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TOWARDS A GIS-BASED CARIBBEAN LAND AND WATER RESOURCES INFORMATION SYSTEM

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ABSTRACT: The management of land and water resources in the Caribbean is a major challenge due to their relatively fixed quantity and smallness, limited and decreasing quality, increasing demand, aversion to natural and human degradation and exogenous influences. For effective and efficient management of these resources, there is need for current and accurate information on the extent and status of these resources. The use of Geographical Information Systems (GIS) and remote sensing are seen as enabling technologies to combat the deficiency in the land and water resources information. The chapter presents examples on the use of GIS in land resources inventory and in evaluation of the carrying capacity of land resources. A Caribbean Land and Water Resources Information System (CLAWRIS) is being proposed that allows for the integration and dissemination of land and water resources data. The chapter underscores the need to develop a strategic development programme that would ensure effective and efficient development of CLAWRIS.

INTRODUCTION

The management of land and water resources in the Caribbean remains a major challenge for resource and economic managers. Many factors that characterize the peculiarity of these resources are responsible for this challenge. These factors include:
Fixed quantity and restricted land area
Limited and decreasing quality
Increasing demand
Aversion to natural and human degradation
Exogenous influences

1.1 Fixed quantity and restricted land area

The relatively small total landmass that forms the archipelagic Caribbean is a resource management challenge compared to the vast water mass that surrounds the region. The land mass and its internal surface and ground water constitute the limited natural resources needed for the socio-economic development of the region. Many of the island states of the region lack surface water and also have limited ground water. The topography is highly undulating and poses challenges to agriculture, housing and urban infrastructural development. The coastal zones have become the only land resource available to satisfy the countries' requirements for socio-economical activities. These limitations have compelled resource planners and managers to seek intensive use as opposed to extensive use of these resources. This has implications for the carrying capacity and sustainability of these resources.

1.2 Limited and decreasing quality

The soils and geology of the region pose challenges to resource management. Due to constraints of aerial extent and quality, the soils permit limited agricultural practices and the steep slopes of the rugged terrain expose the land to accelerated soil erosion. Current agricultural practices that favour hill-side farming, use of fertilizers, pesticides and other Non-point Source (NPS) pollution are major contributors to the loss of quality of the land and water resources of the region. Halting or reducing this effect is a challenge for the sustainable use of these resources.

1.3 Increasing demand

Population pressure is a major contributor to management and use of resources. Even though the population of the region is relatively low, the food consumption pattern is high and the use of the land and water resources for the production of export products has led to an increase in the demand for these limited resources. Large areas of agricultural lands are required not only for domestic food production, but also for production for export market. Managing increasing demand for quality land and water resources in the face of fixed quantity and decreasing quality, challenges the sustainable use of these resources.

1.4 Exposure to natural and human-induced degradation

The Caribbean region is highly prone to severe hurricanes, flooding, landslide, volcanic eruptions, coastal erosion and earthquakes. These natural disasters have caused unforeseen damage to the land and water resources of the region. Potential agricultural lands have been damaged, ground and surface water polluted and urban infrastructure destroyed due to the unpredictable and severe effects of these natural disasters. Human-induced degradation also continues to be a major challenge. Slash and burn farming, untreated sewage, indiscriminate dumping of waste, unplanned land use changes, physical developments in landslide and flood prone lands and indiscriminate exploitation and use of ground water are major causes of land and water resources degradation. Policy and social education are required to mitigate the incidence of these negative impacts.

1.5 Exogenous factors

In addition to the internal challenges, there are exogenous factors that impose constraints on the management of land and water resources in the Caribbean. Trade liberalization, fluctuating foreign exchange, trade agreements and conventions could either lead to intensive use of land and water resources or abandonment of land and water-based economic activities. The unpredictable nature of these factors has posed a major challenge to resource planners and managers in the region.

In order to effectively and efficiently address the impacts of these challenges, there is need for current and accurate information on the extent and status of these resources as well as knowledge of the social and economic factors impacting on their quantity and quality. The information, on the other hand, has varying characteristics that pose challenges for its efficient use. The information may be collected at varying accuracy resolutions, formats and differing classification standards. The use of Geographic Information Systems (GIS) and remote sensing as enabling technologies to combat deficiency in the land and water resource information is discussed in the next section.

2.0 GIS as enabling technologies

Improvements in information technology have provided unimaginable opportunities improvement in data analyses and communications in the last two decades. GIS have provided new and exciting ways of acquiring land and water resource data and also providing efficient means of processing, managing and integrating this data. GIS is an organized collection of computer hardware, software, geographic data and personnel, designed to efficiently *capture, store, update, manipulate, analyze and display* all forms of geographically referenced information (Opadeyi, 1992). Geographic information plays an important role in activities such as environmental monitoring, management of land and water resources and real estate transactions. The areas of GIS applications are numerous and growing. Listed below are major areas of applications that have benefited from developments in GIS (Goodchild and Kemp, 1990):

Management of natural resources
Environmental impact analysis (EIA)

Hazardous or toxic facility siting
Groundwater modelling and contamination tracking
Wildlife habitat analysis
Zoning and review of subdivision plans
Land acquisition and distribution
Maintenance of land ownership records

The increasing use of GIS in the varying professional fields has produced both tangible and intangible benefits that are enough to sustain its use into the future. The following benefits have been advanced for the use of GIS natural resource management (Dale and McLaughlin, 1988; Aronoff, 1989 and Star and Estes, 1990):
Provides integrated data storage and data retrieval capabilities.
Encourages a more systematic approach for the collection of data.
Leads to reduction in the overall costs of data collection and management by facilitating data sharing among users.
Increases comparability and compatibility of diverse data sets.
Makes data accessible to a wider range of decision-makers.
Encourages the spatial analysis of environmental impacts that are otherwise ignored because of analytical difficulties or high cost.

Over the past five years computer hardware and software constraints to GIS development have been reduced. Data acquisition still remains a challenge even with advances in remote sensing technology and decreasing cost of data acquisition. The removal of the intentional error in Global Positioning Systems (GPS) readings and the availability of satellite imagery with one metre spatial resolution have provided some relief to these constraints. The recent commercialization of the IKONOS satellite imagery with the one metre panchromatic and four metre multi-band resolutions is revolutionizing the use of GIS for natural resource management.

GIS has five functional components: data collection and acquisition; data preparation; data integration; data management; data analysis and application (Opadeyi, 1992). *Data collection and acquisition* provide for flexibility in the nature and format of the data required. For example, tabular data currently existing in hardcopy and digital format; graphical data in hardcopy map format; photographs, remote sensing data and analog field data can all be incorporated into a single GIS environment. *Data preparation* is the process of extracting, spatial coding and conversion of field sample data and related data in a form that will provide for easy referencing and ability to cross-reference the data with other data. *Data integration* functionality provides the unique advantage of being able to link spatial data to attribute data and the ability to add any other form of data within the GIS environment. *Data management* functionality in a computer environment provides the infrastructure for the storage, retrieval, merger and generalization of different data categories. *Data analysis and application* functionalities are the main outputs or end products for the use of GIS.

2.1 Special GIS requirements in land and water resources management

The nature and characteristics of land and water resources management applications demand that databases and the computing environments must have the following capabilities: *multi-criteria modelling, time series analysis and data integration.*

Multi-criteria modelling is a basic requirement in environmental management where several factors are investigated for the occurrence and non-occurrence of a phenomenon. The ability of an environmental management system to model the different criteria is very important. The hydrologic cycle and its entities, for example, require a large volume of incompatible data for comprehensive monitoring and management. For example, the parameters that affect the discharge and recharge of the aquifer are varying. Apart from the overlay functions, extensive multi-criteria modelling capabilities are a necessary requirement. The ability to relate changes in atmospheric parameters, domestic and industrial activities, forestry/agricultural practices and soil erosion to the quality of water in an aquifer is far from being an easy multi-criteria model.

Time series analysis is necessitated by the time-dimension or the fourth dimension of hydrologic data. The collection and analysis of hydrologic data is continuous. For prediction and modelling activities, the more historic data available, the better. Most GIS software only covers an epoch of time. Rainfall and temperature data, for example, are daily/hourly data that are forever collected. Special GIS functionalities are required to process and analyse such data.

Data integration flexibility is necessitated by the need to collect data in whatever format and be able to use it within GIS software. Water resources data can be collected using remote sensing, photogrammetry, direct field surveys and telemetric down loading from weather satellites. Data handling and conversion routines must be available for the integration of this disparate information into a common database. Very few GIS software allows for such integration. The extraction of raster images and their conversion to vector file format is an example of the required data integration capability the software must demonstrate.

3.0 The use of GIS in land and water resources management

The use of GIS technology has greatly extended the ability to analyze data on land and water resources for gap analysis, modelling and decision support systems. The increasing capacity of GIS to integrate data from a variety of sources allows for more sophisticated analysis. In this section, examples of how GIS is being used in applications relevant to land and water resources management are provided.

3.1 The use of GIS in water resource management

The use of GIS in water resource management is gaining support. For example, Turner and Kolm (1991) developed a 3-dimensional GIS for groundwater modelling of regional aquifer systems in areas with complex geologic and climatic conditions. Kilborn et. al. (1991) integrated ground water models with GIS, thus providing spatial visualization for the output of the models. Mullen (1991) demonstrated the use of GIS in the assessment of ground water, in particular, analyzing the spatial distribution of atrazine contamination in wells along with data on soil leachability. Tucker and Devine (1991) integrated water quality database with a GIS in order to highlight the spatial and temporal dimensions of the database and to undertake more sophisticated analysis. As a data acquisition tool, Richie and Cooper (1991) utilized "Landsat Multispectral Satellite (MSS)" data in a GIS environment to estimate surface suspended concentration over the Enid Reservoir in North Central Mississippi and Shih and Jordan (1992) integrated remote sensing techniques with GIS to assess regional soil moisture conditions over a 208,354ha. site in southwestern Florida.

Special purpose water quality modelling software can be interfaced with GIS for a fully integrated modelling environment. Such an interface would lead to reduction in data input problems and foster integrated analysis and visualization. This becomes important when water quality data are to be georeferenced for spatial analysis.

Fundamental to the successful development of GIS support for water quality management, is the development of land and water resource databases for the entire management area. The databases would provide support for both qualitative and quantitative analyses of hydrological queries. Attempts are currently being made by several agencies in the Caribbean, to develop such databases through the Caribbean Planning for Adaptation to Global Climate Change (CPACC) Project.

3.2 The use of GIS for Environmental Monitoring

The single most important threat to surface and subsurface water resources is non-point source (NPS) pollution. Agriculture which is vital in meeting the demands for food, is threatened by NPS pollution. GIS is being used to estimate the spatial distribution of NPS pollution such as nitrogen, phosphorus, zinc, lead, and sediment. The ability to accurately assess present and future NPS pollution impacts on the ecosystems at a local and regional scale would provide invaluable information for the management of land and water resources in the Caribbean. The integration of GIS with NPS pollution model can be used to estimate the success of management attempts to reduce pollution loads in water. Assessing NPS pollution is an integrated process and it comprises a number of complexities of scale and position, thus drawing from different fields of science and applied in a spatial context.

In the case of NPS pollutants, Corwin et al. (1999) used a mathematical model within the context of a GIS that describes the appropriate chemical, physical and biological processes involved in the transport of a solute through the vadose. Endreny and Wood (1999) in Central Oklahoma used topographically based land atmosphere transfer scheme (TOPLATS), a GIS-based watershed model, in a water table-driven hydrology routine to identify runoff zones in a specific area of agricultural watershed. Carver et al. (1996) evaluated the field-based GIS methodology for environmental characterization, modelling and decision support and noted the following advantages to the use of GIS:

Improvement of environmental models through interactive field verification procedures;
Greater confidence in data gained through direct involvement in the data collection process;
Operation of positive feedback mechanisms;
Input of local knowledge and experience.

Duguay and Walker (1996) discussed environmental modelling and monitoring with GIS. They stated that remote sensing imagery and ancillary data from GIS are important sources of information for input to ecological and climatic models of seasonal and long-term change. One of the goals of the United States Long-term Ecological Research (LTER) programme is to systematically monitor and study patterns and controls within a variety of natural ecosystems at various spatial and temporal scales. The goal of this study is to monitor changes on the earth's surface as a result of natural and anthropogenic processes. Within LTER, the integration of remote sensing and GIS data sets will be critical towards linking established and detailed ecological studies at plot and landscape levels to regional scale interpretations through ecological simulation and modelling.

Recent cases of drinking water contaminated by pathogens have under scored the importance of preventing livestock waste from entering surface water. It is to this end, that analytical techniques are needed to identify sub watersheds or livestock operations that contribute disproportionately to contamination. A GIS-based transport model (SEDMOD) is used as an index of pathogen loading potential to streams using key transport parameters (Fraser et al., 1998). The transport model together with a livestock density GIS layer, explained 50% of the variation in average faecal coliform discharged from sub-watersheds. Though not perfect in quantitative predictions, the model is useful for predicting the relative contribution of diverse livestock operations within a varied landscape, hence watershed managers can prioritize sites for NPS pollution control.

3.3 The application of GIS in a land resource inventory programme: SALIS

Guided by the need to efficiently and effectively manage land resources, the Trinidad and Tobago Ministry of Agriculture, Lands and Marine Resources (MALMR) developed a GIS parcel-based State Agricultural Land Information System (SALIS). The objectives of SALIS are as follows:

To design and develop an automated information system that could be used to collect, store, retrieve, manipulate, analyze, manage and share land-related data required for the management of state agricultural land.
To implement the use of such a system on a phased-basis in all agricultural districts.
To evaluate the strategies and resources required for a full implementation on all state lands.
To integrate SALIS with other natural resource databases existing e.g. soils, rainfall and elevation databases.

To integrate SALIS with other property management databases existing in other land-related agencies in Trinidad and Tobago.

The SALIS stores for each parcel of State agricultural land, information on the following themes:

Land parcel definition
Official record of tenure
Field investigated tenure
Information on occupier
Information on land rent
Information on land use and level of utilization
Agricultural commodity on land
Information on water supply

Figure 1 is an example of a land use map produced from SALIS and the system is being used to perform the following land management activities:

Area and commodity development planning
Natural resource management
Land rent collection and management
Land valuation processes
Land use planning and management
General estate management
Land tenure regularization
Determining water needs for agricultural development

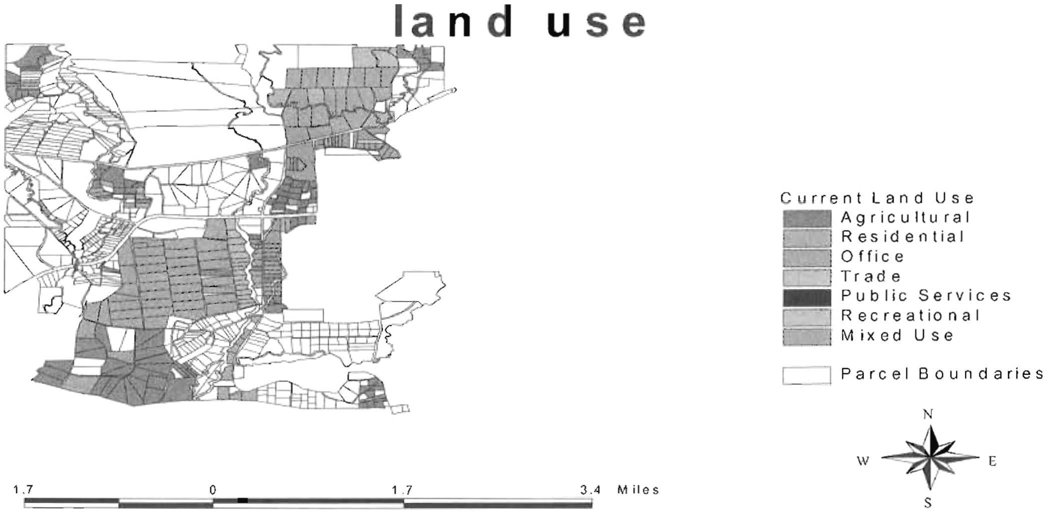

Figure 1. Current land use map derived from SALIS

3.4 GIS as a technique for evaluating the carrying capacity of land resources

The watersheds of the north and northeast Coasts of Trinidad are vitally important for the supply of potable water. The area consisting of beaches, scenic rugged terrain, forests and scattered rural communities, is also very popular for recreational activities. For this reason, the area is targeted for the

development of sustainable this activities. To evaluate its potential for these activities, a carrying capacity study with the following objectives was conducted:
To assess the ecological, physical, infrastructural, socio-cultural, economic and land use context of the study area for sustainable tourism use and development.
To determine the optimum amount and location of activity and development for the area.

The study was undertaken using GIS. Spatial analyses were conducted to objectively identify developable sites for tourism activities. In order to minimize disruption to the ecosystem of the area the following criteria were imposed for a land site to be qualified for physical development:
Be on slopes less than 20 degrees (Category 4)
Not be located on prime agricultural land and steep forested slopes
Not be on ecologically sensitive sites
Not be within Forest Reserves
Not be within existing human settlements
Not be within designated National Parks and Protected Areas
Be on State lands

The GIS data used for the analysis were:
Ecologically sensitive sites (bird and turtle nesting habitats along beaches)
Human settlements and land tenure
Forested areas including forest reserves
Designated national parks and protected areas, scientific reserves
Agricultural land capability classes
Scenic landscapes and national landmarks
Watershed boundaries

Once the digital databases were prepared, spatial analyses were conducted to select developable sites using the given criteria for each of the 12 watersheds. Figure 2 is an example of developable sites in the Maracas watershed. The selected sites were subsequently used to derive potential hotel and guesthouse locations based on the total daily carrying capacity of beaches and trails in proximity to the developable sites.

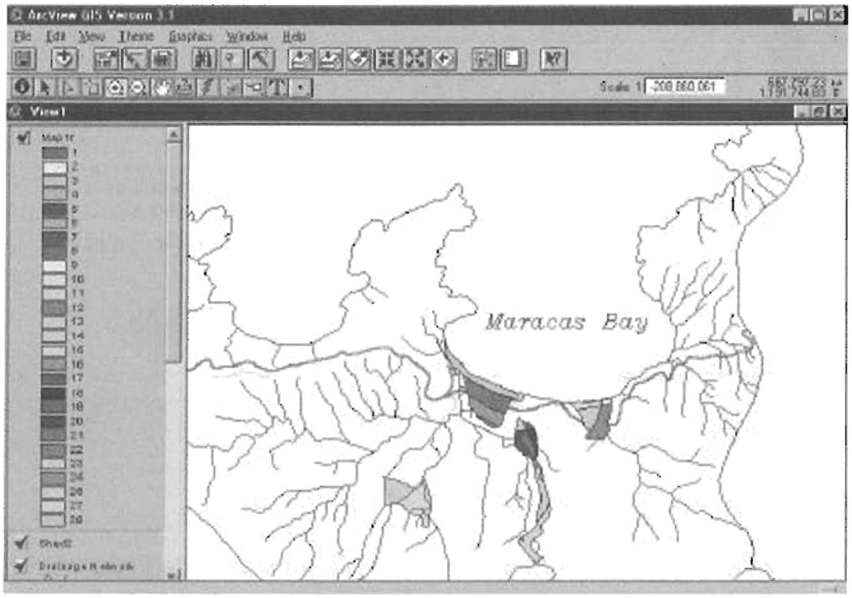

Figure 2: Developable sites in the Maracas watershed

4.0 Building a GIS-based CLAWRIS

The development of a Caribbean Land and Water Resources Information System (CLAWRIS) requires a careful and well thought out design considering the features and complexities of its environmental conditions which are to be monitored. This is particularly so when one considers the cost of data collection, the range of users and uses and the need for longevity of the system. The life cycle of information system can be subdivided into the following main stages: requirement analysis, database design, implementation and maintenance. *Requirement analysis* focuses on the peculiarities of the systems, the applications and the user environment. *Database design* is the building block of the system and it focuses on the conceptual and logical design of the database and other details that will ensure that the system can transform the data into user defined products. The *implementation* stage turns the design into action by physically automating the data and developing user interfaces needed for the effective use of the system. The most critical but often neglected stage is the *maintenance*. This stage ensures that the system remains relevant to current and future needs. This paper addresses only the requirement analysis and database design stages.

4.1 General requirement analysis

CLAWRIS is conceptualized as a regional information system that may be employed by a wide range of users for purposes ranging from simple to complex analysis of land and water issues in the Caribbean. It is therefore necessary that CLAWRIS should have the following design features shown in Figure 3:

Data-driven
Fully integrated
Portability
Multi-scale
Modularity

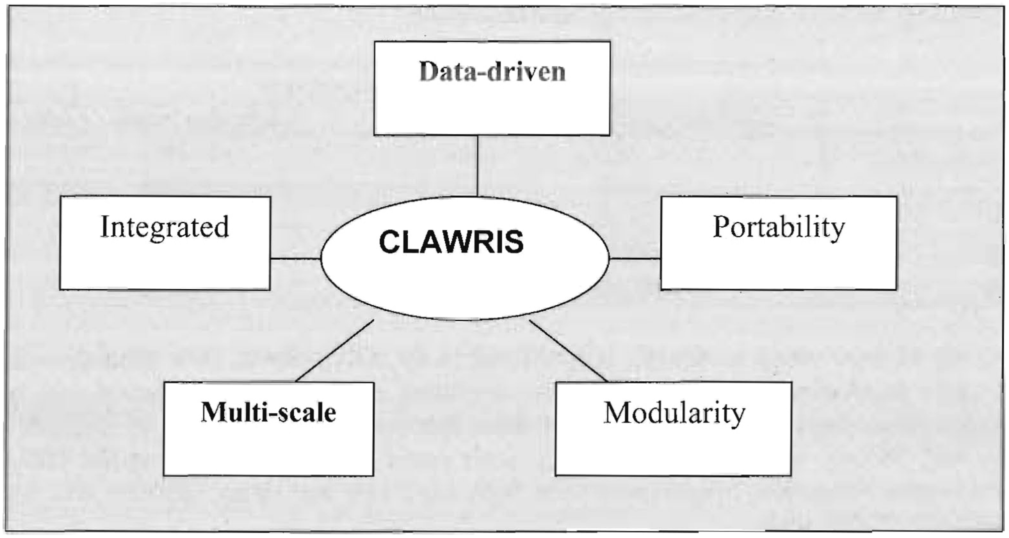

Figure 3: The design feature of CLAWRIS

The *data driven* design approach focuses on explicit characterization of the data entities with little knowledge of the user's needs. It concentrates on building a generic database that can meet the needs of current and future users and it lends itself to being managed through a phased or modular development. The application-driven design is user focused. It normally results from extensive user requirement studies. It assures the users have a clear idea of what they want. It may be inexpensive to develop but runs the risk of not meeting future needs and the needs of other users. An integration of the two design approaches is being advocated for CLAWRIS. Due to the multi-faceted nature of the parameters required for comprehensive land and water resources management, it is required that CLAWRIS has the capability to *integrate data* from different sources and formats. *Portability* should be an important feature of CLAWRIS because of the advantage of being able to implement it at both local and regional levels and it should be possible for it to be moved from one computer environment to another with minimum effort. *Multi-scale* feature allows for the integration of data compiled at different resolution and accuracy as is commonly found in the Caribbean. *Modularity* allows for a phased implementation of CLAWRIS and the capability that ensures an integrated solution. The different applications for the management of land and water resources may thus be built at different times and by different developers.

Conceptual design of CLAWRIS

In order to ensure accuracy and consistency in spatial analysis it is necessary that all the data inputs be of the same coordinate system and map projection.

4.2.1 Resolution of input data

Even though it is perceived that GIS data can be independent of scale, this is a myth. It is a fact that GIS data can be displayed at any scale, the accuracy of the output data however, cannot be better than that of the input. It is therefore important that the resolution of the input should be selected to the satisfaction of the desired output or applications since the scale of a map is directly related to its resolution. The map resolution defines the accuracy with which the location and shape of a ground feature can be shown for a given map scale. Table 1 gives an example of the ground resolution (minimum plot size and minimum length) of objects that can be accurately resolved at different map scales. If a particular application that requires that the location and shape of all buildings in a watershed be known accurately, then the scale of the input map would be 1: 1000 or better.

Table 1: Relationship between map scale and ground resolution

	Ground Resolution	
Map scale	Minimum plot size (Acres)	Minimum length (Feet)
1 : 10,000	<1	105
1 : 24,000	2 –3	250
1 : 100,000	25-50	1050
1 : 250,000	250-500	2600
1 : 500,000	500-1000	5280

The scale of input maps is directly proportional to the data volume, data integration complexity and cost of system development. Small scale or low resolution implies a low volume of data while large scale or high resolution implies a large volume of data. Whereas four map sheets at 1:75,000 cover the island of Trinidad, 38 map sheets at 1:25,000 map scale cover the island. Choosing the 1:25,000 maps will lead to 12.5metre resolution, longer input time, high input cost and larger database size compared to the use of maps at 1:75,000 scale.

Whereas it is desirable that the purpose of the application should determine the resolution of the input data, this ideal condition is sometimes difficult to establish especially in the Caribbean. Available maps exist in different map scales with no resources available for re-mapping at the desired scales. The user is therefore left with no choice but to integrate high-resolution data with those of low-resolution. When this situation occurs, the user should be prepared to interpret the final output using the low resolution and at a later time the level of resolution can be upgraded. If resources permit the generation of higher resolution data using for example IKONOS satellite imagery.

CLAWRIS advocates the acquisition of multi-scale spatial databases to facilitate the different needs of the end-users and to provide efficiency in the management of the system. It is required that the specific resolution of each potential application be defined and specified, based on the needs of the users.

4.2.2 Coordinate system of input data

GIS provide a mechanism for the measurement of spatial phenomena. This spatial measurement must, however, be based on a coordinate system for it to be meaningful to the end users. The design of CLAWRIS is faced with the challenge of selecting the appropriate coordinate system for data storage and mechanisms for converting from one coordinate system to another. Geographic data can either be stored in geographic coordinate system (GCS) or in Projected Coordinate System (PCS). GCS reference location on the surface of a three-dimensional sphere using geographic latitude (Ô) and longitude (ë) of the locations, whereas PSC reference location by employing a two-dimensional plane by measuring the northings (N) and eastings (E) coordinates from the origin. The GCS is global in nature whereas the PCS is local and unique to a small location. The PCS is the result of projecting coordinates from GCS to the two-dimensional surface. The consequence of such projections is the distortion of the spatial properties of the object. For mapping convenience and other historical reasons the States of the Caribbean have been mapped using different map projections.

The challenge in the development of CLAWRIS is in the selection of an appropriate coordinate system for data storage. A detailed understanding of the mapping parameters of each country and island is a prerequisite towards the development of CLAWRIS. In order to facilitate data integration, data sharing and comparative regional analysis, the GCS is considered best suited to CLAWRIS. This decision means each spatial database of all the countries be stored in the GCS. It therefore implies that existing digital data be converted to the GCS. The World Geographic System 1984 (WGS 84) is also considered the best option because of its global popularity. Apart from gaining knowledge of the map parameters of all the countries, it is also important that utility software is readily available to convert the data from one system of coordinates to another. The inclusion of projection utility function in GIS software has provided end-users with the ability to undertake such two-way conversions with minimum expert knowledge.

4.3 Logical database design

Using a data-driven approach, the logical design of CLAWRIS is to be independent of end-user application. Therefore the following logical design elements would be considered:
Data themes
Data layers
Feature type
Primary and related attributes
Selection criteria
Drawing methods

The design of data themes facilitates data referencing and data organization and it ensures reduction in data redundancy. The following criteria can be used to design data themes: (ESR1, 4-71)
Logical similarity among the data
Existence of coincidence feature
Topological continuity
Topological interference
Management responsibilities
Source map scale
Incompatible attributes

Table 2 is the CLAWRIS preliminary data themes. This can be further refined and regrouped to include end-users requirements. Figures 4 to 13 are subsets of digital GIS-based data themes created for Trinidad.

Table 2: CLAWRIS data themes

Natural resources data themes	Atmospheric / climatic data themes
Soils characteristics Hydrology: rivers, dams, lakes, ponds Elevation: contours, bathymetry Land cover, land use Vegetation Forest reserve, natural parks Land tenure/ownership Geology/hydrogeology Sensitive sites, wetlands and reserves Communities and settlements Watersheds Coastlines, bays, beaches Enumeration districts/population Infrastructure data themes Transportation: roads, seaports, airports Water distribution systems Gas distribution systems Electricity distribution systems Telephone distribution systems Sewerage systems Drainage systems Industrial sites Waste disposal sites Social amenities data themes Post offices Fire services Police stations Health facilities Schools Markets Recreational Grounds/Open spaces Places of worship and Historical sites	Rainfall Temperature Humidity Wind Ocean current Wave Salinity

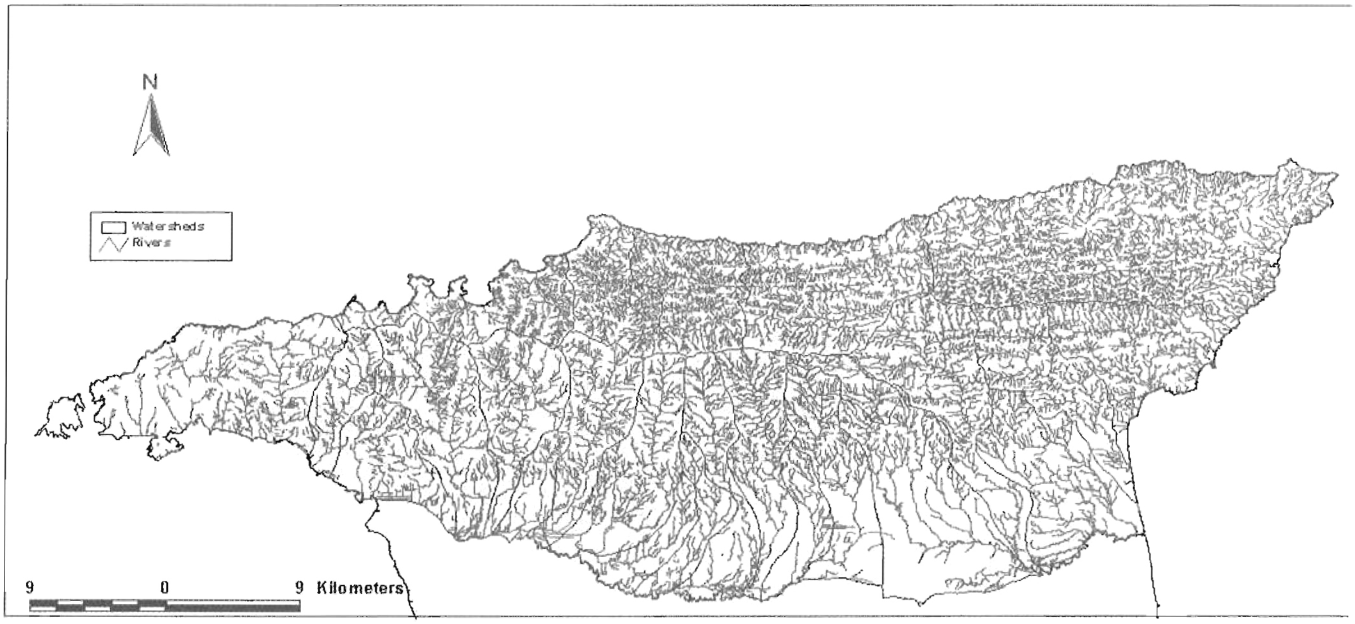

Figure 4: The drainage network and watersheds of Trinidad Northern Range

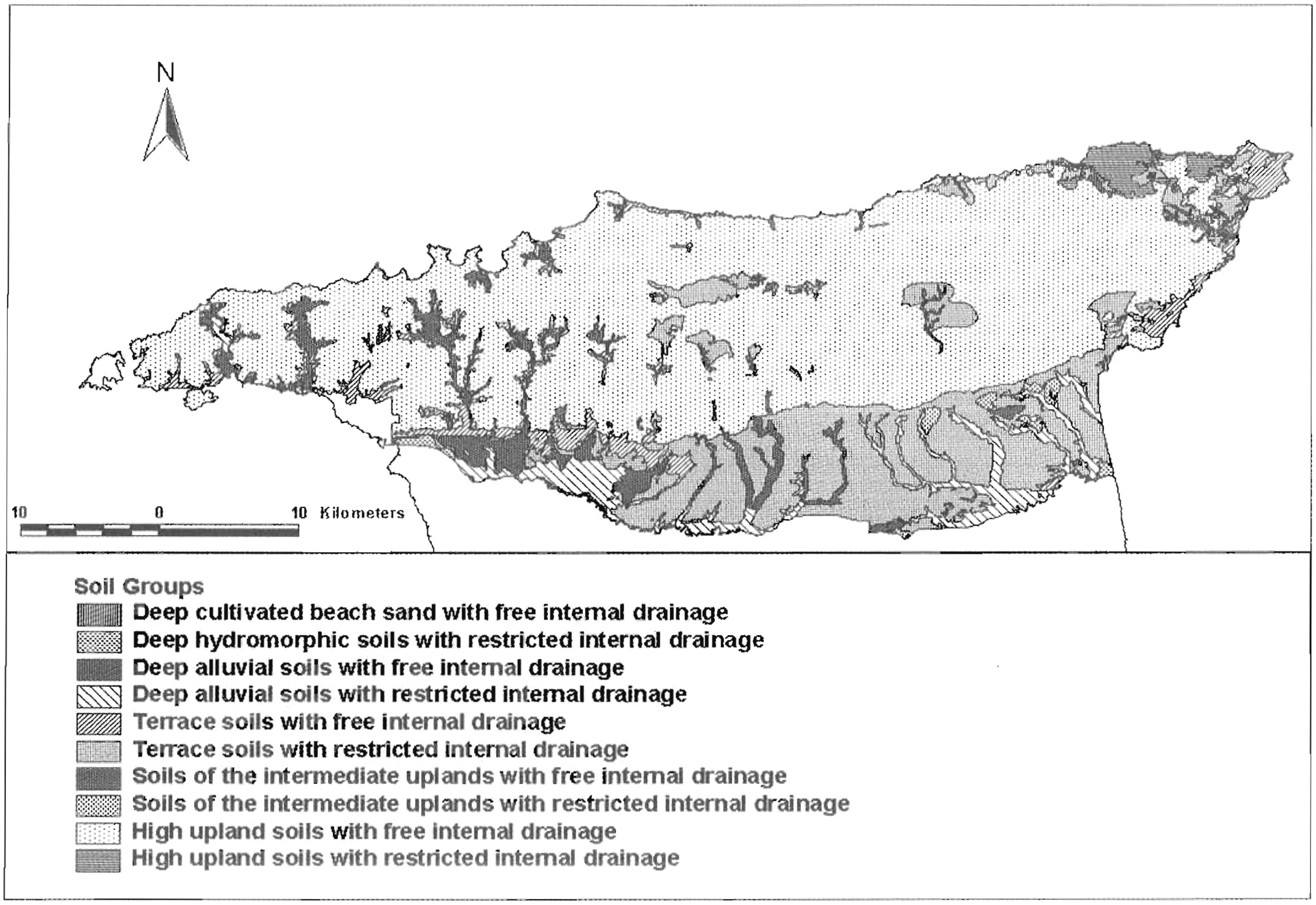

Figure 5: The soil groups of Trinidad Northern Range

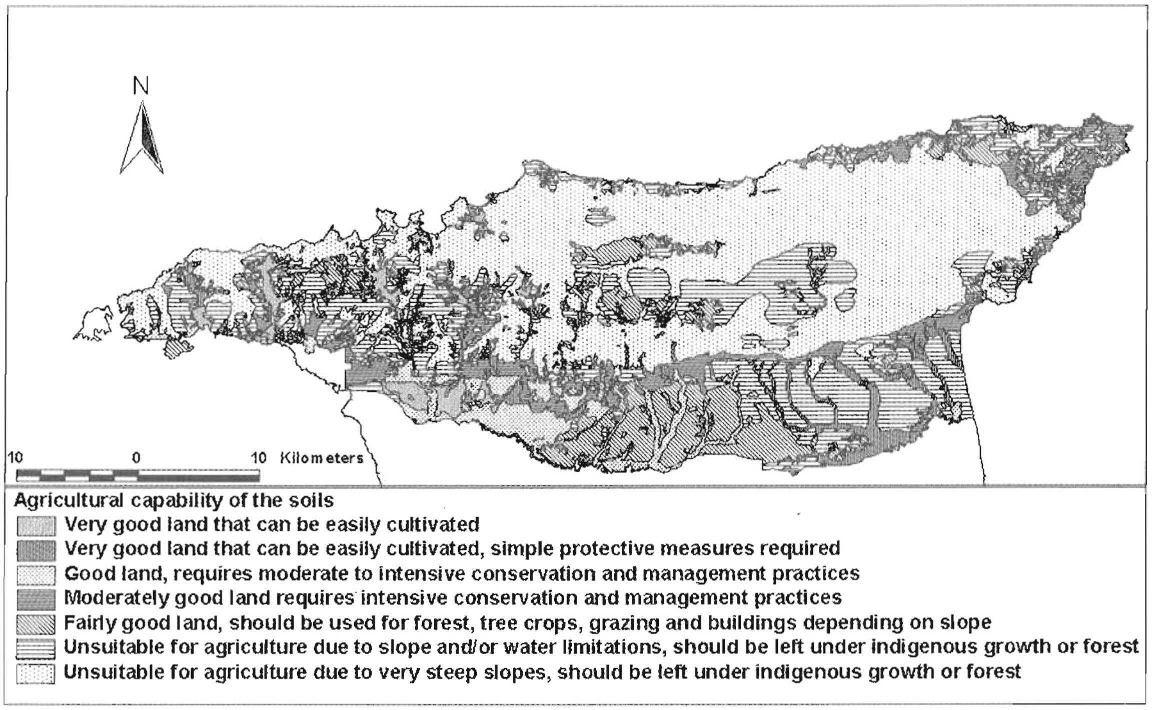

Figure 6: The agricultural capability of the soils of Trinidad Northern Range

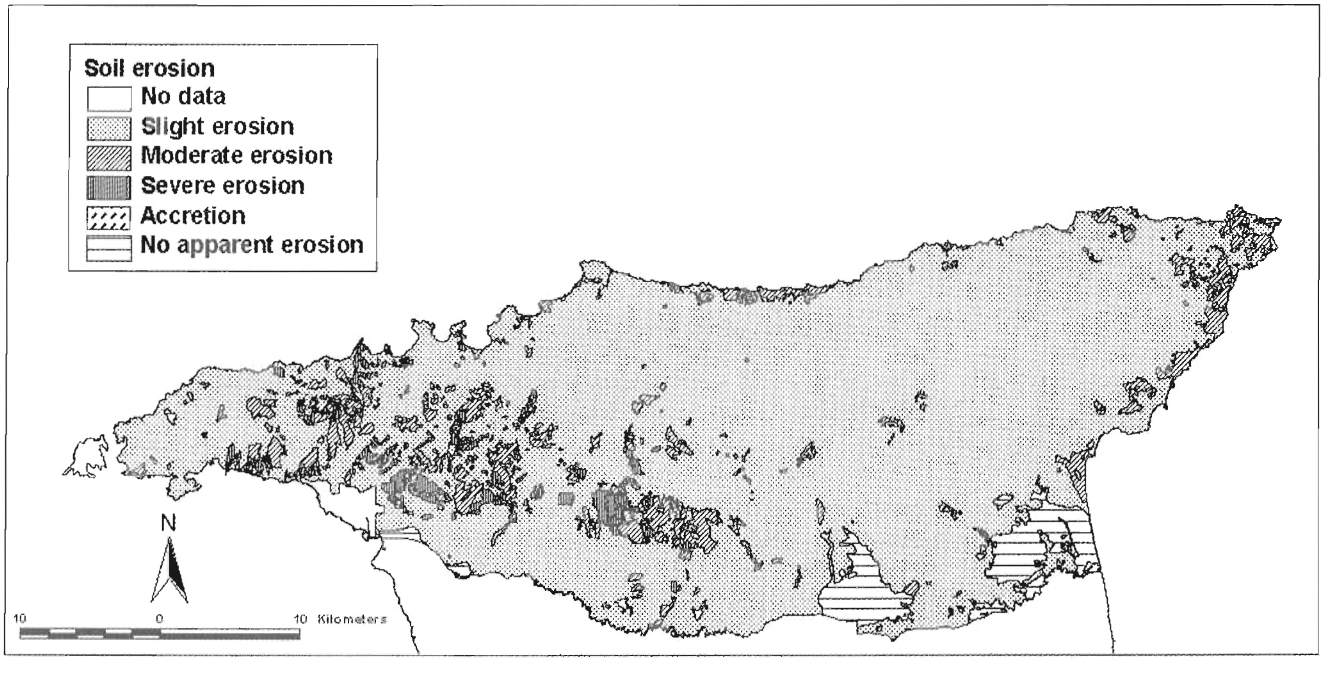

Figure 7: The soil erosion categories of Trinidad Northern Range

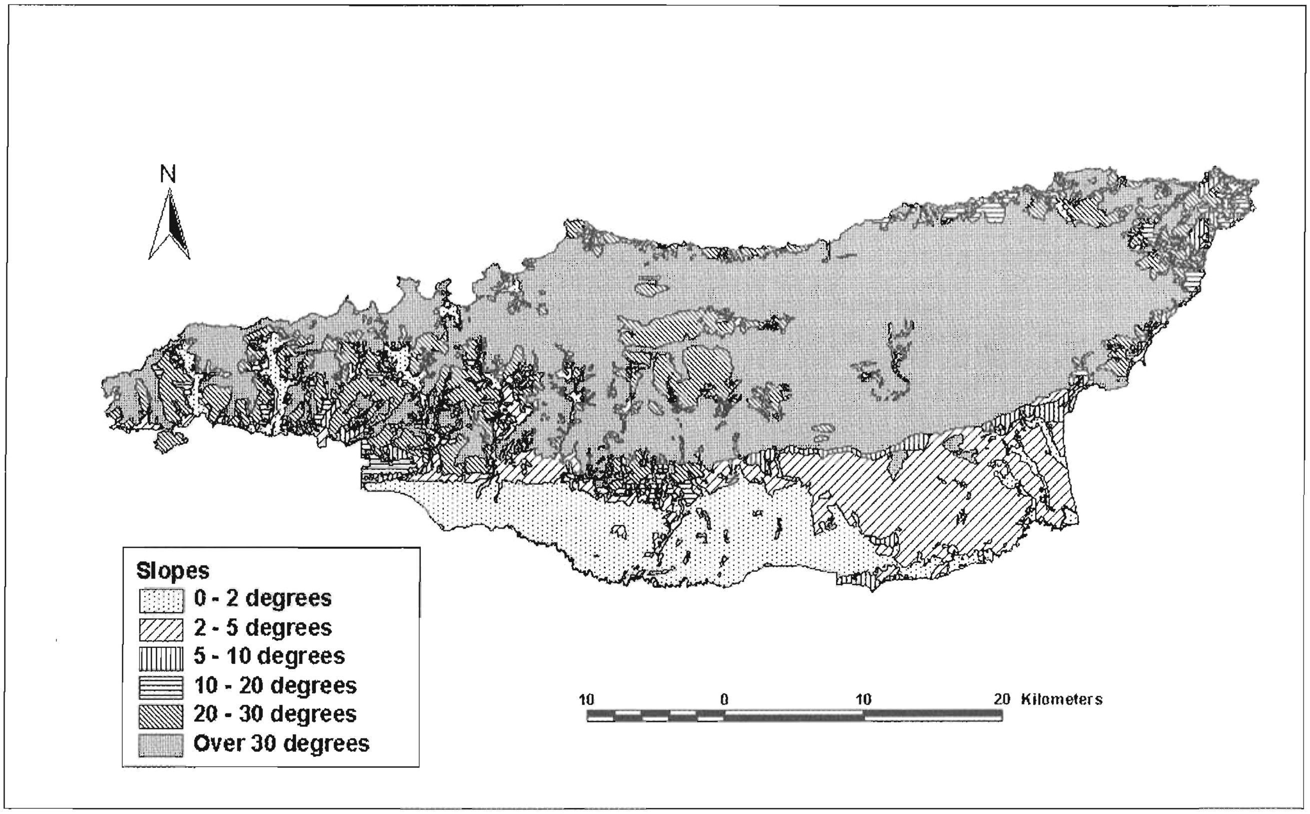

Figure 8: The slope categories of Trinidad Northern Range

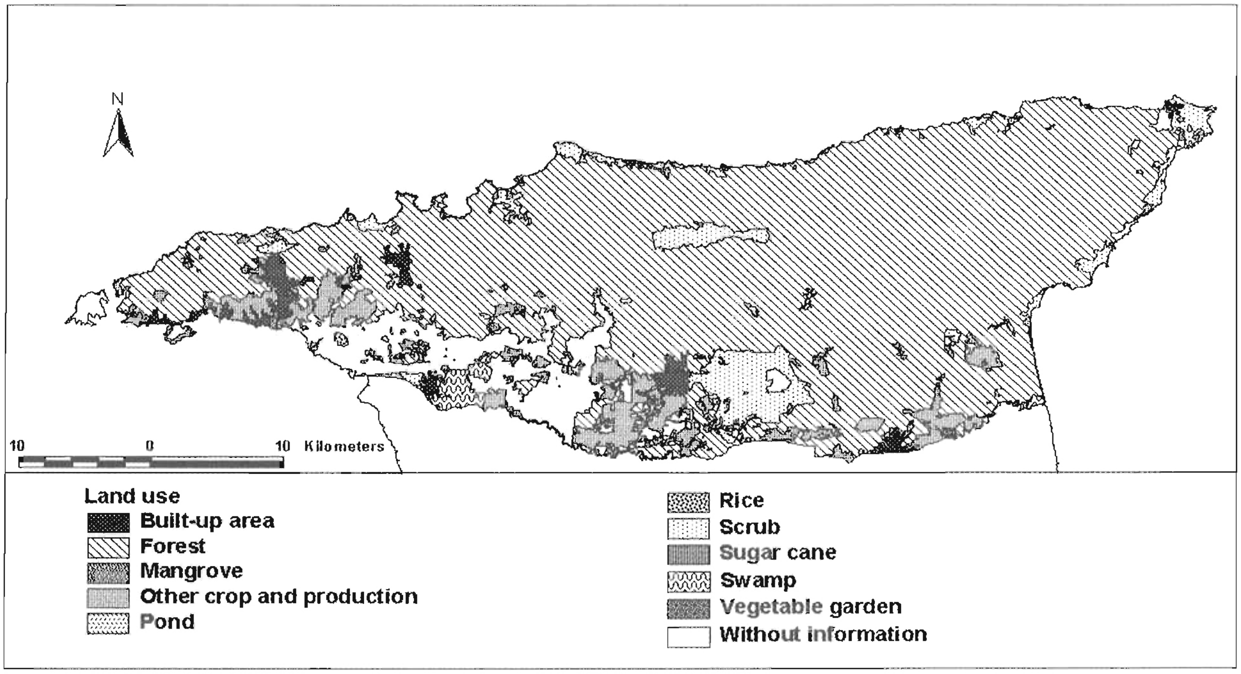

Figure 9: The land use/land cover of Trinidad Northern Range

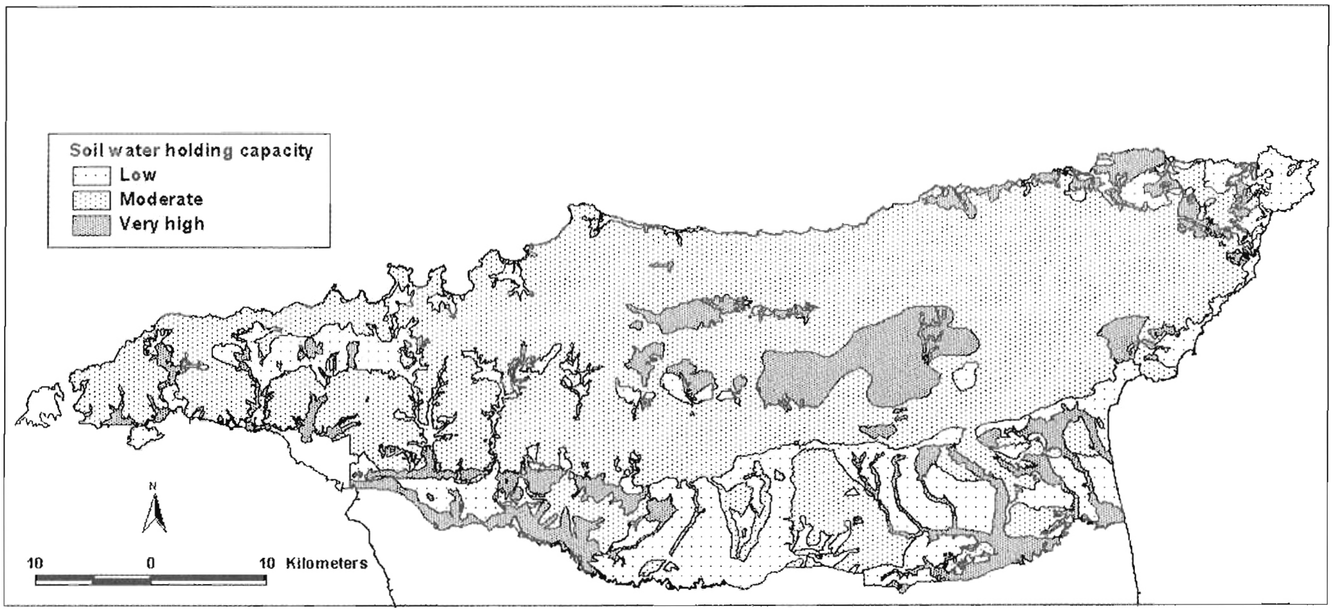

Figure 10: The soil water holding capacity of Trinidad Northern Range

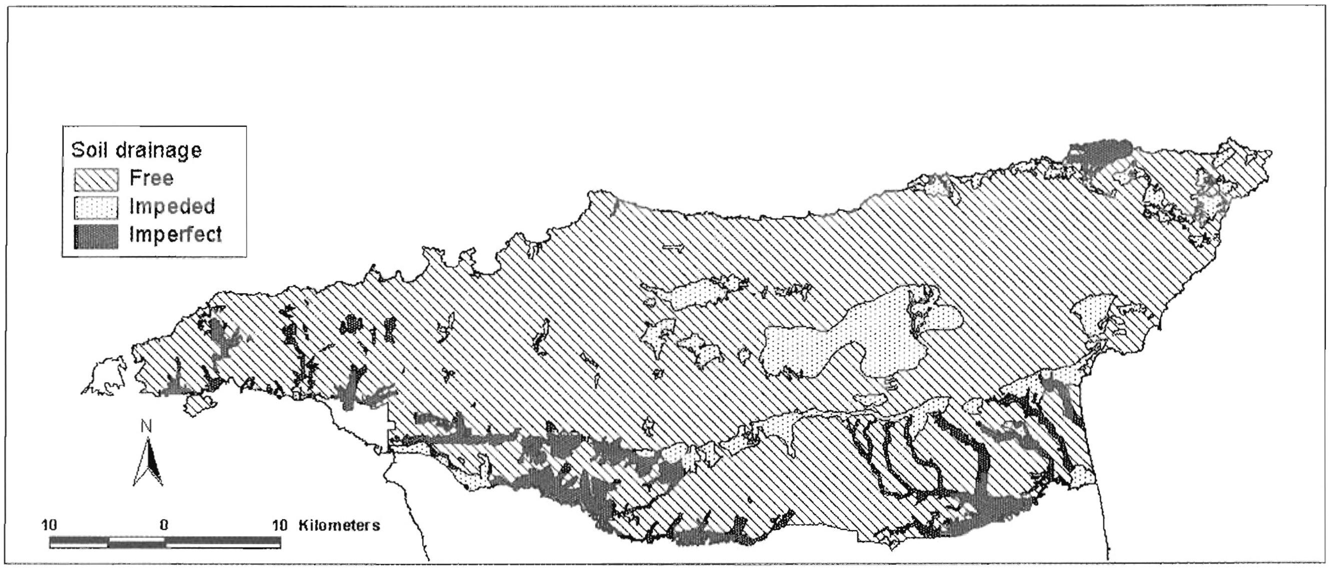

Figure 11: The soil drainage of Trinidad Northern Range

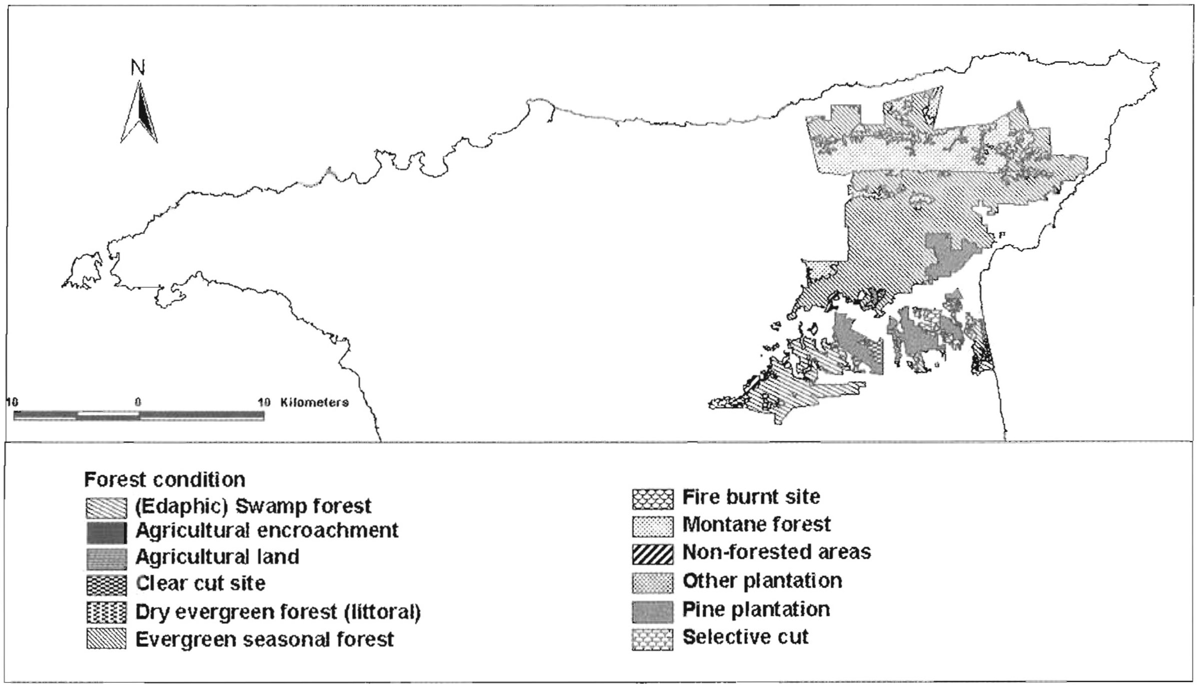

Figure 12: The forest condition of Trinidad Northern Range

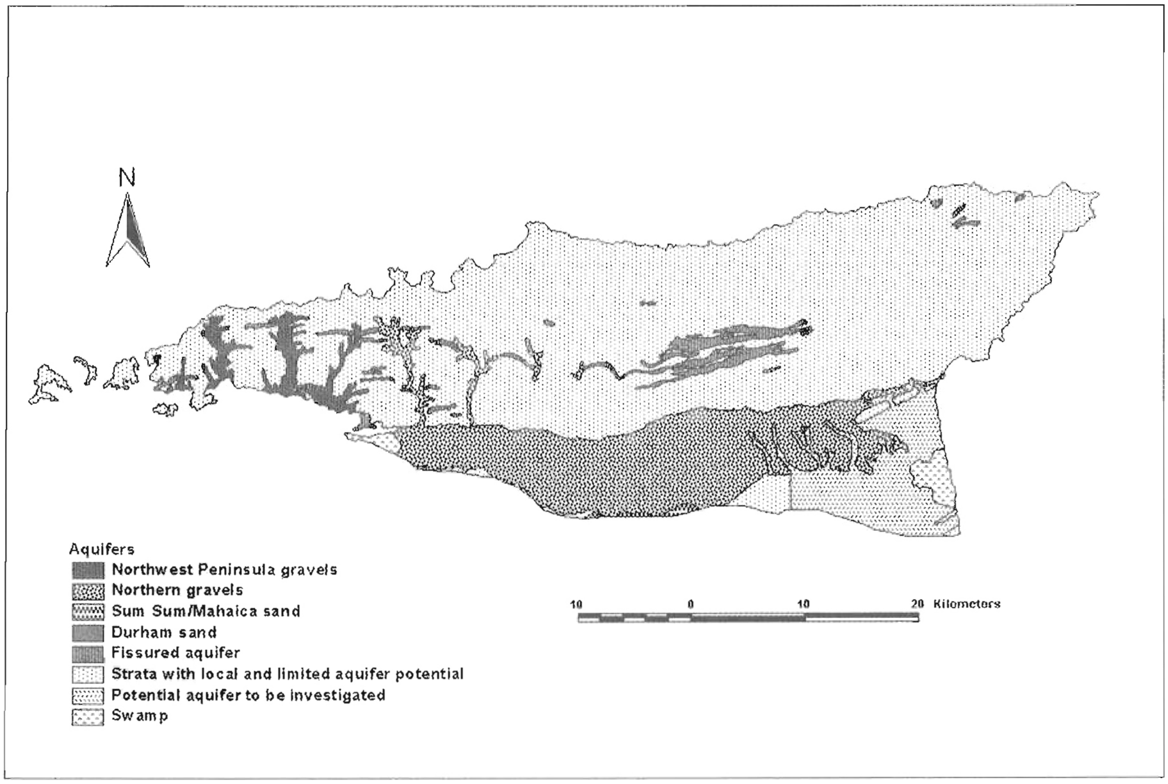

Figure 13: The aquifers of Trinidad Northern Range

5. Conclusions: Towards Effective Use of GIS in the Caribbean

In order for the Caribbean to effectively benefit from the many advantages of GIS, there is a need to develop a strategic development plan. Critical to the plan are the following elements:
Consistent data collection programme
Efficient data management plan
Capacity building
Consistent data models and integrated analysis

Consistent Data Collection Programme: The effective use of GIS for land and water resources management requires a consistent flow of data on the extent and status of these resources. Spatial analyses and resource monitoring programmes can be rendered ineffective with data gaps and incompatible data. Therefore a programme of regular data collection on the status of natural resources is imperative. The use of satellite imagery has made the undertaking of such a programme more affordable to the Small Islands Developing States (SIDS).

Efficient Data Management Plan: In addition to a consistent data collection programme is the need to develop an efficient data management plan. The high investment in data collection may go to waste if the data is not managed efficiently. Data management plans should include data sharing and data dissemination protocols, cost recovery programmes and development of data standards.

Capacity Building: An important element in the effective use of GIS is the availability of trained and experienced personnel. Whereas the SIDS of the Caribbean have invested in GIS hardware and software in the past 10 years, very little investments have been made towards the training and retraining of resource persons required to design, build, use and manage a GIS. A renewed effort is therefore required in building a structured (formal and informal) training programme. An investment in human resources will ensure the sustainable use of GIS.

Consistent Data Models and Integrated Analysis: GIS provide for integrated analysis of land and water resources. Impact analysis and cause-effect models can be efficiently built for different land use scenarios. To be able to undertake such analysis, it is important that a consistent data model be built for the different natural resources in the SIDS of the Caribbean. Land use classification, ecological or ecosystem classification, soils properties and geological features need to be modeled so that cross-island analysis can be undertaken. The absence of such a model will perpetuate the current situation of island-based analysis.

The many opportunities provided by the reducing cost of satellite remote sensing imagery and the powerful functionalities of GIS have made it the technology of today for the Caribbean. The era of planning without information on the nature and stress of the natural resource is fast coming to an end and a programmatic and strategic investment in GIS is required for the effective and efficient management of land and water resources as a matter of great urgency.

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