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## *Responding to the Effects of Climate Change on Agriculture, Fisheries and Tourism in the Caribbean Region Utilising Geoinformatics*

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### *Abstract*

The Caribbean region is undergoing rapid economic development associated with a fast rate of industrialization, urbanisation and population growth. These events often lead to environmental degradation and could threaten the sustainability of agriculture, fisheries and tourism. In turn this could eventually slow down and threaten the pace of economic development. In addition the region is living through a number of events such as sea level rise and global climate change. As a result, there is a real need to understand and attempt to manage these natural and man-made phenomena. This paper argues the need for timely policy decisions on a regional basis with immediate effect in order to develop appropriate mitigation strategies to ensure the integrity of these sectors in the future. However, lack of data and understanding of factors controlling processes on regional basis is a problem. A way forward is by adopting geoinformations to collect and manage the necessary datasets and employing plausible scenarios to evaluate possible mitigation strategies to sustain agriculture, fisheries and tourism in the Caribbean region.

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## INTRODUCTION

Humanity requires three essential elements to exist and develop; these are water, food and energy. However population growth, industrialization and intensive agricultural practices have unsettled the ecological balance leading to environmental degradation and endangering these essentials (Baban, 2001). Water is being degraded by industry worldwide, which releases about 450 cubic km of contaminated water into rivers annually (Clarke, 1991). In the past we have relied on the process of self-purification by rivers and lakes. These seem to have been saturated and are not capable of purification any longer. As a result, the majority of lakes and rivers in Europe are polluted and some 70% of rivers in developing countries such as India and Malaysia are polluted and declared dead (Woodward and Foster, 1997). Another difficulty is population growth, 60 years ago the population was 2 billion, by 2025 this could increase to about 8.5 billion. Currently some 33% of humanity doesn't have adequate quantities of water and by 2025 this percentage is expected to reach 50%. In terms of food, humans are already consuming about 40% of the worldwide plant growth annually. This means the other 30 million species on Earth have to manage with 60% (Myers, 1990). An interesting question is what would happen if we doubled in numbers? The demographic pressures and market incentives to use marginal land have accelerated soil erosion resulting in the loss of valuable agricultural land and increased suspended sediment concentrations and loads in rivers, lakes and reservoirs (Woodward and Foster, 1997;

Baban 1998a). Losing fertile soil will often lead to the addition of nutrients and pesticides to compensate and increase productivity. This in turn leads to increase in sediment borne chemical components (toxic radionuclides, e.g. caesium 137 and platinum 239 and heavy metals e.g. cadmium, zinc and lead) (Clarke, 1991; Baban, 2001).

All of these issues are further complicated by Global Climate Change which is leading to other globally important environmental changes – e.g. in supplies of fresh water, in the cycling of nitrogen and carbon, and in bio-diversity. The impact of these biophysical changes will bring complications to the already difficult task of providing sufficient food of the right quantity and quality for the world's population. An added difficulty is that not all food systems, economies and geographical locations are equally impacted upon and vulnerable to the effects of global environmental change.

## AGRICULTURE, FISHERIES AND TOURISM IN THE CARIBBEAN REGION

The states in the Caribbean have a number of common regional characteristics, which make them vulnerable to climate change impacts. These include; limited physical size and natural resources, high susceptibility to natural hazards, dependence on agriculture and tourism, small local markets and high population densities concentrated on the coastal areas. In addition, the region is experiencing rapid economic development combined with a fast rate of urbanization, population growth and questionable agriculture practices. Consequently there has

been a substantial increase in demand for building material, cleared land and in the amount of industrial and domestic waste produced. Land-based pollutant sources include: sewage, oil hydrocarbons, sediments, nutrients, pesticides, litter and marine debris and toxic wastes (Wade, 1975; WRI, 1992; Gumbs and Blommestein, 1997). The sediments and the pollutants will ultimately be transported to and degrade coastal marine environments. For example when coastal eutrophication occurs in the near shore areas, it prevents recreational use and alters the ecological and aesthetic quality of the environment. As a result the fisheries, tourism and the economy in general will suffer. The main factors causing problems independently and jointly in the Caribbean are described in the following sections.

#### *Population Growth*

The demographic growth of the coastal populations of the region was estimated to be about 3% for 12 countries during the 1980-2000 period. The highest was Guyana with 5.0% and the lowest was Martinique (FR) with 1.4% (WRI, 1992).

The main disposal practices in the region consist of discharging mostly untreated wastewater into coastal marine environment. Therefore, population growth will naturally lead to more poorly treated or untreated sewage wastewaters being discharged into the coastal marine. Increasing health problems will occur through direct contact and by consumption of contaminated fish or shellfish (Ward and Singh, 1987; Broutman and Leonard, 1988) and seasonal episodes of fish kills caused by the depletion of dissolved oxygen in the water (Short, 1991).

Population growth will also impose further changes on the land use; deforestation of river basin watersheds in particular, will increase the sediment loads carried by the rivers causing further problems to fisheries and tourism. Also see 2.2, 2.3 and 2.4.

#### *Agriculture*

The traditional export crops are primarily sugar and bananas, dominate the agricultural sector in terms of income, employment and foreign exchange earnings. With the liberalization of markets in 1995, income from these commodities, particularly bananas, has drastically declined. The Region also produces domestic crops, mainly by small farmers. Agriculture plays an essential role in the region as;

- A large proportion of the population depends on agriculture, directly or indirectly, for their livelihoods. The majority of farmers are small subsistence operators who are depend on agriculture both as a source of income as well as food.
- In most countries of the region, agriculture is the major sector in terms of food and nutrition security, employment, foreign exchange earnings, social and political stability and rural development

Continued economic growth and development will result in an increase in use of marginal agricultural land at the expense of forestlands. The impacts of this on increased turbidity of coastal waters, as a result of riverine transport of eroded soils to the sea, have been known to produce siltation of coastal ecosystems. These trends have the potential to place continuous stress on critical coastal ecosystems, such as coral



reefs. Pesticide (insecticide, herbicides, fungicides, etc.) is used extensively to increase agricultural production. Significant quantities of pesticides are reaching the coastal and marine environment through runoff, erosion and misapplication, where they may affect habitats and contaminate seafood. Adverse climate change impacts on agriculture may invoke responses by producers that result in encroachment and degradation of protected areas. There is a strong association between agriculture, fisheries, tourism, environmental quality and sustainable development. Given that most countries are small island states, such responses by producers may have implications for sustainability of the overall development process. Also see 2.1, 2.3 and 2.4.

### *Fisheries*

Fisheries employ around 130,000 people in the region and a significant revenue earner in some countries, e.g. Belize. Furthermore, fish represents the second highest source of protein and fisheries are key sectors for providing opportunities for rural poor, socio-economically disadvantaged communities in the region. Fishing communities tend to be based in low-lying coastal areas.

Economic development will increase in use of marginal agricultural lands leading to increases eroded soils which will in turn produce siltation of coastal ecosystems placing continuous stress on critical coastal ecosystems, such as coral reefs. This has been confirmed by research conducted on the siltation of coral reefs along the Caribbean coast of Panama, Costa Rica, Nicaragua, etc. (Morelock *et al*, 1979; Cortes

and Risk, 1985). The need to increase agricultural production will also increase the use of pesticide, which will end up in the coastal and marine environment through runoff, erosion and misapplication. This process will degrade and contaminate coastal and marine habitats. Pesticide contamination tends to be highly toxic and accumulates in the coastal and marine biota. Another source of pollution is the discharge of nitrogen and phosphorous compounds in enclosed coastal areas, which often leads to eutrophication. The ecological effects of this phenomenon include algal blooms, changes in aquatic community structure, decreased biological diversity, fish kills and oxygen depletion events (Morelock *et al*, Cortes and Risk, 1985). Also see 2.1, 2.2 and 2.4.

### *Tourism*

The tourism sector is extremely important to the economies of the region. It is the main foreign exchange earner in many of the countries and is also a very large source of employment for the Caribbean people. In the Caribbean there have been large investments in tourism facilities and in some islands the only major investments have been for tourism or tourism related purposes such as hotels, airports and seaports. Most of the larger hotels and related infrastructure (including access roads and tourist oriented services) have been built in coastal areas. The main tourism types in the region are coastal, inland ecotourism, cultural and sports. Coastal tourism is the most important type of tourism in the Caribbean, and is very vulnerable to climate change, especially from rising sea levels, which might result in the elimination or reduction of sand on

beaches as well as damage to coastal infrastructure. Furthermore, tourism could contribute to environmental degradation of the coastal and marine environments. A study showed that in the CARICOM countries, only 25% of the sewage treatment plants operated by hotels and resort complexes were in good operating condition. Additional problems are caused by the increasing traffic of ships and recreational vessels discharging untreated or poorly treated sewage wastewaters directly into the coastal areas (CEP, 1994). Also see 2.1, 2.2 and 2.3.

#### **CLIMATE CHANGE ISSUES**

Earth's climate is changing due to anthropogenic activities worldwide relating mainly to industrialization and land use, and driven by population growth and consumerism, the atmospheric concentration of greenhouse gases (GHGs) has been increasing at an alarming rate, so much so as to enhance the greenhouse effect of the planet and to cause regional climate and climate-related global changes. The IPCC (Intergovernmental Panel on Climate Change) Third Assessment Report (IPCC, 2001) indicates that there is sufficient evidence to link most of the warming observed over the last 50 years to human activities.

Due to the strong influence of the oceans on the climate surrounding the Caribbean islands on the climate, it is expected that changes in ocean circulation and temperatures, as are projected with GHG climate change, will affect both the temperatures and rainfalls of these islands.

The generally accepted prediction is that sea levels will rise during the twenty-first century by between 10 cm and 1 meter, with a 'best guess' of about 50 cm. This is particularly difficult for the Caribbean as the majority of the population and economic activities are concentrated in the coastal zone. Furthermore, natural systems such as mangroves that help protect marine and coastal resources are already being degraded by human activities (CPACC, 2000). Additionally, climate change may affect the character and pattern of tropical storms and hurricanes. These changes are expected to affect the global and regional hydrological cycle. This in turn will affect the distribution and availability of water resources in the Caribbean Region (IPCC, 2001). The expected changes in climate will alter regional agricultural systems with substantial consequences for food production. For example, higher temperatures and changes in rainfall could modify the extent and productivity of land suitable for agriculture. The application of a set of temperature and rainfall sensitivity scenarios on cereal production by the International Institute for Applied Systems Analysis in Austria, revealed a modest increase of cultivable rain-fed land for temperature increases up to 2°C on a global scale (Fisher et al, 2001). If temperature increases further but precipitation patterns and amounts remain at current levels, the extent of cultivable rain-fed land starts to decrease. When both temperature and rainfall amounts increase, the extent of cultivable rain-fed land increases steadily. For example, a temperature increase of 3°C paired with a rainfall increase of 10% would



lead globally to about 4% more cultivable rain-fed land (Fisher *et al*, 2001). These figures are presented in Table 1. In the developed countries this increase is markedly higher, exceeding 25%. In contrast, the developing countries would experience a decrease of 11 %, more specifically, in Central America and the Caribbean, all countries lose production. This unless managed could have serious consequences for food security in the region.

### *The 'Grey Areas' of Scientific Knowledge in the Caribbean Region*

There is little knowledge about the actual impacts of climate change on:

- *Plants:* There is a need for accurate answers for some important questions including; how plants will respond to variations in temperature, precipitation, soil moisture availability, humidity radiation intensity (including UV-B), day length and wind? What is the impact of climate

**Table 1. Possible Changes in Cereal Production (% change) Worldwide based on Possible Increases in Temperature as well as Increases in Temperature Accompanied by Changes in Rainfall (after Fisher *et al*, 2001)**

	Temperature Increase & Rainfall Change						
				+1°C	+2°C	+2°C	+3°C
Region	+1°C	+2°C	+3°C	+5%	+5%	+10%	+10%
Oceania	-4	-5	-9	1	0	4	0
Asia	4	3	-2	5	2	4	0
Africa	-4	-8	-12	-4	-8	-8	-13
Europe and Russia	13	17	20	16	21	24	28
Central America	-1	-4	-9	-4	-6	-9	-13
South America	-4	-11	-20	-7	-13	-14	-23
North America	12	16	20	16	21	24	28
Developing Countries	-1	-6	-11	-2	-6	-6	-11
Developed Countries	11	15	18	15	19	22	25
World	4	3	1	5	5	6	4

change on plant growth and crop yield across the region and in specific locations?

- *Agricultural soils:* Here the questions include - What is the: Impact of increases in soil temperature on soil water content, physical processes and biological activity? Impact on soil structure and salinity? Impact on soil organic matter and on soil organisms?
- *Fisheries:* What is the impact of the increase in sea surface temperature on

loss of biodiversity, decreased eco-system health and resilience; increased frequency of storms & hurricanes and damage to nursery areas? What is the specific geographical impact of sea level rise on coastal habitat loss, saltwater intrusion of coastal and estuarine wetlands? The impact of changes in circulation patterns on key migrations of oceanic pelagic species?

- *Tourism:* The questions here include; how increased temperature and sea level rise will impact on tourism in terms of coastal erosion, elimination or reduction of sand on beaches as well as damage to coastal infra-structure? Which regions will be affected most? The impact of the degradation of coastal and marine environments due to human activities on specific regions? What will be the impact of temperate countries in the Northern Hemisphere getting warmer?

#### A POSSIBLE WAY FORWARD

As a consequence of above, there is need to determine strategies to cope with the uncertainties of the effects of global environmental change on agriculture, fisheries and tourism, and to analyze the environmental and societal consequences of adaptation strategies. This process will require understanding the links between environmental change and societal well being, and promoting effective interventions. This in turn will require:

- (i) Developing a scientific understanding of the processes involved on the regional scale in order to answer key questions such as:
  - How will global environmental change can affect agriculture, fisheries and tourism throughout the region
  - How vulnerable are these sectors in different parts of the region?
  - Which different community groups will be most disadvantaged?
  - How might different parts of the region adapt their agriculture,

fisheries and tourism to cope with both global environmental change and changing demands?

- What would be the environmental and societal consequences of adaptation to these changes?
- (ii) Identifying the tools for collecting, managing and analysing the necessary data sets.
  - (iii) Developing plausible scenarios to account for the effects of climate change on agriculture, fisheries and tourism.
  - (iv) Developing a regional agenda to deal with these issues.

#### *Understanding the 'Grey Areas' on the National and Regional Scale*

The understanding component of scientific enquiries is often fulfilled by seeking patterns and processes. This process often starts with observation followed by asking basic fundamental questions such as What? Where? and When? in order to map the distribution of a phenomena in space and time. Then the question Why is asked in order to understand the nature and cause of any significant relationships. Getting all of the information during various relevant time frames will provide the monitoring followed by an attempt to reduce reality to manageable proportions, mimic the processes in the real world, as we best understand it, and estimate the impact of various activities on specific natural resources through modelling (Baban, 2001)(Fig 1).

However, it should be mentioned that there is a severe shortage of reliable and compatible data sets in the region. In addition there is no clear understanding of



the processes involved on the national and regional scale. However, these obstacles can be managed by using Geoinformatics, which encompass Remote Sensing (RS), Geographical Information Science (GIS) and Global Positioning Systems (GPS). Geoinformatics contains the necessary tools to collect, handle and analyse the necessary data sets as well as expanding our knowledge of the processes involved at the appropriate scales. These tools include:

(i) *Remote Sensing*: The prime objective of RS is to extract environmental and natural resources data needed for a better understanding of various components of our environment (Lo, 1986). The fundamental basis of most remote sensing investigation is based on the wavelength-distribution of electro-magnetic energy transmitted or reflected by land use/cover types, which provides signatures of the materials involved. It follows that the consequences of changes in land use/cover and in coastal/marine environments will be associated by an alteration in the optical properties of the study area (Lillesand and Kiefer, 1994; Baban, 1998b). The analysis of remotely sensed data is primarily concerned with mapping and quantifying such characteristic spectral signatures for all the relevant features to environmental management. However, at first the raw image will need to be adjusted and numerically processed through a number of stages (e.g. correcting the image for any distortions and degradations, increasing the apparent distinction between the features to optimise visual interpretation, and to maximise the contrast between features of interest) producing an optimised image for use. Finally,

the image will need to be calibrated with a number of measured relevant parameters on the ground 'ground referenced samples'. In addition the researcher will need to be familiar with the following basic concepts (Baban, 2001):

- *spatial resolution*: the smallest feature size that can be studied in an image. This translates into a measure of the smallness of objects on that ground that can be distinguished as separate entities
- *spectral resolution*: sensor capability to record spectral information at a particular range of wavelengths. Some sensors are broad-band and capable of recording energy across a range of wavelengths. Others are finely adjusted perhaps to the discrete reflectance frequency of a particular type of sediments.
- *radiometric resolution*: the amount of electromagnetic energy falling on a satellite sensor varies more or less continuously but the actual range of energies that can be recorded, and the precision of the measurements, depend on the operating range and radiometric resolution of the instrument.
- *temporal resolution*: as satellites are placed in regular orbits, they can regularly revisit a given location on the Earth. The time between visits depends on the angular field of view of the sensor, the latitude and longitude of the area of interest, and the characteristics of the satellite orbit.

Remotely sensed data can provide vital information for managing the environment



particularly on a regional scale. This is according to Baban (1999a) is mainly due to:

- providing information for monitoring change over appropriate time periods and conducting time-series studies. One of the problems involved in studying the environment is the

extreme variability of many phenomena over time. Geostationary satellites such as NOAA or Meteosat, or the combination of geosynchronous satellites in the Landsat series or SPOT series, can provide the necessary information.

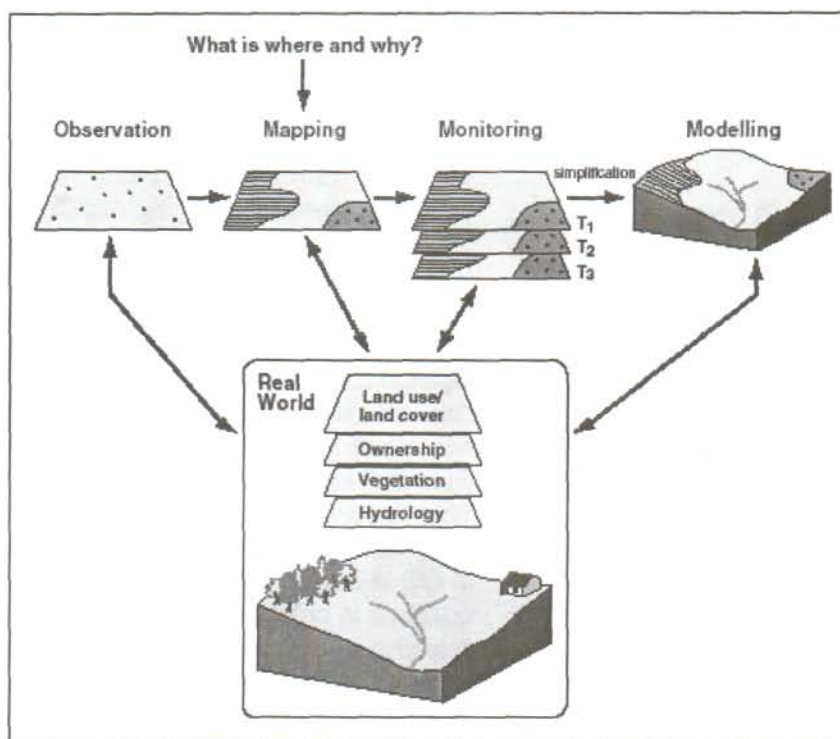


Fig 1. Understanding and Managing Environmental Phenomena (after Baban, 2001)

- the synoptic coverage provides information for vast areas. As certain phenomena are transient it is very important to obtain information at regional basis at specific points in time.
- conducting detailed analyses based on combinations of high and low resolution data. Images with various

resolutions are essential for examining regional and site-specific problems.

- providing information on the topography and relief. SPOT images can be used to compile a topographical map with an elevation accuracy of 5 to 10 m.
- providing data for areas that have no ground measurements based on the interpolation of area-based information from sampled sites with similar attributes; subject only to the size of the area and the spatial resolution of the imagery.

Despite problems with levels of cloud cover, remotely sensed data possess a great potential in a region like the Caribbean, despite cloud cover, which has a large geographical area. Agricultural systems are simple, pollution is confined and limited and regular ground referenced data can be gathered from various establishments. Remote sensing can be used effectively for surveying, inventorying, mapping and monitoring the environmental problems both on land and coastal marine domains in the Caribbean region. Therefore increasing our understanding of the environment (Fig 1) particularly as high resolution images, sub one meter, are becoming available for the region. Remotely sensed data have been used successfully to provide relevant information on catchment characteristics, e.g. mapping and monitoring the spatial extent of various types of land use and land cover including; changes in agricultural land (Baban and Luke, 2000) (Fig 2) mapping parent material type, soils, vegetation type and canopy densities (Lo, 1986; Barrett and Curtis, 1992) as well as

coastal and marine environments (Baban, 1995). Remotely sensed data can also be utilised to provide the necessary area based land use/cover parameters to run conventional mathematical models as well as plausible scenarios used to simulate environmental response to different conditions / management scenarios (Baban and Wan-Yusof, 2001).

(ii) *Geographical Information Science*: GIS has evolved for handling diverse data sets for specific geographic areas by using co-ordinates as the basis for an information system. GIS also promotes spatial thinking, which is a method of assessing a situation based on perception of information that includes location, and a structural approach to problem solving. Therefore, based on the spatial nature of the acquired data, GIS can be used effectively to; firstly, input, store, organise and analyse the ground referenced data, then to integrate these data with data from satellite imagery and other sources. Secondly, GIS is used to answer What is Where and Why? by employing the spatial analysis, visualization and query capabilities of GIS to answer What is Where and Why? questions in order to identify environmental degradation/ pollution problems and their geographical locations (Baban, 2001). These answers will increase our understating of the 'grey areas' (Fig 1). Furthermore, GIS can be used to construct and simulate various management scenarios responding to various conditions of global climate change and sea level rise at specific locations. Then, to establish, which is the most suited scenario for a location under a given set of constraints (Baban, 1997; Jones, 1997). Finally, GIS are designed for assembling,



integrating and analysing spatial data in a decision-making context. Information provided by GIS can be used at operational, management and strategic planning levels by a variety of users including the scientific community including the scientific community, universities and decision makers and legislative bodies (Morain *et al*, 1996, Heywood *et al*, 1998).

(iii) *GPS and GNSS*: Global Positioning Systems (GPS) are space-based radio positioning systems that provide 24 hour three-dimensional position, velocity and time information. The satellites transmit timing information, satellite location information and satellite health information. The user requires a special radio receiver - a GPS receiver - to receive the transmissions from the satellite. The GPS receiver contains a specialized computer that calculates the location based on the satellite signals. The satellites are controlled and monitored from ground stations, which monitor the satellites for health and accuracy. Maintenance commands, orbital parameters and timing corrections are uploaded from the ground on a periodic basis. The NAVSTAR system, operated by the US Department of Defense, is the first GPS system widely available to civilian users. The Russian GPS system, GLONASS, is similar in operation and may prove complimentary to the NAVSTAR system.

(iv) Both NAVSTAR and GLONASS provide two sets of positioning signals. The higher accuracy system is reserved for each country's military use. The lower accuracy system is freely available to civilian users.

Some GPS receivers have the ability to store attribute information in addition to position information. Position and attribute information can be stored in a GIS to help users manage their assets more efficiently.

(iv) *Global Navigation Satellite Systems (GNSS)* are extended GPS systems, providing users with sufficient accuracy and integrity information to be useable for critical navigation applications. A GNSS uses satellite positioning techniques to provide users with accurate and timely navigation information. A global positioning system is a subset of a global navigation satellite system because a GPS system need only provide the ability to determine position information. A GNSS must include: real time navigation information, autonomous integrity checking, and accuracy sufficient for safe navigation. There are currently no GNSS systems in operation; however, several are planned and should be operational within the next decade. These systems will use either or both NAVSTAR and GLONASS to provide positioning, along with other components to improve accuracy and provide fast warning of problems. GNSS systems promise radical improvements to many systems that impact on our understanding. By combining GPS with Remote sensing and GIS, we will be better able to identify and manage our natural resources.

*Modelling Based on Plausible Scenarios*  
Models generally use scientific knowledge and expertise to develop management approaches based on expectations for the future. Science has many approaches for





Fig 2. A Land Use/Cover Map for Nuneaton area in the UK Produced by Using Retrospective Ground Referenced and Remotely Sensed Data (after Baban and Luke, 2000)

devising an understanding of the future. These include prediction, forecasting, and projecting, each with its own methods, certainties, and formulas for estimating probabilities. However, these methods require detailed datasets taken over a number of years. Furthermore, they tend to ignore novel situations, surprises, and regime shifts. In the Caribbean, scenario planning is a must due to the lack of sufficient and accurate datasets to run 'hard' mathematical models. Therefore, this approach is a practical way to start now whilst datasets are being collected and compiled towards enhancing our understanding and conducting a more detailed studies in the future.

Scenarios are probable alternative futures, each an example of what might happen under particular assumptions. They provide an indication of what might happen, but not definitive probabilities and can be used as a systematic method for thinking creatively about complex, uncertain futures. In this case, the concern is with scenarios that forecast changes in agriculture, fisheries and tourism due to global climate change and sea level rise. Some scenarios are forward-looking "forecasts" that describe the emergence of future conditions from current conditions and driving forces. Others are "backcasts" that begin with an image of the future and seek to identify plausible development pathways for getting there.

A plausible future is a statement about the condition of a social-ecological system, over a specified time horizon that is consistent with relevant scientific understanding. Plausible futures are usually considered in sets of three or four scenarios. Their purpose is to outline the diversity of possible outcomes, broaden discussion of what the future may bring, and provide a test bed for proposed policies or management actions. The decision maker may prefer policies or actions, which are robust, i.e. lead to acceptable outcomes under a wide range of plausible futures. The notion of plausible futures and their use in decision making has been well documented in the literature Cocks (1999), Rotmans *et al.* (2000), Sala *et al.* (2000) and Shell International (2002).

Building scenarios will start with the *current state* of the system (Figure 3). The state description may be a quantitative set of accounts or a description of important processes, conditions, and uncertainties, or both. The current state can be, and sometimes is, understood in the context of its historical evolution. The dynamics are introduced through a set of *driving forces* and trends that impel the system forward. They condition but do not necessarily determine the future trajectory, which can branch in novel directions at critical thresholds of uncertainty. The potential for surprise is referred to as *sideswipes* in the figure, for example, a world war, a pandemic, abrupt climate change and a technological wildcard. *Human choice* is of course a major element of the scenario story line. The figure underscores one aspect of human choice that is particularly germane, the capacity to imagine alternative futures

and to act intentionally. Positive and negative images of the future can act through human agency as a material magnetic and repulsive forces on system dynamics, referred to in the figure as *attractors* and *repulsors* (Raskin, 2002).

#### *Developing a Caribbean Agenda*

The potential impact of climate change, including climate variability, is anticipated to gradually but severely degrade the agricultural resource base in the Caribbean (soils, water, salt water intrusion etc) or alter environmental conditions thereby resulting in declining productivity of crops, livestock and fisheries. Tourism will also be significantly affected. Clearly, agriculture, fisheries and tourism are at risk to climate change and climate variability. A *business as usual scenario* would only serve to further exacerbate the regions food security, degrade agriculture and fisheries and damage tourism.

However, climate change impact on the Caribbean agriculture, fisheries and tourism is not a *fate accompli*. There is a lot that could be done to mitigate such potential negative impacts. For example, in cases where precipitation decreases irrigation must be given a greater consideration as long as the water is available, with more scientific scheduling and quantification. Where water is costly, improved irrigation systems such as the drip system can replace over-bed sprinkling and furrow irrigation. Consideration should also be given to enhancing water conservation. Furthermore, crop varieties and/or species suited to the potential climate could be introduced to



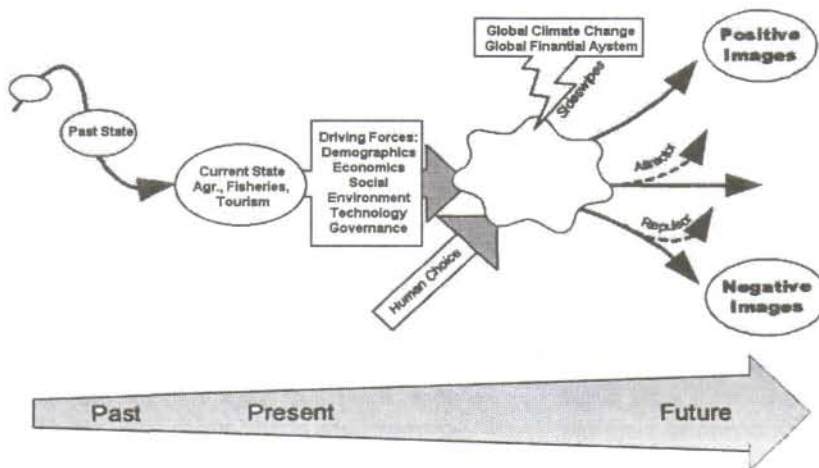


Fig. 3. Scenario Dynamics for Agriculture, Fisheries and Tourism in the Caribbean Region (adapted from Raskin, 2002).

maintain high yields. In areas where optimum temperatures would be dates, fertilizer application and pest and disease management.

Ensuring the integrity of agriculture, fisheries and tourism sectors in the future requires a proactive policy and programme response at the regional and national levels with respect to:

- Sensitization to the issues and potential risks
- The identification of cost-effective mitigation measures
- The design of strategies for implementation of mitigation measures.

Given the gestation associated with the study of climate change and the identification of appropriate cost-effective mitigation measures, the time for initiation action is now.

It is anticipated that the adaptation measures could be expensive, however, given what is at stake the region doesn't seem to have a choice but to proceed as soon as possible. This consequence of global warming is suffered by the developing world whilst it has clearly been created by the developed world. This should provide the region with a lever that could be used to extract concessions from the industrialized world in terms of financial assistance as well as technology transfer, trade agreements and debt relief. More generally, it highlights the inequality that currently exists between north and south, placing this issue firmly on the political agenda



## CONCLUSIONS

The Caribbean region is experiencing a rapid rate of population growth, economic development and urbanization leading to the degradation of the environment and natural resources. The region is also facing the effects of global climate change and associated sea level rise. All of these are placing increasing pressures on the agriculture, fisheries and tourism sectors. These processes if not managed could eventually slow down and threaten the pace of economic development in the region.

Consequently, there is a real need to understand the impacts of development activities and external forces with the view to design intervention strategies to ensure the integrity of agriculture, fisheries and tourism. The first hurdle towards achieving this objective is the shortage of reliable and compatible data sets as well the existence of 'gray areas' in the scientific knowledge regarding some of the processes involved on the national and regional scale. This hurdle can be managed by adopting geoinformatics, which contains the necessary tools (Remote sensing, GPS/GNSS, GIS) to collect, handle and analyse the necessary data sets as well as expanding our knowledge of the processes involved at the appropriate scales. Our knowledge and understanding can be further enhanced, under the circumstance, by using plausible scenarios to examine alternative futures based on different intervention strategies. This can be managed within a GIS framework. The outcomes can then be used to manage the impacts of global warming and sea level rise

in the region as a whole and in specific geographical locations. The second hurdle is the lack of political will and effective policies to sensitize to the issues, identify cost effective and practical mitigation measures as well as strategies for implementing mitigation measures. Overcoming this hurdle will require hard work however, the scientific outcomes, possible practical solutions from the first hurdle and continuous public education and action by civil society will and must win the argument so the region can have a prosperous future.

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