, education and information.

Indigenous research and experimental development work are important in that they use science and technology to gain a better understanding of the immediate environment in order to derive tangible physical benefits. Equally important are the results of those scientific and technological activities, which have a worldwide impact.

Science and technology in the Caribbean

At their first meeting in Kingston, Jamaica, 6-7 April 1983, Caribbean Ministers with responsibility for science and technology emphasized the pivotal and pervasive role which science and technology plays in the development process and stresses the critical importance of regional cooperation in its application to development in the Caribbean. The ministers identified agri-industry and science and technology information as immediate priority areas for concerted action at the national and regional levels. They, however, noted that there were a number of other wide-ranging issues, which required in-depth study with a view to formulating a comprehensive science and technology action plan for the subregion.

Efforts at addressing development issues in the Caribbean have not always been coordinated and the science and technology components of the development process have been, by and large, neglected. The traditional export sector in the Caribbean can be said to be relatively well served by technology, albeit for the most part, foreign technologies. However, there is a large underdeveloped sector, which, with timely technological intervention, can be made to be more significantly productive and competitive. The development of this sector can significantly increase foreign exchange earnings as well as increase employment and thus make an important contribution to the economy. Endogenous technological development is therefore required in this sector to propel it to the level of activity at which its true potential can be realized.

The continual development and application of science and technology in the Caribbean will depend significantly on the creation of the appropriate climate and infrastructure. This is especially important if science and technology is to become an integral part of Caribbean culture, and the recognition that science and technology matters are the concern of not just a few, but of the whole society. Programmes designed to create such acceptance and general understanding needs to be encouraged.

It is important to identify technology that is appropriate to the Caribbean. This does not necessarily imply the use of simple technology, but rather technologies which are appropriate to our climate, size and available resources. Whatever the choice of technology, however, it is necessary that the social dimension be always considered, to, among other things, relieve the chronic unemployment situation in the Caribbean. This would require a trained workforce which can apply those technologies to produce a Caribbean in which we would all like to live and pass down unspoiled to our children.

A vision of the Caribbean in the future

We see the Caribbean of the future as a part of the world where the people have a high quality of life with the entire population having its basic needs satisfied - food, clothing, shelter, education, health care and employment. Such a people should live in an environment of equally high quality, one that has not been destroyed by the development process. This Caribbean would have adapted to a way of life in a multi-cultural society, attentive to the needs of others and dedicated to the preservation of the best of our traditions.

The development of the human resources and the application of science and technology in the regional context must address such a vision. Never before have the challenges facing the Caribbean been greater. The effects of globalization and the emergence of new high-tech economies have impacted on our way of life and very existence. Thankfully, Caribbean leaders have accepted the goal of a single market and economy, and as difficult as this undertaking may be, there appears to be no other hope for the survival of the region. The region's human resources must be developed to serve this end and science and technology must be applied in all aspects of development. Economic policies must be balanced with an awareness of social consequences particularly the employment factor. There has to be attention to ethics and alleviation of the problems of the marginalized and the weak.

Role of science and technology in achieving this vision

If the vision is to be achieved, we must take the decisions that will make it happen and not proceed on an unplanned development path. There clearly is a need both at the regional and local levels to pay serious attention to the application of Science and Technology to the development process. A system must be developed to manage science and technology at all levels given the scarce resource base of the Caribbean. We need to institutionalize short, medium and long-term planning and avoid crisis management.

There must be clear policy directions and the preparation of plans based on these policies. The preparation of plans would also entail the identification of resources for the implementation

and for monitoring/evaluation devices to ensure that the plans are effectively carried out. It must be recognized that any macro-economic decision has science and technology implications. For example, increasing the capacity of a hotel has implications for water, roads, electricity, food supply, sewage, waste disposal, etc. Decisions cannot be made in the absence of serious science and technology input and consultation with the various players/sectors involved. For all the above to be effective, science and technology must be well-organized at the local level and given a firm place by way of councils, or other mechanisms in the national planning process.

There is need for ongoing consultation to inform policy and some mechanism to facilitate regional consultation. The work of regional institutions, such as the universities and other research and training institutions must address regional problems (in agriculture, in industry, health, etc.). These institutions must also produce the manpower to carry out the tasks that need to be done in the Caribbean region. There must be cooperation to avoid duplication of effort and regional support must therefore be forthcoming.

The education system has an important role to play in the application of science and technology to development. We must ensure that the entire population has adequate skills in reading, oral and written communication and calculation, and we must build on this base to produce a computer literate society. There is need to popularize science and technology, to indicate to the population that science and technology is involved in all activities. Science and technology awareness must become part of the culture.

We must recognize that much innovation comes from the ground floor and our general work force must become better educated. We need to introduce throughout, the concept of looking for best practice whether in agriculture, in industry, in the entertainment sector, to serve as showcases of what can be achieved when all the parameters are factored into a development plan and strategy.

In summary, science and technology should be used to:

- (a) Optimize the benefits to be derived from the exploitation of available resources while protecting the environment;
- (b) Develop and make use of skilled human resources as the critical engine for transformation and growth;
- (c) Create dynamism in existing and future Caribbean agriculture and industry to enable rapid adjustment to technological, market and other changes which affect competitiveness;
- (d) Promote and foster a climate conducive to the development, exchange and effective use of technology within the region;
- (e) Ensure the most cost-effective methods of acquiring and using technology developed and available within and outside the region; and

- (f) Preserve and enrich the cultural heritage of the peoples of the region.

Science and technology issues for the small States and the Caribbean

In 1994 the United Nations adopted a Programme of Action for Small Island States (SIDS-POA). The Programme described the broad outlines of the science and technology issues on small States. The following programme will build upon the SIDS/POA and provide the science and technology needs for implementation.

Science and technology are crucial for the achievement of sustainable development. There would be considerable benefit if all countries incorporated more environmentally friendly technologies. However, in Small Island Developing States (SIDS), science and technological capacity remains underdeveloped both in terms of research and development institutions and the availability of scientists to serve such institutions on a sustained basis. At the same time, some island peoples survive on traditional knowledge and its application. These are being threatened in SIDS, increasingly driven to adopt technologies and scientific understanding. A better integration of contemporary and traditional knowledge could also prove beneficial.

Many new environmentally sound technologies relevant to economic activities in SIDS are becoming available. Information concerning these and the ability to assess them are crucial for technological change to achieve sustainable development. Science and technological capacity require trained people to serve in production enterprises, to engage in training and to help in the assessment and adaptation of imported technologies.

SIDS will benefit from increased access to imported technologies to facilitate their sustainable development. However, improved capacity to tap local knowledge and to develop environmentally sound endogenous technologies is also important in a number of areas including agriculture, agricultural processing, construction, communications and marine sciences, as an important step towards sustainable development.

Trained people are needed in a wider range of fields to ensure adequate training and capacity for environmental impact and technology assessment. Limited national capacities mean that in some of these areas, emphasis would have to be given to regional and sub-regional approaches and joint ventures with the international community. Encouragement of private sector involvement could also be very important because of limited governmental capacity to undertake both training and research and development.

The science and technology management issues relating to the promotion of science and technology in the region

(a) Ensure that science and technology policy is closely linked to national environmental strategies and sustainable development plans and is responsive to local and sectoral sustainable development needs, emphasizing self-sufficiency, the minimization of import dependency and promotion of exports.

(b) Greater emphasis on research and development, as well as on training for science and technology and economic development generally, and for environmental and technology assessment in particular. The need to refine analytical tools for natural resource accounting; and encourage the development and use of information and communications technology to overcome size and isolation problems.

(c) Promotion of research and development in areas where endogenous technologies and traditional practices have great relevance, including agriculture, agricultural processing, waste-recycling, ethnobiology and biotechnology, construction and renewable energy, ensuring that mechanisms are in place for the appropriate protection of intellectual property rights in accordance with relevant international conventions.

(d) Encouraging the use of endogenous environmentally friendly technologies through regulations, standards and economic incentives.

(e) Developing and/or ensuring access to databases on environmentally sound technologies of local relevance and collecting consistent time-series data as part of the monitoring and evaluation process.

(f) The promotion and strengthening of the role of women in science and technology disciplines.

(g) The establishment of Technology Extension Services (TES) at the national level to assist in the dissemination, adaptation and introduction of appropriate technologies. Such a service would also provide inputs from the field to research institutions and decision-makers to help in the development of new technologies and products as well as ensuring quality control and proper maintenance mechanisms and practices.

Climate change and sea-level rise

SIDS are particularly vulnerable to global climate change, climate variability and sea-level rise. As most populations, agricultural lands and infrastructures of SIDS exist in the coastal zone, any rise in sea level will have significant and profound effects on the economies and on the living conditions of the population of those countries. The very survival of certain low-lying countries would be threatened by sea level rise.

The process established by the Framework Convention on Climate Change and the ongoing negotiations of its Intergovernmental Negotiating Committee are important international actions aimed at addressing the threat of climate change, mitigating its adverse impacts on SIDS and assisting them in adapting to the adverse consequences. It is becoming clear that the commitments, in particular those related to emissions of greenhouse gases should be considered inadequate for the long term and further action may be required to make satisfactory progress towards achieving the objective of the Convention. In that regard, the consideration at the first meeting of the Conference of the Parties of the adequacy of those and all other relevant commitments under the Convention, in particular those aimed at achieving effective adaptive response measures, is of the utmost importance to small island developing

States and the international community. The development and use of renewable sources of energy and the dissemination of sound and efficient energy technologies are seen as having a central role in mitigating the adverse impact of climate change.

The science and technology management issues relating to climate change issues

- (a) To monitor, survey and collect data on climate change and sea level using the following technologies, and taking the necessary actions as soon as possible.
- A comprehensive regional programme for the establishment of Geographic Information Systems (GIS), supported by national data collection and interpreting capabilities. GIS allows manipulation of many types of data in a single spatial framework based on the development of a comprehensive database. It facilitates the overlay of many simple thematic maps, allowing for an integrated study of the data, ease of manipulation and integrated analysis and planning. GIS software is readily available in the region from various sources. At a lower level, tide gauges should be placed and monitored at selected areas to provide information on a regional basis for computer modeling and for use in GIS.
 - Electricity generation utilizing wind, solar and biogas energy. Electricity generation from these sources has developed to the point that they are competitive in most instances with conventional fuel generation. In some Caribbean countries the potential exists for geothermal and/or hydroelectricity generation which has also become competitive. A number of these technologies are now in use in the developed as well as the developing countries (these include Germany, Britain, Australia, India, Guadeloupe and Aruba). Wind energy systems, in particular, are being installed at a rapid pace in Northern Europe and in the United States and these are proving to be reliable and competitive in the overall energy budget. Generating plants can easily be operational now with proper business arrangements.
 - Site assessment - work done in the 1970s by the Caribbean Development Bank (CDB) should be revisited in light of improved technologies and methodologies. The Germans and the Dutch appear to be leading the way in research and development especially in wind and hybrid systems, and both British and American research programmes have developed good systems. Pilot wind turbines should be installed and grid connected for testing.

- Solar energy technology - This has become competitive in some instances and is now in wide use in a variety of situations. In the Caribbean hot water heaters are in general use in Barbados and Saint Lucia as a result of policy instruments that promote their use. Solar energy technologies are also used for other activities, e.g. street lighting, especially in remote areas where the cost of making conventional energy available may be prohibitive for a number of reasons.

Natural and environmental disasters

SIDS are prone to extremely damaging natural disasters, primarily in the form of cyclones, volcanic eruptions and earthquakes. In some islands, the range of these disasters includes storm surges, landslides, extended droughts and extensive floods. A recent study by the former Office of the United Nations Disaster Relief Coordinator (currently the Department of Humanitarian Affairs of the United Nations Secretariat) has shown that at least 13 of the 25 most disaster-prone countries are SIDS. Due to climate change, such events, including drought, are perceived to be occurring with increasing frequency and intensity. These natural disasters are of special concern to SIDS because of their small size, dependence on agriculture and tourism which are particularly vulnerable to natural and environmental disasters, narrow resource base and the pervasive impact of such events on their people, environment and economies. For those affected by these natural disasters, these particular characteristics mean that the economic, social and environmental consequences are long lasting and the costs of rehabilitation are high as a percentage of gross national product. For similar reasons the impact of oil-spills and other environmental disasters can also be severe.

The science and technology management issues relating to natural and environmental disaster issues

- (a) The establishment of Standards Bureaux to assist in testing and quality control in the construction industry and road building programmes. For example, a critical element in the construction industry is the strength of the materials used in buildings, especially concrete and clay blocks, and proper cement mixing ratios for casting beams, etc. In many Caribbean countries, individual or local brick making is not regulated. It is suggested that the establishment of a Technology Extension Service at the national level will assist in field monitoring, information exchange and training in these and other aspects of the building industry.
- (b) Much of disaster mitigation work is dependent on activities that take place in agriculture (soil erosion) the marine environment (sand mining and other factors that lead to beach erosion) and road construction (poor drainage and improper road design) to name a few activities. If these are addressed in the manner outlined in the various sections it is anticipated that disasters could be avoided by about 50 percent.

Management of wastes

The limited land areas and resources for safe disposal, growing populations and increasing imports of polluting and hazardous substances combine to make pollution prevention and the management of wastes a critical issue for SIDS. Wastes in SIDS tend to be highly visible, but due to their limited capacity to monitor the waste stream, the true extent of the problem remains poorly understood. For small islands, the disposal of wastes is a serious constraint to sustainable development. Both land and sea-based sources of pollution require urgent attention.

All small island developing States share the problem of safely disposing of solid and liquid wastes, particularly as a result of urbanization, resulting in contamination of groundwater and lagoon areas. Point source pollution from industrial wastes and sewage, inappropriately sited and poorly managed garbage dumps and disposal of toxic chemicals are significant contributors to marine pollution and coastal degradation. Limited land areas makes the option of landfill disposal unsustainable in the long term. Incineration, while reducing the volume of wastes, is prohibitive in terms of cost and still requires disposal of ash containing potentially hazardous substances in high concentrations. Pressure on forests to provide fuel wood and to expand agricultural development, together with a high use of agricultural chemicals also aggravates downstream pollution and sedimentation problems.

The science and technology management issues relating to management of waste issues

- (a) A reduction in the use of plastics. In some instances, waste management can be addressed simply by developing, implementing and enforcing sound policy. For example, an incentive can be given to customers who come to shop with their plastic or, preferably, paper bags, thus reducing the amount of plastic now used in stores. The safe disposal of plastics is gaining prominence and research is continuing. High Temperature Incinerators are now available that can reduce the ash content and mitigate the chemical reactions that create additional problems for disposal. Such an incinerator was on display at SUSTECH 1994, manufactured by Hoskinson Pyrolytic Incineration Systems. (See Directory of Exhibitors - SUSTECH '94, available as an information document.)
- (b) Waste treatment poses different and sometimes difficult technological problems. Domestic waste disposal and treatment remain a problem in many of the Caribbean islands, especially in the small villages and rural areas where centralized treatment can be costly for a number of reasons: low output, large distance between homes, lack of electricity for operating plants etc. However, small-scale technologies exist for dealing with these problems especially using renewable energy sources for power. EnviroWaste Co. in the Virgin Islands has the technology for small-scale plants and improved large-scale treatment plants. The Faculty of Engineering at the University of the West Indies (UWI) is researching an

oxidation method using oil drums that will allow for the development of small treatment units.

- (c) Another factor in waste management is activity in the agricultural sector. While most agricultural waste is biodegradable, chemical waste from insecticides and pesticides continues to be a serious problem in small States where leaching occurs and eventual passage time to the ground water and the marine environment is very short. In order to combat this problem, which effectively means a reduction in and possibly elimination of the use of these chemicals, integrated pest control measures with strong emphasis on biological control should be undertaken. Research work at the University of the West Indies should be supported. As well, the Caribbean Agricultural Development Institute (CARDI) and the Inter American Institute for Cooperation on Agriculture (IICA) should place more emphasis on this area and in the area of genetics in general to develop resistant species.

Coastal and marine resources

Population pressures on most countries make the development of the marine resources indispensable to sustainable development of countries as in most cases carrying capacity of landmass have been reached. However, because most of the technologies that have been developed and available are for terrestrial development and, because the cost of the development of marine technology is high in comparison to terrestrial technology, marine science and technology have not developed at the rate and scale to propel development in most islands where, with the 200 mile Exclusive Economic Zone (EEZ) within the Law of the Sea Convention, marine space is larger than land space.

Unfortunately, though, increased terrestrial activity and population pressures are fast eroding any advantages that there may be in the development of the marine resources, as pollution and environmental degradation take their toll on the marine ecosystem. Reversing the trend calls for increased efforts to achieve efficient products, changing practices and instituting, pollution control in the terrestrial environment, as well as increased research, development and conservation measures in the marine environment. These need to be done as a matter of urgency if the resources that are presently available in the marine environment are to be maintained.

The myth that all the sea's resources are unlimited and automatically replenished is slowly being replaced by the positive concepts of sustainable exploitation and management. This has been seen from a global standpoint and has now become an integral part of research and development issues on the sea. Sustainable development is the medium through which the economist, the developer and the ecologist can come together to incorporate marine environmental and conservation issues as criteria for projects and policies, and as determining factors in the success of regional development. However, current approaches to the management of marine and coastal resources have not always proved capable of achieving sustainable development goals, as the need for quick solutions to unemployment and debt servicing have

forced States to accept projects that are not necessarily properly thought out for their effect on the environment.

Effective management and policy development can only be accomplished by guided research activities, and an understanding of the processes taking place in the environment, as well as long term views on development strategies.

Development issues

The value of the sea and the importance of its resources are now being recognized as indicators for the standard of living experienced by most States of the region. This is supported by the fact that the United Nations Convention on the Law of the Sea devoted one-third of its articles to sustainable development and management of the sea's resources, training, research applications and the development and transfer of marine technology.

The States of the region have recognized the need to build the capacity in the region to take charge of their marine development and become less dependent on outside expertise. However, individual governments alone have been unable to develop the capacity for addressing their marine problems and have been plagued by lack of finances, personnel and the inability to promote meaningful regional cooperation and collaboration. International organizations and foreign donor agencies continue to provide the means for research and development, but their orientation has not always been region specific. In that respect it is imperative that regional institutions take up responsibility for orienting research activities to the benefit of the entire region.

Marine activities in the region have generally involved individual research institutions and universities, and projects of the various governmental and non-governmental organizations have accessed expert staff from these sources. The region's capability and potential for marine technological development are reflected in the work of these institutions which, up to now, have been piece-meal. Present trends and restrictions therefor imply that future research activities will continue along a similar path, with the main focus on data collection and monitoring programmes.

However much the international community can or is willing to assist, regional efforts must be geared to researching and adapting available technology and information to the local context. This can be done through collaboration, systematic programmes of technology transfer, exchange of scientists and information and language training.

Programme proposals

The following programmes are identified for development and implementation to address areas not emphasized by present regional programmes and research institutions. The programmes incorporate research implementation and community participation, where possible, factors identified as important in the promotion of sustainable development, as communities take on greater responsibilities for their own development and advancement.

- (a) Marine science/oceanography.
- (b) Mapping of near shore coastal waters as a guideline for coastal development.
- (c) Tourism, since this has become an integral part of development strategy in the wider Caribbean and many of the economies of the region are very much dependent on this activity.

Coastal areas are considered most valuable lands for commercial development. The smaller the island, however, the more coastline it has relative to land area and therefore the greater the pressure on that coastline. Additionally, a large part of a coastal nation's natural resource is to be found in the coastal areas as well as a large percentage of the population. Unplanned development therefore can lead to health hazards, environmental problems such as erosion and pollution, and declines in fishing and tourist industries.

The location of hotels and other similar tourist attractions on the coasts have always been considered from an economic standpoint. However, with emphasis now being placed on ecological and environmental concerns, environmental factors must be considered in the development plans, to reduce the effect and even negate effects on the marine ecosystems. In determining the areas best suited, from an ecological standpoint, for hotel construction and other such activities, a number of physical, social and environmental factors have to be considered. Of primary importance will be the physical, biological and chemical aspects of the near-shore and beach areas. The capacity of both areas to sustain such activities will have to be determined. To that end, the following research work needs to be undertaken:

- (a) Coastline surveys and assessment of changes occurring, or that have occurred over time;
- (b) Study of coastal erosion patterns and rates;
- (c) Monitoring man-made and natural changes in the geology of the coastal zone;
- (d) Mapping sedimentation distribution, rates and transport paths;
- (e) Mapping the extent and quality of coastal vegetation and wetlands including diversity of plant species and effects of pollution;

- (f) Systematic measurements of tides, currents, waves, water temperatures, salinity, stratification and turbulence;
- (g) Circulation patterns to determine flushing rates and pollutant dispersion;
- (h). Determination of potential areas for sewage and waste discharge outside of the main area. The mapping of these near-shore areas will provide the necessary data for the development of numerical models that can be adapted to different locations and can assist in the development planning process with regard to environmental preservation.

Technological needs in order to carry out the above programme

- (a) Geographic Information System (GIS) Technology must be made available and encouraged in the region. Training seminars and workshops should be undertaken, and use of the technology and key institutions must be identified to provide technical assistance when required.
- (b) Remote sensing technology/capability must be made available in selected institutions in the region as well as data analysis capability.
- (c) Cartographic technology and capability.
- (d) Chemical, physical and geological oceanography techniques should be improved particularly in institutions within the small island chain.

Since a number of the smaller nations do not have tertiary institutions that can support such technological undertakings, a regional programme of training and support should be put in place to facilitate the above work and provide technical assistance to researchers and developers.

Fisheries biology and management

Declines in the fish stocks of the commercialized species such as tuna, snapper and lobster have been well documented and, are reflected in smaller catches and smaller size of fish by both local fishermen and large fishing vessels. Most of the commercial species of fish are considered over-exploited and cannot withstand unregulated fishing efforts for much longer. Management of these fisheries is thus becoming urgent. However, there is still a lot of research that needs to be done on the biology and systematics of these species, especially in respect to restocking and the production of fingerlings and fries.

In order to relieve the pressure on the traditional commercialized species, it is important that a programme of research be undertaken on the lesser commercially important species, such as grunts, parrot fish, etc., so that they too might not become over exploited if and when they become commercially important on a more universal basis. Information on their biology will also provide data for understanding total fisheries interaction, which is indispensable to proper management techniques.

In the Gulf of Mexico and the Caribbean Sea, less than half of the reef fish stocks have even been assessed yet, already, all but one of the assessed stocks are over utilized. Consideration could be given to the establishment of fishery reserves in which no consumptive uses are permitted. Reserves have been demonstrated to aid in the recovery and enhancement of fisheries. The importance of coral reefs, grass beds, and estuaries to the preservation of fisheries cannot be overemphasized. Research activities that will enhance knowledge of these ecosystems and habitats will go a long way towards ensuring proper management and preservation of stock.

Additionally, consideration may need to be given to the year-to-year allocation of fishing rights within a country's Exclusive Economic Zone to fishing vessels of other countries. This would require research into stock sizes, distribution and behaviour patterns of major stocks.

Coastal communities are often quite knowledgeable of their surrounding fisheries and should be encouraged to participate in management programmes.

Technological needs

Fisheries and marine biology techniques that are of particular importance to this programme element are:

- (a) Fish genetics;
- (b) Fish breeding - hatchery and nursery maintenance;
- (c) Fish stocking and stock analysis techniques;
- (d) Management of multi-species fisheries.

Research work using these techniques on such species as lobster, conch, snapper and tuna will go a long way towards maintaining fish stocks.

On the management side, the techniques and technologies needed include:

- (a) Determination and studies of reef and grass bed dynamics;
- (b) Dynamics of plankton and productivity;
- (c) Management of multi-species, stock estimates and stock dynamics techniques;
- (d) Stock assessment;
- (e) High technology methods to include acoustic and remote servicing.

Species specific fisheries biological work will, of course, continue to be important and must be encouraged.

Promoting improved fishing techniques and gear to improve efficiency

The factors that have impacted directly on the present status of regional fisheries are:

- (a) Type of vessel used

- (b) Fishing gear employed
- (c) Fishing techniques
- (d) Methodologies.

These factors, and the extent which they affect fisheries, are dependent on the fishermen and the fisheries sector. This sector represents the target group for information and technology transfer. Improvements in fishing vessel and gear technology aimed at raising fuel and catch efficiency, together with fishing techniques based on responsible fishing and sustainable exploitation should be achieved within a localized context. This must be done for each designated area and the target species.

A mix of large capital intensive and small, labour intensive fishing capabilities should be pursued by the States in the region in keeping with present practice. However, there is need for research in fuel efficient crafts and engines and improved fishing gear especially at the level of the artisanal fisheries. While the investment in the artisanal fisheries is considered low, it is sometimes out of reach of traditional fishermen. There is therefore need for research into multi-purpose gear, especially engines that can be used also for activities on land by the fisherman.

Technological needs

- (a) A vessel designed to achieve efficiency of operations - the traditional canoe as an artisanal-fishing vessel has limitations for range, capacity and efficiency, and refrigeration capability. Alternative designs are proving to be costly and require substantial changes in artisanal fishery styles. Taking into consideration that artisanal fishing instead of large scale commercial fishing in the Caribbean region may be the least resource depleting method, a design that is less expensive, but with more space and refrigeration capacity needs to be explored. Fishing boat design may also need to be area specific with respect to material use and fishing habits.
- (b) Fishing gear technology - work needs to be done on such aspects as fish attractants, particularly of the under-exploited species, fish trap design and size to minimize fish loss and facilitate hauling. While efficiency in terms of catch per unit effort must be taken into consideration in the use of fishing gear, management and conservation factors must also be borne in mind in the design and utilization of fishing gear.
- (c) Multipurpose engine designs - At present, most artisanal fisheries use outboard motors to power their boats. Inboard engines power some larger boats. However, both types of engines are limited to just powering the boat when in use. In both cases also these engines represent a considerable investment to the fishermen. Research work is needed in the adaptation of these engines to perform other duties, based on the other activities of the fishermen, such as net or line hauling.

- (d) The use of solar energy to provide refrigeration or power where possible.

Mariculture and aquaculture

It is estimated that the Caribbean Sea has over seven hundred species of algae, of which a few species of the red algae are cultivated for food. Most of the species used are in the preparation of drinks (seamoss) with the genus *Gracilaria* being the most widely used. However, others like *Gelidium*, *Hypnea* and *Ceramium* contain agar, which has a variety of uses. Agar is widely used in industry as thickener and emulsifier in many processed foods, in fabric and leather manufacture, in pharmaceutical and cosmetic products, as a bacteriological medium and as a raw material for the production of agarose. Agarose is used mainly for biotechnological applications where agar cannot be used due to the presence of varying and undefined ionic moieties.

In experiments on the cultivation of *Gracilaria* in Saint Lucia it has been seen that the culture substrate serves as a breeding ground for lobster, and on many occasions the farmers have had to carefully remove small lobsters from the *Gracilaria* before harvesting. In the field of marine biotechnology, emerging technologies give prospects for establishing market-oriented industries. There is also the potential for the use of some species of algae as soil enhancers, conditioners and even fertilizers, or as growth agents for some plants. The prospects for development in algology, biotechnology and general aquaculture are very good in the region and research needs to be developed to harness this vast reservoir of resources especially for the smaller countries, where the shortage of land area is already critical.

Technological needs

- (a) Research in algology and marine biology is of low priority in the region at present. This needs to be revised if proper use is to be made of the numerous species of algae available in the region, and if these species are to be conserved.
- (b) Marine biotechnology techniques, particularly extraction, tissue culture and micro-techniques, should be developed in leading institutions of the region.
- (c) Research work on the uses of marine algae on terrestrial agricultural production.
- (d) Technological work in breeding, larval development and genetic manipulation must be undertaken, especially in the over exploited species.
- (e) The achievements in aquaculture, especially on tilapia, need to be replicated on the marine and brackish water species.

Pollution control and amelioration

Along with tourism infrastructure, a large percentage of the population of Caribbean people live along the coast lines. This results in a considerable amount of effluent being discharged into the ocean, with varying degrees of treatment. In some cases treatment costs are high and some companies are not always inclined to go through all the required processing before discharge. In other cases lack of monitoring and policing allow companies to be nonchalant about obligations and responsibilities, especially in equipment selection and maintenance, resulting in frequent breakdowns and malfunctioning. All of these add to the unacceptable levels of pollutants that eventually enter the marine ecosystem.

The effects of the above scenario have been well documented and need not be elaborated upon here.

Technological needs

- (a) Research in pollution control technologies that will address all of these problems as well as providing low cost and small-scale units for the small poor populations along the coastal areas. While efforts are being made to reverse existing situations, simultaneous action needs to be taken to deal with the problem of waste generation at source, in both the domestic and industrial sectors, as well as in agriculture.
- (b) The training of personnel to engage in the development of techniques to identify, measure and monitor pollutants affecting the coastal and marine ecosystem, and in the related areas of drafting and enforcement of policies and regulations to contain and reduce the problem.
- (c) The development of small-scale sewage treatment plants that are water efficient, or which use alternative energy sources.

Ocean energy

There is scope in the region for ocean energy projects, in terms of reduction in fuel cost-savings. These savings could then be allocated to environmentally sound projects, and in the reduction of pollution from conventional energy sources. However, of the different types, Ocean Thermal Energy Conversion (OTEC) is the most promising, though work on wave energy technology is commercially available. OTEC technology is readily available in the pilot plant stages, though there is need for further research into cold water pipes. In addition, the economic feasibility of the technology can be greatly improved through multi-function applications such as fresh water production, refrigeration and mariculture applications. Advances in wind and solar energy technologies, themselves in the clean energy group, and the high cost of ocean energy technology, however may delay the development of ocean energy products.

Technological needs

- (a) Bathymetry, isotherm, wave climate, morphology and tidal variation studies and methods. Though these could be had in a good oceanography programme, existing data are insufficient for policy decisions. There is also need for training in data analysis.

Sustainable development in Small Island Developing States depends largely on coastal and marine resources. Their small land area means that these States are effectively coastal entities. Population and economic development — both subsistence and cash — are concentrated in the coastal zone. The establishment of the 200-mile exclusive economic zone has vastly extended the fisheries and other marine resources available to small island developing States. Their high dependence on coastal and marine resources emphasizes the need for appropriate and effective management.

The development and management of programmes designed to achieve ecologically and economically sustainable utilization of coastal and marine resources are major challenges for Small Island Developing States. The lack of an integrated approach to coastal and marine area management has limited the effectiveness of past and present management measures. This is resulting increasingly in coastal habitats being degraded through pollution, natural resources being over-exploited and growing conflicts between competing resource uses. Development patterns have also had an adverse impact on traditional management systems. In many cases the effects of natural hazards and extreme events, such as hurricanes/cyclones/typhoons, storm surges and abnormally high tides have exacerbated these impacts.

The science and technology management issues relating to coastal and marine resources issues

- (a) Information gathered from the tide gauges recommended above will be useful for inputting into coastal zone management activity. However a critical element lacking in most of the islands is coastal mapping, especially to determine near-shore dynamics that will provide information as to beach erosion, areas of relief and accretion in respect of sand, and the status of mangroves and wetlands. The GIS recommended above would also be helpful in mapping and identifying zones that are critical for planning.
- (b) The COSALC I project sponsored by UNESCO and implemented by the University of Puerto Rico's Sea Grant College Program should be supported and encouraged in all the islands. (Contact: Dr. Gillian Cambers UPR Sea Grant Program, P O Box 5000, Mayaguez, P R 00681-5000. Fax (787) 834-4726).
- (c) There is ample evidence to show that most of the reefs in the region have been under stress due to increased activities in the tourism industry. The dynamics of the reef system and its place in the ecology of the near shore

and fisheries are well known. Every effort must be made to regulate activity on or near the reefs and to attempt to allow these reefs to regenerate if possible. As well, artificial reef building using old tyres as substrate should be encouraged, an idea that has worked well in some islands and that will also reduce the pollution problems on land.

- (d) The myth that the region is well served with fish must be dispelled. It is well known that while tropical waters may abound with different species of marine life, the relative amounts in each specie are rather limited since primary productivity is also limited due to the lack of nutrients in the water. This large number of species ensures distribution in the, food chain and, therefore, removes pressure from any one niche. An additional benefit of that system is a high diversity of species.
- (e) The implications for commercial or artesanal fisheries are therefore critical for decision-making in terms of investment by fishermen and the advice given to them by fisheries extensionists.
- (f) There is need for increased research in the biology of the non- commercial species and in fish population studies particularly related to small diverse populations and migratory species. Standard population dynamics modeling are available but need to be tested against the Caribbean scenario.

Additional work is required in vessel and gear design in the fisheries industry of the region. (See Annex 1). In addition, better collaboration should be developed between institutions such as the Institute of Marine Affairs (IMA) in Trinidad and Tobago, the University of the West Indies (UWI), University of Guyana (UG), the University of Puerto Rico (UPR) and the University of the United States Virgin Islands (UVI). These institutions should agree on research priorities and promote excellence in this area.

Freshwater resources

Freshwater resources are vital for meeting basic needs and inadequate protection of the quality and supply of freshwater resources can set important limits to sustainable development. Because of their small size and particular geological, topographical and climatic conditions, many Small Island Developing States face severe constraints in terms of both the quality and quantity of freshwater. Many health hazards in developing countries are related to poor water quality and limited water quantity. This is particularly the case for low-lying coral-based islands where groundwater supplies are limited and these are protected only by a thin permeable soil. Even where rainfall is abundant, access to clean water has been restricted by lack of adequate storage facilities and effective delivery systems.

Inadequate action to safeguard watershed areas and groundwater resources poses a further long term threat, while in urban areas rapid population growth, changes in economic

strategies and a growing per capita use of freshwater are significant challenges. In this context, sound long-term management strategies for water catchment and storage areas including treatment and distribution of limited water supplies are of particular economic and environmental importance. Such strategies may involve substantial capital investment and ongoing maintenance programmes, which may affect the real cost of water. A common threat to the freshwater resources of Small Island Developing States is the contamination of supply by human and livestock waste, industry related pollution and in some cases, pesticides and other agricultural chemicals.

The science and technology management issues relating to freshwater resources issues

- (a) There is much that a proper water policy can do to control domestic water use and avoid wastage. In the United States Virgin Islands, for example, homeowners are required to build cisterns for their own water supply. This policy puts the onus on the owner to conserve water. Variations of such a policy can be looked at for implementation in other Caribbean countries.
- (b) Water Conservation - In this respect forestry management and, in some cases, reforestation is a critical factor. However, in view of the limited land space and the need for land for other agricultural activities integrated forestry and land use technologies must be employed. Every effort must be made to reduce agricultural activities on slopes especially those of over 20 percent and in some cases denuded hillsides should be restored through the planting of trees and other soil conservation measures. Mixed cropping systems, especially with tree crops, should be encouraged wherever possible as this is not only to help in water conservation but also in the promotion of soil fertility and pest control. The Food and Agriculture Organization's (FAO) Tropical Forest Action Plan should be revisited and implemented.
- (c) Irrigation programmes – These must be monitored to avoid wastage and, as far as possible, drip irrigation with timers should be used instead of overhead sprayers. Furrow irrigation is preferable to overhead spray if drip irrigation cannot be employed. Such a programme will also recharge ground water systems.
- (d) Desalination plants using reverse osmosis technology is readily available and at a relatively low cost. However, it is argued that there is sufficient rainfall in the region to meet individual country needs if proper policies and technologies are applied. Relevant here is the findings contained in the document produced by the Caribbean Council for Science and Technology - *Background Paper on Water Resource Conservation in the context of Sustainable Development*.

Land resources

The small size of most Small Island Developing States, coupled with land tenure systems, soil types, relief and climatic variation, limit the area available for urban settlement, agriculture, mining, commercial forestry, tourism, and other infrastructure, and create intense competition between land use options. Most aspects of environmental management in small island developing States are directly dependent on, or influenced by, the planning and utilization of land resources. This is intimately linked to coastal zone management and protection in Small Island Developing States.

For human requirements to be met in a sustainable manner, competing demands for the use of land resources must be resolved, and more effective and efficient ways of using these natural resources developed and adopted. As populations grow in Small Island Developing States, there is need for resolution of competing demands, particularly where land is limited and where commercial development of comparatively large tracts of land can result in shifts in small scale and subsistence agriculture to marginal lands.

The major long-term land management issue in Small Island Developing States is degradation of the limited area due to a variety of factors, including overuse because of high population pressure on a limited resource base; deforestation due to unsustainable commercial logging or permanent conversion to agricultural or grazing pursuits; and other episodic events, such as fire. Natural events such as catastrophic cyclones are also major contributors. Land degradation of this kind results in accelerated erosion and resultant decline in fertility and productivity, deterioration in water quality and siltation of rivers, lagoons and reefs. Deforestation is also linked to a decline in the continuity and quality of village water supply, depletion of genetic, wood and non-wood plant resources, and the fading away of traditional forest, lagoon and reef-based subsistence life systems.

The science and technology management issues relating to land resources issues

- (a) Soil and land capability surveys and mapping to be followed by land use plans should be undertaken for all the islands as an extension of the proposed GIS.
- (b) Soil conservation and erosion control structures, such as stone barriers, contour drains, terraces, grass barriers, etc., should be built and maintained in proper condition. Whereas in large States inland soil erosion can be a source of rich soil deposits in plains and valleys, in small States the soil quickly finds its way to the sea to silt coral reefs, increase turbidity in the oceans thus severely affecting the marine environment.
- (c) Increased irrigation for crops and pasture is creating strain on both soil and water use. It has been shown that drip irrigation is not only more economical to operate, but also less likely to create waterlogged conditions and/or loosen soil particles that can easily be carried away through erosion.

- (d) The question of soil fertility is becoming a serious problem in the region. Because of shortage of land, soils cannot be allowed to lie fallow. However, the increasing use of fertilizers, pesticides and herbicides are fast altering the chemical composition and balance of the soils, through leaching and residual effects.
- (e) Such technologies and practices as composting and manuring should be encouraged in order to retain soil fertility. In addition biological pest control should be researched and practiced to a greater extent in order to reduce the amount of chemicals now used in agriculture. (See the Action Plan from Inter-Regional Conference of Small Island Countries on Sustainable Development and Environment in Agriculture, Forestry and Fisheries, Barbados, 7-10 April, 1992). Also relevant here are IICA, CARDI and UWI reports.

Energy resources

Small Island Developing States are currently heavily dependent on imported petroleum products, largely for transport and electricity generation, energy often accounting for more than 12 per cent of imports. The current uses of these fuels tend to be highly inefficient. Increased efficiency through appropriate technology and national energy policies and management measures will reap both financial and environmental benefits for Small Island Developing States.

Renewable energy resources of Small Island Developing States vary greatly. All have substantial solar resources, which have still not been developed to their full potential. Wind potential is highly variable with location, both within and between countries. Hydroelectric power is a possibility only for some islands. Biomass endowment is common but unequal. Studies of the potential for geothermal, ocean thermal energy conversion and wave energy are continuing.

Several constraints to large-scale commercial use of renewable energy resources remain. These include technology development, investment costs, available indigenous skills and management capabilities. Small-scale application for rural electrification has been sporadic. The use of renewable energy resources as substantial commercial fuels by Small Island Developing States is dependent on the development and commercial production of appropriate technologies.

The science and technology management issues relating to energy resources
issues

- (a) Implement appropriate public education and awareness programmes, including consumer incentives to promote energy conservation.

- (b) Promote the efficient use of energy and the development of environmentally sound sources of energy and energy efficient technologies, paying special attention to the possibilities of using, where appropriate, economic instruments and incentive structures and the increasing economic possibilities of renewable sources of energy.
- (c) Establish and/or strengthen, where appropriate, research capabilities in the development and promotion of new and renewable sources of energy, including wind, solar, geothermal, hydroelectric, ocean thermal energy conversion, wave and biomass.
- (d) Strengthen research capabilities and develop technologies to encourage the efficient utilization of non-renewable sources of energy.

Tourism resources

Tourism has contributed much to the development of Small Island Developing States and, as one of only a few development options for Small Island Developing States, will continue to be very important for their future growth. It could also stimulate the development of other sectors. However, if not properly planned and managed, it could significantly degrade the environment on which it is so dependent. The fragility and interdependence of coastal zones and the unspoiled areas on which eco-tourism depends calls for careful management. One of the special tourist attractions of Small Island Developing States is the distinctiveness of their cultures. The diversity and fragility of their environments is reflected in the diversity and fragility of their cultures. The protection of the former is an important condition for the protection of the latter.

The science and technology management issues relating to tourism resources issues

- (a) The need to adopt integrated planning and policies to ensure sustainable tourism development, with particular attention to land-use planning and coastal zone management, requiring environmental impact assessments for all tourism projects; continuous monitoring of the environmental impact of all tourism activities; and the development of guidelines and standards for design and construction, taking into account energy and water consumption, the generation and the disposal of wastes and land degradation, the proper management and protection of eco-tourism attractions, and the carrying capacity of areas for tourism.
- (b) Although there is evidence of the use of Environmental Impact Assessment (EIA) in planning, presently EIAs are more often used to provide information on what to do to correct what is perceived to be an unpopular decision. Ideally, EIA's should indicate not just short term

and/or correctable dangers but also the longer term changes and effects that may not be easily corrected or reversed.

- (c) From an ecological view, the greatest strain put on the marine environment is in respect of the tourism industry. Such decisions as where to site hotels, marinas and game parks, as well as the carrying capacities of bays and estuaries, require reliable information on beach and near shore dynamics.

While models exist for arriving at answers, there is serious lack of information and data to input into these models. It is hoped that the programme outlined in the Marine Resources section will address these problems.

Biodiversity resources

Small Island Developing States are renowned for their species diversity and endemism. However, due to the small size, isolation and fragility of island ecosystems, their biological diversity is among the most threatened in the world. Deforestation, coral reef deterioration, habitat degradation and loss and the introduction of non-indigenous species are the most significant causes of loss of biodiversity in Small Island Developing States. In the past, there has been a strong emphasis on the collection of more information. In SIDS where limited and biologically precious resources are being threatened, while lack of sufficient information is often cited as a rationale for inaction, there is often enough information to identify areas requiring in situ conservation. Although more information will be important to develop appropriate management plans, information collection should no longer be a prior condition for in situ conservation projects.

The science and technology management issues relating to biodiversity resources issues

- (a) Additional research work is needed in the biosystematics of the flora and fauna existing in the eco-systems of Caribbean territories.
- (b) There is need for more genetics and microbiology/microtechnique work at the regional institutions. Such programmes will also make a valuable contribution to the development of biotechnology work and pest control research.
- (c) Formulate and implement integrated strategies for the conservation and sustainable use of terrestrial and marine biodiversity. This may be done particularly for endemic species, and should include protection from the introduction of certain non-indigenous species and identification of sites of high biological significance for the conservation of biological diversity

and/or for eco-tourism and other sustainable development opportunities, such as sustainable agriculture, training and research.

- (d) Promote community support for the conservation of biological diversity and the designation of protected areas through concentration on educational strategies that increase awareness of the significance of biodiversity conservation and particularly the fundamental importance of a diverse biological resource base to resource-owning communities.

Transport and communication

Transport and communication are the lifelines linking Small Island Developing States with the outside world, with each other and within their own countries. They are an important means of achieving sustainable development. Distance and isolation have resulted in relatively high transport costs, including insurance, for many small island developing States. The quality and frequency of international shipping and air services are largely beyond the control of island States. Domestic markets are too small to provide economies of scale and the remoteness of many rural areas and outer-island communities constrains options and increases costs. While national airlines are necessary to serve the local market, especially in archipelagic States, they tend to fragment the regional market. The constraining influence of these factors on the sustainable development of island countries cannot be underestimated.

The environmental uses associated with transport and communications development, including quarantine, also need to be properly addressed. Such issues include land transport, which has been found to be one of the greatest contributors to degradation of the urban environment, both at national and regional levels, and which appears to have lagged behind improvements and major changes in transport services.

A major challenge is to devise innovative approaches to resolving transport and communications problems, for example, the development of low-cost, high-tech methods for the moving of cargo and improving community access to telephone, radio and related services. A further challenge is to improve the management and maintenance of existing transport and communications infrastructure. In building new infrastructure, particular consideration needs to be given to maintenance and recurrent cost issues.

The science and technology management issues relating to transport and communications issues

- (a) Technological needs in these areas will invariably be met by imported technology. It is, however, important that clauses are put in agreements to promote technology transfer and efforts made to obtain best available technologies. Sound policy and instruments will be key factors in these activities.

Human resource development

Human beings are at the centre of concerns for sustainable development and thus significant attention must be given to projects that will enhance the quality of human life in small island developing States. Projects should be undertaken not only with a view to the contribution that individuals, groups, communities and nations can make towards sustainable development, but more importantly, how these projects will ultimately affect the well-being of those living in Small Island Developing States.

The size and vulnerability of Small Island Developing States necessitates that special attention be paid to population issues, education and training, and health, for effective human resource development. Poor health, social services, nutrition and housing; low levels of female participation in development; poor education systems; information and means for the responsible planning of family size and inadequate family planning services demonstrate the need for attention to human resource den, together with the uncounted costs of drug abuse, which contributes to rising health costs; increased unemployment and diversion of scarce human resources all demonstrate the need for attention to human resource development issues. High population densities and growth, as well as depopulation in some areas, are constraints to achieving sustainable development in many small island developing States. Increasing attention must be given to the concept of island carrying capacity and environmental health, especially for fragile and highly populated environments in urban areas, coastal zones and hillsides.

The strengthening of national educational and training mechanisms is a matter of high priority. This is essential to facilitate the flow of information on sustainable development issues, enhance public awareness of the environment and to encourage participation in the implementation of effective solutions. A key requirement is to promote access to and improve the quality of basic education.

Environmental education and science training, particularly on issues specific to Small Island Developing States, is essential to developing environmental awareness. Training in environmental management and sustainable development is needed at all levels of the education system. For professional training, multidisciplinary approaches are needed. There is a demand for knowledge on the environment to meet both educational and professional needs. Areas in which more training is greatly needed are science and technology generally, technology assessment, environmental impact assessment, environmental management and sustainable development, environmental chemistry, environmental engineering, physical planning and the development of geographic information systems, and information and communications technology.

The science and technology management issues relating to human resources development

- (a) Computer literacy programmes should be instituted in all schools beginning at the primary level. In addition, greater emphasis should be placed on technical programmes especially in machine, small craft and appliances and instrument servicing.

- (b) Encourage the use of computers to develop models for sustainable development projects that are community based, in schools.
- (c) Apprenticeship programmes that provide hands-on training should be instituted at both secondary and tertiary level institutions. As well, incubating technology centres and technology adaptation centres should be established in the region to promote technological development.

Information technology

Serious attention must be paid to the area of information and information technology. Planners in both the public and private sectors must have access to the latest information applicable to their field. Information databases must be established and constantly updated. Training of persons in this area is also important. It should be noted that a lot of relevant information might be available in places where we do not often look, for example, South and Central America, Africa, India, the South Pacific.

The region should know everything there is to know about the goods, commodities, and services that it uses to make a "living". There is need too, for up-to-date information on the trading situation with respect to both imports and exports. Rapid market intelligence on what is surplus or in short supply in various part of the region is important especially with regard to perishables - fresh fruit, vegetables and meat products. Government trade may handle these task divisions, but there could also be private sector initiatives for particular products. Institutions involved in research and development, technology-packaging etc. must be effectively networked to avoid duplication of effort. Innovation generated must, as quickly as possible be brought to the attention of potential users.

Computer technology

It has already been identified that we need to develop computer literate society. Further, the universities and technical colleges must develop for the region a cadre of persons who can develop software. There is already some movement in this direction in the region, but it needs to be accelerated. The possibility exists for jobs and the earning of foreign exchange in this area. At another level, the possibility of jobs in the data-processing industry must be considered and young workers prepared for this.

In summary, information and computer technology must be made to work for the region in a variety of ways as follows:

- (a) Keeping abreast of the latest in areas that are of primary concern to the subregion, including rapid market intelligence for crop availability in the region - where surpluses exists, where shortages are, shipping movements in relation to the preceding as an example.

- (b) Providing early warning systems in disaster preparedness.
- (c) Allowing distance education to reach scattered communities.
- (d) Enabling cheaper and regular communication between personnel in the region via tele-conferencing, given the importance of frequent consultation. In this regard there is need to reduce the cost of telecommunication.
- (e) Sharing information in health matters, education, market intelligence, law and order etc.
- (f) Allowing surveillance of the EEZ.
- (g) Allowing information resident in remote databases to become available.
- (h) Using off-shore financial services as a means to reduce unemployment.

PRIORITY PROGRAMME FOR SCIENCE AND TECHNOLOGY MANAGEMENT IN THE CARIBBEAN--2000

The role of science and technology in the development process has long been recognized by developed countries and recently by the newly industrialized countries. Increasingly, therefore, attention is being paid to how Science and Technology has been, and is now managed in countries that have made strides in the development process.

The countries of the Caribbean, being small countries, have a particular difficulty in emulating success stories due to the inappropriateness of the strategies of large countries and, the lack of examples of small sized development theory, especially involving science and technology, create added burdens for the interpretation of factors responsible for development. In other words, present paradigms of development are large-State oriented.

Yet, to the extent that development is about people, and people of small States have the same aspirations, needs, wants and obligations, economic growth and development must take place in these countries if the quality of life of the population is to be enhanced. In addition, there is not yet put forward, a development model that is free of science and technology, and the advances in science and technology can, if properly utilized address many of the pressing problems of small States.

However, a major constraint in small States is the lack of financial resources to address all problems equally and at the same time. There is therefore the need to prioritize the issues in order to make the most of limited resources, both financial and human.

The nature of small States

Development problems of small States are characterized by a number of factors including:

- Fragile ecosystems
- Lack of critical mass of scientists and technologists
- High unit cost of goods and services
- Limited financial resources
- Limited natural resources
- Limited institutional capability
- Limited internal market.

The interplay of these problems causes severe constraints to the development process. For example, a fragile ecosystem requires good management practices which itself can be developed by good institutions through research. These require large capital outlays and a core of highly trained persons to do the necessary research and develop the modules. Agricultural activity which is a must for the survival of any State is very costly and non-competitive and in some cases poor practices do more harm to the environment. On the other hand, most small islands can benefit from a relatively large EEZ that is usually underutilized.

What then are the tasks facing the small States of the Caribbean? And what are the programmes that must be put in place to ensure the quality of life for its peoples, using science and technology as a vehicle for development?

Preservation and management of the environment

Environment preservation and management should be tackled from the standpoint of ongoing activities. To the extent that Caribbean economies are primarily agriculture based and, secondly, tourism economies, the introduction of appropriate technologies in these two sectors are indispensable for the preservation and management of the environment. Present agricultural practices call for large-scale use of pesticides and this must be addressed through research in bio-control.

The science and technology management dimensions to correct the above are therefore:

- (a) Increasing research and the generation of knowledge and technologies in biological pest control.
- (b) Increasing research and the development of technologies for small-scale treatment plants and waste treatment and management.
- (c) Soil and water conservation measures implemented to maintain ecosystem integrity.

Increased agricultural activity tends to put pressure on land space and ultimately affects forested areas. Policies and programmes for the preservation and management of forests must be put in place.

By and large, investments in fisheries education have paid off in the Caribbean and artisanal fishermen are more conscious of the need to preserve both the fisheries on which they depend and the environments that support these fisheries. Unfortunately, poor planning especially in the tourist sector negates the gains made by the fisheries department. The conversion of mangroves and swamps to marinas are startling examples of this practice. Policies and programmes must therefore be put in place for the protection of natural fisheries habitats, to include mangroves and reefs.

In the tourism sector, the large volume of waste generated is not always disposed of properly. Solid waste management, especially of plastic products, remains a problem for small countries. In addition, the treatment of effluents, and human excreta is particularly bothersome, especially in small communities without treatment plants and when secondary treatment discharges are located close to the shoreline.

Agriculture

The agricultural policy and programme in small States must deal critically with two main issues, namely, food security and environmental protection. Notwithstanding the high unit cost of production, it is unthinkable that an island population will be in the position of not being able to feed itself, or even provide the bare minimum of a portion of its dietary requirements. However, with limited land space there may be constraints to the type and amount of food that can be produced. In such a situation, proper technologies can address the under-mentioned problems adequately.

- Land space - a balance must be arrived at between mono-crop and multi-crop systems in order to make the most of available land and yet preserve the environment. To that end, it may be necessary to identify niche markets for products that can fetch a relatively high price with limited supplies. This will require the application of good transformation technologies, quality assurance measures and if the "green product" approach is used, agronomic practices that limit the use of inorganic pesticides.
- For small States, integrated multi-crop systems must be applied to maximize land and diversifying production patterns must be adopted. The benefits of such practices are well documented in the literature. Another beneficial approach would be to identify crops that are suited for available soil with the necessary soil testing and analyses undertaken. A number of crops are indigenous to the region but have been little researched.

- Soil and water conservation have already been addressed in the earlier section but must be emphasized again. Erosion is a particularly serious problem of small States. Besides depleting the land of its fertility, good topsoil finds its way very quickly into the surrounding shores. There it affects reef growth and the general quality of the inshore waters.
- Fisheries - Tropical waters are not generally abundant in fisheries though species variation may be abundant. There is, therefore, a dependency on migratory species. In order to take advantage of this situation, two distinct fishing seasons are recognized - inshore reef fishing and the pelagic offshore fishing. However, because the majority of inshore fisheries are artisanal little is known about the biology and ecology of these species, and this area has tended to be over fished because of the relative ease of fishing methods. Migratory fishing on the other hand requires much larger capital outlay and time investment. For that reason the fishery is in healthier shape but, again very little is known in the region of the biology and ecology of the major species in the fishery.

The science and technology challenges in agriculture are:

- (a) Research and technological development in multicrop systems.
- (b) Programmes for integrated watershed management.
- (c) Soil and water conservation policies, technologies and practices.
- (d) Research and technological development in post harvest physiology.
- (e) Research and technological development in product transformation.
- (f) Research and technological development in integrated pest control and management with emphasis on bio-control.
- (g) Establishment of quality assurance mechanisms.
- (h) Research in the biology and ecology of non-pelagic fisheries.
- (i) Development of tools for the management of small fisheries.
- (j) Development of technologies for sustainable fishing in small fisheries to include fishing gear.
- (k) Research and technological development in mariculture and aquaculture to replenish stocks where possible.

Tourism

Although the industry has significant importance for the small Caribbean States, it is virtually controlled from outside the region. However, there are some sectors of the industry that can be improved through the application of appropriate technologies and policies.

The factors deciding the siting and location of hotels are not based on scientific and technological analyses and that is a major shortcoming. In addition the large scale generation of waste of all types and the subsequent treatment and disposal of these pose serious problems

for small States. Recycling addresses only some of the problems, especially in plastics, but still leave many unresolved problems as what to do with the final product.

The industry though offers the opportunity for linkages, especially in the agriculture and the handicraft industry but strategic decisions have to be made for these to be successful. Products, both raw and transformed, can be incorporated into the industry but issues of quality and reliability of supplies have plagued the long term planning for this nexus. There is therefore, the need for research and development work to develop technologies for transforming raw materials into good products that can be presented to this market.

Science and technology dimensions in this sector are:

- (a) Research and development in small scale waste treatment plants.
- (b) Scientific approach to hotel siting and planning.
- (c) Integrated approach to water use to include the marine environment.

Biotechnology

No discipline offers greater potential for small States to seriously address and overcome the problems associated with size than developments in biotechnology. Whether in agricultural production, where better varieties of crops can be had; in transformation, where raw materials can be made presentable in quality and given an extended shelf life; or in the tourism industry where solutions can be had for degeneration and degradation of waste, biotechnology offers great prospects for arriving at sustainable development if applied and used sensibly and scientifically. Its potential benefits to the health sector are also well recognized in the fight to combat many of the diseases and sicknesses that plague mankind.

Investment in biotechnology, however, is costly and a rational approach has to be taken on the areas in which biotechnology will be applied. This will call for some prioritizing of activities based on resources available. At the same time, better regional and international cooperation mechanisms can help to augment the research base of the small States and help overcome the constraints of finance and problem solving.

The science and technology challenges in biotechnology are:

- (a) Selective research and technological development in bio-control.
- (b) Increased and improved tissue culture practices and facilities.
- (c) Research on waste treatment.

Energy

The present relatively low cost of energy cannot be taken as a given and recognizing the importance of energy in the development process, small States must take steps to cushion themselves against drastic increases in energy costs. To this end, and since Caribbean countries are blessed with ample sources of renewable or alternative energy sources these should be explored to the fullest. At present wind energy offers good possibilities for grid or off-grid

connections at reasonable and competitive costs. Solar energy though not yet competitive for grid connections, present real possibilities for lighting in remote and inaccessible areas and for crop drying. A number of Caribbean countries do have the potential for geothermal energy harnessing. The successful operation of a 5-megawatt geothermal energy plant in Guadeloupe demonstrates that such possibilities exist, and the operation of a grid connected wind farm in Curaçao provides the proof for wind energy development. As well, much work has already been done at the University of the West Indies on solar applications.

The science and technological challenges in energy are:

- (a) Research and technological development of small solar systems particularly for crop drying.
- (b) Research in the identification of wind regimes and sites for application to the region.
- (c) Introduction of pilot plants in wind energy development.
- (d) Regional collaboration on alternative sources of energy to encourage information exchange and sharing and technological development.

Science education

The contribution of a scientifically literate population to the development effort is well known. However, although the region can boast of a few good scientists and technologies, science and technology remain in the realm of exclusivity and elitism. That is made so by the elitist approach to education that obtains in the region. To address this shortcoming a massive educational programme at all levels must be initiated to make Science and Technology part of the culture of the population. Only then will the necessary constituents be available for advocacy, so necessary in policy and decision making. Teachers have to be retrained to present science and technology problems as every day problems and to instill in children, especially at the primary level, a curiosity and problem solving approach. Secondary and tertiary level education must take on hands on approach, and the technical and vocational programmes must be geared to employment in the most obvious fields initially.

The science and technology priorities associated with education are:

- (a) A training programme for primary school teachers teaching them how to use the environment as a living laboratory and to how to impart such knowledge to students.
- (b) Training teachers to develop skills for integrating the various subsets of science in the curriculum and to include mathematics as a subset of science.

- (c) Training for communication specialists to incorporate science and technology in their portfolio.
- (d) Science popularization programmes using the media for the dissemination of information on science and technology.
- (e) Incorporation of practical work in the curricula at secondary and tertiary institutions especially in such areas as agriculture, engineering and other technology oriented programmes.

Industrial and technological development

Small States cannot enjoy the luxury of having science and technology programmes that are not merged with the productive sector, especially to industry and agriculture. To that end partnerships should be developed early between the existing industries and the institutions of science and technology in the States. Only by such associations can the problem-solving approach be applied, entrepreneurship promoted, and new products developed to meet the needs of the market. Such a nexus will also ensure that training and education programmes are relevant to the needs of industry. Industry can then support research and development work thereby creating the conditions for indigenous capacity building.

Small and medium sized industries remain the backbone of the economies of small States. Every effort must be made to ensure their survival and to encourage their growth and graduation.

The science and technology dimensions for this nexus are:

- (a) The establishment of science and technology extension programmes to service industry especially small and medium sized industries.
- (b) Support for the establishment of and the promotion of standards and quality assurance programmes and mechanisms and institutions to provide technological assistance and services to industry.
- (c) Establishment of and support for research and technology institutions to generate new technologies for industry and to provide for technology transfer mechanisms.
- (d) Establishment of business and technology incubators where small and medium sized business can develop.

The environment for the promotion of science and technology management in small States

The first condition for the promotion of science and technology in small States is the availability of a clearly enunciated policy for development and identification of the roles of science and technology in that development process. Other important considerations are:

- (a) A systematic approach to programme prioritizing.
- (b) Long-term commitment to and financing for the science and technology programmes identified in the development policy.
- (c) The establishment of institutions and agencies with proper mandates for carrying out the programmes.
- (d) Rationalization of mandates and responsibilities of institutions with responsibilities for implementing programmes.
- (e) A consultative approach in the development of programmes.
- (f) A commitment at all levels - political, bureaucratic and at the level of the population at large, to a participatory and integrated approach to development.

The small size of the States should not be seen only as an impediment to development but also as an opportunity since their small size should make them more manageable. The problem remains that present development paradigms have not seriously considered the case of the small State from a systematic integrated approach to the definition of development. Economic theory, political economy theory, scientific research, technological developments and even present political theory have been all large State oriented. What is needed is an approach to development with the small States as the center of investigation. Maybe then the structures, institutions, policy frameworks and implementation methodologies will be emerging to give meaning to the small State dilemma and show the way forward..

We will need to establish a Center for Policy, Research and Implementation Strategies in the Development Theory of Small States in order to arrive at models that do not have large State biases that tend to cloud judgement and skew present research and interpretation.

Regional and international cooperation and the development of centres of excellence

The Preparatory Committee for the Global Conference on Sustainable Development of Small Island Developing States recognized that the development and management of programmes designed to achieve ecologically and economically sustainable utilization of coastal and marine resources are major challenges for Small Island Developing States. Even when the larger littoral States of the wider Caribbean are included, the problem remains difficult due to the nature of the marine environment in which there is mobility of species, of pollutants and contaminants and where processes are not national or area specific.

The capacity of the region should, therefore, be strengthened and developed where necessary, to monitor events, collect data and set legislative regimes that can transcend national interests, as well as harmonize policies and strategies for coordination of the sustainable management and utilization of the coastal and marine resources.

For coordination, whether at national or regional levels, to take place there must be not only willingness, but also a well-defined mechanism for the promotion, management and the financing of such coordination. In fact, the lack of this clear institutional framework has resulted in the failure of many previous initiatives and attempts.

In that respect, the call is made here for the establishment of Centres of Excellence in the wider Caribbean area. Such centres will be responsible for priority setting, high level research, and resource mobilization for longer-term programmes.

The proposal of UNIDO and UNEP to establish a Marine Industrial Technology Centre in the region should be pursued and, when this centre is operational, it should serve to develop and adapt technologies, and network the many research institutions in the region.

It would be worthwhile studying the experiences of other regions and collaborative work should be encouraged with other extra regional institutions. Such regions as the Pacific, Western Asia and the Mediterranean come readily to mind, as well as the coastal areas of Africa with similar problems of both geography and development.

Such a centre should be established in a small State, financed by all States and staffed primarily by experienced individuals from small States. The international community, of course, would be expected to assist, but the programmes should be small State focused rather than developing State focused in which the special problems of the very small developing States are generally lost.

