Organization of American States

USAID

Drought Hazard Assessment and Mapping for Antigua and Barbuda

Post-Georges Disaster Mitigation Project in Antigua & Barbuda and St. Kitts & Nevis

April 2001

This report was prepared under contract with the OAS by Ivor Jackson, Ivor Jackson & Associates, Environmental & Landuse Planning and Landscape Architecture, P.O. Box 1327, St. John's, Antigua. Tel/fax: 268 460 1469. E-mail ijacks@candw.ag.

CONTENTS

CONTENTS (Continued)

List Of Tables

1.0 BACKGROUND

1.1 Introduction

The Organization of American States (OAS) as part of its Post-Georges Disaster Mitigation Project (PGDM) commissioned this drought hazard assessment and mapping study for Antigua/Barbuda.

One of the major objectives of the PGDM is the "development of national goals, objectives and actions to reduce the vulnerability of Antigua/Barbuda … to the effects of natural hazards."

1.2 Terms of Reference

The Terms of Reference (TOR) for the study is attached as Appendix 1. There are two major component products of this assignment, (i) a drought hazard assessment report and (ii) island wide GIS data layers depicting drought hazard risk areas and drought hazard maps for Antigua/Barbuda.

1.3 Methodology

1.3.1 Data Collection

Data for map preparation and for drought assessment were collected using secondary sources, reports, maps, personal communication and limited field observations.

1.3.2 Mapping

Maps were first manually prepared and then digitized using GIS application, Arc View.

1.4 Definitions

For the purposes of the study and in agreement with relevant authorities, a definition of drought has been drafted, as indicated below. Other relevant definitions are also provided to facilitate both the drought hazard assessment and mapping work.

1.4.1 Drought

Drought is a recurrent feature of Antigua/Barbuda's climate. It occurs when there is an extended period of deficiency in precipitation (relative to what is considered normal), which is then insufficient to meet economic, social and environmental demands. Given their relatively small size, drought effects in Antigua and Barbuda are felt island-wide.

For reasons of analysis and in view of the need to determine appropriate responses to drought impacts and vulnerability, drought is defined as having three critical but inter-related components (as taken from the US National Drought Mitigation Center's definition) namely:

- Meteorological drought
- Agricultural drought
- Hydrological drought

a) Meteorological drought

Meteorological drought is defined mainly by deficiencies in precipitation. Along with deficient rainfall, conditions during drought may be accompanied or aggravated by high temperatures, strong winds, low relative humidity, greater sunshine and less cloud cover.

These conditions can be expected to bring increased evaporation and transpiration, reduced water infiltration into soils and a reduction in deep percolation and ground water recharge.

The Antigua/Barbuda Meteorological Office (Met Office) has categorized drought from slight to extreme, as shown in Table 1.

Table 1 Categories of Drought, as Defined by % of Average Yearly Rainfall of 40.98 inches (Antigua)

Category Drought	Rainfall (inches)	% of Ave. Annual Rainfall
Slight	38.93	95
Mild	36.88	90
Moderate	32.78	85
Moderate/ Severe	30.74	80
Severe	28.69	75
Extreme	24.50	70

(Source: Meteorological Office, 2001)

Based on annual rainfall assigned to each category by the MET Office, some form of drought occurred in Antigua in 20 of the 40 years between 1960 and 2000. Rainfall records for the period were collected by the Met Office (see Appendix 2).

This does not match public recollection and perception of drought. A more simplified definition of meteorological drought using the Met Office's Moderately Severe category, as the cut-off point would provide a definition more in keeping with public perception.

Meteorological drought for Antigua/Barbuda is defined using a precipitation level of 80% or less of yearly average rainfall (or < 30.74 inches, Antigua and < 27.79 inches, Barbuda) for a drought year. A limitation in using this definition is that drought designation is mostly done on the basis of a calendar year and usually after the event occurs.

For the purpose of drought preparedness, it is suggested that precipitation deficiencies over a six (6) month period could be used to predict an imminent drought.

For example, if the average monthly rainfall for the dry period of the year, January to April, (2.06 inches for Antigua) is experienced over a six (6) month period, it would in public perception signal that a drought was imminent. At the end of a six (6) month period in which total rainfall is < 12.36 inches, effects associated with meteorological drought would begin to emerge.

b) Agricultural drought

Agricultural drought occurs when plant water demands cannot be met due to soil water deficiency resulting from dryness brought on by meteorological or hydrological drought.

In such cases plant water stress may be evidenced from reduced biomass and plant yield. One common indicator species is the "evergreen" ficus, which responds by first dropping most or all its leaves followed by the death of its stems.

c) Hydrological drought

Conditions associated with meteorological drought represent the earlier signs of drought followed by effects of agricultural drought because plants are highly dependent on stored soil water.

Hydrological drought can be considered a third stage in the evolution of drought conditions evidenced by significant reduction in surface reservoirs, drying of dams and wetlands. In this phase of drought, livestock may be severely impacted and other sectors begin to feel the devastation.

1.4.2 Drought Hazard

A drought related hazard is an event in which a significant reduction of water brings about severe economic, social and environmental hardships to the population of Antigua/Barbuda.

1.4.3 Drought Vulnerability

Vulnerability to drought is defined as economic, social and environmental characteristics and practices of the country's population that make it susceptible to the effects of a drought. Vulnerability is reduced by the ability to effectively plan for, anticipate, cope with and recover from droughts.

1.4.4 Drought Risk

The potential adverse effects of droughts viewed in relation to their frequency and severity combined with the vulnerability of Antigua/Barbuda's population determines the risk to such events.

1.4.5 Use of the Term Drought

In this report, reference is made to the meteorological, hydrological or agricultural drought as appropriate. A simple working definition of drought could not be developed for this assessment because of varying perceptions of drought even for persons familiar with drought hazard assessment literature.

Broad-based discussions are needed between persons involved with drought mitigation planning and those involved with sectors affected by drought in order to build consensus and capacity to manage drought.

2.0 ASSESSMENT

2.1 Meteorological Conditions

2.1.1 Precipitation

Antigua

Average annual rainfall for Antigua is 40.98 inches (Met Office, 2001). Rainfall records for Antigua 1950 – 1984, as reported by the Island Resources Foundation (IRF), using APUA as its source, are summarized in Appendix 3. Records from 1960 – 2000 based on observations at Coolidge by the Met Office are given in Appendix 2.

Both are presented because of variations, which suggest that the data was obtained from two different stations. Attempts to determine the position of the rainfall station from which APUA records were taken were unsuccessful. Both records show significant variability in precipitation between years from 1950 to 2000.

A rainfall map, showing "long average annual isohyetals" (IRF, 1991, after Hill, 1966) indicates important variability between sections of Antigua, with the volcanic hilly region in the south/southwest having up to 55 inches/year, while coastal areas in the southeast, east and northeast experiencing 35 inches/year.

Based on the average rainfall for coastal areas as cited by the isohyetals, precipitation >35inches/year (87.5% of average annual rainfall) would not constitute drought conditions, or else such areas would be in a state of constant drought.

IRF identified two periods between 1950 and 1990 as "periods of prolonged drought" for Antigua. These are 1964 to 1968, when the average rainfall was 31.53 inches, and 1983 to 1984, when the average rainfall was 27.75 inches.

In the Met Office records, eight (8) years between 1960 and 2000 experienced rainfall below 30.74 inches and could therefore be considered drought years for Antigua.

Variation in monthly rainfall is another important consideration in drought management. The data show that precipitation is highest during the months of August to December (wet season) and lowest between January and April (dry season).

Average wet season rainfall is 4.6 inches /month, while average dry season rainfall is 2.06 inches/month.

Therefore, for four months of the year (January to April) the average rainfall of 2.06 inches is 60% of average monthly rainfall for the 12 months of the year (3.41 inches) but the period is not long enough to be perceived by the population as drought.

It is assumed however, that if dry season conditions were extended for six (6) months (12.36 inches of rainfall) this would, in public perception, constitute drought conditions.

A critical constraint in the use of rainfall data is the distribution of rainfall stations. Stations are lacking in the drier areas of the southeast, east and north of Antigua, where shallow soils and the relative exposure to winds and marine influences tend to make such areas relatively more susceptible to the effects of drought.

In past years there were 70-95 rain gauges located around Antigua (IRF, 1991). Most are no longer in use.

Barbuda

The average annual rainfall for Barbuda between 1965 and 2000 was 34.74 inches (Met Office, 2001). During this period, if < 27.79 inches/year of rain is used to define meteorological drought, then drought years were experienced in 1966, 1967, 1968, 1971, 1977, 1983, 1990, 1991, 1994 and 2000.

2.1.2 Temperature

Average temperatures are 29 degrees C (82.2 F) during the summer and 24 degrees C (75.2F) during the winter months. Extreme highs of 34 degrees C (93.2F) in August and 15 degrees C (59F) in January have been recorded (IRF).

Despite their small size, both islands have topographic and landscape features (including urban development), localized wind patterns and soil characteristics that result in temperature variations over the island. Such temperature differences are not captured due to a shortage of temperature recording stations.

Existing temperature stations record surface temperatures. Soil temperatures, which are critical to the performance of some plants and to agricultural crops, are not normally recorded.

2.1.3 Winds

Easterly trade winds form a critical component of Antigua/Barbuda's climate. Yearly average wind speeds between 1969 and 1995 recorded at the Coolidge Met Office, Antigua, was 12 knots.

Highest average wind speed is recorded for the month of July (14.2 knots). Critically, the lowest average wind speeds are for the months of September, October, November, which are the three wettest months of the year (see Table 2).

Table 2 also shows that the average wind speed for the driest months of the year is 12.7 knots compared to the yearly average of 12 knots. Average relative humidity is significantly higher in the wet months.

Table 2: Rainfall, Windspeed and Relative Humidity, Driest and Wettest months of the Year

	Rainfall (inches)	Windspeed (knots)	Relative Humidity
Dry months			
January	2.34	12.8	81.0
February	1.53	12.4	81.0
March	1.77	12.1	81.0
June	2.01	13.4	82.0
Ave.	1.91	12.7	81.25
Wet Months			
September	5.29	10.8	84.0
October	5.11	9.6	85.0
November	5.14	10.5	85.0
Ave.	5.18	10.3	84.6

(Source: Met Office, 2001)

Note: Average monthly rainfall data is based on records from 1960-2000. Average monthly windspeed data is based on records from 1969 – 1995 and average monthly relative humidity data based on records, 1960-1995.

Relatively speaking, winds are normally stronger in the dryer months when bare soils are exposed to its forces. Actual monthly windspeed data were not obtained so as to determine if this relationship holds true for extended dry periods (droughts).

It does suggest that wind speed is one factor that makes soils more vulnerable to erosion during drought.

The records indicate that between 1991 and 1995 the prevailing wind direction was 090 degrees for eight months of the year – shifting slightly to 100 degrees for the months of April, June, and October and 110 degrees during the month of May.

The drying effects of wind on soil is particularly critical for exposed east facing slopes of the southeast, east and northeast of Antigua and the Highlands on Barbuda's east coast.

The stronger winds of the drier months rapidly remove moisture from soils, affecting in particular plants with shallow root systems.

The direct physical effects of the wind, combined with salt in the air contribute to the wilting of plants. Wilting also occurs from deficiencies in moisture. These localized effects have not been sufficiently studied although their understanding is critical to the assessment of areas susceptible to drought.

Wind data for Barbuda was not obtained but it is assumed that average wind speeds do not vary significantly from Antigua.

2.1.4 Relative Exposure of Slopes

The exposure of slopes to wind and sunlight affects vegetation and soils and rates of evaporation and transpiration. These influence localized climatic conditions, which may in turn affect conditions for grazing and growing crops.

For example, light increases transpiration (evaporation of moisture from leaf surfaces) rates more than it does evaporation rates (from water bodies, soil). On the other hand wind increases evaporation rates more than transpiration rates (OAS, 1991).

East facing slopes, particularly those at the shoreline, therefore experience relatively higher evaporation and transpiration rates than western facing slopes, where the afternoon sun has a greater effect on transpiration rates than does exposure to winds.

The critically exposed east facing slopes near the coast in the Mamora/Isaac Hill region of Antigua exemplifies the effects of wind and light, along with the effects of overgrazing by its barren landscape.

Western facing slopes in the higher volcanic region of Antigua enjoy relatively better precipitation due to convective influences. In this case, warmer air rising over the land surface at the higher elevations cools and condenses releasing its moisture on slopes west and northwest at the Shekerley Mountains range.

Here, the area of influence is relatively small and the elevation not high enough to cause the warming of descending air and subsequent withholding of moisture. As a result, the arid conditions experienced on the lee of mountains in Central America for example from orographic precipitation do not exist.

2.1.5 Relative Humidity

Average relative humidity for dry and wet months was given in Table 2 based on MET Office records. In addition, the IRF (1991) reporting from Loveless (1960) and Atkins (1983) claims that the mean relative humidity for Antigua is in the low 80's in the morning and low 70's in the evening.

Relative humidity is said to be higher in Antigua than in Barbuda and some of the other islands. Heavy dews deposited at night on the island are believed to contribute to water balance, particularly in drier areas. The amount of water gained through this form of precipitation has not been measured.

2.1.6 Sunshine and Cloud Cover

Antigua/Barbuda experiences ample periods of sunshine throughout the course of a year including the wet season. The islands experience dense cloud cover (as different from scattered clouds) for much less than half of the year.

Hence despite having average relative humidity higher than neighboring islands, Antigua is normally dry and temperatures relatively high. Because of the relationship of temperature to evapo-transpiration, rates for the latter are considered on par with other countries in the Leeward Islands.

2.1.7 Evaporation and Transpiration

a) Evaporation

Evaporation rates for water bodies and soils in Antigua/Barbuda are not generally available. Evaporation and seepage rates were calculated for Potworks Reservoir (between 152 and 188 ha in reservoir area) during November 1995 to May 1996.

The results, given in Table 3, show that total evaporation and seepage for the seven (7) month period (1.59 million cu m) was over two times the amount of water supplied from the reservoir (691,091 cu. m). This is of critical significance to water management during drought.

Although evaporation rates and volumes were not separated, the results indicate the relative quantities of water than can be expected to be lost from surface water bodies including municipal and agricultural storage reservoirs and dams.

Table 3 Water Balance at Potworks Reservoir Nov 1995-May 1996

Ave. Rainfall (monthly)	46.428mm
Total Rainfall (7 months)	325mm
Reservoir Area	173.7 ha
Monthly ave. reservoir vol.	3.4 mil. cu. m
Total reservoir vol.	23.8 mil cu. m
Monthly rate evaporation/seepage	155mm
Monthly ave. evaporation/seepage	227,628 cu m
Total evaporation/seepage	1.59 mil. cu. m
Monthly ave. water supply	98,727 cu. m
Total water supply	691,091 cu. m

(Source: Ministry of Trade & Planning, Government of Antigua)

Comparable estimates for other surface water bodies were not available and no such studies have been done to estimate evaporation from soils. However, it is assumed that evaporation rates increase in areas where the soil has been exposed by overgrazing.

2.2 General Environmental Conditions

2.2.1 Geology

Antigua has a volcanic region (the hilly southern portion of the island) and a limestone region at the northern part of the island. A central plain, referred to as the third volcanic region, contains stratified volcanic detritus and agglomerates derived from the influences of the volcanic and limestone regions. Barbuda is of limestone formation.

Geology influences soil type and vegetation. In the case of Antigua and Barbuda, volcanic formation affects and differentiates topography. Geology is therefore an underlying factor contributing to the assessment of drought impacts.

2.2.2 Slopes

Slopes in the volcanic region of Antigua are mainly between 11 and 20 degrees (steeper in some cases), while in the limestone and central plain region slopes are generally less than 10 degrees. In Barbuda, less than 1% of the slopes are over 10 degrees and these are found in the Highlands (see Table 4). Slope classes are mapped on the drought hazard assessment slope data map for Antigua and on the slope data map for Barbuda.

Table 4 Slope Classes, Barbuda

Slope Class (degrees)	Area (acres)	%
0-2	8,396	22.87
2-5	18,514	50.41
5-10	9,794	26.67
10-20	20	0.05
Total	36,724	100.0

(Source: OAS, 1992)

2.2.3 Soils

Antigua

Hill et al did a detailed soil survey of Antigua and Barbuda for the College of Tropical Agriculture, UWI, Trinidad in 1966. They identified 33 soil types. Atkins (1983) reported by IRF (1991) grouped the 33 soil types for Antigua into four (4) general categories, namely:

- *Deep, alluvial, colluvial soils* found mainly in the narrow valleys of the volcanic region
- *Deep, Kaolinitic clay* found mainly in the central plain
- *Shallow soils* found in the volcanic region, and in the limestone region north of St. Johns (extending roughly from the airport in the east to Weatherills in the northwest)
- *Complex of shallow and deep soils*, found in the northeastern section of the limestone region

The soil data map for Antigua is based on these four (4) soil classes.

Deep alluvial soils of finer texture in the valleys of the volcanic region and the deep clay soils of the central plains and pockets of the limestone region have good moisture retention capacity. Plants in such areas will benefit if the depth to ground water provides a reliable supply of moisture without being waterlogged.

With soil texture and position in relation to ground water conducive to moisture retention, and with soils less prone to erosion, such areas are less vulnerable to drought than areas of steep slopes and shallow soils.

The shallow soils of the volcanic region are neutral to slightly acidic and well drained. Moisture retention is relatively less than in deep alluvial or deep clay soils.

However, moisture retention is improved in undisturbed areas where significant amounts of organic matter are deposited on the forest floor. Drought effects on soils in these areas are less severe than in disturbed open woodland areas with similar slope and shallowness of soil.

Soil loss from denuded landscape in areas with steep slopes and shallow soils is significant and are exacerbated by drought. Soil erosion is accompanied by a gradual loss of soil nutrients and plant cover recovery is slow or may not occur. This characteristic is obvious in areas that have experienced extensive clearing and grazing.

Generally shallow soils are relatively more vulnerable to drought and the presence of shallow soils is therefore used as a criterion in mapping areas at risk to drought.

Soils in most of the central plain are well drained but there are areas of heavy clay and poor drainage. Heavy clays may hold moisture longer, which is helpful in dry periods, but restrict crop growth in normal conditions.

Soils in the limestone region are mostly alkaline and are light where there is an overlay of calcareous sandstones, heavy over calcareous grits and deep and well drained over calcareous marls (IRF, 1991). Well-drained soils lose moisture quickly so that plants in such areas reach wilting point relatively quickly in dry periods.

As with the shallow soils of the volcanic region, the shallow soils found in some parts of the limestone region represent major management challenges for soil and moisture conservation where land has been cleared or intensively grazed.

Barbuda

Following the work of Hill et al (1966), soils of Barbuda were mapped by the OAS (1992). The OAS soil classification has been used in the preparation of the drought hazard soils data map for Barbuda. This classification places soils in six (6) series, namely:

- *Codrington cla*y found main around Codrington and to its south and southeast extending to the coast, in flat areas (2-5 degrees). These soils are considered suitable for agriculture but are limited by shallowness, stoniness and in some cases salinity

- *Barbuda clay loam* found in the Highlands in 5-20 degree slopes. Lands are marginal or unsuitable to cultivation. A critical characteristic of these soils is moderate to severe erosion resulting in between 50% to total top soil loss

- *Blackmere clay loam* found in approximately 1/3 of Barbuda, in areas east, southeast and northeast of Codrington, at the southeastern tip of the island, at Goat, Rabbit and Kid islands and at the narrow sand bar separating the west shoreline and Codrington Lagoon. Land in this series slopes <10 degrees and is characterized by varying limitations of shallowness, stoniness, salinity and compaction

- *Beach sand* found at beaches and overlaying the critical aquifer at Palmetto Point

- *Mangrove, Swamp* found in the mangroves of Codrington Lagoon and in the swamps at the southern section of the island

- *Salina* found fringing sections of the Codrington Lagoon and the major swamp in the south of the island

2.2.4 Vegetation

Antigua

Horwith and Lindsay carried out a detailed vegetation classification for Antigua in 1990s but did not map their results. Attempts to obtain or review a copy of the report were not successful.

The Forestry Division has plans to undertake mapping of the island's vegetation. Vegetation zones have been altered in the last 20 years from clearing for residential developments and from extensive grazing by small ruminants.

In the absence of a detailed up-to-date vegetation classification, mapping and digitization of vegetation was done using a combination of sources, along with field observations. Main sources were IRF (1991), who adopted earlier works and the OAS (1992) land use map.

Vegetation categories mapped (see drought hazard assessment vegetation data map for Antigua) are:

- *Cactus scrub* accounting for almost 2/3 of the land area and being the parts of the island in which most settlement and grazing activity occur. Cactus Scrub areas vary in percentage cover of Acacias, Lucaena, logwood and other woody species and in some cases have significant grass cover

- *Dry woodland* mainly found in sections of the east coast and pockets at the northern parts of the island. This vegetation category has been impacted severely by grazing and building and is being transformed to cactus scrub in some areas.

- *Moist forest* found mainly in the volcanic south and southwest, where higher elevations and steeper slopes limit access and human interference. While moist forest is the predominant vegetation type of this zone, areas of drier vegetation assemblages exist. Chances of maintaining the remaining moist forests in the volcanic region are good because land-use threats are less than in forested areas of the central plain and limestone regions.

Failure to protect remaining forests will further deepen the island's vulnerability to drought. Since the abandonment of large-scale sugarcane cultivation in 1974 Antigua has not experienced any appreciable gain in new cactus scrub formation that would lead in succession to dry woodland and eventually moist forests where precipitation is adequate. Trends suggest that the percentage cover of Acacias and other wooded thorny species found in cactus scrub areas could further decline in the next decade and, as a result, further reduce total forest cover on Antigua.

- *Mangrove woodland, Swamp* found in coastal areas. The use of mangroves as wattle for fish-pots and for charcoal has declined in the last 20 years. Human impacts are mostly from cutting or filling for coastal development, while significant damage from hurricanes have been sustained. Grazing, which adversely affects other vegetation types, has had no direct physical impacts on mangroves and swamp vegetation.

Barbuda

Barbuda's vegetation has been mapped for this assignment (see drought hazard assessment vegetation data map for Barbuda) using the following categories:

- *Dry woodland* covering the Highlands, areas at the northern section of the island and at the west coast sand bar separating the sea from the Codrington Lagoon.

- *Cactus scrub* covering most of the rest of the island.

- *Coconut plantation* in the Palmetto Point and near Coco Point.

- *Mangrove* fringing areas of the Codrington Lagoon.

- *Salina vegetation* fringing the Codrington Lagoon and Goat Island Flush.

- *Swamp vegetation*.

2.2.5 Soil Water Deficiencies

OAS (1992) provides estimates of evapo-transpiration and irrigation requirements for the Green Castle and Coolidge regions of Antigua and the Codrington region of Barbuda. Based on the results irrigation would be required for the months of February and March, June and July for the three areas, to counter moisture deficits resulting from higher evapo-transpiration rates.

While actual evapo-transpiration rates are not available to most farms, crop and livestock farmers and ornamental gardeners are very much aware of the rate at which plants reach their wilting point in shallow soils where little or no water is available during dry spells.

Deficiencies in soil water is readily discernable by a deteriorated "brown" landscape, particularly obvious in areas of extensive grass cover over shallow well drained soils. Even when water is available through irrigation, the rate of soil water loss increases where water conservation measures such as mulching or the use of windbreaks are not used.

Where soil water loss leads to reduced biomass in grass or plant species that are normally readily available to small ruminants, goats in particular browse beyond their normal range feeding on crops and ornamental plants. In such cases adverse environmental conditions lead to economic or financial loss to affected persons.

2.2.6 Water Resources

Antigua

Watershed boundaries for Antigua were mapped using IRF (1991), who quoted McMillan (1985) and OAS (1992). According to IRF, eighty-six (86) watersheds were initially defined by Halcrow (1977) and these were reduced to thirteen (13) by McMillan.

These same boundaries have been used by the OAS (1992) and for this assessment (see drought hazard assessment watershed data map for Antigua). Each watershed has a defined drainage system and can be considered a hydrological unit of utmost relevance to drought management.

Watershed 1, which drains to Nonsuch Bay on the east coast and Watershed 2, which drains to Hanson's Bay on the west coast are two of the most significant watersheds for the storage of surface water for domestic and agricultural use.

Upland stream-flow at watersheds draining the southwest volcanic region is less affected by land use, in particular grazing, than most other watersheds.

Stream-flow is not permanent for all watercourses in Antigua, although Cooks Creek that flows through Creekside maintains water for most of the year.

Storage capacities for all municipal and agricultural reservoirs are given on the Watershed map for Antigua and summarized in Section 2.4.

Wells are mapped using OAS (1992) but the Water Division of the Antigua Public Utilities Authority (APUA) has been reluctant to provide updated information on water resources and infrastructure for security reasons. For this reason, aquifers for Antigua were not mapped because no other source has been identified.

Barbuda

Ten watersheds have been identified for Barbuda (see drought hazard assessment watershed data map for Barbuda), although boundary definitions are not finite due to its unique topographical features. Watershed 1 includes the Palmetto aquifer – considered at one time to be the best quality aquifer on the island but has been contaminated by sand mining and grazing.

Drainage from all other watersheds originates in the Highlands.

A number of wells are shown on the watershed data map for Barbuda. In addition to these are numerous wells dug and used by individual households not linked to municipal water supply.

A number of sinkholes exist in the Highlands area. These include sinkholes at Brian Cave and Dark Cave, both with depth to the water table (J. Mussington, pers. comm.).

The above suggests that the fresh ground water reserves are extensive in Barbuda but poorly managed. There are no records on the number of private household wells and pumping is unregulated.

Management of fresh water resources in Barbuda would seem to be a critical issue requiring immediate attention. An initial effort should be the mapping of all privately used wells. In the longterm two initiatives should be considered.

One is a comprehensive investigation of fresh water resources; there is no indication that this has ever been done. The other is an appropriate regulatory regime seeking to manage ground water against contamination from land uses and over-extraction by private households.

2.3 Land Use and Land Management Practices

2.3.1 Crop and Vegetable Farming

2.3.1.1 Major Farming Areas

Antigua

Crop and vegetable farming occur in pockets throughout the island. Some of these pockets are located in the narrow valleys with deep alluvial soils of the volcanic southwest. Others appear just as often in the central plains and limestone regions where the topsoil is less thick.

Apart from valley topography there are no readily discernable spatial patterns to cultivation and there are no farm belts. Precipitation, moisture retention and pH often determine the choice of crop so that most of the bananas grown on farms are planted in the valley below Fig Tree Hill, an area receiving relatively good rainfall and protection from wind.

Most of the pineapples on the island are planted in the valleys of the volcanic region where soils tend to be neutral or slightly acidic in contrast to the more alkaline soils of the limestone region.

The moisture-loving banana is planted in numerous household gardens. Mango trees seem to thrive better in areas of higher rainfall and are quite obvious along the Fig Tree Drive.

One thing noticeable about the location of farms is the relative distance of some in the volcanic region from the main road. In some of these cases infrastructure costs for water connection for irrigation may be prohibitive. Farms in the central plain and limestone regions are generally better positioned in relation to the main road and water mains.

2.3.1.2 Type of Crops

The drought hazard assessment land use data map prepared in this assignment grouped crop and vegetable farming and tree crops under the land use designation, agriculture.

Under the OAS resources assessment project, cultivation uses were detailed by type and watershed. The approximate acreage for each use was also given. The types of uses are provided below, along with an indication of where crops are mostly grown.

Reference made to the main locations of each category is drawn from OAS (1992) with some slight modifications. It is assumed that the acreage under the various crops has since changed but that the relative distribution of crops among watersheds has not changed significantly:

- *Sugar cane* grown mostly in watersheds 54-62 and 63-66. For good yield, sugarcane requires abundant moisture and deep adequately drained soils. Growing it in these relatively dryer watersheds of the limestone region in areas with shallow soils increases vulnerability to drought.

- *Cotton* grown in watersheds 1, 54-62 and 67-77.

- *Coconut* grown mainly in watersheds 2, 4-11, 12-20, 63-66 and 78-84. Plants are mostly found in sandy soils but coconuts grow well in other soils also, as long as there is an adequate supply of ground water with the water table being 150 – 180 cm (60 – 72 inches) (Weir, 1980). Conditions are favorable for coconuts in the areas grown, so that it is perhaps the least vulnerable to drought among perennial crops.

- *Fruit trees* mainly mangoes, 63% of acreage in watersheds 4-11 and 12-20. Higher rainfall and pockets of deep soil in these volcanic area watersheds are advantageous to perennial tree crops, which require soils with good moisture retention and depth to allow tap root development.

- *Pineapple* grown mainly in watershed 12-20. Acidic and well-drained soils of this watershed are suitable for pineapples, which could be grown in other areas where similar conditions exist. Pineapples do not require soils with high moisture retention and is therefore less vulnerable than many crops to dry conditions.

- *Banana* grown mainly in watershed 12-20 but can be found in household gardens around the country. The plant favors the deep fertile soils with adequate moisture of the valleys in the volcanic region. Bananas are over 90% water but moisture deficiencies during droughts retard plant growth and fruit development.

- *Food crops* including yams, sweet potato and maize, grown in all watersheds except 3, 78-84 and 85-86. These crops have varying soil and moisture requirements. Vulnerability to drought depends on where they are planted;

- *Vegetable crops* including eggplant, tomato, sweet pepper, beans and okra, grown in all watersheds. Vulnerability to drought is relative to location, soil type, moisture and other factors.

Barbuda

Food crops are grown in pockets on soils with limitations such as shallowness, stoniness, salinity or low rainfall. These limitations suggest high vulnerability to drought.

Pockets of food crops are shown on the drought hazard land use data map for Barbuda. Food is also grown in Palmetto Point but the area could not be mapped because of insufficient data.

It should be understood that shifting cultivation due to rainfall deficiencies and shallow soils is a feature of farming on the island.

Shifting agriculture occurs in the low and highlands, where the practice is to fence an area, then clear and burn the vegetation before planting (J. Mussington, pers. comm.). Areas are abandoned when conditions are no longer suited to productive farming.

Coconuts are grown in sandy soils where the water table provides a reliable supply of moisture. Vulnerability to drought is low.

2.3.1.3 Farming Practices

Crops unsuitable to some areas are in many cases planted because land tenure reduces options and choices available to farmers. However, where crops match land capability, farming practices in which little attention is paid to soil and moisture conservation increase vulnerability to drought.

2.3.2 Livestock Farming

2.3.2.1 Livestock Population

Table 5 shows the livestock population in Antigua and Barbuda in 1984. Figures obtained from the Veterinary Division on current livestock for Antigua indicate a significant increase in the goat and sheep populations.

Table 6 shows that the goat population for Antigua in 2001 is four (4) times its size in 1984. Today's sheep population in Antigua is also almost four (4) times the number for 1984.

Figures provided by the Livestock Division show significant declines in the sheep, goats and cattle populations in Barbuda to 146, 252 and 29 respectively in 2001. This suggests that the impact of grazing on the landscape has been less in recent years.

Table 5 Livestock Population in Antigua/Barbuda, 1984

Livestock	Antigua	Barbuda
Cattle	9,992	1,072
Sheep	5,619	473
Goats	9,319	229
Pigs	2,425	12
Chickens	19, 554	529
Horses	179	184
Donkeys	713	215
Total	47,801	2,714

(Source: IRF, as reported in the 1984 Agricultural Census)

Table 6 Cattle, Sheep and Goat Populations Antigua, 2001

Livestock	Population
Cattle	15,364
Sheep	21,294
Goats	37,995

(Source: Veterinary Livestock Division)

2.3.2.2 Livestock Distribution

Antigua

Grazing areas have been mapped in this assessment (see land use data map). Grazing designations on the map follow those used by the OAS in its Natural Resources Assessment Project report, 1992 and are as summarized:

a) *Improved pasture:* former cultivated lands, now managed in most cases (sometimes fenced) to control grazing. Antigua Hay grass (*Dichanthium aristatum*) and Seymour grass (*Bothriocloa pertusa*) are the dominant forage grasses. Acacia and other thorny species are maintained at less than 10% cover. Major areas of improved pasture can be found along the Factory Road, St. Phillips and south and southwest of Creekside. Improved pastures occur on flat to gently sloping lands.

b) *Rough Grazing:* former sugar lands, consisting mainly of Antigua Hay and Seymour grass and with Acacia cover in excess of 20% (OAS, 1992). This form of grazing is the most extensive in the island's central plains, occurring on deep as well as shallow soils. Rough grazing is also prevalent the northern limestone area of the island. Grazing lands are not fenced

c) *Mixed Scrub and Rough Grazing:* Abandoned sugar lands at the stage of vegetation succession where Acacias and other thorny scrub are dominant. This type of grazing occurs mostly in the central plains and limestone region. It also occurs extensively in the volcanic area between English Harbour, Isaac Hill and Mamora Bay.

d) *Woodland Grazing*. This category is not mapped or described fully in the OAS report. OAS does make reference to small ruminants grazing on slopes with scant bush cover in volcanic areas. The extent of this form of grazing is however more significant than implied.

Large populations of goats (mainly) and sheep graze extensively in the Shirley Heights/Block House area and on wooded slopes of varying thickness in vegetation cover north and west of Falmouth.

Grazing by goats in rough pastures, mixed scrub or wooded areas alters and degrade vegetation zones, accelerates soil and nutrient loss and renders areas susceptible to impacts from drought.

Barbuda

Small pockets of improved pasture are mapped for Barbuda on the drought hazard land use data map. This map also indicates a fairly extensive area of the lowlands designated mixed scrub and rough grazing.

Most of the grazing by goats, sheep and cattle occur in this area but these animals also range in the highlands. In addition, deer, and feral pigs, donkeys and horses also graze the highlands.

2.3.2.3 Livestock Management Practices

Antigua

Improved grazing occurs on lands owned, leased or rented by farmers, who shoulder capital and recurrent expenses for managed livestock operations. Cattle are common to such operations but many also manage sheep.

Tethered cattle and sheep represent another form of management without fences done by landless or land owning farmers. There are however, thousands of goats that are owned by landless farmers who exercise little control over where the animals graze. In fact, goats grazing some of the volcanic slopes are in some cases considered “wild.”

Goat and sheep farmers tend to ignore damages caused by their livestock to cultivated crops and gardens. They also seem to be oblivious to the environmental damages caused by overgrazing.

Existing penalties are not effective enough to halt inimical grazing practices. The tradition of impounding livestock caught damaging crops and gardens no longer exist because most, if not all, the pounds have been abandoned.

Barbuda

Untethered livestock is less of a problem to farms and gardens in Barbuda than in Antigua. Also, the decline in livestock populations since 1984 would have reduced the impacts on the landscape and habitats normally associated with overgrazing. Nevertheless, grazing remains largely uncontrolled. Its impacts on the vegetation of the highlands, where shallow soils is already a constraint to plant growth, is an aspect of landscape and habitat vulnerability to drought that should be of major concern.

2.3.2.4 Markets and Prices

One of the reasons for the significant increase in the sheep and goat populations between 1984 and 2001 is the existence of a strong local market. The price for mutton and lamb in Antigua is EC$7 per lb retail and live weight animals fetch an average of EC$3 per lb.

The demand for lamb and mutton, along with low overheads for managing un-tethered small ruminants and a weak policy to deter harmful grazing practices, provide conditions fertile to the continued growth of the sheep and goat populations in Antigua.

2.3.3 Settlements and Communities

a) Population

The population of Antigua decreased from 64,129 in 1970 to 58,114 in 1991, while that of Barbuda increased to 1,241 from 1,071. Population declined in all parishes but major losses occurred in St. Phillips, which lost more than half its 1970 population and accounted for 36% of total population decline in Antigua.

Other parishes with significant declines were St. Mary’s 25% and St. Paul’s, 16% of total population loss between 1970 and 1991.

Appendix 4 shows a breakdown of the 1991 population and population density by parish. Population density for

Antigua is 538 persons per sq. mile but in St. John's City, the density is 7,419 persons per sq. mile.

The high population density for St. John's City makes it relatively more vulnerable to drought than other settlements with respect to water demand and supply.

Many households, particularly in areas such as the Point, Gray's Green and Ovals do not have much space for above ground water storage and therefore must rely almost completely on piped water without the benefit of storage, a critical requirement when water must be rationed.

It is interesting that while the population decreased, the number of households increased from 15,405 for both Antigua and Barbuda in 1970 to 18,808 in 1991. This correlates with the visible growth in new housing within the 20-year period.

Data on new housing, which should be available from the DCA, is not reliable because a significant number of new houses were constructed without planning permission in the period.

Given the decline in national population figures, population growth per se does not adversely affect the country's ability to deal with drought. However, continued entrance of migrant workers to Antigua can increase vulnerability in areas of St. John's poorly equipped with water storage infrastructure. These are the areas that new migrant workers are attracted to because of more affordable rents and a convenient location to downtown St. John's.

In addition, the growth of new households is being accompanied by per capita increases in water use as the material well being of residents improves.

b) Settlement Distribution

Settlements are distributed island wide but most of Antigua's population lives in the central plains and limestone region. With the exception of John Hughes and Sawcolts, traditional settlements in the volcanic region are located mainly in the valleys or foot of slopes. Traditionally the village developed as a core entity surrounded by farmlands. Crop and vegetable farming were for most persons the primary agricultural activity linked geographically and socio-economically to households.

Subsistence livestock farming has now replaced crops and vegetables as the farming activity in which household members can be involved while working full time at other jobs. This is partly responsible for the increase of goat and sheep populations and the devastation that leaves the landscape more prone to drought impacts.

c) Residential Development Trends

Residential trends are changing the relationship between village and farm in Antigua. The same is not yet true for Barbuda.

In Antigua, government's policy of providing liberally sized housing lots (1/2 to 1 acre lots) often below market value is one of the factors that precipitated a trend towards lower density residential development and the growing urbanization of formerly cultivated lands.

Another factor is the increase in vehicular ownership allowing mobility to the population and less dependence on public transportation. Infrastructure to serve low-density residential growth is more costly than for compact settlements and has been subsidized by government to a large degree.

The implications have not been studied neither with respect to the financial burden on government or the long-term effects on land and environmental management.

With regard to this assessment, the cost of infrastructure for water distribution is a factor that impacts on the country's capacity to manage water needs in dry periods and more so in drought conditions.

2.3.4 Hotels and Tourist Zones

a) Distribution

Tourism is Antigua's main foreign exchange earning industry. Hotels constitute the major tourism sub-sector but cruise and yachting tourism also contribute significantly to tourism earnings and jobs.

The number of properties and rooms in Antigua and Barbuda is shown in Table 7.

Beach hotels and other vacation accommodation constitute the major component of the tourism plant's land-based accommodation. Major tourism zones are Antigua's north coast, Five Islands' peninsula (including Deep Bay and Hawksbill Bay, Jolly Beach/Jolly Harbour), Long Bay Coastline and Falmouth Harbour/English Harbour.

Table 7 Tourism Accommodation in Antigua and Barbuda, 2001

Accommodation	# Properties	# Rooms
Antigua		
Hotels	40	2644
Guest Houses	8	59
Apts/Cottages/Villas	42	291
Sub total	90	2994
Barbuda	4	111
Total	94	3105

(Source: Antigua Hotels & Tourist Association)

Table 8 Distribution of Hotel Properties by Watershed

Watershed	# Properties	# Rooms
Antigua		
• 67-77 (Northcoast)	31	1104
• 78-84 (Five Islands Peninsula)	6	525
• 4-11 (Jolly Harbour/ Jolly Beach)	6	704
• 27-46 (Falmouth/English Harbour/St. James	8	292
• 54-62 (Longbay Coastline)	4	220
Other	45	149
Sub Total	90	2994
Barbuda	4	111
Total	94	3105

Since the effective management of land uses within the hydrological unit of the watershed helps to mitigate vulnerability to droughts, the distribution of hotel properties and rooms by watersheds is provided in Table 8.

Ninety five percent (95%) of tourist accommodation rooms fall in five (5) watersheds, two of which are in the volcanic region, two in the limestone region (except for properties in St. John's) and one in the central plain.

In general hotels do not affect upland run-off or erosion, since most are located at the coastline. Rather, hotels can be affected by upland run-off and erosion problems resulting from other forms of land use. Such problems may include pollution and turbidity impacts on bathing areas.

Overgrazing can cause both. It also degrades the landscape, which adversely impacts the quality of the visitor experience, particularly during droughts. For example, Watershed 27-46 (Falmouth/English Harbour/St. James) with its 292 rooms has one of the largest population of goats and sheep on the island and perhaps the highest density of grazing and browsing small ruminants.

Portions of the landscape seen from the scenic drive to historic Lookout (Shirley's Heights) and Block House have been devastated. Drought now has a more telling effect on the area.

On the other hand, demand for water by hotels, yachts and cruise ships has grown. Per capita water use by stay-over hotel visitors is significantly more than resident demand; up to 300 gals / day /person in one study against an average of <100 gals/day for residents.

2.4 Infrastructure

2.4.1 Dams and other Storage Reservoirs

Antigua

Surface water in Antigua is stored in ten (10) medium to small reservoirs and 550 ponds and earthen dams, with a total capacity of approximately 6 million cu meters (6000 acre ft or 1.6 billion imperial gallons) (Ministry of Trade and Planning, Antigua and Barbuda, 2000).

The location and capacity of agricultural and municipal reservoirs are shown in Tables 9 and 10 respectively, and also shown on the drought hazard watersheds data map for Antigua.

Table 9 Location and Capacity of Agricultural Reservoirs, Antigua

Reservoir	Location	Storage (cu. meters)
Bethesda	Bethesda	537,000
Red Hill	Red Hill	46,000
Gunthorpes#4	Gunthorpes	26,000
Gunthorpes#5	Gunthorpes	67,000
Oliver's Dam	Olivers	59,000
ASF Dams	Sugar Factory	116,000
Langfords	Sugar factory	110,000
Gaynors	Collins	32,000
Bendals	Bendals	23,000
Total		1,016,000

(Source: Ministry of Trade and Planning, Antigua and Barbuda)

Table 10 Municipal Reservoirs, Antigua

Reservoir	Drainage Area (ha)	Spillway Elevation (m)	Storage Volume (cu. meters)
Potworks	2,430	20.42	4,142,000
Collins	172	11.89	342,000
Wallings	44	150.88	51,680
Fig Tree	72	112.78	2,280
Dunnings	146	30.38	136,040
Break-necks #1	56	73.15	20,50
Break-Necks #2	48	39.93	76,380
Hamilton	175	46.94	104,120
Body Ponds/ Fisher	779	27.43	101,460
Total	**3,922**		**4,976,480**

(Source: Ministry of Trade and Planning, Antigua and Barbuda)

2.4.2 Wells

Antigua

Ground water in Antigua is drawn from about 50 active wells, located in several well fields, as given in Table 11.

Most of the municipal and agricultural water in Antigua are stored in six (6) watersheds (Table 12). According to the Ministry of Planning (1997), these watersheds also account for 80% of ground water yield from wells.

Table 11 Major Well Fields of Antigua

Well Field	**# wells**	**Location**	**Capacity (igpd)**	**Target Area**
Bendals	13	Bendals	n/a	Ben-dals Valley
The Valley	20	BlubberC hris-tian, Roses, Oragne Valleys	n/a	n/a
Cades Bay/ Clare-mount	5	Cades Bay/Clare -mount	30,000	Old Road, Urlings John-sons Point, Crabb Hill
Follies	5	John Hughes/ Sweetes	40,000	N/a
Bristol Springs/ Collings	7	East of Collings Reser-voir	150,000	Willi-kies New-field St. Phil-lips Mill Reef Bethes-da

(Source: Ministry of Trade and Planning, Antigua and Barbuda)

Table 12 Water Storage and Well Yield by Major Watersheds, Antigua

Watershed	Storage (cubic meters) Agri.	Municipal	Ground Water (mil. cu. m/yr)
1	30,600	4,010,000	220,000
2	200,400	278,000	390,000
3	334,500	-	-
4-11	9,200	166,000	610,000
47-53	540,000	-	-
63-66	33,400	-	-
Total	1,148,100	4,454,000	1,220,000

(Source: Ministry of Planning)

Barbuda

Well water is supplied by APUA to households in the central section of Codrington. Information on the number of households connected to mains supply or on the volume of water supplied was not obtained.

Numerous private wells exist and the water is used for bathing, flushing toilets and for watering gardens. The water quality is not monitored. Water for drinking and cooking is taken mainly from cisterns, even for households with mains supply.

Public wells in the lowlands (in or adjacent to Codrington) are equipped with concrete troughs, which are used mainly for watering livestock. Wells sunk at the Palmetto aquifer are used for farms and livestock.

2.4.3 Desalt and other Water Treatment Plants

Two desalination plants, both located at Crabbs Peninsula, produce water for the national supply network. A flash distillation plant owned by government produces 2.8 million gpd and a reverse osmosis plant, owned by a private company, produces 800,000 gpd.

The government owned desalination plant was commissioned and built after the 1983-84 drought when Potworks Dam, which provided over 50% of municipal water, went dry.

Desalinated water currently meets 62% of Antigua's municipal water needs. This helps to cushion the country from water related shocks associated with droughts but production costs are much higher than other sources.

Production costs cited by the Ministry of Planning, based on information from the Antigua Public Utilities Authority (APUA), are:

- *Ground water*: US$2.50 per cu. meter
- *Surface water:* US$3.00 per cu. meter
- *Desalinated water*: US$4.70 per cu. meter

Water production cost by APUA is far in excess of water revenues. This is partly the result of the high cost of desalinated water but government's policy to keep water rates in check is part of the reason.

Predictions by the Ministry of Planning (1997) shows a continued negative gap between water revenues and production costs up to the year 2020, averaging over US$8 million per year.

Water subsidies cannot be sustained forever, so that investment to increase ground and surface water supplies is being considered. This would help to reduce the negative gap between revenues and production costs but would not be the full solution.

The uncertainties over future climate change, variable precipitation and the continued growth in the demand for water means a continued reliance on desalination during average rainfall and more so during periods of drought.

Private Reverse Osmosis Plants

Several hotels now have reverse osmosis (RO) plants. Some were installed as a result of water shortages experienced in past droughts. Curtain bluff has a

50,000 gpd RO plant. An RO plant located on the Jolly Harbour property but operated by an independent contractor has a design capacity for 120,000 gpd but produces and sells an average of 70,000 gpd to the Jolly Harbour Resort complex. The supplier is able to offer water at lower rates than APUA, suggesting that APUA should be able to produce desalination water at lower than its current costs.

Feed water to supply RO plants is taken from the sea in most cases. At Jolly Harbour 20% of the feed water (35,000 gals per day) is drawn from a brackish well on the property (Ivor Jackson & Associates, 2000). The rest comes from the sea.

If the yield of the well drops during periods of hydrological drought a higher percentage of feed water is drawn from the sea at the marina basin. RO plants therefore reduce the vulnerability of hotels to meteorological and hydrological droughts.

2.4.4 Wastewater Treatment Plants

Few hotels on the island have water treatment plants that allow the reuse of treated wastewater. Jolly Harbour has a plant with design capacity to treat 500,000 gpd. The current wastewater load at Jolly Beach Hotel and Jolly Harbour Villas – the main users of the plant – is less than 120,000 gpd at high occupancy and less at lower occupancy. The treated wastewater is used to irrigate an 18-hole golf course. This significantly reduces the reliance on potable water for irrigation and brings the cost of water down.

2.4.5 Irrigation Systems

Agriculture

The acreage of cultivated land that currently has access to irrigation water could not be determined. Water sold by APUA at the agricultural rate has been averaging 198,000 cu. m per year, based on figures provided by the Ministry of Planning.

The high cost of municipal water used for agriculture acts as a deterrent to irrigation.

Hotels and Golf Courses

Most hotels use some form of irrigation system for landscaping. Smaller properties use either hand held hoses or moveable sprinkler systems. Larger properties may have pop-up sprinkler systems or in some cases micro-irrigation systems (drip) using simple “soaker” hoses.

Unfortunately, there is no available data on the percentage of properties using one system or the next. Environmental audits done for a number of hotels in the region indicate significant wastage of water from inappropriate water use, including poor irrigation practices.

Where selected plants do not match soil and microclimatic conditions the tendency is to compensate by excessive watering. This happens in Antigua, although the extent is not known, and will continue until properties adopt more conscious water conservation methods.

Water requirements for golf courses can be in excess of 150,000 gallons per day for 18-hole courses, depending on the quality sought for putting greens and fairways. The course at Jolly Harbour uses between 90,000 and 125,000 gallons/day. The actual amount depends on rainfall.

Fortunately, most of this is met by treated wastewater, which is adequate as long as occupancy levels remain above 70%. Except for periods when low occupancy levels fail to generate enough wastewater volume, the golf course does not make any significant demand on national water supply.

2.4.6 Water Distribution

Variable pressure in water distribution creates problems for consumers. High pressure in some areas causes frequent leaks on the mains and consumer distribution lines. Low pressure in other areas results in inadequate flows and inconvenience to users.

2.4.7 Roof Catchment and Storage Cisterns

Roof catchment and storage in concrete cisterns cistern, metal or plastic tanks or metal drums is a traditional and accepted practice, particularly for homes. It is now a planning requirement for new developments to make adequate provision for water storage on property.

The standards for residences and hotels now being used by the Development Control Authority (DCA) are:

Residences: 10 gallons per sq. ft. of roof area.

Hotels: 10 gallons per sq. ft. of roof area. Where hotels use reverse osmosis (RO) plants to augment water supply, the minimum standards for roof catchment/storage are less rigidly applied.

2.5 Water Supply and Demand

Water supply for Antigua and Barbuda averages 4.5 million cubic m per year from sources as shown in Table 13:

According to the Ministry of Planning 42% of total water supply was unaccounted for, 31% was used by domestic consumers, 17.7% by commercial and hotel users and 4.4% by agricultural users.

The Ministry of Planning in its 1997 climate change water resource sector study predicts that total water demand will be:

Year 2000: 4.2 million cu meters/yr
2010: 5.8 million cu meters/yr.

Table 13 Water Supply, Antigua/Barbuda, 1996

Source	Volume (Million cu. m/year)	% Total
Ground water (APUA)	0.6	13
Surface water (APUA)	0.9	20
Private roof catchment (Estimated)	0.1	2
Private dams (Estimated)	0.1	2
Desalination (APUA)	2.8	63
Total	4.5	100

(Source: Ministry of Planning, 1997)

It is presumed that the available supply would increase by reducing the amount of water that is lost from the system.

Assumptions made by the Ministry of Planning are that the population would grow to 72,300 by 2000 and 81,000 by 2010, and that per capita domestic water consumption would remain at 0.63 cu meter/day through to 2010.

These projections require careful monitoring because there is a degree of uncertainty associated with water demands – one such reason being the difficulty in predicting growth in the tourism sector.

Water demand management therefore is major issue for drought mitigation for two reasons:

- Insufficient information on unaccounted for water.

- High production costs and hence high consumption costs, which are believed to mask true demand from the agricultural sector.

3.0 IMPACT AND VULNERABILITY

3.1 Historic Drought

This section of the report reviews the impacts of past droughts on the islands and the response to the adverse effects experienced.

3.1.1 Description of Drought Events

Based on the meteorological definition for drought described in Section 1.4.1, a total of eight (8) droughts occurred in Antigua and ten (10) in Barbuda between 1960 and 2000 (see Table 13).

Table 13 Drought Years in Antigua/ Barbuda 1960 – 2000

Year	Rainfall (Inches)	
	Antigua	Barbuda
1966	27.52	12.89
1967	29.14	22.87
1968	25.09	27.79
1971	--	26.37
1973	25.98	--
1977	--	25.65
1983	22.31	20.67*
1990	--	24.17
1991	30.49	23.64
1994	30.49	25.04
1997	26.46	--
2000	n/a	23.30

(Source: Met Office, 2001)
* *Rainfall for December not included*

Between 1966 and 1968 there were three consecutive years of rainfall below 30 inches in Antigua. However, the 1983 drought, which extended into 1984, was the one that most people in Antigua remember.

It lasted from January 1983 to August 1984. In this 18-month period, monthly rainfall exceeded three inches twice, in August of 1983 and March 1984. Total rainfall for 1983 was 22.31 inches and for the first eight (8) months of 1984, 16.48 inches. The drought was ended by 8.54 inches of rain in September 1984. Between September and December 1984, 29.38 inches of rain were recorded.

Because of its severity and impacts, this drought could be ranked as the "drought of record" for Antigua, meaning the drought remembered as having the greatest impact on the island. This drought and its impacts are described in the following pages. The impacts described are mainly for Antigua.

Rainfall records indicate that Barbuda experienced its severest drought in 1966 during the period, when rainfall for the year was 12.89 inches. Unfortunately, a review of the impacts of this drought was not possible during this assessment.

3.1.2 Drought Impacts

3.1.2.1 Environmental Impacts

a) Watershed and Habitat Degradation

Watershed Impacts

Antigua received only 22 inches of rain in 1983, Barbuda less up to November of that year. By the time the drought entered its second year, marked changes in watershed and vegetation conditions were obvious.

Drought impacts were particularly severe in watersheds, such as 27-46, 47-53, 54-62 (see watersheds data map, Antigua) where plants with shallow root systems on shallow soils were among the first to be affected by deficiencies in soil water.

For undeveloped areas of such watersheds seeking to re-establish an eco-system integrity after years of cultivation and charcoal burning significant losses in biomass productivity were experienced. This occurred even in thorny woodland vegetation associations, where acacias (*Acacia spp*.), logwood (*Haematoxylum campechianum*) and wild tamarind (*Leucaena glauca*) species are well adopted to shallow soils with low fertility and moisture deficient conditions.

No studies were made of soil conditions during the drought. It is assumed that moisture deficiencies eventually led to reduced soil fertility. The combined effect of water deficiency on shallow as well as deep root plants was progressive decline in the plant conditions.

Leaf and stem loss in herbaceous and woody plants were followed by plant mortality in certain species. As plants wilted and died, canopy cover decreased in wooded areas and the landscape generally became visibly brown, dusty and harsh looking.

In Antigua/Barbuda, prolonged periods in which the landscape is visibly stressed are linked to hard-times; a disposition that can be traced to a time when rain fed agriculture provided the major source of income and livelihood for rural families.

The reduction and, in some cases, disappearance of plant cover exposed soils to the erosive force of winds and water when it eventually rained. Soil lost during the drought and the subsequent reduction in soil fertility, interrupted the process of ecosystem evolution occurring in watershed habitats prior to the drought event.

Habitat Degradation

In Antigua/Barbuda it is difficult to distinguish between habitats for wildlife and rangelands for wandering and uncontrolled livestock. For example, because parts of the landscape of the area delineated as Nelson’s Dockyard National Park is steep and not readily accessible for agriculture and logging for charcoal they provide reasonable seclusion for birds, amphibians (frogs) reptiles (lizards) and mammals to reside.

The Highlands of Barbuda is a critical habitat for the Fallow Deer (*Dama dama*) and other mammals.

However, these areas also serve as rangelands for extensive grazing (often times intensive) of goats and sheep. Livestock population densities in these areas are in excess of what is considered sustainable for like ecosystems.

Before the drought, habitats were already susceptible because of overgrazing and thus suffered doubly with the extended periods of below normal precipitation. Habitat conditions then deteriorated for both wildlife and livestock in critical watersheds.

One constraint in assessing habitat impacts from grazing is the absence of detailed listings of plant species preferred by goats. Unlike cattle and sheep, goats browse (rather than graze) normally on various herbaceous plants and woody shrubs along with ornamental plants if they gain access to household gardens.

Since biomass production of grass used by livestock in Antigua declines faster relative to many species used by goats, grazing livestock are likely to reach the critical threshold of nutritional stress earlier than goats.

Thus, of the 47,801 livestock said to be in Antigua and 2,714 in Barbuda in 1984, goats are likely to have been the ones with lowest mortality from the drought.

It is not known if these figures reflected mortality associated with the drought or if most of the livestock mortality occurred after the field surveys for the census were done.

3.1.2.2 Economic Impacts

a) Agriculture

Food Crops

The 1984 agricultural census of Antigua and Barbuda identified 6,000 farmers (70% of which were part time) in the country, 4,658 farms, and a total acreage farmed of 6,225 acres. (IRF, 1991). Landless farmers operated about 50% of the farms and 40% of the farms were under two acres. There were 66 farms in Antigua that were larger than 10 acres.

It is assumed that these figures represent the existing situation at the start of the drought. Also of importance to the understanding of drought impact is the breakdown between commercial and non-commercial production, namely:

- Thirty percent of production was done for home use only
- Thirty-three percent for home use mainly
- Thirty-seven percent for commercial use, mainly for domestic consumption

A range of food crops and fruits comprise most of the agricultural production. At the time of the drought cultivation of crops for export, such as sugar cane and cotton had been discontinued.

Data from the census indicate significant declines in produce after 1984 for some crops, such as bananas (685,000 lbs 1984, 185,000 lbs, 1988), pineapples (448,000 lbs in 1984, 278,000 lbs in 1988), sweet potatoes (1,076,000 lbs in 1984, 482,000 lbs in 1988).

On the other hand, crops such as mangoes (401,000 lbs in 1984, 1, 322,000 lbs in 1988), beets, grapefruits, limes and eggplants showed marked increases after 1984.

The census data does not correspond with anecdotal accounts in all cases. For example, one would expect that banana being a crop heavily dependent on water, would have suffered declines in yield between 1983 and 1984.

Most farms in Antigua/Barbuda were at the time of the drought (and still are) rain dependent. The number of irrigated farms was not known for the time.

As a result, widespread crop failure was reported as a consequence of the drought. Even for farms with access to potable water, rationing of supplies meant that priority for scarce water was given to hotels and households.

Livestock

The number of livestock that died during the drought was not determined. Residents however remember images of cattle and sheep lying along the wayside. The rains that ended the drought also took the lives of several cows around the Potworks Dam area.

It seemed that some of the cattle were too weak from malnutrition to avoid the floodwaters and were washed along the watercourses.

The drought affected the health, weight (hence marketability) and productivity of livestock. Hot weather caused heat stress, which is said to reduce fertility through sperm damage. Hot weather also affects libido in male animals, decreases milk production in cows and kills chickens (Dr. Paul Cadogan, 2000).

Animals also suffered from dehydration caused by shortages of water, when dams dried and water flowing through the pipes was not enough to meet the growing demands.

In some cases, livestock farmers killed their animals to avoid death from the effects of the drought. In other cases, animals that died from drought effects were butchered and sold without the knowledge of consumers, causing great alarm when this was discovered.

The economic impacts could therefore be summarized as:

- Setbacks to the development of small and large herds due to the drought's effects on the productive capacities of animals.

- Reduction of weight and hence marketable volume of meat because of under-nourishment.

- Reduced marketability of animals and their products due to the mal-nourished appearance of animals and the feeling (real or imagined) that they were afflicted by disease brought on by the drought.

- Reduction in the supply of local meats, creating more dependency on imported meat products.

- Significant income loss to livestock farmers.

Absence of Drought Insurance

The economic impacts on agriculture from drought were compounded by the absence of drought insurance for crops and livestock. Insurance is lacking for three key reasons:

- Insurers do not perceive this as a feasibly investment of resources, given the relatively small sizes of farms and livestock herds.

- Even if crop and livestock insurance for drought was available, small farmers most likely would not have seen the need. With the small size and subsistence nature of many operations, paying insurance premiums would have been considered an additional financial burden.

- Crop insurance is not integral to the small farm culture in Antigua/Barbuda.

In the absence of being able to file claims for crop damages and/or loss, farmers had to absorb their own financial losses. The experience was difficult and stressful for many farmers and in some cases it dampened the enthusiasm for future investment in agriculture.

b) Tourism

Landscape, Product and Climate

Antigua/Barbuda's tourism is promoted mainly on the strength of the quality of its beaches, climate and sea. Although not featured prominently in promotional literature, the scenic qualities and the overall attractiveness of the landscape are also critical to an enjoyable visitor experience.

Drought adversely affects the quality of the biological landscape (that is the living landscape of plants and animals) and the physical (non-living) landscape; the latter due mainly to the heat and dust associated with extended periods of low precipitation.

The general quality of the visitor experience was affected by relatively hotter and drier conditions, a degraded landscape and a less friendly disposition of residents under the stress from the drought. Uncomfortable and unattractive environmental conditions would have impacted negatively on decisions to take tours and hikes.

While these impacts may not have caused tourists to shorten their vacation, they could possibly have impacted negatively on decisions to make return visits. The potential future income lost from return visits or from potential visits from friends who might have been influenced to visit if their experiences were more positive, cannot be determined. Failure to quantify economic loss in this case, however, should not reduce the significance of drought effects on the tourist product.

Water Shortages

The hotel sector, like all other sectors was affected by water shortages. Tourists are known to be highly intolerant of water deficiencies. Apart from the inconvenience, the implications for hygiene and health figure prominently in how they value the vacation experience.

Although priority was given to hotels in water rationing, all properties were reportedly affected. Most properties lacked back-up water storage facilities of minimum standard size and even where such facilities were adequately sized in accordance with building standards capacities were irrelevant in the extended period of very low rainfall.

The economic effects from the drought on hotels resulted from:

- Shortening of vacation because of water problems and related inconveniences.
- Cancellations by potential guests because of the water problems revealed to them by travel agents or the media.
- Cost for purchasing water.
- Loss of income from all of the above.

Impacts on Property Landscapes

Properties reported damage and in many cases loss of ornamental plants. Such losses would have been more pronounced in exposed areas and in rapidly drained soils. The latter would include the sandy soils of some coastal properties.

Loss of Revenue to Hotels

Hotels incurred revenue loss. It would appear, however, that records on actual amounts are not available. Because of changes in hotel management since 1984, reliable estimates on revenue loss could not be obtained.

The existence of the Crabbs desalination plant in the more recent drought in 1995 effectively reduced impacts related to domestic water supply.

Effects on Workers

The income loss to hotels also translated into hardships for hotel workers. Some were laid off during the period.

Restaurants

Drought impacts also extended to the restaurants. Restaurants serving local cuisine were affected by shortages in agricultural produce and meats. They were also affected by water shortages.

c) Settlements

The effects of the 1983-84 drought on households was as severe and, in some cases, more so than hotels. Many houses went without piped water for weeks at a time.

Drought conditions in 1983-84 affected:

- Household income
- Sanitation and Health
- School and work

(Water was actually barged from Dominica during the more severe periods of the drought and used to augment supplies to homes and hotels).

Household Income

Households where the main income earners were farmers (crop or livestock) experienced severe cuts in income and suffered from shortages in food. Generally, the reduction in crop yield, along with deteriorated livestock health and livestock mortality adversely affected food supply nationally.

Sanitation and Health

Extreme water shortages, such as those that occurred in periods of the 1983-84 drought, impact hygiene and sanitation, which in turn affect health. There are however no available reports on the impacts on the health of the population from the drought.

School and Work

Water shortages also created inconveniences to workers and school children of households, where available water had to be rationed between various household uses, for example, laundry, bathing, cooking, livestock.

3.2 Future Vulnerability

3.2.1 Agriculture

Crops

At the time of the 1983-84 drought, Antigua relied on surface water reservoirs to provide most of its potable water. Water supply was readily affected by meteorological drought and the country was highly vulnerable during periods of low rainfall.

Desalination now accounts for 62% of potable water and generally households and hotels have become significantly less vulnerability to deficiencies in rainfall. However, vulnerability remains high for crop farming because many farmers perceive the cost of water as one of the factors working against profitability.

A heavy reliance is still placed on rainfall to provide the moisture needed by crops, even when water from mains is available for irrigation.

Variable climate and precipitation remain over-riding critical natural factors contributing to the vulnerability of crop farming to drought. Practices (human factors) contributing to vulnerability include:

- Poor crop location in relation to soil and other factors that restrict plant growth and crop yield. Failure to match crops to land capability remains a problem. OAS produced land capability maps for Antigua and Barbuda in 1992. These should be used as the basis for building the awareness of farmers for better crop selection, along with improved soil and water conservation practices.

- Cost of irrigation.

- Water conservation practices – mulching is being used at Claremont Farms to conserve moisture in the growing of pineapples. A micro-irrigation (drip) system is used to conserve water. This is one of a growing number of examples where water conservation is being practiced. Unfortunately, most farmers do not seem inclined to use such conservation methods. The cost of mulch (organic or plastic) and the cost of water saving irrigation systems may act as deterrents to better conservation practices.

- *Soil conservation practices* – mulching not only conserves moisture but also protects soil from the forces of erosion. Soil particles do not bond adequately in the absence of soil moisture. As a result, erosion accelerates during periods of drought. Sloping terrain and areas exposed to wind are mostly affected. Nutrient loss accompanies erosion, so that crop yield is affected. Vulnerability can be reduced if constraints to wider use of mulch by farmers are removed.

- *Absence of drought insurance* – Farmers will continue to shoulder financial losses resulting from drought, because it is unlikely that local insurance companies will provide drought insurance for crops in the near future. Consideration should however be given to the design of a drought relief program by government, which could seek to access donor funding to assist farmers.

Livestock

Overgrazing. Overgrazing is perhaps the primary contributing factor to Antigua and Barbuda's vulnerability to drought. Reducing vulnerability in this respect requires drastic reduction in the goat populations and rigid control over where livestock are allowed to graze.

To achieve these aims without causing unbearable economic dislocation and hardship to livestock farmers will require strategic planning, broad-based consultations with stakeholder groups and public awareness to build public support for actions to be taken.

Such actions should evolve from a national program and campaign to reduce the impacts of goats on the landscape, environment and crops. The program should have two primary components:

- Population control – seeking to achieve population grazing density limits that can be sustained.

- Restoration of forest or landscape areas that are displaying desert-like characteristics due to overgrazing.

Adequate resources would need to be applied for research, institutional building, public awareness and policy formulation in the implementation of the program.

Policy Issues

Reducing vulnerability to drought for both crop and livestock farming will require a number of critical policy initiatives, including:

- Incentives to achieve better soil and water conservation practices.

- Reduction in water rates for irrigation, through subsidy or other means.

- Development of adequate institutional infrastructure and coordinating mechanisms for drought planning and management, drought preparedness and drought warning. (This is relevant to other sectors, also, including tourism and settlements).

- Support for drought related research, monitoring, planning and mitigation.

- Regulation of livestock access to public owned lands.

- Stiffer penalties for livestock owners for damage to crops and gardens.

3.2.2 Tourism

After the 1983-84 drought a number of hotels installed reverse osmosis (RO) plants and have become less vulnerable to droughts as a result. Most hotels, guesthouses, villas and other forms of visitor accommodation properties still depend on APUA for most of their potable water supply.

Although the existence of the desalination plants makes water supply more dependable, properties without the capacity to produce most of their potable water are still affected by rationing.

The extent of their vulnerability could not be determined in this assessment because a detailed survey of on-site water infrastructure, including production plants, roof catchment and storage capacity was not possible.

Based on discussions with a number of hotel managers, water conservation practices by hotels are limited to the use of water saving toilets and showerheads, which have become standard for many manufacturers of bathroom fixtures.

A lot of water is believed to be still wasted on properties due to leaks, poor irrigation practices, absence of a reliable level of wastewater treatment to allow reuse for landscaping and failure to meter water for different major property uses so as to detect waste.

An inventory of tourism properties, including marinas and golf courses, should be considered to determine their preparedness to deal with future droughts. The inventory could be done with the involvement of the Antigua Hotels and Tourism Association (AHTA) and should cover among other things:

- Sources of water supply
- On-site water production capacity where appropriate
- Onsite water storage
- Irrigation systems
- Water conservation practices
- Methods for detecting water loss from leaks and faulty equipment

3.2.3 Settlements

Antigua

Like hotels, water supply to settlements has improved with the use of desalinated water by APUA. Vulnerability has been reduced with respect to water supply but most settlements are still affected by water rationing during droughts. This is expected to continue in the future unless APUA decides to increase water production from desalination on its own or with the use of private contractors.

The relatively higher cost of producing desalinated water, compared to ground and surface water, is a major constraint to providing water that would not be affected by variable rainfall. High cost notwithstanding, a commitment to increasing desalinated water production may be required to reduce the vulnerability of settlements as water demands increase in the future.

In Antigua, water loss from evaporation and seepage at surface reservoirs is an issue without a cost-effective solution. In Nevis, where potable water is stored in tanks, such loss from evaporation and seepage does not occur.

Despite the need to ration water in droughts, water is frequently lost due to leaks from supply mains that APUA is often slow to repair. The occurrence of this in the future will increase the country's vulnerability to drought.

In Barbuda, a major ground water aquifer has been affected by sand mining activity. Land and resource use will need to be managed in the future to ensure that this key water resource is not further compromised.

Finally, although most building supply stores carry water saving toilets, showerheads and faucets, there has been no national water conservation campaign that targets households.

New homes should be provided with incentives to install water saving fixtures and old households provided similar incentives to retrofit fixtures in order to conserve water. This would lessen the impact of drought on households.

Barbuda

Although a large percentage of households in Barbuda are without mains connection, vulnerability to drought is reduced by extensive nature of ground water resources on the island.

A relatively high water table (3-4 ft. in some parts of Codrington) allows households to use wells to supplement rain or mains water. However, water from wells is often brackish and they risk contamination by virtue of their location relative to septic tanks and soakways.

Water quality is therefore a critical issue particularly in periods of drought when cistern water is not available for drinking and cooking.

The use of a reverse osmosis (RO) plant to ensure a more reliable supply of potable water for Barbuda was proposed by APUA in 1996 but rejected by residents because wastewater from the plant would have been dumped in the Codrington lagoon (J. Mussington, pers. comm..). Desalination remains an option to be reconsidered in seeking to reduce future vulnerability to drought. Desalting brackish water should be less costly than using sea water, while the further exploration of ground water reserves could provide a cost-effective source of fresh water for future use.

3.3 Institutional Arrangements

3.3.1 Key Agencies

Institutional capacity to manage drought is a critical factor in reducing vulnerability to drought events. Key agencies dealing with drought include APUA, the Department of Agriculture, the Livestock Division, Ministry of Planning, DCA and the National Office of Disaster Preparedness (NODS).

The approach to planning, research and data management with respect to drought is ad hoc. The correct orientation and a commitment to drought impact mitigation, including adequate resource allocation and training of selected staff, are required.

3.3.2 Procedures and Information

It is recognized that drought is a recurring event in Antigua/Barbuda. However, apart from actions being taken to reduce problems related to potable water, there are no clear procedures in place to mitigate drought impacts and drought information management is disorganized.

To improve the capacity for drought management, drought effects must be documented and a database to assist with decision making is needed. Also, procedures for drought awareness and building of public support for drought mitigation are critical measures to be considered.

4.0 ANALYSIS OF AREAS AT RISK

4.1 Understanding and Applying the Concept of Risk

Drought risk for the purposes of this analysis is considered as having two (2) contributing factors, namely:

- Recurring environmental or meteorological events or natural physical characteristics beyond the control of man.

- Human practices (policy or land use) that make the population vulnerable to natural events and characteristics.

a) Natural risk factors

- Variable climate (periodic low rainfall)
- Exposure to wind and marine influences
- Exposure to excessive sunlight based on orientation to sun
- Problem soils, resulting from geological history, that may be soils that are shallow, stony, erosion prone, have poor infiltration, heavily leached or lacking in nutrients

b) Land use practices leading to vulnerability

- Removal of forest cover, for agriculture, housing or other needs
- Overgrazing (high density livestock populations)
- Cultivation on steep slopes
- Disregard for water and soil conservation practices
- High per capita water consumption;

c) Policy

- Subsidized water costs
- Government land sales policy and subsidized infrastructure
- Lack of drought insurance
- Lack of drought relief programs.

4.2 Areas At Risk to Drought

4.2.1 Drought Risk Criteria for Mapping

Mapping of areas on the basis of their risk to drought – namely, low, moderate, high, very high – is based on a set of criteria. Each criterion is given a value of one (1) and the total value of an area determines its rank:

Low drought risk	<4
Moderate drought risk	5-6
High drought risk	7-8
Very high drought risk	>9

Drought risk criteria used for mapping are shown in Table 15. A description of the criteria follows:

a) Meteorological/Environmental

< 40 inches Rainfall Areas that experience < 40 inches of rain annually are meteorological disadvantaged not withstanding the wet periods of the year when soil moisture may be in excess of plant needs. For most of the year plants can be expected to experience moisture stress.

Exposure to wind and marine influences Areas with excessive exposure to wind and marine influences are determined by location, topography and slope type, using the PGDM base map with contours. These areas were noted but not mapped in assigning numerical values for drought risk ranking.

Table 15 Drought Risk Criteria

Environmental Meteorological	
• Rainfall < 35 inches	1
• Exposure to wind and marine	1
influences	1
• Shallow soils	1
• Slopes >11°	1
• Cactus scrub vegetation	1
Hydrological/Infrastructure	
• Absence of wells	1
• Absence of agricultural reservoirs	1
Human/Landuse	
• Crazing	1
• Crop location	1
• Population density > 5,000 per sq. mile	1

Areas on the east coast of Antigua and Barbuda are relatively more exposed to prevailing winds and hence more prone to wind erosion. Where they occur close to the sea, salt in atmospheric moisture retard the growth of most plants, except those that have become naturalized or adjusted to such conditions. However, vegetation recovery on cleared or overgrazed slopes then becomes very slow, irrespective of plant adaptability. When this happens vulnerability to drought increases. East facing convex slopes close to the sea are particularly prone to wind erosion and desertification if overgrazed.

Shallow Soils. Shallow soils have limited moisture retention capacity and are often lacking in nutrients. Root development is often retarded because of poor soil structure. When such areas lose forest cover by clearing and are subjected to heavy grazing vegetation recovery is very slow and in some cases never occurs. This results in a trend to desertification. For Antigua, areas of shallow soils coincide with moderate to steep slopes.

Slopes > 11°. These are in Antigua and not Barbuda. Where such slopes have retained forest cover particularly moist forest or dry evergreen woodland, they are less prone to erosion and better able to retain moisture than slopes that have lost natural vegetation cover. Habitat degradation from drought is less severe on slopes in the former category.

Cactus Scrub Vegetation. For Antigua and Barbuda, the cactus scrub designation includes areas that were formerly cultivated and are now abandoned to extensive livestock grazing. The lack of dense vegetation cover in many parts of this vegetation zone encourages grazing and browsing by sheep and goats, major factors contributing to the vulnerability of the landscape to drought. Such areas visually exemplify the brown, harsh and oftentimes depressing conditions of droughts.

The Cactus Scrub designation, as used on the vegetation maps for Antigua and Barbuda, includes remnants of naturalized vegetation, which evolved on account of meteorological and other environmental influences, along with vegetation in various stages of succession after being cleared or cultivated.

The former may include combinations of Acacia spp, lucaena and other legumes, agaves, cactus and other xerophitic species, all well adjusted to drought conditions. This type of association is considerably less vulnerable to drought except where coverage is sparse enough to allow overgrazing or browsing of the under storey. Where this happens, soil erosion or compaction can adversely affect soil fertility or otherwise retard plant growth.

Vulnerability is therefore more associated with Cactus scrub areas, where vegetative associations are less adopted to drought conditions or where land uses create imbalances in the landscape that may lead to severe erosion, desertification or flooding.

A weakness in using this criterion is the lack of adequate vegetation information that would allow a more detailed classification of the various types of vegetation associations found within the Cactus Scrub designation. Work is therefore needed to update, detail and more comprehensively map vegetation for both islands.

Notwithstanding the weakness in vegetation data and the drought resistant nature of many plant species found in the vegetation zone, Cactus Scrub areas remain vulnerable to drought for several reasons:

- Goats appear to like the general dryness of this type of landscape and appear to favor a number of herbaceous plants and other shrubs found on it.

- Where drought resistant species (example, Acacia spp., Logwood, Black Pearl) are established with sparse vegetative wood cover, over-grazing of under storey vegetation leads to erosion and slower plant re-growth.

- Where grass offers adequate cover for soil and moisture during normal conditions rapid loss of biomass due to water deficiencies in the soil and from grazing leaves the soil exposed.

- Extensive grazing in Cactus Scrub areas adversely affect plant diversity and the ecology of some areas; species liked by goats and sheep have difficulties surviving, while an invasive plant such as Neem (toxic to goats) becomes dominant in the landscape.

- Ornamental plants introduced in gardens falling in this general vegetation category are often not suited to local conditions – for example, water loving plants cultivated in areas with low precipitation. Such plants die quickly where water is not available for extended periods.

Exposure to Sun – This was also considered as a criterion but was not used for mapping drought risk because it requires very site-specific analysis of an area's topography, contours and vegetation to determine how these affect the amount of shade it enjoys during sunlight.

Concave slopes facing north or south enjoy relatively longer periods of shade during the day than east and west facing slopes. This may create slight but critical temperature differences amenable to moisture retention, vegetation and crop growth. This criterion can therefore be applied where detailed analysis of slope orientation to sunlight and shade is possible.

b) Hydrological/Infrastructure

Absence of wells. These are areas with no wells or known significant ground water deposits. In the absence of wells untapped ground water resources could be exploited with hastily drilled wells to offer relief in extended periods of drought. Information to map aquifers was not obtained. Water production information by wells in various watersheds was obtained and used in drought risk ranking for Antigua.

Absence of agricultural reservoirs – areas with no agricultural dams or not enough ponds available to livestock farmers. Agricultural reservoirs or ponds may run dry in an extended drought but nevertheless provide a critical source of water for farmers as long as it is available. Municipal and agricultural reservoirs and ponds are mapped on the watershed data map for Antigua.

c) Human/LandUse

Grazing. Grazing densities of > 6 goats or sheep per hectare or 1.5 cattle per hectare for pasture areas without irrigation are not considered sustainable. It is common knowledge that there are areas in the country that are excessively grazed. Although figures on the livestock populations for Antigua and Barbuda are available, population densities by areas are not known.

Where livestock densities are in excess of sustainable limits in improved (managed) pastures, impacts are mostly felt within the boundaries of the fenced pasture. Vulnerability from grazing is therefore due mainly to the threats to crops, gardens and habitats posed by un-tethered livestock found in Mixed Scrub and Grazing and Rough Grazing categories delineated in the land use data maps for Antigua and Barbuda.

Livestock population and grazing density data by area (preferably watersheds) is required to strengthen vulnerability and impact analysis.

High Population Densities >5,000 per square mile. St. John's is the only settlement with this level of population density. Vulnerability linked to density derives mainly from limited space and poor soil conditions that limit storage capacity above or below ground.

Households built on small lots in parts of Point, Gray's Green and Ovals are particularly vulnerable. Such households are dependent mainly on piped water (attached to the house or available at stand pipes) and are unable to adequately store water when it has to be rationed.

Crops Location. This criterion targets areas located > 1 mile from mains supply. This applies to water loving crops in the volcanic region of Antigua as well as crops with lower water requirements grown in dryer areas. The latter is more drought resistant but vulnerability increases where there is no access to water supply mains.

Mango, which constitutes the major tree crop in the country, is less prone to

damage from soil water loss than most perennial crops but is vulnerable nevertheless.
Since the information to map water mains could not be acquired, the relative location of crops to main and secondary roads was used to assume their relative distance from water mains. Water distribution information, including variations in water pressure along the distribution network is required to reinforce the use of this criterion and to adjust drought maps as appropriate.

Crops are also vulnerable where their location relative to grazing activity may render them susceptible to damage from livestock, particularly during drought, when feed material becomes scarce.

Denuded Slopes. Country wide mapping of denuded slopes was not possible during this assessment due to time constraints and therefore the criterion was not used in drought risk ranking. However, some of these areas are included in rough grazing land use designation on the land use data map for Antigua.

Such areas should be specifically mapped in the future since they provide ready evidence of how poor land use practices can create vulnerability to drought.

Denuded slopes are areas where vegetation is almost absent and where most of the topsoil has been lost. They are indicative of a process, which started with the clearing for agriculture or firewood but have not recovered due to a combination of factors, namely, accelerated erosion, persistent and intense grazing and exposure to wind and marine influences.

Such areas exist on the southeast of Antigua between the Indian Creek area and Christian Hill. Some of these areas (slopes and associated valleys) are undergoing a process of desertification, which can only be reversed if the contributing landuse practices are curtailed. Such practices render the areas vulnerable to meteorological agents that hasten land degradation.

4.2.2 Area and Issues for Priority Attention

a) Areas

The east, north and southeast of Antigua contain areas of high and very high risk to drought. Environmental and land use factors comprise to make the region of the country the most vulnerable to drought. Within this region, the area requiring the most urgent attention falls within watershed 27-46, one of two watersheds ranked as being at very high risk to drought.

The area is at the extreme southeast of the island (between English Harbour and St. James Club). Environmental and human (landuse) factors combining to make this area highly vulnerable to drought include:

- Low rainfall
- Shallow soils
- Slopes exposed to wind and marine influences
- Overgrazing – the area has one of the highest goat population

Denuded slopes and narrow valleys in areas forming part of the Nelson's Dockyard National Park provide visual images of a severely degraded landscape and imminent desertification.

Similar trends are being experienced in other watersheds but perhaps not with the same degree of devastation. It is suggested that watershed 27-46 be considered for undertaking a pilot project seeking to provide strategies for reducing vulnerability and risk to drought.

The project should include:

- Forest monitoring program, particularly for cactus scrub and dry forest areas subject to threats from overgrazing. One objective would be to determine carrying capacity for livestock grazing and livestock population densities that should be allowed.
- Ecosystem studies aimed at better understanding the critical relationships between dietary requirements of goats and sheep, soil and moisture needs of preferred plant species and other ecosystem characteristics critical to understanding how plants and animals respond to drought.
- A landscape restoration component aimed at reversing trends towards desertification.
- The development of methodologies and approaches to involve livestock farmers in mitigating livestock impacts.
- The development of policy initiatives to reduce vulnerability and risk to drought.

Successful results of the pilot project would be replicated in other parts of the country.

In Barbuda, the Palmetto Point, parts of the highlands, Codrington lagoon and the northern section of the island with Salinas, lagoons and mangroves are considered of low to moderate risk to drought. Most of the remaining lowlands are considered of high risk. No part of the island was categorized in the very high drought risk category.

b) Major issues

While the pilot project is being used to test approaches for mitigating the impacts of drought, actions should be considered and implemented to address other issues, including:

- ***Overgrazing***. This is perhaps the singly most critical factor contributing to the country's vulnerability to drought. Trends in vegetation, habitat and landscape degradation, key factors contributing to the country's vulnerability to drought, will not be reversed until overgrazing is controlled.

- ***Meteorological data***. A nationwide network of meteorological stations is needed collect data and monitor rainfall, evapo-transpiration, relative humidity, etc., to improve the country's database for informed analysis and decision-making.

- ***Vegetation classification and mapping***. Existing vegetation data is inadequate for drought management. A vegetation classification and mapping project should be undertaken to improve the capacity required for managing various vegetation zones against drought impacts. Classification should include a description of soil and moisture requirements of key plant species within each vegetation class.

- ***Agricultural water storage infrastructure.*** The mapped data indicate an imbalance in the distribution of agricultural storage reservoirs and ponds. Vulnerability to droughts could be reduced for livestock and some crops by investment in additional reservoir and pond capacity in selected watersheds.

- ***Potable water.*** Water rationing by APUA in February and March, 2001, indicates that desalinated water (62% of the total water production of 4.5 million cu.m/yr) has reduced but not eliminated vulnerability in respect of potable water supply. Since rainfall does not affect water production by desalination, rationing is necessary because of limitations or constrains in the supply of ground and surface water, which account for 33% of total production. Additional water production capacity and/or storage are required if vulnerability is to be reduced in the future. This will be more so if significant growth occurs in the hotel and commercial sector, which now accounts for 17.5% of current water consumption. The same will be true if major growth occurs in domestic water consumption, which currently accounts for 30% of current total consumption.

5.0 DROUGHT MAPPING

5.1 Data Collection and Sources

Data for drought hazard mapping were obtained from:

- Past projects and project reports, e.g. the OAS Natural Resources Assessment, Application and Projects for the Agricultural Sector of Antigua/Barbuda.
- Government agencies, such as the Coolidge Met Office, Ministry of Planning and the Development Control Authority (DCA). In the latter case, maps from the Draft National Physical Development Plan were used.
- Field observations.

Relevant sources are credited on individual maps.

5.2 Structure and Content of Maps

The drought hazard maps for Antigua and Barbuda were produced by analyzing ArcView GIS generated data maps with the following titles:

- Mean Rainfall Isohyets (Antigua)
- Vegetation (Antigua and Barbuda)
- Slope (Antigua and Barbuda)
- Watersheds (Antigua and Barbuda)
- Soils (Antigua and Barbuda)
- Land Use (Antigua and Barbuda)

The structure (content) of the each data set is given in Appendix 5.

5.3 Analysis of Data

Data was analyzed using ArcView. The Risk Criteria, identified in Section 4.0, were used as vulnerability themes and spatially manipulated by:

(i) Analyzing the spatial occurrence of vulnerability themes in the various watershed units. This was used to rank Antigua's watersheds in relation to drought risk based on numerical scores given in Appendix 6 (a). A similar system was used for Barbuda despite the fact that not all watershed boundaries are fully defined. Numerical scores for Barbuda's watersheds are given in Appendix 6 (b). Acreage data for land covered by relevant themes, e.g. grazing was not calculated but could be done in the future when vegetation and other data are updated;

(ii) Overlaying (intersecting, as opposed to merging in ArcView GIS terminology) the themes to determine areas of critical risk.

In relation to (i), watersheds were given drought risk ranks as shown in Table 16 for Antigua and Table 17 for Barbuda.

By overlaying themes from data sets, critical areas within the watersheds that require remedial policy and land management actions can be identified.

Table 16 Drought Risk Ranking of Antigua Watersheds

Level of Risk	**Watersheds**
Low	1, 2, 3
Moderate	4-11, 12-20, 21-26,
High	47-53, 54-62, 63-66, 78-84, 85-86
Very High	27-46, 67-77

Table 17 Drought Risk Ranking of Barbuda Watersheds

Level of Risk	Watersheds
Low	I, X
Moderate	V, VI, VII, VIII
High	II, III, IV, IX
Very High	--

5.4 Map Use and Limitations

a) Map Use

The maps can be used for sector, strategic or development planning, disaster mitigation planning and drought management. The watershed, as a hydrological unit, with a common drainage basin is considered the most appropriate physical space for managing drought even though precipitation levels may vary within its boundaries.

Hence, the ranking of watersheds in relation to drought risk provides the necessary background for further investigation and mitigation of drought impacts.

For any given watershed, themes from data sets (maps) can be over-laid or merged to highlight actual or potential impacts from drought, as shown in the following examples:

a) ***Overlay*: Cactus Scrub vegetation + Rough Grazing and Mixed Scrub/Rough Grazing.**
Result: Tells the extent to which grazing impacts on this vegetation zone. Areas that fall outside of where the two themes intersect are often characterized by dense Acacia and other woody or thorny species, dense enough to discourage foraging by goats and sheep.

Mitigation strategies to protect such areas, which may be the least degraded of the Cactus Scrub associations, will require updating field data for more accurate mapping and/or detailed reclassification of the Cactus Scrub vegetation zone.

b) ***Overlay*. Grazing + > 11 degree slopes + exposed slopes (east-coast, Antigua) + < 40 inches rainfall**. Result: Indicates areas of actual or potential landscape degradation, where vegetation re-growth is retarded; also indicates actual and potential areas of soil erosion from wind and rain;

c) ***Merge*. Agriculture (crops) + rough grazing & mixed scrub/rough grazing.** Result: actual or potential threats to crops from livestock.

Limitations in Use of Maps

The maps can be used as references to drought mitigation planning and drought impact assessment. Data inadequacies should however determine the extent to which maps can be used to make decisions without additional research and field observations.

Attention should be given to weaknesses in various maps, namely:

- **Mean Rainfall Isohyets (Antigua).** There are not enough rainfall stations in Antigua and Barbuda to generate accurate lines of equal rainfall (isohyets). The map for Antigua was adopted from sources that did not indicate how many rainfall stations were used in producing the isohyets. A rainfall map was not produced for

Barbuda because the data was not available. An adequate number of rainfall stations for both islands need to be installed and data collected on a regular basis.

- **Vegetation (Antigua and Barbuda).** No detailed and up-to-date maps produced from vegetation studies are available for either island. The vegetation maps are produced using different land use mapping sources and very limited field observation. Vegetation maps based on thorough field investigations and an agreed classification system is critical to drought mitigation.

- **Slope (Antigua and Barbuda).** The slope maps provide general rather than detailed slope categorization. Detailed slope analysis can be generated by GIS from the PGDM contour map. This should be done where site specific assessment of drought impact and mitigation is required.

- **Watersheds (Antigua and Barbuda).** Watershed boundaries were verified by study of a DOS contour map for Antigua and are believed to be accurate for Barbuda. The boundaries of critical aquifers were not mapped because the information was not obtained. This should be plotted as the information is obtained and where possible an investigation made of the effects of land uses in watersheds on aquifer recharge.

- **Soils (Antigua and Barbuda).** The soil classification used for both islands is general but adequate for this assessment. More detailed soil maps have been digitized for another study in the PGDM project and can be used for specific area analysis.

- **Land Use (Antigua and Barbuda).** Land use for Antigua was updated by the DCA (1999), after the OAS (1992), and adopted with slight modifications for the Antigua land use data map. The Barbuda map was updated from the OAS, 1992. Land use is however undergoing continuous change in Antigua and should be updated as significant changes are observed, particularly where practices could lead to increased vulnerability to drought.

6.0 INDICATORS FOR FUTURE IDENTIFICATION OF DROUGHTS

This section summarizes and describes indicators that suggest approaching or actual drought conditions. These indicators are discussed under the following categories:

- Meteorological/Environmental
- Hydrological
- Agricultural
- Socio-economic

a) Environmental Indicators

- ***Reduction in biomass production of common grass species.*** Early warning is wilting, as grass roots become progressively damaged by lack of soil water. Grass cover becomes patchier as fallen leaf debris is blown away by wind in exposed areas. Homeowners find no need to use lawn mowers.

- ***Leaf fall and litter in Forests***. The Forestry Division uses the increase in leaf fall and litter (detritus) on the forest floor as one indicator of drought. No measurement of volume of weight is done. Since leaf fall varies between species, measurement would need to be correlated with plant associations.

  In Cactus Scrub forests, xerophytes (plants growing in dry areas) with small hard leaves can decrease water loss when the area begins to get drier and will drop their leaves in prolonged drought.

- ***Damage to "indicator" plant species***. The Ficus, planted as hedge or trees, normally stays green; its small and shiny leaves limit moisture loss and its wide spreading root system allows it to seek moisture and nutrients beyond its drip line. When the Ficus loses a lot of its leaves it is an indication that the country is in a period of prolonged drought.

Some types of xerophytes, (succulents, such as cacti and agaves) utilize stored water in dry periods without noticeable damage. In fact, such plants can survive for weeks when uprooted, so that signs of damage (dried leaves or broken stems) may be an indication of negative water balance resulted from extended drought.

b) Hydrological

Reduction in Ground Water levels. The APUA Water Division uses ground water levels at various well fields as an indicator of hydrological drought.

The approximate average water levels of selected well fields in Antigua are provided in Table 18. The table also gives the approximate levels for each field that is indicative of drought conditions.

There is a time lag between meteorological and agricultural drought conditions and hydrological drought as indicated by ground water levels. The latter occurs later but the time lag cannot be accurately predicted in the absence of rainfall data that could be correlated with rates of pumping and recharge, for the watersheds in which the well fields occur.

Recovery from meteorological and agriculture droughts occurs in advance of the replenishment of ground water to average levels. Again, the data does not exist to accurately predict the gap in time between these events.

Table 18 Drought Indicator Levels at Well Fields, Antigua

Well	Ave. Level	Drought Level
	(ft. below grade)	
Bendals	40	60
Cades Bay	25-3	45-50
Claremont/ Old Road	25-30	45-50
Collins/ Bristol	15-25	25-45
Follies	50-60	70-80
The Valley	30-40	50-60

(Source: V. Yearwood, Water Division, APUA)

Water level figures given by APUA are approximations. This leaves room for more precision in measuring water levels as they recede as the basis for making decisions on water rationing.

Reduction of Water Levels at Municipal Reservoirs. Receding water levels at municipal reservoirs is another drought indicator used by APUA. However, it was not determined if specific indicator levels for the various municipal reservoirs were established. Indicator levels at selected reservoirs could be determined over a period of time by widening the scope of monitoring to measure consistently meteorological and hydrological data, including, rainfall, temperature, wind speed, evaporation and seepage.

Water Rationing. APUA begins to ration water before ground water levels recede to critical points. In fact, the decision to begin rationing water appears to be influenced by perceived meteorological and agricultural drought conditions.

Reduction of Water Levels at Agricultural Reservoirs. This is another indicator observed but not measured by authorities.

c) Agricultural

Livestock

Livestock gain water from drinking water, foraging plants and water molecules produced in the breakdown of food. They lose water through urine, feces and water evaporated through skin and lungs.

Some livestock can reabsorb water in their intestines to produce dryer feces and can reduce water used to excrete nitrogenous wastes of the urine (Brewer, 1994).

As animals well adapted to drought conditions goats are presumed to use similar physiological measures to conserve water. Despite this, they and other livestock will show signs of stress during extended drought:

- ***Weight loss***. Symptoms are reduced muscle density, visible ribs. Effects are more associated with tethered livestock. However, untethered animals foraging larger areas for food use more energy and may suffer similar weight loss.
- Higher incidence of disease.
- Unusual high incidence of miscarriage among pregnant females.

Crops

Indicators may include:

- Negative water balance as evidenced from wilting and ultimately death of plants in extended droughts.

- Unusually high incidence of diseases, as plants are unable to obtain needed moisture and nutrients from the soil.

d) Socio-economic

Socio-economic indicators include changes in water use practices by households and businesses:

- Storage of water in existing or temporary storage facilities as a result of water rationing.

- Reduction of water used for landscaping of household and hotel gardens.

- Regular trucking of water to meet water deficit due to rationing.

- Higher incidence of respiratory ailments due to excessive dust in a very dry landscape. Respiratory ailments related to drought are not recorded for Antigua and Barbuda but are generally considered a drought related health impact.

References

Brewer. Richard. 1994. *The Science of Ecology. Second Edition.*

Cadogan, Paul. Dr. 2000. Quoted in article, *Extreme Weather Distresses Regional Farmers*. Caribbean Edition, Executive Time, page 13.

Hill, I.D, Lang, D.M, Vernon, K.C. 1966. *Soil and Land Use Surveys Antigua and Barbuda*. Regional Research Centre, Imperial College of Tropical Agriculture, University of the West Indies, Trinidad.

Ivor Jackson & Associates. 2000. *Environmental Audit/Assessment, Jolly Harbour, Antigua*

Island Resources Foundation (IRF). 1991. *Antigua and Barbuda Environmental Profile*

Ministry of Trade and Planning, Government of Antigua. 1997. *Case Study of Climate Change Impacts and Adaptation Assessments in Antigua and Barbuda. Water Resources Sector.* Jerry Fernandez et al, Study Team Participants.

National Drought Mitigation Center. 1995. *Categories of Drought Definitions.*

OAS. 1991. Desertification Hazard Assessment (Chapter 9).

OAS, Department of Regional Development and Environment. 1992. *Natural Resources Assessment Application, and Projects for the Agricultural Sector of Antigua and Barbuda.* Report and Maps

Weir, Collin, C. 1980. *Caribbean Soils.*

APPENDICES

Appendix 1 Tasks Outlined in Terms of Reference

Under this contract, the consultant will undertake the following activities for Antigua, Barbuda:

a) Meet with the relevant agencies and individuals to collect reports and data on drought hazards. These are to include both agencies that collect information on drought and those representing sectors affected by drought (e.g., tourism, agriculture, water authorities, economic and physical planning. Document current information and procedures regarding drought, existing definitions of drought, designated lead agencies and existing policies and plans.

b) Undertake a drought hazard vulnerability assessment for Antigua and Barbuda. The assessment is to be consistent with current drought hazard assessment methodologies and with reporting needs for Antigua/Barbuda under the Convention to Combat Desertification. Activities under the hazard assessment include:

   i) Compile historic evidence of drought effects on critical sectors. To the extent possible, the social, economic and environmental impacts of these events are to be described. From this information, develop a working definition of drought and indicators for future identification of future drought events.

   ii) Compile information on and assess causes of drought. Included in this investigation are the contributions of precipitation patterns, controlled and uncontrolled grazing, soil types and development.

   iii) Identify the sectors most at risk to the effects of drought. Assess the vulnerability of these sectors to drought and determine the level of preparedness for future events. Meet with representatives of these sectors to determine appropriate responses to any gaps in preparedness.

   iv) Produce island-wide geographic information system (GIS) data layers depicting drought hazard risk zones in Antigua/Barbuda. These data are to be in an Arc/Info or ArcView-compatible format, geo-referenced to the common mapping standard for the islands, and accompanied by appropriate GIS metadata.

   v) Using the GIS data described above, produce island-wide drought hazard maps for Antigua and Barbuda. These maps will depict areas of high, medium and low-risk to drought. All maps are to include a common set of reference features (e.g, roads, settlement areas), to be provided by the PDGM for this purpose, and will conform to the PDGM hazard map layout, as defined by GS/OAS. Where appropriate, information on vulnerable sectors is to be included on these maps.

c) Produce a technical report of the drought hazard assessment. This report should include a proposed definition of drought in the context of the islands and indicators for future identification of drought events. This technical report should also identify key contacts on each island for drought hazards.
d) Produce non-technical summaries of the drought hazard assessment. This summary should be suitable for distribution independent of the technical summary and should be approximately 2500 words in length.

Appendix 2 Average Yearly Rainfall, Recorded at the Meteorological Office, V.C. Bird International Airport (Antigua), 1960 – 2000

Year	Rainfall	Year	Rainfall
1960	33.12	1981	57.12
1961	32.97	1982	43.24
1962	48.38	**1983**	**22.31**
1964	33.65	1984	45.86
1965	36.37	1985	46.64
1966	**27.52**	1986	35.12
1967	**29.14**	1987	56.23
1968	**25.09**	1988	51.82
1969	49.79	1989	43.32
1970	64.72	1990	40.46
1971	41.19	1991	30.49
1972	38.83	1992	47.22
1973	**25.98**	1993	39.70
1974	52.33	1994	30.47
1975	36.49	1995	50.27
1976	36.78	1996	36.04
1977	38.44	1997	**26.46**
1978	49.29	1998	49.87
1979	67.29	1999	62.01
1980	32.15	2000	30.96
Ave			40.95

(Source: Met Office, 2001)

Appendix 3 Antigua Annual Rainfall, 1950 – 1990 (Inches)

Year	Rainfall	Year	Rainfall
1950	50.05	1971	45.18
1951	60.79	1972	45.92
1952	56.78	1973	27.73
1953	29.15	1974	50.70
1954	41.58	1975	37.78
1955	46.89	1976	40.89
1956	49.42	1977	38.50
1957	43.79	1978	49.00
1958	47.35	1979	66.00
1959	41.55	1980	33.00
1960	40.76	1981	58.00
1961	40.58	1982	40.00
1962	50.91	1983	22.26
1963	44.06	1984	33.25
1964	34.46	1985	----
1965	31.69	1986	35.12
1966	29.74	1987	56.23
1967	34.58	1988	51.82
1968	27.19	1989	43.32
1969	52.05	1990	21.73*
1970	61.23		

*8 months

(Source: IRF, 1991, after APUA)

Appendix 4 Population Density, Antigua and Barbuda, 1991

Parish	Area (sq. miles)	Population	Density (persons/sq. mile)
St. John's	28.5	35,635	1,250
- St. John's City	2.9	21,514	7,419
- St. John's Rural	25.6	14,121	552
St. George's	9.3	4,473	484
St. Peter's	12.8	3,622	284
St. Phillip's	17.0	2,964	174
St. Paul's	18.5	6,117	331
St. Mary's	22.8	5,303	241
Antigua	108.0	58,114	538
Barbuda	62.0	1,241	20

(Source: Development Control Authority, as taken from Population and Housing Census, 1991)

Appendix 5 Structure (Content) of Mapped Data Sets, Antigua and Barbuda

Data Set Map Title	Content (Legend)
Antigua	
Antigua Mean Annual Rainfall Isohyets (inches)	Rainfall isohyets
Antigua Vegetation	Cactus Scrub; Dry woodland; Moist Forest/Dry Woodland; Mangrove Woodland/swamp
Antigua Slope Classes	0-2, 3-11, 11-20 and 21-30 degree slopes
Antigua Watersheds	Watershed boundaries; Watershed numbers; Agricultural reservoirs; Municipal reservoirs; Ponds
Antigua Soils	Deep/alluvial/ colluvial; Deep kaolinitic clay; Shallow soils; Complex of shallow and deep soils
Antigua Land Use	Agriculture; Citronella grass; Improved pasture; Mixed scrub and rough grazing; Rough grazing; Woodland; Urban settlement; Settlement; Swamp/mangrove; Tourism; Recreational/Historic area; Industrial; Airport; Military uses; Freshwater; Salt pond
Barbuda	
Barbuda Vegetation	Woodland (limestone area); Cactus scrub; Mangrove; Salina vegetation
Barbuda Slope Classes	0-2, 2-5, 5-10, 10-20 degree slopes
Barbuda Watersheds	Watershed boundaries; Watershed numbers
Barbuda Soils	Codrington Clay; Barbuda clay loam; Blackmere clay loam; Beach sand; Mangrove/swamp; Salina
Barbuda Land Use	Food crops; Coconut plantation; improved pasture; Mixed Scrub and rough grazing; Settlement; Tourism; Airstrip; Industrial area

Appendix 6(a) Drought Risk Totals by Watersheds, Antigua

Watersheds

Criteria	**1**	**2**	**3**	**4-11**	**12-20**	**21-26**	**27-46**	**47-53**	**54-62**	**63-66**	**67-77**	**78-84**	**85-86**
Cactus scrub vegetation	1	1	1	1	1	1	1	1	1	1	1	1	1
> 11 degree slopes	0	1	1	1	1	0	1	1	0	0	1	1	0
Shallow soils	0	0	0	1	1	1	1	1	1	1	1	1	1
Grazing	1	1	1	1	0	0	1	1	1	1	1	1	1
Rainfall < 40 inches/yr	1	0	0	0	0	0	1	1	1	1	1	0	0
Pop. Density >5000 persons/sq mile	0	0	0	0	0	0	0	0	0	0	1	0	0
Crops (agriculture)	1	1	1	1	1	1	1	1	1	1	1	1	1
Absence of wells	0	0	1	0	0	1	1	1	1	1	1	1	1
Absence of agricultural reservoirs	0	0	0	1	1	1	1	0	1	1	1	1	1
Exposure to winds and marine influences	0	0	0	0	0	1	1	1	1	1	1	1	1
Total	**4**	**3**	**4**	**6**	**5**	**6**	**9**	**7**	**8**	**8**	**10**	**8**	**7**

Appendix 6(b) Drought Risk Totals by Watersheds, Barbuda

Watersheds

Criteria	**I**	**II**	**III**	**IV**	**V**	**VI**	**VII**	**VIII**	**IX**	**X**
Cactus scrub vegetation	1	1	1	0	0	0	0	0	1	0
> 11 degree slopes	0	0	0	0	0	0	0	0	0	0
Shallow soils	0	1	1	1	1	1	1	1	1	1
Grazing	1	1	1	1	0	0	0	0	1	0
Rainfall < 40 inches/yr	1	1	1	1	1	1	1	1	1	1
Pop. Density >5000 persons/sq mile	0	0	0	0	0	0	0	0	0	0
Crops (agriculture)	0	1	1	1	0	0	0	0	1	0
Absence of wells	0	0	1	1	1	1	1	1	0	1
Absence of agricultural reservoirs	1	1	1	1	1	1	1	1	1	1
Exposure to winds and marine influences	0	0	0	0	1	1	1	1	0	0
Total	**4**	**6**	**7**	**6**	**5**	**5**	**5**	**5**	**6**	**4**

Notes:
Watersheds IV and VIII have relatively small areas of cactus scrub compared to overall acreage, hence the scores.
There are two very small areas of >11°slopes in watersheds II and III that were ignored in scoring.
No wells were mapped for watershed I but the assigned score is due to the presence of an important aquifer.

Appendix 7 Map References, from Antigua and Barbuda Country Environmental Profile, IRF, 1991

Appendix 8 List of Contacts

1. Mr. McRonnie Henry, Forestry Division, Ministry of Agriculture
2. Dr. Robinson, Chief Vetenary Officer, Livestock Division, Ministry of Agriculture
3. Mrs. Cheryl Kanyuira, Livestock Division
4. Ms. Veronica Yearwood, Antigua Public Utilities Authority (APUA)
5. Mr. Patrick Jeremiah, Head, Antigua/Barbuda Met Office
6. Mr. Keithly Meade, Climatologist, Antigua/Barbuda Met Office,
7. Dr. Debra Thomas, Development Control Authority
8. Mr. Jerry Fernandez, Ministry of Planning
9. Mr. Ernest Benjamin, Ministry of Planning
10. Mrs. Cynthia Simon, Antigua Hotel and Tourist Association
11. Mr. Rob Sherman, Chairman, Antigua Hotel and Tourist Association
12. Mr. Clarence Johnson, Siboney Beach Hotel
13. Mr. Arthur Edmond, Antigua Village
14. Mr. John Mussington, Barbuda