# LAND USE CHANGE IN WESTERN BARBADOS

## 1950 - 1980

Peter W. Wilson

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Department of Geography
McGill University
Montreal, Quebec

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by

Peter W. Wilson

## Abstract

The intent of this research was to study the relationship between land use change and land capability in western Barbados for the period 1950-1980.

A review of land use change that occurred before 1950 was first conducted. This was followed by an analysis of the physical, political and economic factors that affect land use change in contemporary Barbados. Emphasis was placed on government land use policy as expressed in the Physical Development Plan, published in 1970. A series of hypotheses was then developed to predict land use change trends for the period 1950-1980.

In testing the hypotheses, land use data derived from the interpretation of aerial photographs from four study years (1950, 1964, 1972, 1980) was first classified according to a system developed specifically for this work. Land capability data sets were then generated from thematic maps. Computer comparison of land use and land capability variables was then performed for each of the four study years.

Results indicate that government legislation introduced during the late 1960's and early 1970's curtailed the development of land with high agricultural potential for tourism and urban purposes.

Department of Geography

M.Sc.

# CHANGEMENT D'UTILISATION DES TERRES DANS LA PARTIE OUEST DE LA BARBADE 1950-1980

par

Peter Wilson

## RÉSUMÉ

Notre recherche visait l'étude du rapport entre le changement d'utilisation des terres et le potentiel de celles-ci dans la partie ouest de la Barbade, de 1950 à 1980.

Après avoir examiné les changements d'utilisation avant 1950, nous avons analysé les facteurs physiques, politiques et économiques influant sur ce processus dans la barbade contemporaine. Nous nous sommes particulièrement attardés à la politique gouvernementale d'utilisation des terres telle que la décrivait le Plan de développement publié en 1970. Une série d'hypothèses furent ensuite élaborées afin d'identifier les tendances marquant le changement d'utilisation pour la période de 1950 à 1980.

Afin de vérifier ces hypothèses, nous avons d'abord classé nos données suivant un système établi à cette fin; les données sur l'utilisation provenaient de l'interprétation de photographies aériennes pour les années 1950, 1964, 1972 et 1980. Celles sur le potentiel ont été obtenues au moyen de cartes thématiques. Nous avons donc comparé sur ordinateur les variables d'utilisation et de potentiel pour chacune des quatre années à l'étude.

Les résultats montrent que la législation adoptée vers la fin des années 1960 et le début des années 1970 a restreint le développement touristique ou urbain des terres à fort potentiel agricole.

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# INTRODUCTION

The West Indian Island of Barbados is located at latitude 13°4'N, longitude 59°37'W. It is a mere 430 square kilometers (166 square miles) in area, yet supports a population of 246,082 (Europa Yearbook: 1981, p.1621). Population density is thus 572 persons per square kilometer (1,482 per square mile), one of the highest national values in the world. This urban-like population density has prompted some observers to describe Barbados as "a city with sugar cane growing in the suburbs" (West and Augelli: 1976, p.191).

West and Augelli describe the impact that the combination of Barbados' high population density and limited total arable land have had on the intensity of land use:

> The enormous pressure of population has resulted in much more intensive farming here than elsewhere in the Caribbean. Every bit of productive land is used. The forests and thickets that once covered the island have vanished; over 55% of the total area is tilled; and what land cannot be worked is put to other uses (1976, p.193).

Clearly one of the major concerns of the people of Barbados is that they obtain maximum benefit from the limited amount of land at their disposal.

In order for land use change to be implemented at the optimum location, it is essential that the land capability of each site under consideration be known. In other words,

a knowledge of the geographical distribution and limitations of the physical land characteristics is essential for a variety of planning purposes.

The purpose of this study is to examine the characteristics and attributes of the different types of land in western Barbados and to determine the extent to which changes in land use can be related to land capability and the basic site characteristics of the land in that area. The underlying objective of the work, in other words, is to document land use / land capability relationships as they have evolved in western Barbados, with an eye towards planning for future development in the area. The thesis is organized in six chapters and it is useful at this stage to indicate the sequence in which the various aspects are treated.

Chapter One:

The physical characteristics of Barbados are examined in a general way in this chapter. The location of the island, its size, shape, physiography, soils and climate are summarized as a setting for a more rigorous treatment of the significant physical parameters of the West Coast Study Area in Chapter Three.

Chapter Two:

This research is concerned with land use change between 1950 and 1980. In order to guage the significance

of the changes that occurred during this thirty year period, it is essential that the reader have a good understanding of the nature and extent of the land use changes that took place on Barbados before 1950. Chapter Two, thus, provides an historical account of land use change between the time of first settlement and the beginning of the 1950-1980 study period.

Chapter Three:

With an understanding of both the land use pattern that existed on Barbados in 1950 (Chapter Two) and the physical structure upon which that pattern had been imposed (Chapter One), it is possible to examine in detail the physical and economic factors (including those resulting from government legislation) that have influenced land use in western Barbados throughout the three decade study period considered in this work. Following an introduction (Section One), the location, size, shape, and subdivisions of the West Coast Study Area are described (Section Two).

Section Three is devoted to the definition of optimum land use / land capability relationships. The effects on land use of soil type, soil depth, terrain slope and rainfall are all examined individually.

The physical factors are important in determining the potential for land use change. However, there exists another set of variables that are equally critical. It is often found that decisions to change land use are based

solely on economic considerations. Such changes are often induced without regard for the optimum land use / land capability relationships defined above. These economically induced land use change decisions are most often made on the basis of the location and availability of land, while ignoring its potential for agricultural productivity. Section Four of Chapter Three deals with economic influences on land use / land capability relationships in general, and with the topics of land scarcity and proximity in particular.

Government interest in ensuring the most efficient use of land as defined in terms of land capability led to the preparation of a physical development plan for Barbados in the mid-1960's. This plan is highly significant in three respects: (1) for the acknowledgement that beneficial land use change can only be achieved when optimum land use / land capability relationships are understood and maintained, (2) for recognizing that economic influences often neglect and even destroy optimum land use / land capability relationships, to the long-term detriment of both the island's ecosystem and economy, and (3) for its recommendations regarding (a) the protection of land with high agricultural potential, and (b) the planned and controlled development of urban areas. Knowledge of the conclusions and recommendations of the Physical Development Plan is a prerequisite to the formulation of hypotheses regarding land use change in western Barbados for the period

1950-1980. Because the plan was adopted by the government, and many of its provisions are now enforced by law, the plan's conclusions and recommendations are reviewed in the fifth, and final, section of Chapter Three.

The review of the findings and suggestions of the Physical Development Plan provides an excellent opportunity for the formulation of hypotheses regarding anticipated land use change and its relationship to land capability. Fourteen hypotheses are presented with reference to the physical, economic and governmental influences that affect land use change in western Barbados. Land tenure / land capability relationships as observed by some recent scholars (Prescott 1967, Persaud 1968, and Henshall 1964) are also reviewed, in order that a hypothesis on this subject can be formulated.

Chapter Four:

A scheme of land use classification is developed in this chapter that is specifically designed for the Barbadian situation. In keeping with convention, three major land use groups (1) Agricultural Land, (2) Unused Land and, (3) Developed Land are recognized. Each group is subdivided into two distinct land use types that are specifically chosen for application in the testing of the land use change hypotheses formulated for the West Coast Study Area. Each of the six land use types ('A'/ 'Grazing and Unused Land', 'B'/ 'Plantation Agriculture', 'C'/ 'Peasant Agriculture',

'D'/ 'Uncleared and Overgrown Land', 'E'/ 'Tourism and Recreation Land', and 'F'/ 'Urban Land') is described in detail and is accompanied by aerial photographs for illustrative purposes.

Chapter Five:

Chapter Five begins with a description of the application of the land use classification to the study of land use change. This is followed by a general analysis of land use change in the West Coast Study Area for all three time periods. The research hypotheses presented in Chapter Three are then tested, through the comparison of land use change to land capability and site parameters (soil type, soil depth, terrain slope, rainfall, and proximity to the coast). Relationships between land use change and land capability are identified and the different hypotheses are accepted, rejected, or redefined.

Chapter Five is followed by a general conclusion, which summarizes the intent and results of the research.

# CHAPTER ONE: LOCATION, PHYSIOGRAPHY, SOILS, CLIMATE

## Location, Shape and Size:

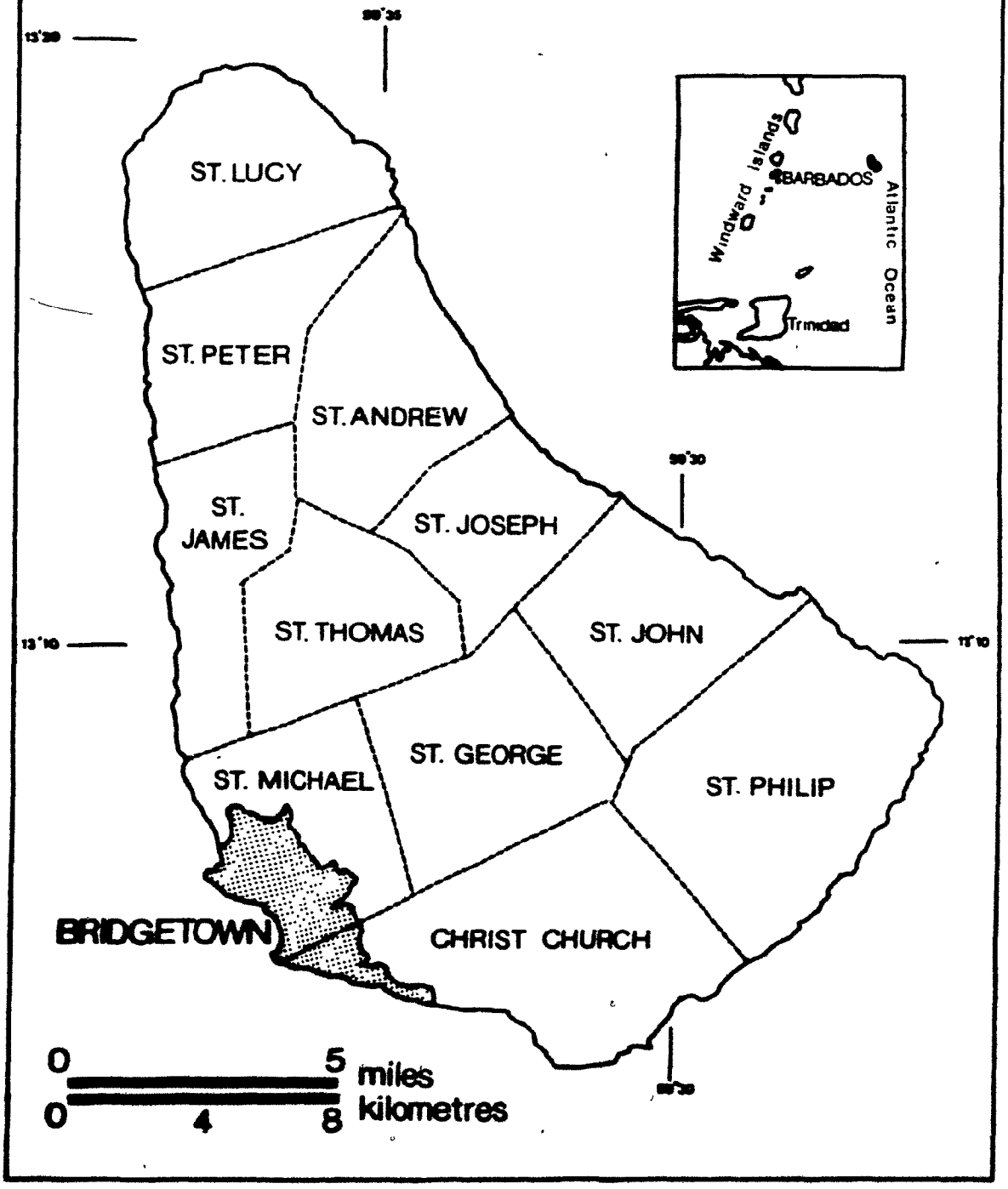
The West Indian Island of Barbados is located at latitude 13°4'N, longitude 59°37'W. It lies 165 kilometers (102 miles) east of its nearest neighbours, St. Vincent and St. Lucia. The island is approximately pear-shaped, being 34 kilometers (21 miles) long from north to south and just under 23 kilometers (14 miles) across at its widest point. Barbados is 430 square kilometers (166 square miles, 106,470 acres, 43,105 hectares) in area. Figure 1.1 illustrates the location, shape and size of Barbados.

## Physiographic Evolution and Present Physiography:

Barbados, unlike its Caribbean neighbours, is not of volcanic origin. Rather, the island is a small, emergent section of a much larger submarine geological structure known as the Barbados Ridge (MacIntyre: 1970, p.9). As such, it lies on a bed of sedimentary, rather than igneous rock.

The original sedimentary deposits, the Scotland Series, were laid down in a muddy sea that existed in the area some sixty to seventy million years ago, during the upper Cretaceous and early Tertiary periods. Following extensive folding, faulting, and uplifting, these rocks were

FIGURE 1.1 BARBADOS (Location, Size, Shape)
(After Oyelese; 1964, p. 57)



covered by argillaceous deposits known as the Oceanic Series (Macpherson: 1974, p.77).

The sedimentary material that today forms the Barbados Ridge at one time took the form of a continental rise, overlying the oceanic crust along the northern edge of South America (Chase and Bunce: 1969, p.1419). The continental rise gave way to the Barbados Ridge as a result of the thrusting of the oceanic crust beneath the Lesser Antilles Arc during the Cenozoic era. The resultant crumpling, thickening, and accumulation of the sedimentary rock that once composed the continental rise led to the formation of the Barbados Ridge, and thus to the underlying structure of, what is today, the island of Barbados (Chase and Bunce: 1969, p.1419).

The shaping of the surface of the island into the form in which we know it today was a more recent process. Coral reefs began to form over the Oceanic Series about 600,000 years ago. These reefs developed in shallow water as the rocks that today form the core of the island were uplifted. It was the elevating influence of tectonic pressure, resulting from the compression of Tertiary sediments along the junction of the Atlantic and Caribbean plates that caused the elevation of the reefs, and, as a result, approximately eighty-five percent of the island of Barbados is at the present day covered by an elevated Quaternary limestone cap (Bird: 1977, p.32).

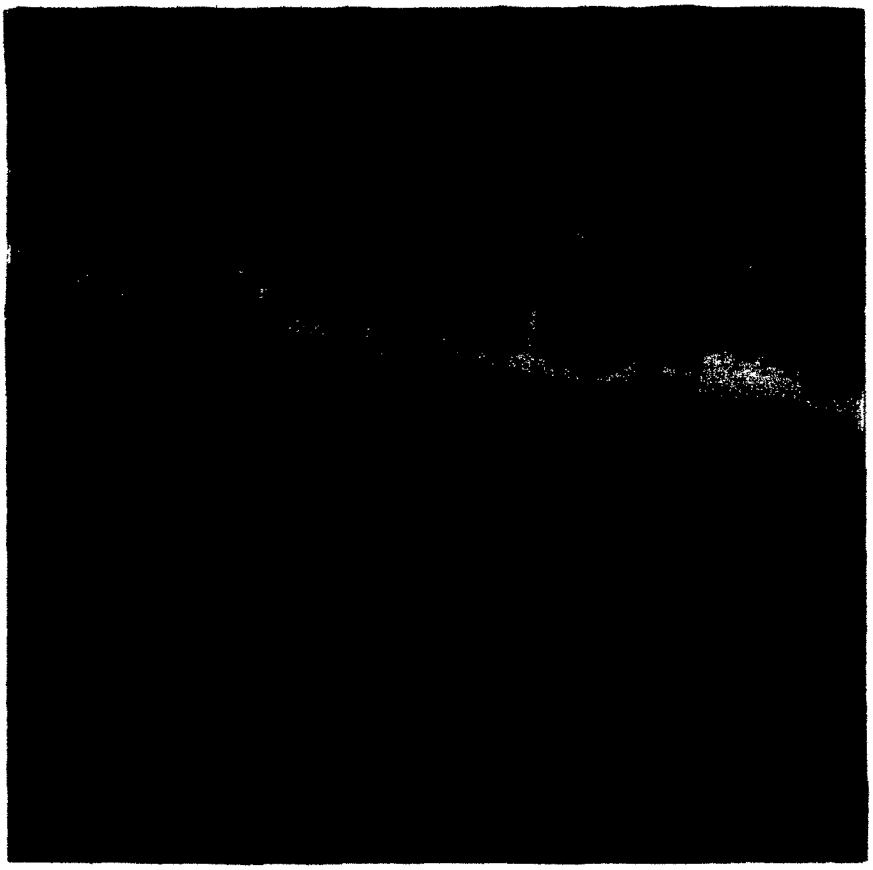


Figure 1.2 Aerial photograph illustrating reef formation near the town of Fitts, on the west coast of Barbados

The limestone attains a maximum thickness of one hundred meters (three hundred feet) in some areas, but has been completely eroded away in others. In particular, the Scotland District, on the island's northeast side, is devoid of coral. In this area, the underlying clay and sandstone of the original Scotland Series are exposed.

COLOURED PICTURES
Images en couleur

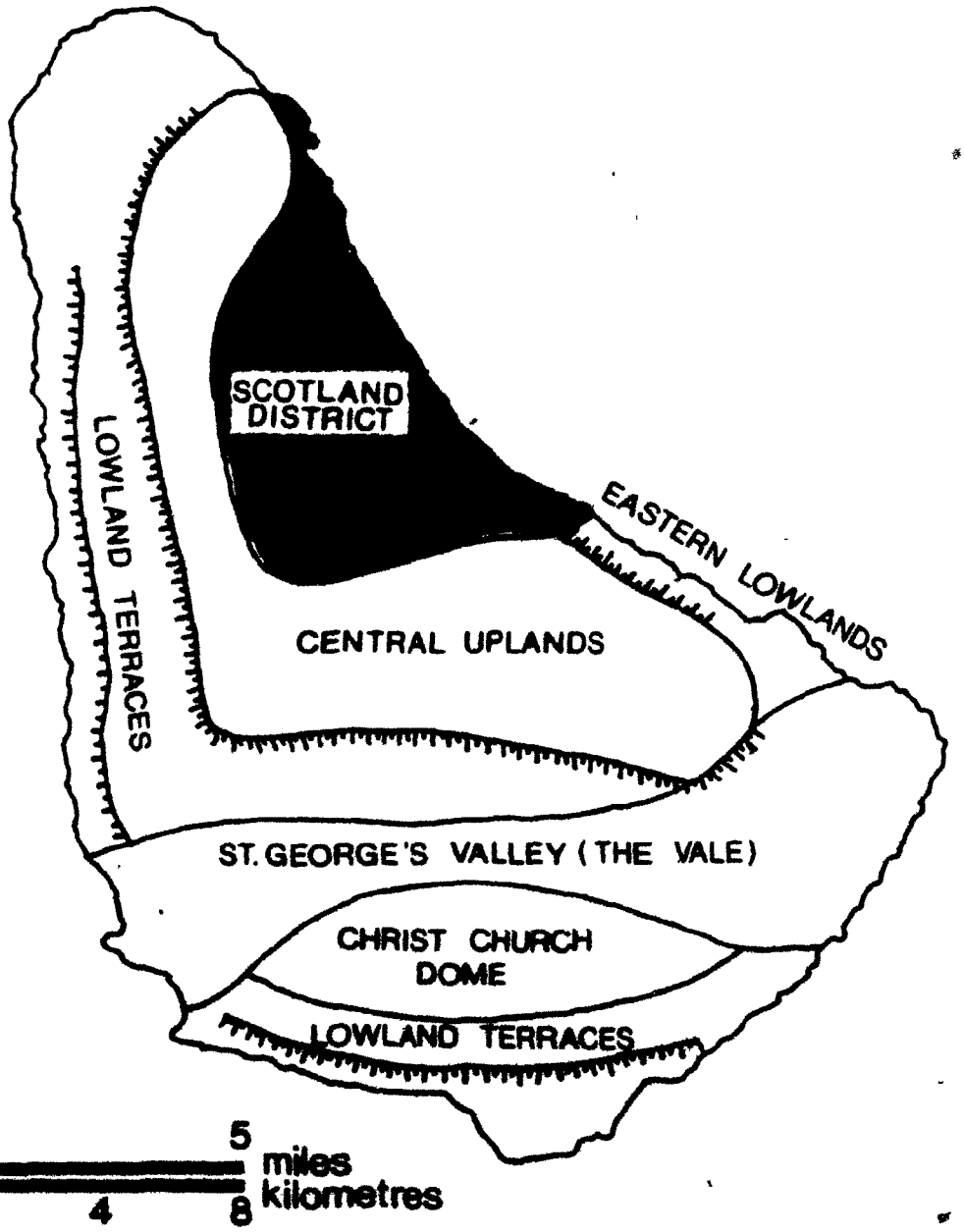
The Scotland District is the most rugged of the six physiographic regions of Barbados. In fact, aside from the amphitheatre-shaped Scotland District and its immediate surroundings, Barbados is a flat island, especially when compared with its volcanic neighbours. Figure 1.3 illustrates the six physiographic regions of Barbados.

From the highest point in the Central Uplands (Mt. Hillaby, 340 meters, 1,115 feet above sea level), the land descends north, south, and west in a series of gently sloping terraces. And although the Vale, Lowland Terraces, Eastern Lowlands and Christ Church Dome each represent distinct physiographic regions, all are characterized by gentle slopes. This observation is borne out by slope measurements recorded by Garnier, who found that only one percent of the total land area of Barbados has slopes of more than ten degrees, while almost seventy percent of the land has slopes of five degrees or less. Table 1.1 summarizes the degree and extent of the slope of Barbados' terrain.

Table 1.1 Degree and extent of terrain slope (Data Source: Garnier, 1975)

| Slope Factor | Percent Area |
|---|---|
| $<5^{o}$ | 68 |
| $5^{o} - 10^{o}$ | 31 |
| $>10^{o}$ | 1 |
| TOTAL: | 100 |

FIGURE 1.3 THE SIX PHYSIOGRAPHIC REGIONS OF BABADOS
(After Macpherson: 1974, p. 77)



West Coast Terraces:

Brief mention has been made of the terraces that line the west coast of Barbados. Given that they are the predominant landscape feature of the West Coast Study Area considered in this work, and that their study has resulted in a significant re-evaluation of theories on the physiographic evolution of the island as a whole, this section is devoted to a brief examination of their origin.

It was stated earlier that Barbados is covered by a Quarternary limestone cap of varying thickness. Along the west and south sides of the island, this cap takes the form of a series of raised coral terraces that run parallel to the two coasts.

Theories on the formation of these terraces fall into one of two groups, as defined by Mesolella (1969, p.252). The "erosionist" school believed that the entire coral cap formed contemporaneously prior to uplift of the island. Terraces were explained as being the result of wave abrasion and faulting acting on the cap as it was uplifted by tectonic forces. A theory closer to the present school of thought was presented by the "depositionists", who felt that Barbados had been periodically surrounded by individual reef tracts during its emergence.

Inconsistencies in each of these two schools of thought led Mesolella (1969, p.250-274) to conduct field investigations of some eight hundred natural and man-made

terrace exposures. The result was that, although he did accept the basic view of the depositionists that "...the terraces of the coral cap represent a succession of uplifted reef tracts" (1969, p.253), Mesolella's model of terrace formation was to develop further following closer examination.

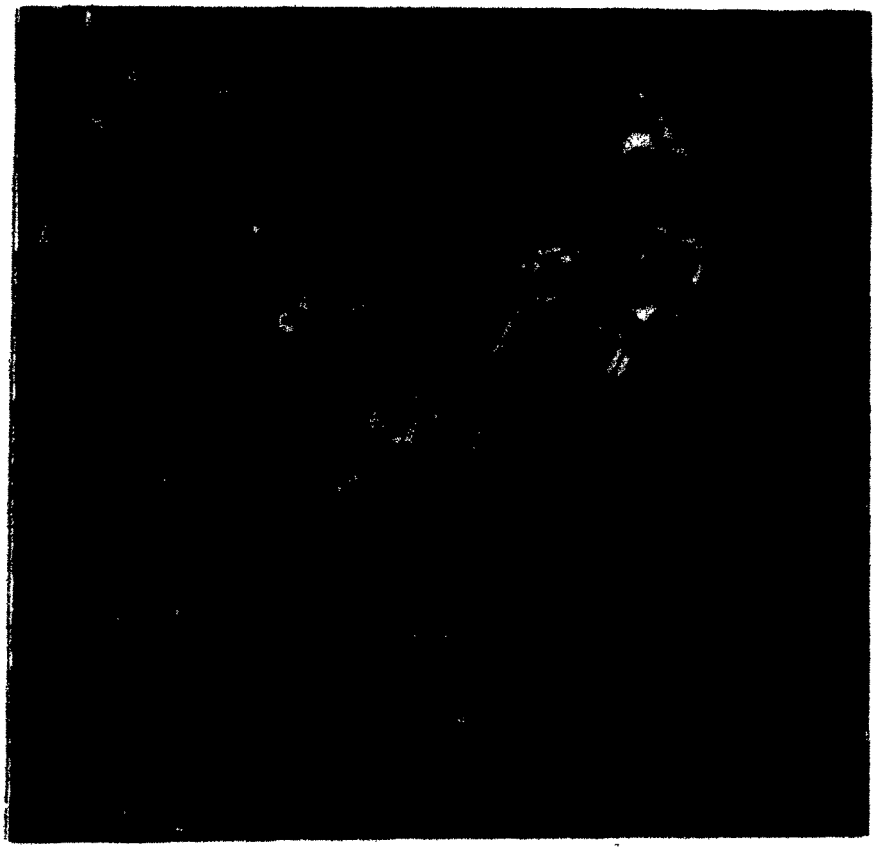


**Figure 1.4** Aerial photograph illustrating terrace running parallel to the west coast

COLOURED PICTURES
Images en couleur

Radiometric dating of the coral terraces using the thorium-230 / uranium-234 method indicates that the corals from the lowest terrace are approximately 82,000 years old, while those of the third terrace have a radiometric age of 125,000 years. These dates show good correspondence with periods of high eustatic sea-levels during the Tertiary. As a result of this correlation, Mesolella concluded (1969, p.254) that the elevated coral terraces found in the West Coast Study Area are "a product of world-wide eustatic changes of sea level...superimposed upon an emerging land mass".

The way in which these terraces formed profoundly affected the development of the slope, soil and drainage patterns of the land in the West Coast Study Area. These parameters, in turn, are the most significant factors in the land capability / land use relationship which is studied in this work.

Soils:

Detailed descriptions of the soil associations of the West Coast Study Area are included in a later section. The following overview of soil types on Barbados is presented as a general introduction.

The soils of Barbados can be divided into two broad categories. The first category is composed of those soils that have developed over the limestone cap. The second category consists entirely of the soils of the Scotland

District. We shall concern ourselves here with the first group only, as it covers eighty-five percent of the island and incorporates all of the soils found in the West Coast Study Area.

The 'coralline' soils of Group One are mainly clay soils, having evolved through a series of processes - the erosion of the limestone cap and the addition of ash from periodic volcano eruptions on neighbouring islands. These falls of ash have contributed greatly to increasing the fertility of Barbados' soils.

The coralline soils, while almost all alkaline in nature, can, nonetheless, be divided into nine associations. Four of these associations are found in the West Coast Study Area and are described briefly below.

The **Black Association** is composed of dominantly immature smectoid (montmorillonitic) clay soils overlying coral limestone. This association is found over 14.29% of the West Coast Study Area. Four associates - Normal, Shallow, Very Shallow and Poorly Drained - are present to varying extents.

The most common soil association in the West Coast Study Area is the **Grey-Brown Association**, found over 75.49% of the region. Like the Black Association, the Grey-Brown Association is dominantly smectoid in nature, although it may contain as much as 25% kandoid (koalin mineral) clay. The Grey-Brown Association is more mature than the Black Association, being found at slightly higher

elevations and in somewhat more humid regions. Four associates are present to varying extents in the West Coast Study Area. These are Normal, Shallow, Very Shallow and Poorly Drained. Furthermore, two variants, the Leeward Coast Variant and the Sandy Variant should be noted. Each of these in turn has both Normal and Shallow Associates.

The Coastal Association is the least common of the four soil types found in the West Coast Study Area, covering a mere 2.55 percent of the region. The Coastal soils cover other thin immature soils developed over coral limestone in areas of low and poorly distributed rainfall. Only one of the six associates of the Coastal Association is found in the West Coast Study Area. In fact, this associate is not strictly a member of the Coastal Association but was included in this category because it closely resembles the other members. In profile this soil is very similar to the Grey-Brown Association, except that it has a high content of coral grit distributed uniformly throughout the profile.

A final soil group worthy of mention is the Red Sand Association. This soil type is composed of light, sandy material and forms a thin strip parallel to the terraces that line the west coast. This association is relatively immature, shallow, and generally unproductive. Normal and Shallow associates are present. The Red Sand Association is found over 7.6 percent of the West Coast Study Area.

Rainfall/Climate:

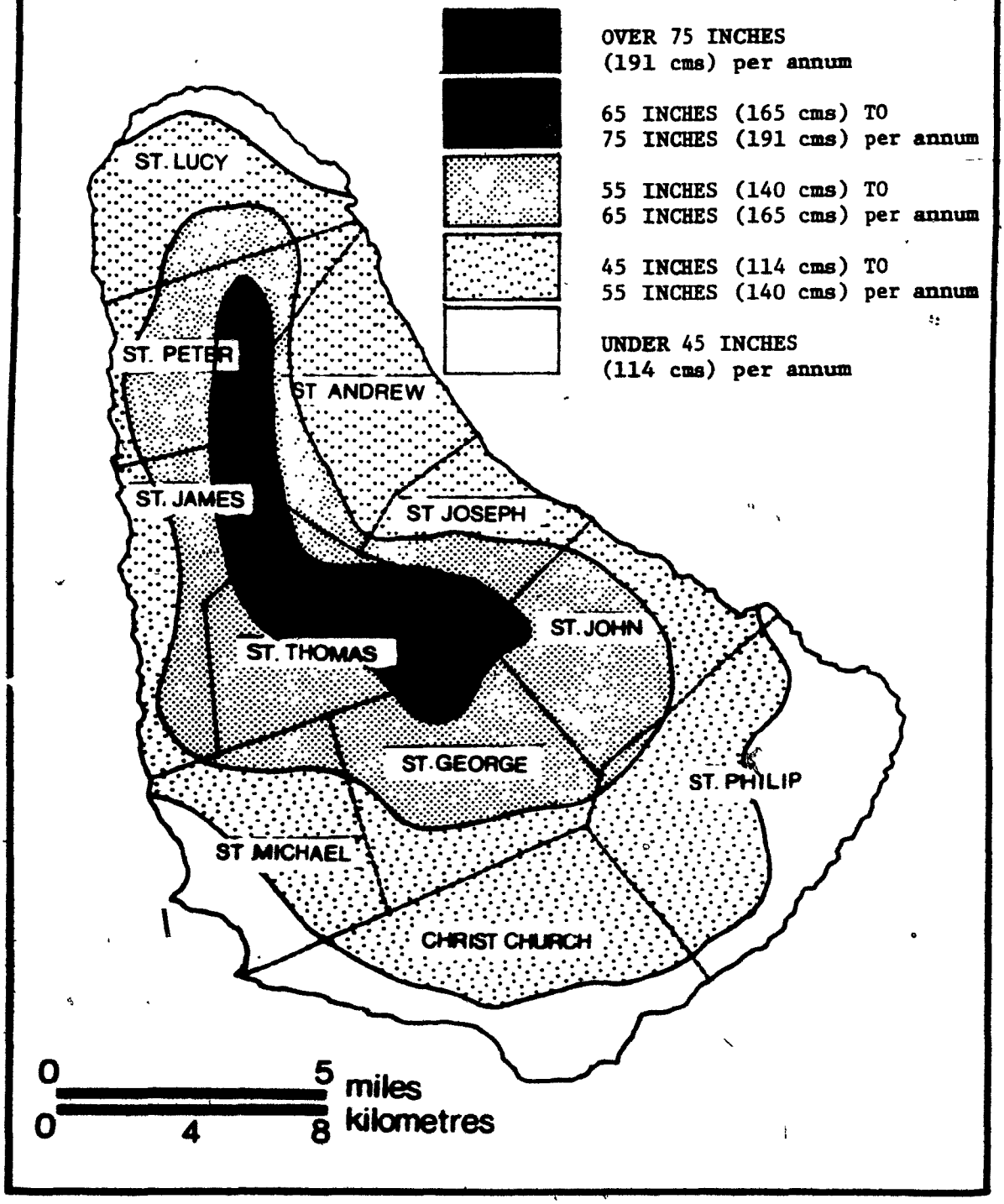
Barbados has a Maritime Tropical climate with a variable rainfall regime. In fact, the 'average annual rainfall' statistic is one of the least meaningful descriptors of Barbados' climate. Rainfall on the island is extremely variable, whether considered areally, annually, or seasonally. Figure 1.5 illustrates the extraordinary areal variation in annual rainfall for the island as a whole.

An average annual rainfall difference in excess of 30 inches (76 centimeters), from less than 45 inches (114 centimeters) per annum to more than 75 inches (190 centimeters) per annum, is a vast range for an island that is a mere 430 square kilometers (166 square miles) in area. The average annual rainfall statistic is equally variable in an absolute sense. Table 1.2 compares a wet and dry year on Barbados in terms of annual rainfall at two locations.

Table 1.2 Annual rainfall at two locations
(After Vernon and Carroll: 1965, p.4)

| Area | 1929 (Normal Year) | 1930 (Dry Year) | 1938 (Wet Year) |
|---|---|---|---|
| High Rainfall Area (Lion Castle) | 198 cms | 141 cms | 317 cms |
| Low Rainfall Area (Codrington) | 115 cms | 75 cms | 215 cms |

## FIGURE 1.5 ANNUAL RAINFALL
(After Macpherson: 1974, p. 78)



The seasonal distribution of rainfall is generally consistent year to year, there being a dry season between January and May and a wet season from June to December. It is usual for about 75 percent of the annual precititation to fall during the wet season. Even these seasonal variations do not represent a hard and fast rule, however. While there is a distinct dry seasons in the lowlands, the higher regions of the island seldom experience a pronounced variation in seasonal rainfall.

A final rainfall anomaly worthy of mention is the pattern of rain "streets" that occurs mainly in the West Coast Study Area. Wilson (1980, p.19) describes "a pattern of rainfall characterized by parallel east to west lines of rain showers separated by clear sky...(occurring) simultaneously over a ten mile section of the coast, usually at night". The extent to which this rainfall pattern has influenced the land systems or land use patterns of the west coast is not yet known.

Unlike rainfall, humidity and temperature are relatively predictable elements of the Barbadian climate. Humidity averages 71 percent for the dry season and 76 percent for the wet season. And while temperatures have been known to fall below 16° C (60° F) or rise above 32° C (90° F), these are both rare occurrences. Temperatures normally range from 23° C (74° F) to 30° C (87° F) during the wet season, with lows and highs

during the dry season being about one or two degrees Centigrade (three or four degrees Fahrenheit) lower (Vernon and Carroll: 1965, p.4).

In conclusion, the climate of Barbados as a whole, and of the West Coast Study Area in particular, is relatively stable and consistent. The major exception to this generalization is rainfall. Rainfall has played a major role in shaping the soils of the West Coast Study Area. Furthermore, variations in average annual rainfall in excess of fifty centimeters (twenty inches) in the West Coast Study Area are significant in terms of crop choice and productivity. As a result, rainfall is considered in this work to be a significant land capability variable and is compared with land use change data to determine its role in shaping land use patterns in western Barbados.

## CHAPTER TWO: THE HISTORY OF LAND USE CHANGE TO 1950

The history of Barbados is a great story. Rich with tales of exploration, settlement, war, the slave trade, hurricanes, and a cast of hundreds of colourful characters. Interesting as they are, however, these subjects are best read about in detail in history books. In the review of Barbadian history presented in the next few pages, the emphasis will be placed on those events that played a part in shaping the land use pattern of the island. In other words, the intent is to view history through a geographer's eyes and to concentrate on those dates and events which had a significant impact on changing the landscape of Barbados between the time of first settlement and the year 1950. It is hoped that such a review will provide the background necessary to understanding the land use situation as it had evolved up to the beginning of the 1950-1980 study period chosen for this work.

This historical overview is presented in two sections: (1) first settlement to 1650, and (2) 1650 to 1950.

### First Settlement to 1650:

Until recently, most authors on Barbadian history (Lynch: 1972, p.13; Tree: 1972, p.9) believed that it was the Arawak Amerindians who were the first people to come to Barbados. Hoyos (1978, p.7), on the other hand, claims that

it was in fact the Barrancoid people who established the first permanent settlement on the island, at about the time of Christ. Such settlement predates the arrival of the Arawaks by at least eight hundred years. Artifacts have been found which seem to substantiate his claim that the Barrancoid people lived on Barbados for some six hundred years. Although the Barrancoids introduced agriculture to Barbados, the extent to which the natural landscape was altered is thought to be negligible.

Two hundred years after the Barrancoids deserted Barbados, the Arawaks arrived. It is known that the Arawaks were also an agricultural society. The generally productive soil conditions enabled them to cultivate such crops as cassava, maize, pawpaws, peanuts, squash, guavas, pineapples, tobacco, cotton, and berries of various sorts (Hoyos: 1978, p.4). The Arawaks lived on Barbados for five hundred years before being driven out by the pugnacious and cannibalistic Caribs.

The Caribs inhabited Barbados for over three centuries. They, too, practiced agriculture, but were less adept at farming than the Arawaks, being a nomadic people (Hoyos: 1978, p.9). It is unlikely, therfore, that they altered the landscape of the island to any great extent.

The next group to visit Barbados was probably the Spanish Cedulla of 1511. The Spanish had little interest in the island, as it was devoid of mineral wealth. It is possible, however, that the Spanish took the Caribs away

from Barbados, using them as slaves in their mines in Puerto Rico (Tree: 1972, p.9).

The first recorded discovery of Barbados by Europeans was the landing of Pedro a Campos in 1536. Campos was a Portuguese navigator who left hogs to breed on the island so that shipwrecked mariners would have a supply of meat (Starkey: 1939, p.51).

British colonization of Barbados began with the arrival of settlers on the "William and John". The eighty men who arrived in February, 1627 found an uninhabited island that was heavily forested right to the shore. Watts (1963, p.29) concluded from extensive reading of early reports of Barbadian vegetation that the early settlers found "a tropical forest which covered the greater part of the island", and that, "the natural vegetation had been largely untouched by the hand of man at the time of English colonization" (Watt: 1963, p.28). It seems likely that three species of mangrove, (Rhizopora mangle, Laguncularia racemosa, or Avicennia nitidia), manchineel (Hippomane mancinella), wild fig (Ficus laurifolia), palmito (Euterpe globosa) and locust (Hymenia courbaril) trees were all flourishing on Barbados when the first settlers arrived (Watts: 1963, p.32-36).

Within less than four years, some alteration of the landscape had taken place. Watts (1963, p.30) stated that "...it is certain that considerable interference with the

vegetation by man had already taken place (by 1631)". Sir Henry Colt, an early settler, has left a contemporary (1631) description of the impact of burning and its effect on the forest - "...here and there a great timber tree half burned, in another place a rafter singed all black, there stands a shrub of a tree above two yards high, all the earth covered black with cinders" (Watts: 1963, p.30). Further evidence that the British were burning and cutting down the forests of Barbados shortly after their arrival is offered by Joannes de Laet, who wrote in 1630 that "Les Anglais...(ont) coupé les bois pour y cultiver du tabac" (de Laet: 1640, p.30). As fast as the natural forest was being cut down, the settlers planted fruit trees and other crops. De Laet (1640, p.30) reported that the English "...ont porté des autres Isles des arbres fruictiers, comme orangers et autres".

The complete clearing of the forest was necessary for the proper and orderly planting of crops, although it was possible, and indeed necessary, to plant some crops between felled trees while awaiting complete clearing of the land. Richard Ligon, a visitor to Barbados in the late 1640's, described the way in which much land was first put into service:

> At the time we came first there we found both potatoes, maies, and bonavistas, planted between the boughes, the trees lying long upon the ground; so far short was the ground then of being cleared (Ligon: 1653, p.9).

For the first half of the 1630's, nearly 2,000 settlers worked small holdings themselves, growing maize, potatoes, bonavista, cassava, yams, plantains, bananas, oranges, lemons, limes, melons, and pineapples for local consumption; as well as cotton, tobacco, and indigo for export to England (Tree: 1972, p.14).

It was in 1637 that a Dutchman arrived in Barbados from Brazil, bringing with him a number of sugar cane plants. He grew the first plants on the property of Colonel William Drax, in the Parish of St. John. This simple action, the result of one man's work, led in time to the most significant land use change in the history of Barbados; a change that has never been reversed.

As soon as it was realized that the soil and climate of most of Barbados was conducive to sugar production, the amount of cane planted on the island was rapidly increased. Tree (1972, p.22) has described the consequences:

> In a few years the aspect of the land had completely changed. The forests had been cut down and the smallholder was gradually being eliminated. By 1655 there were 745 plantations (on Barbados).

Innes (1967, p.79) has described the usual size and system of land tenure that evolved as plantation owners forced out the small landholders:

> The landscape of the early period seems then to have been rapidly transformed from one of thick woods to one of estates, held in a loose form of lease-hold from the island's proprietor, the Earl of Carlisle. The units seem to have been estates

> of about 100 acres average size, though sub-division of these to subtenants was common, many of these subtenants being indentured servants of the estate operator, rather than free men.

Tree (1972, p.30) has confirmed that rising land values and the rapid expansion of the plantation system resulted in the almost complete clearing of the island's forests by the mid 17th century:

> By 1650 the island had pretty well taken on the shape in which we see it today. With the exception of Turner Hall Woods, the forests had been cut down, and sugar reigned supreme.

Thus, in less than twenty-five years, the English had cleared Barbados of almost all of its forest cover and had established a plantation system based on sugar cane. The entire colonial economy would soon be geared to the production of this one crop. As a result, little would change on Barbados in terms of land use in the next three hundred years.

1650 to 1950:

Although the three hundred year period from 1650 to 1950 saw little change in land use in Barbados, a review of these three centuries is interesting in terms of changes in both productivity and land ownership / distribution. Soil exhaustion, environmental disasters, the slave trade, changing foreign and domestic government policy, and technological advances all had profound influences on both

the decision to maintain a monocrop sugar economy, and the way in which land was managed under that economy. These historical events influenced the establishment of the land management system that was being practiced at the beginning of the 1950-1980 study period considered in this work.

1650 to 1700: At first the English had difficulty with sugar production. Ligon (1650, p.19) comments that "the secrets of the work not being well understood, the Sugars they made were very inconsiderable and little worth for two or three years". But frequent visits by Dutch experts, combined with trips to Brazil by wealthy plantation owners who were anxious to learn the trade, quickly paid dividends in the form of increased production. In fact, by the time Ligon left the island in 1650, "they were much better'd; for then they had the skill to know when the canes were ripe, which was not till they were fifteen months old; and before they gathered them at twelve" (Ligon: 1650, p.20).

The Civil War in England during the 1640's saw the Dutch, rather than the British, develop the economy of Barbados. Dutch ships transported Barbadian agricultural products such as sugar, tobacco and cotton to the Continent, returning to Barbados with important tools and other commodities necessary to the further development of the island. This period ended with the Navigation Act of 1650, which prohibited foreign ships from trading with British colonies. Tree (1972, p.34) quotes Bryan Edwards as writing

(in The History of the West Indies, 1819) that the Navigation Act, "however essential to the interests of the Empire at large, is a memorable epoch whence we may date the rapid decline of her (Barbados') population, and consequently her strength and opulence".

Edwards' conclusion seems to be an over-simplification of the situation, however, because the statistics indicate that the total population of Barbados did not experience a "rapid decline", although there was a significant decrease in the number of whites living on the island. Although it is probably true that the Navigation Act exacerbated the problem of smallholders being forced out by the accumulation of land in the hands of a wealthy minority, resulting in the establishment of large plantations employing black slaves, this resulted, in the short term at least, in what Tree (1972, p.40) has called "...the apex of Barbados' prosperity".

1700 to 1800: This late 17th century prosperity was not to last for long. A number of factors combined to bring about a decline in sales of Barbadian sugar in the 1700's: (1) France, Britain, Spain, and the North American Colonies were all at war for extended periods during the 18th century, disrupting trade. The movement of both sugar and slaves was affected; (2) the French islands of the Caribbean began sugar production on relatively recently cleared land, supplying their own needs; (3) the Dutch began to develop the sugar industry in Java, which was able to

produce sugar at low cost, and, finally; (4) a Prussian chemist by the name of Margraf developed an inexpensive process to extract sugar from beetroot (Tree: 1972, p.43).

It was already becoming clear to the Barbadians that there were serious problems in basing their economy on a single crop that was dependent on favourable international markets. Thus, the Barbadian planters were frustrated not by an inability to produce enough good sugar, but by an unstable international situation which severely curtailed trade with their markets. A more serious, but as yet unforseen crisis, a decline in sugar quality and production, was about to face the island during the second half of the century.

By 1750, the majority of cleared land on Barbados had been in service without proper care for so long that it was no longer capable of high yields. The combination of extensive and intensive farming of the land was beginning to take its toll. Starkey (1939, p.94) quotes the 1747 Governor's Report to the Board of Trade:

> The whole island is cultivated by the Inhabitants in some manner or other, except such parts as are worn out or Impoverished, that the labour of manuring the same would not be recompensed, of which sort there are several thousand acres...

It is hardly surprising that the rich soil of Barbados was beginning to show signs of exhaustion due to overcropping. By this time the land had been cultivated for over a century by a group of people that was more concerned

with short-term profit than long-term planning. Bridenbaugh (1972, p.10) described the 'get-rich-quick' mentality of the original English promoters of Barbados:

> Desire, verging on greed, for land advancement, rank and power, as well as desire to participate in the recently uncovered opportunities to exploit tropical soils for the production of exotic staple crops, animated the promoters of the first permanent English colonies begun at St. Christopher in 1624 and Barbados in 1627.

This attitude, put into practice for over one hundred years, was now beginning to deprive Barbados of its only wealth, its soil. To add to their problems, Barbadian sugar producers were still facing an international trade situation that was uncertain at best. By the late 1700's, the trade problem had evolved into a crisis.

Links with the outside world were almost totally severed in the 1770's and 1780's by the American War of Independence and its aftermath. Severe curtailment of trade, which resulted in a serious food shortage on Barbados, coincided with both the reduction in soil productivity already described, and a devastating hurricane in 1780. Poyer (1801, p.449) described the disastrous effect the storm had on local agriculture: "those luxuriant fields, which the day before teemed with nature's most valuable productions, now resembled the dreary, inhospitable regions which had never yielded to the arts of cultivation".

The 18th century, which had begun as one of the most prosperous periods in Barbados' history, ended with the island in ruins. Poor soil, a monocrop export economy that was vulnerable to foreign trade problems during an unstable era, and the almost complete destruction of the sugar crop by a hurricane in 1780, all combined to drastically reduce sugar exports. In 1798, Edwards (p.90) provided an indication of the decline in productivity, noting that whereas "in 1761 the average crop of sugar was 25,000 hogsheads", the average export from 1784 to 1786, "did not exceed 9,554". These low export figures, and the problems that caused them, were painting a bleak picture of the future for the island's inhabitants, as they prepared to enter the 19th century.

1800 to 1900: If ever there was a time for a major land use change on Barbados, the beginning of the 19th century was it. Foreign trade problems, soil exhaustion, and severe food shortages throughout the latter half of the 1700's made the monocrop sugar economy of that era look rather uninviting, in retrospect. All that was needed was the opportunity to start again, with a different land use plan. That opportunity was provided by the hurricane of 1780.

> The loss of human life was estimated at 4,326, and the loss sustained by the colony at 1,320,564 pounds Sterling. Most of the livestock and cattle perished; the canes, corn and ground provisions were totally destroyed, and famine again

> threatened the survivors (Tree: 1972, p.59).

There is, however, no evidence of any serious consideration of such a change. Only one reference to the idea of changing Barbados' dependence on sugar has been found. According to Tree (1972, p.88), an Englishman by the name of Joshua Steele set out shortly after the hurricane of 1780 to see how he could make social and economic improvements through diversification of the island's economy. Steele was apparently elected to the Barbadian Assembly, which had no interest in his plans. Tree (1972) makes no further mention of Steele, other than to say that he set up a society to further promote his ideas. However, given the strengthening of the commitment to sugar plantation agriculture that occurred throughout the next century, it is safe to assume that Steele was less than successful.

The fact that Barbados was not only to maintain, but further expand its sugar plantation economy during the 19th century is an indication of both the confidence of the plantation owners and the extent to which Barbados was controlled by London. A 430 square kilometer (166 square mile), agriculturally self-sufficient territory in the Caribbean would be of little use to either the British, who had by this time developed a national sweet tooth, or the wealthy Barbadian land owners, who had left England to make their fortunes, not simply subsist on a tropical island.

The result was that plantation owners decided to replant sugar following the hurricane, and the Imperial government elected to offer them financial support. Davy, writing in 1854 (p.112), described the more careful land management practices that had by that time come into common use as a result of the soil exhaustion problem of the late 1700's:

> Three objects may be considered common and directing ones, on which the system more or less depends, viz., first, the production of as much sugar as possible, for profit; secondly, the preserving of a certain extent of land in pasture, for the support of livestock; and, thirdly, the growing of "ground provisions" consisting of roots and grain, the yam and sweet potato, the maize or indian corn or others; some selected as rotation crops, some, especially the grain...in aid of forage.

By the mid-1800's, about 100,000 of Barbados' 106,000 acres were under some form of cultivation. Approximately half of this acreage was planted in sugar in any given year (Davy: 1854, p.112). Productivity per acre was increasing yearly, as more farmers adopted the practices of crop rotation and fertilization described above. As early as 1837, Sturge and Harvey (p.152) were able to report on the improved productivity of Barbados:

> Paradoxical as it may seem, it is yet evident, that it owes its superior wealth to its exhausted soil and dense population. "By repeated croppings, the soil (of Barbados) had become less than half a century since, so much worn, as to be almost unproductive in the sugar

> cane; but by the substitution of other crops, particularly the Guinea corn, a system of soiling and tethering cattle was introduced, which has not only been the means of retrieving the lands, but has, perhaps, made them more productive than ever".

Just as the plantation owners were recovering from the near loss of their soil, they were faced with the near loss of their labour force, as the English government finally put an end to slavery. The abolition of the slave trade, which officially occurred in 1808, did not actually lead to the emancipation of slaves in Barbados until 1834. Surprisingly, though, the abolition of slavery did not result in the dissolution of the plantation system. Nor did it result, to any great extent, in a change in land use on the island (although land distribution would ultimately be affected by this historic event).

The plantation system in Barbados survived the end of slavery mainly because the emancipated slaves could not find land of their own. Lowenthal (1957, p.453) believes that "...no vain experimentation with new commodities was found necessary...because...the Negroes remained on the estates; they had no where else to go, there was scarcely an acre of land free, they must work for the sugar planters or starve". So little affected was the availability of labour, in fact, that the four year period immediately following emancipation saw an actual increase in the production of Barbados sugar

(Hoyos: 1978, p.125). The domestic situation, then, was not a hinderance to plantation sugar production.

In the late 19th century, the island once again fell victim to external pressures. This was not surprising, because sugar was still being produced by slave labour in the East Indies, Cuba, Brazil, and Louisiana; and European countries were producing beet sugar. The price of Barbadian sugar was no longer competitive. Paradoxically, the Barbadian solution to this problem was the same as it had been at the time of the economic crisis of the 1780's - cane production was increased. Hoyos (1978, p.137) reports that cane acreage doubled between 1838 and 1852. Not only was sugar now being grown more extensively, it was also being grown more intensively. Chemicals and green manure were employed for the first time. Mulching became a widespread practice, and fields were "jobbed-out" weekly to labourers who would weed them. Technological advancements, including steam power and the plough, were becoming accepted. These improvements in technique and technology enabled the plantation system to survive, albeit precariously, for the next twenty years.

By the late 1870's, however, the sugar industry of the West Indies was in such dire straits that a Royal Commission was established to investigate the situation. The findings of the Commission emphasized the seriousness of the industry's problems.

> Sugar, rum and molasses constitute the principal items of export, and represent in fact 97 to 98 percent of the total exports of the produce of the colony. Barbados is, therefore, wholly dependent on the cultivation of sugar (West India Royal Commission Relating to the Sugar Industry: 1898, p.97).

This was a most serious situation, given that the Commissioners' view of the sugar industry in the West Indies was that a crisis would be reached in a very few years. The Report (p.17) predicted that the crisis would be characterized by the abandonment of the less productive sugar plantations, a process which had already begun.

The abandonment of plantations did, in fact, start to become more commonplace in the latter half of the 19th century. With abandonment came financial ruin and the end of a dream for the plantation owner. The landless peasant, on the other hand, correctly saw this as an opportunity to purchase a small plot. Davy (1854, p.148) noted that "...the coloured race have a great desire to possess land" and he described (p.159) the agricultural success that resulted from their determination. "The culture of the small properties is remarkable, ...there may be seen growing side by side or intermixed, almost all the different vegetables which are in request in the island".

Thus, the severe financial problems of the plantation owners, combined with a large landless population that was now free to own land, resulted in the beginning of a shift from large scale sugar production to the small scale farming

of provisions. This shift, which took place over the next fifty years, did not lead to the dominance of small-scale agriculture in the Barbadian economy, however. The authors of The Report of The West India Royal Commission Relating to the Sugar Industry were perhaps prophetic when they wrote in 1898 that "...it is not impossible for the two systems, of large estates and peasant holdings, to exist side-by-side with mutual advantage" (p.18). This "side-by-side" co-existence of plantations and peasant holdings was to evolve throughout the first half of the 20th century to become the most distinctive characteristic of the Barbadian landscape by the beginning of the 1950-1980 study period considered in this work.

1900 to 1950: The beginning of the 20th century saw yet another external force alter Barbadian land use. The availability of work on the construction of the Panama Canal and in North American cities led many Barbadians to leave the island in search of employment. Lowenthal (1957, p.455) has stated that at least 70,000 Barbadians left the island between 1904 and 1921. Most of those who left sent money home, in order that relatives could purchase land. Mbogua (1961, p.24) has reported that during the twelve year period between 1903 and 1914 the breaking up of plantations by speculators, combined with the availability of "Panama Money" led to the "large scale" selling of small plots to peasants.

Yet another period of serious economic hardship for plantation owners occurred with the fall of sugar prices following the First World War. In particular, the years 1921 to 1927 saw a large sell-out of plantations to the peasants. Peasants continued to purchase small plots of land from dissolved plantations throughout the first half of this century.

A boom in the purchase of peasant holdings recurred between 1941 and 1946. As with previous rapid increases in peasant holdings, this period of extensive buying occurred "in inverse relationship to the prosperity of sugar cane on the world market, and in direct relation to the volume of migrant labour abroad" (Griffith: 1973, p.51). In this case, labourers from Barbados were emigrating to the United States to assist the War effort. The money they earned, combined with the swelling of the peasant population on their return, contributed to the increased purchases of peasant plots. The extent of these purchases is documented in Table 2.1, which illustrates the rise of peasant property ownership in Barbados between emancipation and the beginning of the 1950-1980 study period.

A second trend paralleled the purchase of land by Barbadian peasants following emancipation in 1834. That was the establishment and expansion of independent villages, which began almost immediately following the abolition of slavery, and has continued to the present day.

The development of peasant villages paralleled the purchases of small plots in a psychological, as well as an historical sense, being an attempt on the part of the peasants to achieve a degree of freedom from both physical and economic slavery:

> ...in order to escape the economic tyranny of the planters, the labourer had to be free to offer his services at his own discretion... The acquisition of land and the establishment of peasant villages, therefore, were the means by which the ultimate end (to slavery) was sought (Griffith: 1973, p.54).

Table 2.1 Number of peasant holdings 1840-1946

| YEAR | NUMBER | DESCRIPTION | SOURCE |
|---|---|---|---|
| 1840 | 1,307 | Legally Owned | Prescott, 1967 |
| 1851 | 3,537 | Freehold | Henshall, 1964 |
| 1851 | 3,537 | Freehold | Prescott, 1967 |
| 1915 | 14,000 | Under 5 acres | Brack, 1964 |
| 1915 | 14,000 | Under 5 acres | Henshall, 1964 |
| 1915 | 14,000 | Under 5 acres | Prescott, 1967 |
| 1929 | 18,000 | Under 10 acres | Brack, 1964 |
| 1929 | 18,000 | Under 10 acres | Henshall, 1964 |
| 1929 | 18,002 | Under 10 acres | Prescott, 1967 |
| 1935 | 18,039 | Under 10 acres | Prescott, 1967 |
| 1939 | 18,805 | Under 30 acres | Henshall,1964 |
| 1942 | 18,805 | Under 10 acres | Prescott, 1967 |
| 1946 | 30,725 | Under 10 acres | Brack, 1964 |
| 1946 | 30,752 | Under 10 acres | Henshall, 1964 |
| 1946 | 30,752 | Under 10 acres | Prescott, 1967 |

Barbados, in 1950, was an island quite different from the one discovered by the British three centuries before. It had evolved first from a tree-covered, uninhabited island to a small, self-sufficient colony. Sugar cane and the beginning of plantation agriculture then eliminated the smallholder and led to the establishment of a small group of wealthy land owners who controlled thousands of landless slaves. Economic hardship ultimately resulted in the collapse of the weaker plantations, enabling the emancipated slaves to purchase land. By 1950, the island had evolved into a mosaic of sugar plantations, small peasant holdings, and independent villages.

It is likely that the Barbados of today would resemble the way the island looked in 1950, had it not been for two major external influences. Technology and tourism, and the new prosperity that came with them, were about to change Barbadian land use faster than at any time since the clearing of the forests three hundred years earlier.

# CHAPTER THREE

# LAND USE / LAND CAPABILITY HYPOTHESES

## Section One: Introduction

Having outlined the geography and history of land use change in Barbados as a whole in Chapters One and Two respectively, it is now possible to present the research hypotheses of this work. This chapter is devoted to the formulation of hypotheses regarding anticipated changes in land use / land capability relationships for western Barbados. It begins with a description of the location, size, shape and sub-divisions of the West Coast Study Area that was defined for the purposes of this research.

Hypotheses relating to changing land use / land capability relationships naturally have their basis in an understanding of the physical, economic, and legislative influences that combine to determine land use patterns. The formulation of hypotheses in this chapter is, therefore, performed in conjunction with an examination of the relationships between land use and each of the physical, economic and governmental controls which have exerted an influence. Thus, following a description of the West Coast Study Area in Section Two, the soil types, soil depths, terrain slopes and rainfall statistics of the region are examined individually in Section Three. These physical parameters are described with reference to their effect on land use potential, in order that optimum land use / land

capability relationships can be defined.

Land capability, as defined by the basic inherent physical qualities of the land, occasionally results in an absolute restriction of land use change options. More frequently, however, a number of options exist. In western Barbados, land use change in areas where a number of possibilities exist is always a product of economic and/or governmental impetus. For the purposes of this work, a land use change resulting from an economic impetus is defined as one which is primarily motivated by profit considerations. The building of hotels and golf courses and the profitable transformation of land use out of cane production and into market gardening following the fall of sugar prices are all examples of economically induced land use changes. The fourth section of this chapter deals with economic influences on land use change. Emphasis is placed on the concepts of land scarcity and proximity.

If land capability and the profit motive were allowed to interact to induce land use change without restrictions, the land use pattern of western Barbados would be significantly different from what it is today. Since the early 1970's, however, the government has sought to control land use change in order to maintain optimum land use / land capability relationships. Government involvement in influencing land use change has taken two forms: (1) government induced land use change, and (2) government regulation of economically induced land use change.

Government induced land use change is defined as any transformation of land use that is made by a government agency working on behalf of the public and not motivated by considerations of economic profit. Examples of government induced land use change include the expropriation of land for the building of public housing and the designation of national parks for the enjoyment of the public. Government regulation, on the other hand, includes laws that prohibit development on agricultural land and restrict hotel construction to designated sections of beach. The fifth section of Chapter Three outlines government concerns about uncontrolled land use change and describes the measures taken to ensure that maximum benefit is achieved for the people of Barbados from changes in land use.

By this point in Chapter Three, the inter-relationships between the physical, economic and governmental controls on land use change will have been fully described and can be merged into the twenty research hypotheses which will be tested in later chapters. In formulating the hypotheses, five aspects are considered: (1) the most likely situations for land use change, (2) the most likely sequence of change (i.e. Land Use Type 'A' to Land Use Type 'B'), (3) the decade in which the changes are expected to have occurred, (4) the most likely reasons for the change (i.e. the motivation for the change and in particular, the extent to which land capability was either a consideration or a determining factor, (5) the anticipated percentage change in land use during the period of study.

## Section Two: The West Coast Study Area

The West Coast Study Area is a roughly rectangular region, extending from the St. James - St. Michael parish boundary on the south to the St. Peter - St. Lucy boundary on the north. It is approximately 15.5 kilometers from north to south and averages about 2.6 kilometers from east to west. It has a precise area of 38.95 square kilometers (3,895 hectares). The coast forms the study area's western boundary, while its eastern extremity is marked by Highway 2. The rationale for the use of this region as a land use change study area is explained below.

The high degree of detail sought with respect to land capability and land use change necessitated the choice of a relatively small study area. A further requirement was that the area must be dynamic with respect to land use change. Furthermore, since the findings need to be extrapolated to the whole island, it was important to select an area where the land use changes were representative. The West Coast Study Area was defined with these considerations in mind.

It was on the west coast that the first settlers landed, the first forests were cleared, and the first agriculture was established. The importance of the area has not diminished since those first days, despite vast changes in its character. In fact, land use has changed more

extensively on the west coast than in any other region of Barbados. This fact alone makes it a natural choice for a land use change study area.

To study land use change effectively, it is an advantage to have some factors held constant. In the case of a study such as this, where land use is related to land capability, it is important to have a relatively simple spatial pattern of physical landscape featutres and cultural elements. In this respect, the West Coast Study Area is ideal.

The straight north-south coastline with its beach of almost uniform quality is one such constant. The limestone terraces that run parallel to the coast and provide a natural east-west zonation are another consistent feature.

Many of the cultural features of the area also display a relatively simple pattern. For example, Highway 1 runs parallel to the coast, linking the three urban areas of Speightstown, Holetown and Bridgetown, which are located along it at constant intervals. This fact, combined with the location of Bridgetown (the primate city and only seaport of Barbados) directly south of the area, makes it relatively easy to isolate the socio-economic factors which have contributed to land use change. A second road, Highway 2, which parallels the limestone terraces at an average distance from the coast of about 2.6 kilometers, provides a convenient eastern boundary. Parish borders form the northern and southern boundaries of the West Coast Study

Area, which is about 15.5 kilometers in length and almost 39 square kilometers in size. It thus comprises about nine percent of the island's total area.

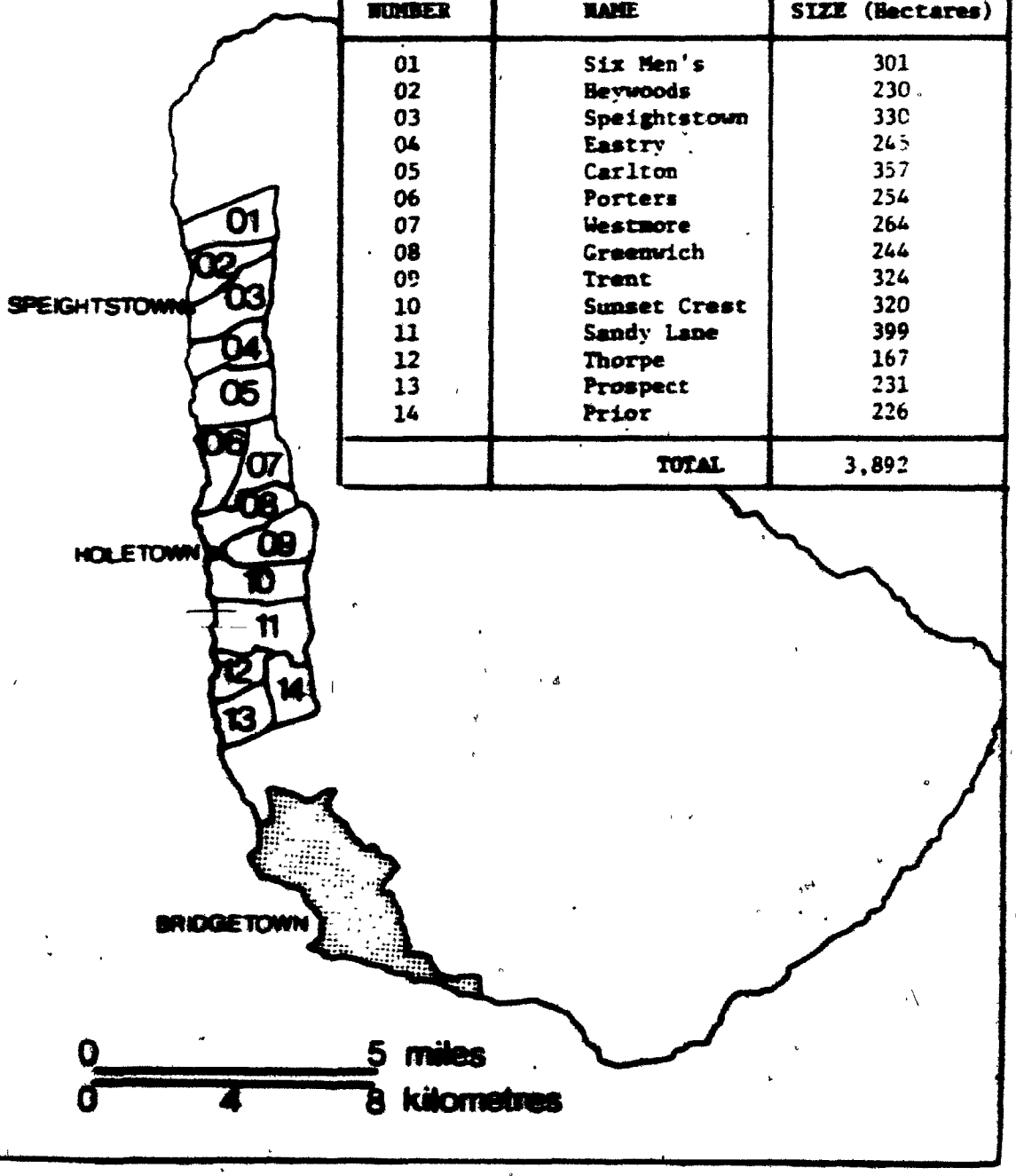
Despite its small size and the relative uniformity of some of its landscape and cultural features, the West Coast Study Area is a very diverse region in terms of land capability. Within its boundaries there are four soil associations, fifteen soil types, soil depths ranging from zero to more than 46 centimeters (zero to > 18 inches), terrain slopes ranging from zero to over 30 degrees, spatial variation in average annual rainfall in excess of 51 centimeters (20 inches), and a range in the extent of the dry season from one to six months, depending on the area. Superimposed upon this pattern are the six land use types that will be described more specifically in Chapter Four, as well as the proximity relationships between individual sites and the coast.

In order to enter all of these variables into a computer for the 38,636 data points that are used to define the West Coast Study Area, it was necessary to subdivide the region into fourteen sub-units. The precise boundaries of each of these sub-units are defined in the appendix at the end of this work.

Figure 3.1 illustrates the size, location and subdivisions of the West Coast Study Area.

# FIGURE 3.1 SUB-UNITS OF THE WEST COAST STUDY AREA

| NUMBER | NAME | SIZE (Hectares) |
|---|---|---|
| 01 | Six Men's | 301 |
| 02 | Heywoods | 230 |
| 03 | Speightstown | 330 |
| 04 | Eastry | 245 |
| 05 | Carlton | 357 |
| 06 | Porters | 254 |
| 07 | Westmore | 264 |
| 08 | Greenwich | 244 |
| 09 | Trent | 324 |
| 10 | Sunset Crest | 320 |
| 11 | Sandy Lane | 399 |
| 12 | Thorpe | 167 |
| 13 | Prospect | 231 |
| 14 | Prior | 226 |
| | TOTAL | 3,892 |



## Section Three: Physical Factors Affecting Land Use

### Soil Types of the West Coast Study Area

The soils of the coral region of Barbados were divided up by Vernon and Carroll (1965) into nine associations. An association is defined (P.13) as "a group of soils developed from the same parent material within one climatic area and representing a range of profile types produced as a result of differences in drainage". Four of the nine associations defined by Vernon and Carroll as belonging to the coral region of Barbados are found in the West Coast Study Area. These are indicated with their mapping symbol and percent coverage in Table 3.1.

Table 3.1 Soil types of the West Coast Study Area

| Mapping Symbol | Soil Association | Percent Area Coverage |
|---|---|---|
| A | Black | 14.29 |
| B | Grey - Brown | 75.49 |
| C | Red Sand | 7.67 |
| D | Coastal | 2.55 |
| | TOTAL: | 100.00 |

Common Genetic Infuences: All of the soil types found in the West Coast Study Area owe their existence to the combined effects of erosion of the Quaternary limestone cap and the deposition of volcanic dust from periodic eruptions on neighbouring islands. There is some disagreement,

however, as to the relative significance of these two processes.

Upon cursory examination, it seems logical that the greater part of the soil was formed by the weathering of the limestone cap, with the ash deposits playing a secondary role. Vernon and Carroll (1965, p.15) have disputed this conclusion, however. They report Harrison's (1928) estimate that the formation of one cubic foot (28.32 litres) of residual Red clay would require the solution by carbonated water of approximately 55 cubic feet (1.56 kilolitres) of coral rock. This 55:1 ratio would surely be reflected by extensive karst features, none of which exist on Barbados:

> The coral rocks, however, show none of the extensive karst features that would be expected to reflect such a process. Only weak karstification, such as simple small dolines, is seen in Barbados. There are also vertical cliffs and very small scarps present that would not survive extensive solution (Vernon and Carroll: 1965, p.15).

The conclusion that karstification cannot account for the greater part of the parent material in the soils of western Barbados leads to the suggestion that the wind blown transfer and deposition of volcanic ash from the other islands of the Lesser Antilles was a significant process in the formation of the soils of that region. This theory is supported by statistics (Vernon and Carroll: 1965, p. 15) that indicate that thirty-four tons of volcanic ash per acre

(76,334 kilograms per hectare) were deposited on Barbados in 1902 and 1903 from the eruption of Mt. Pelée in Martinique.

Differences in Soil Genesis: The processes of erosion of the coral cap and the deposition of volcanic ash are common to all four of the soil associations found in the West Coast Study Area. Perhaps of more importance in this study than the aspects of soil genesis which are common to the four soil associations are those which serve to differentiate them. It is these processes which have led to the development of the distinct characteristics of the four west coast soil associations.

The Black and Grey-Brown Associations together comprise ninety percent of the soil in the West Coast Study Area. These two associations are similar in that they are both dominantly smectoid clay soils that overlie coral limestone. The Grey-Brown soils are found below the Upland Plateau at elevations of less than 122 meters (400 feet) above sea level. The soils of the Black Association are generally restricted to the Coastal Lowlands. Given the model of Barbados' slow physiographic evolution, it is apparent that the higher, Grey-Brown Association consists of more mature soils than does the Black Association of the Coastal Lowlands. This in turn implies that a number of genetic factors have influenced these two soil associations to differing extents.

The most obvious genetic difference between these two soil types is the effect of weathering. The Grey-Brown soils have been exposed to weathering for a longer period than have the Black soils. Furthermore, the Grey-Brown Association is found predominantly in the wetter upland regions, which receive about 25 centimeters (ten inches) more rainfall annually than do the Coastal Lowlands, where the Black soils are found.

The major effect of weathering is to vary the amount of kandite and smectite in the soil. Rodrigues (1950) commented on the variation in clay minerology with elevation, noting that at higher elevations the clay composition is 70 percent kandite and 23 percent smectite compared with 70 percent smectite and 23 percent kandite at lower elevations.

Vernon and Carroll acknowledge the higher percentage of kandoid clay in the Grey-Brown Association than in the Black Association. They also accept the theory that differential weathering played an important role in bringing about this difference. The caution, however, that theories that explain the zonation of west coast soil types solely in terms of a typical age sequence "rest on the assumption that no further material was added to the soil..." (1965, p.15). The accepted importance of volcanic ash deposits to the formation of Barbadian soils is thought by Vernon and Carroll to have had a <u>differential</u>, rather than a uniform affect on these west coast soil associations. They state (1965, p.15) that "...great quantities of volcanic ash fell

on Barbados, and that land at higher elevations received and retained far more ash than at lower altitude".

A final genetic factor that may explain some of the differences between the Black Association and the Grey-Brown Association is the deposition of detrital material on the coral reefs that were later elevated. Vernon and Carroll (1965, p.15) report on Harrison's (1928) finding that the "quartz" of soils at higher elevations is predominantly secondary and chalcedonic, while the quartz found in lower level soils (such as those of the Black Association) is mostly quartz sand. Harrison (1928) believed that

> ...at low elevations the soil would be partly derived from detrital material deposited on still submerged coral, in particular material from the sediments underlying the coral cap, which would then be at a higher level than the growing coral reef.

This process may also account for the high proportion of quartz grains found in the soils of the Red Sand Association. Other possible explanations for the formation of the Red Sand Association include (1) the erosion of a former section of the Barbados Ridge, and/or (2) the transportation by ocean currents of quartz grains derived originally from the sandy strata of the Scotland District. All of these theories are supported by the observation that the Red Sand Association is extremely restricted in its areal distribution and is never found on either higher or lower terraces.

Vernon and Carroll (1965, p.27) make only brief mention of other factors which may have contributed to the genesis of soils of the Coastal Association. They state that soils of this association are thin and immature and are found to have "developed over coral limestone wherever rainfall is low and poorly distributed and wherever soils are exposed to strong winds and salt blast".

Having outlined the different factors that led to the formation of the four soil associations of the West Coast Study Area, it is necessary to examine the characteristics of each soil type in more detail. Details of the soil texture, including the area coverage of the different texture classes, are shown in Figure 3.2.

The soils of the <u>Black Association</u> take their name from their uniformly dark coloured profile, likely caused by the sorption of organic matter upon montmorillonitic clay. Covering 14.29 percent of the West Coast Study Area, this soil type is composed predominantly of immature smectoid clay, having been formed in a sub-humid climate with a mean annual rainfall of between 40 and 55 inches (102 - 140 cms). Although clay comprises nearly sixty percent of this soil type, sand (14%) and silt (9%) are also present in significant quantities. The precise physical make-up of the soils of the Black Association is presented in Figure 3.2. Chemically, the soils of the Black Association are similar to those of the more mature Grey-Brown Association, except in the amounts of

exchangeable magnesium and readily soluble phosphate. The pH of the soils of the Black Association ranges from 7.3 to 7.8. Calcium carbonate values reach 15 percent and cation exchange capacities are high. Both exchangeable calcium and magnesium are high, but exchangeable potassium levels are low. Organic matter averages about 4 percent and readily soluble phosphate is low. A comparison of the chemical properties of the soils of the Black Association with those of other west coast soil types is presented in Table 3.2.

Where well drained, the soils of the Black Association can produce good yields when planted with sugar cane. However, Vernon and Carroll (1965, p.37) have noted that other types of land use would be equally suitable for this soil:

> These soils are now mostly in a cane - short-term root crop rotation. Experience elsewhere has shown that this kind of soil is best used for grass crops and it would appear that cane is likely to give the best return under the ecomomic conditions of the foreseeable future. The introduction of Pangola or other grasses must be largely a matter of economics. Much can be done to improve cane and root crop agronomy for this group of soils.

It should be emphasized here that depth has a major influence on the productivity of these soils. It will be seen in a later section that stoniness, erosion hazard, limitations to cane root penetration, drainage, permeability, and moisture supplying capability all vary

## Table 3.2 CHEMICAL PROPERTIES OF WEST COAST SOIL ASSOCIATIONS

| Soil Association | pH | Calcium Carbonate | Cation Exchange | Exchangeable | | | Organic Matter | Readily Soluble Phosphate |
|---|---|---|---|---|---|---|---|---|
| | | | | Calcium | Magnesium | Potassium | | |
| BLACK | 7.3 - 7.8 | 15% | High 60 m.e./100g | High | High | Low | 4% | Low |
| GREY-BROWN | 7.5 | 15% | High 50 - 60 m.e./100 g | Pre-dominant Cation | Low | Low | 3 - 5% | Very High |
| RED SAND | 7.5 | 0% | Base Exchange Capacity 10 - 15 m.e. % | Major Exchange-able Base | Moderate | Very Low | Low | Some Values Quite High |
| COASTAL | No Information Available | | | | | | | |

Data Source: Vernon and Carroll, 1965

significantly in the soils of the Black Association, depending on whether the soil is of normal, shallow, or very shallow depth.

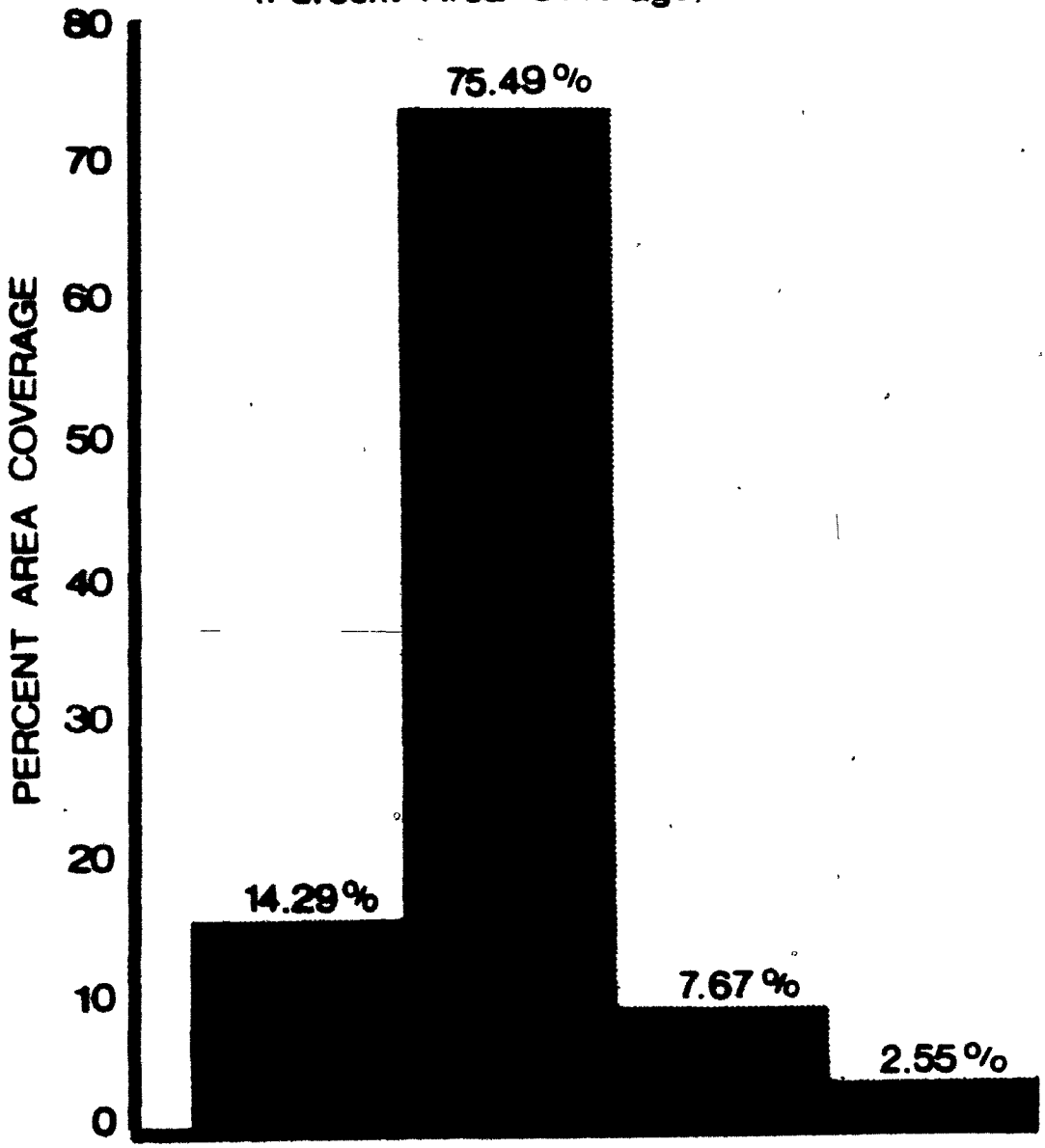
The soils of the Grey-Brown Association consist principally of mixed smectoid and kandoid clay. These soils are found to have formed over moderately soft limestone in a sub-humid climate with mean annual rainfall ranging from 50 to 60 inches (127 - 152 cms).

As mentioned in the preceding section on soil genesis, the Grey-Brown Association is similar to the Black Association, but is somewhat more mature. Like those of the Black Association, the soils of the Grey-Brown Association are predominantly clay (65%), with relatively low sand and silt content - 10 percent and 9 percent respectively.

It was noted earlier that the amount of kandoid clay in the soils of the Grey-Brown Association differs from one area to another, in some instances reaching ratios of one part kandoid to three parts smectoid. A number of other local variations are noted by Vernon and Carroll (1965, p.18):

> Along the leeward coast this soil changes and its colours and horizon arrangements are then similar to those of the Yellow-Brown Association of the Upland Plateau, but the structure and consistence remain that of the Grey-Brown Association. Also included in this association are soils contaminated by sandy wash from the neighbouring "Red Sand" soils.

FIGURE 3.2 SOIL ASSOCIATIONS OF THE WEST COAST STUDY AREA
(Percent Area Coverage)




Data Source: Vernon and Carroll, 1965

## TABLE 3.2A PHYSICAL NATURE OF WEST COAST SOILS

| Soil Association | BLACK | GREY-BROWN | RED SAND | COASTAL |
|---|---|---|---|---|
| Coarse Sand | 2.51% | 2.21% | 26.74% | No Info. |
| Fine Sand | 11.24% | 7.58% | 36.19% | No Info. |
| Silt | 9.16% | 9.48% | 3.67% | No Info. |
| Clay | 59.52% | 65.04% | 24.57% | No Info. |
| Moisture | 8.80% | 7.46% | 2.92% | No Info. |
| $CaCO_3$ | 7.08% | 5.43% | 5.38% | No Info. |
| Loss in Solution | 2.19% | 2.62% | 0.94% | No Info. |
| TOTAL: | 100.50% | 99.83% | 100.41% | No Info. |

Data Source: Vernon and Carroll, 1965

Vernon and Carroll (1965, p.18) also note that in some places the Grey-Brown soils grade into the Black Association.

Chemically, the Grey-Brown Association is almost identical to the Black Association. The major difference between these two soil types is in the amounts of exchangeable magnesium and readily soluble phosphate. The Grey-Brown soils are lower in exchangeable magnesium but much higher in readily soluble phosphate than are the less mature black soils. The chemical properties of both associations are listed in Table 3.2.

The Grey-Brown soils cover more than 75 percent of the West Coast Study Area, exceeding the percent coverage of the second most common soil type, the Black Association, by more than five times. Fortunatley these soils are extremely well suited to cane production. As with the Black Association, however, the depth of the soil is an extremely important consideration in determining its hydrological and agronomic properties. These are reviewed in a later section.

The soils of the Red Sand Association are some of the least productive on Barbados. Fortunately they are extremely restricted in their areal extent and cover less than eight percent of the West Coast Study Area.

The Red Sands are, as their name suggests, restricted in productivity by the high percentage of sand (63%) in their make-up. Less than 25 percent of this soil type is

clay. The textural characteristics of the Red Sand Association are indicated in Figure 3.2.

The pH of the Red Sands shows the same alkaline value (7.5) as for the soils of the Black and the Grey-Brown Associations. Here the chemical similarity between these soil types ends, however. There is no calcium carbonate in the Red Sands, nor are there appreciable levels of organic matter or exchangeable potassium.

Hydrological and agronomic properties vary with depth, but not to the extent found in the two major soil types of the West Coast Study Area. Hydrological and agronomic restrictions to agricultural potential are observed regardless of depth. After noting that cane production is not efficient on these soils, Vernon and Carroll (1965, p.37) suggest that they may prove to be moderately good for vegetable growing, but caution that "great care will be necessary if there is any attempt to diversify on these soils and much more agronomic information is required for them, as they are amongst the least fertile soils in the coral region".

No specific physical, chemical, hydrological, agronomic or cane root system data is available for the soils of the Coastal Association. Covering a mere 2.55 percent of the West Coast Study Area, these soils are extremely unproductive. Being shallow, rocky, and restricted to the drier areas, they are best suited to ground-nuts and oil seed crops. Vernon and Carroll

(1965, p.37) note that "many of the rocky coastal lands are moderately flat and open and the cutting of grass for stock feed could possibly be mechanised. Tamarind trees appear to thrive here. This group of soils also offers potential building and recreational sites".

## Soil Depth

Soil Depth is an important factor in determining the land use of an area, particularly with regard to agricultural potential. In the soil survey of Barbados (Vernon and Carroll, 1965), three categories of soil depth are recognized: (i) Normal - profiles in excess of 46 cms (18 ins.); (ii) Shallow - profiles of 25 to 46 cms (10 - 18 ins.); (iii) Very Shallow - profiles of less than 25 cms (10 ins.).

The majority (61%) of soils in this study have normal depth profiles. Shallow profiles occur in 21 percent of the study area and are more or less equally distributed between the Black, Grey-Brown and Red Sand Associations. Very Shallow soils cover 18 percent of the area and are common to the Black and Grey-Brown Associations only.

The complete breakdown of soil types according to depth is listed in Table 3.3.

Table 3.3 Soil depths in the West Coast Study Area. Percent areal extent by soil association. Figures in parentheses indicate percent area significance of each soil phase for the study area as a whole.

| Association | Normal | Shallow | Very Shallow | Total |
|---|---|---|---|---|
| BLACK | 63.89<br>( 9.13) | 15.64<br>( 2.23) | 20.47<br>( 2.92) | 100.00<br>( 14.28) |
| GREY-BROWN | 55.84<br>(42.15) | 24.74<br>(18.68) | 19.42<br>(14.66) | 100.00<br>( 75.49) |
| RED SAND | 96.90<br>( 7.44) | 3.10<br>0.24 | 0.00<br>0.00 | 100.00<br>( 7.68) |
| COASTAL | 100.00<br>( 2.55) | 0.00<br>( 0.00) | 0.00<br>( 0.00) | 100:00<br>( 2.55) |
| TOTAL: | (61.27) | (21.15) | (17.58) | (100.00) |

## Drainage Characteristics of West Coast Soils

Soil depth is the most significant factor affecting the soil drainage of the west coast associations.

(1) Black and Grey-Brown Asociation soils of normal depth are found to have good moisture holding characteristics. Soil drainage is slow and so there is a good supply of moisture available for crops such as sugar cane. In areas of flat land, the normal depth soils of the Black and Grey-Brown Associations occasionally have poor drainage and permeability characteristics combined with either a relatively high permanent water table or a seasonally fluctuating water table at 5 - 13 centimeters (2 - 5 ins). Despite these drainage problems, however,

these soils are efficient cane producers when properly managed, as their moisture supplying capacity is good.

Black and Grey-Brown Association soils of shallow depth are more rapidly drained. Permeability is increased and moisture retention reduced. These well drained smectoid clays are well suited to cane production except in areas where factors such as slope or accessibility restrictions make cane cultivation difficult. In such areas these soils are well suited for use as pastures.

The very shallow phases of the Black and Grey-Brown soil associations have rapid external drainage. They are very permeable and there is an insufficient moisture capacity to support economically viable agricultural production in areas of low rainfall. Vernon and Carroll (1965 p.36-37) note that most of these soils are found in areas of "rabland". They suggest, however, that despite the low potential of these soils in dry areas, some gullies in the higher rainfall regions could be used for "food forest". They suggest that timber crops, such as mountain mahoe, could also be tried in the highest rainfall areas. It should be noted that these soils provide excellent building sites.

(2) Red Sand Association soils, in general, have moderately rapid drainage. The sandy texture of this soil type results in low moisture supplying capacity. Drainage and permeability are greater in the shallow phase of this soil type, further reducing the moisture supplying capacity.

## Table 3.4 DRAINAGE CHARACTERISTICS OF WEST COAST SOILS

| Soil Association | BLACK | | | GREY - BROWN | | RED SANDS | | COASTAL |
|---|---|---|---|---|---|---|---|---|
| Depth Phase | Normal | Shallow | Very Shallow | Normal | Shallow (*) | Normal | Shallow | |
| EXTERNAL DRAINAGE | Slow | Medium | Rapid | Slow to Medium | Medium | Slow to Medium | Medium | No Info. |
| INTERNAL DRAINAGE | Slow to Medium | Medium to Rapid | Very Rapid | Medium to Slow | Medium to Rapid | Medium | Medium to Rapid | No Info. |
| OVERALL DRAINAGE | Imperfect or moderately well drained | Well Drained | Excessive | Slow to Moderate | Moderate | Well Drained | Somewnat Excessive | No Info. |
| PERMEABILITY | Slow | Moderate | Rapid | Moderate to Well Drained | Well Drained | Moderate | Moderately Rapid | No Info. |
| MOISTURE SUPPLYING CAPACITY | Moderate to High | Low to Moderate | Very Low | Moderate to High | Low to Moderate | Low | Very Low | No Info. |
| WATER TABLE | Seasonal Perched 16"/40cm | ---- | ---- | Seasonal Perched 18"/46 cm | ---- | ---- | ---- | No Info. |

(*) No information is available for the Very Shallow Associate of the Grey-Brown Association.

Data Source: Vernon and Carroll, 1965

(3) **Coastal Association** soils exhibit only the normal depth phase in the West Coast Study Area.

## Agronomic Characteristics of West Coast Soils

The stoniness, erosion hazard and root penetration limitations of the soils of the West Coast Study Area all vary significantly with the depth of the soil. The relationship between these variables and soil depth is the same for both the **Black and Grey-Brown Associations**.

Soils of both these associations that are of normal depth have the advantages of low stoniness and a nearly insignificant erosion hazard. There are no factors inhibiting root development in the zero to six inch (0 - 15 cm) horizon and so cane rooting occurs rapidly and evenly. The 6 - 18 inch (15 - 46 cm) and 18 - 36 inch (46 - 91 cm) horizons are both less conducive to root development because of the massive character of the soil. However, this is not a serious problem for sugar cane because of the extensive root system which can develop close to the surface.

It was mentioned in the section on soil drainage that some areas with soils of the Black and Grey-Brown Associations are poorly drained. Poor drainage does not, however, appear to have a serious effect on root development in sugar cane.

The shallow phases of both the Black and Grey-Brown Associations predominate on slopes between 4 and 10 degrees. Shallow profiles are characterized by slightly higher

stoniness and erosion hazards, but neither of these variables proves to be a limitation to cane production. In fact, the shallow soils of the Black and Grey-Brown Associations appear to have more extensive and more active rooting than do the normal depth soils, perhaps because of their looser texture. And while bedrock limits root penetration to 18 inches (46 cms) or less, it provides a solid base upon which strong cane rooting can occur.

No cane production is possible on the very shallow phases of the Black or Grey-Brown Associations. Extreme stoniness, rocky outcrops, a high erosion hazard, poor drainage properties and the existence of bedrock at 10 inches (25 cms) or less combine to make cane farming impossible on these soils.

The problems just described also apply to the shallow phase of the Red Sand Association, thus restricting cane production to the normal depth phase of this soil type.

The normal phase of the Red Sands is not stoney, but it does have a high risk of erosion. Furthermore, packing in the massive structure of the deeper sub-surface horizons limits root penetration to 36 inches (91 cms). Even with this limitation, root development is not restricted, cane root systems are active and root density is high. This is further evidence that the low agricultural potential of this soil type is due primarily to low fertility and poor drainage characteristics.

## Table 3.5 CANE ROOT SYSTEM DATA FOR WEST COAST SOILS

| Soil Association | BLACK | | | GREY - BROWN | | | RED SANDS | | COASTAL |
|---|---|---|---|---|---|---|---|---|---|
| Depth Phase | Normal | Shallow | Very Shallow | Normal | Shallow | Very Shallow | Normal | Shallow | |
| 0 - 6 ins.<br>0 - 15 cms. | 8a | 8a | ---- | 9a | 9a | ---- | 9a | ---- | No Info. |
| 6 - 18 ins.<br>15 - 46 cms. | 3a/b to 3b | 4a | ---- | 4a/b to 4b | 5a/b to 4a/b | ---- | 6a/b to 3a/b | ---- | No Info. |
| 18 - 36 ins.<br>46 - 91 cms. | 3b/c to 1b/c | ---- | ---- | 3b to 2b/c | ---- | ---- | 2b | ---- | No Info. |
| Rooting on to Coral | Sparse but Definite | Strong | ---- | Moderate | Strong | ---- | ---- | ---- | No Info. |

Root Systems are scored 0 - 10 on the amount of rooting present and 'a', 'b', 'c' for active, inhibited and restricted or dead roots respectively.

Data Source: Vernon and Carroll, 1965

The soils of the **Coastal Association** are uniformly shallow, rocky, infertile and incapable of cane production. Soil depth thus plays no roll in determining the agronomic features of this association.

Terrain Slope:

In carrying out the slope classification for the West Coast Study Area, six catergories of slope were recognized: $0^{o}-2^{o}$, $2^{o}-5^{o}$, $5^{o}-10^{o}$, $10^{o}-20^{o}$, $20^{o}-30^{o}$, and $>30^{o}$. It was mentioned in the Introduction that most of Barbados is characterized by gentle slopes. This is particularly true of the West Coast Study Area, where steep slopes occur only on the sides of gullies and along the terrace edges. The slope statistics for the West Coast Study Area are as follows:

Table 3.6 Slope statistics

| Mapping Symbol | Slope Class | Percent Area Coverage |
|---|---|---|
| A | $0^{o} - 2^{o}$ | 4.57 |
| B | $2^{o} - 5^{o}$ | 20.60 |
| C | $5^{o} - 10^{o}$ | 49.18 |
| D | $10^{o} - 20^{o}$ | 18.09 |
| E | $20^{o} - 30^{o}$ | 5.84 |
| F | $> 30^{o}$ | 1.72 |
| | | TOTAL: 100.00 |

## Table 3.7 AGRONOMIC FEATURES OF WEST COAST SOILS

| Soil Association | BLACK | | | GREY-BROWN | | | RED SANDS | | COASTAL |
|---|---|---|---|---|---|---|---|---|---|
| Depth Phase | Normal | Shallow | Very Shallow | Normal | Shallow | Very Shallow | Normal | Shallow | |
| DOMINANT SLOPE (°) | 2 - 10 | 4 - 10 | >10 | 2 - 10 | 4 - 20 | >10 | 2 - 10 | 4 - 20 | No Info. |
| Map Classes | B-C | B-C | D-E-F | B-C | C-D | D-E-F | B-C | C-D | No Info. |
| STONINESS | Some stones | Stony | Very stony with rocky outcrops | Few stones | Stony | Very stony with rocky outcrops | Few stones | Stony | No Info. |
| EROSION HAZARD | Slight | Slight to Moderate | Moderate to High | Slight | Slight to Moderate | Moderate to High | Moderate to High | High | No Info. |
| LIMITATIONS TO ROOT PENETRATION | Structureless subsoil | Bedrock at ≤ 18" (46 cms) | Bedrock at ≤ 10" (25 cms) | Poorly structured subsoil | Bedrock at ≤ 20" (51 cms) | Bedrock at ≤ 10" (25 cms) | Massive structure in C horizon | Bedrock at ≤ 18" (46 cms) | No Info. |

Data Source: Vernon and Carroll, 1965

Regardless of soil type, higher slope factors result in shallower soils and the concomitant problems of stoniness, erosion hazards, poor drainage characteristics and generally low fertility.

**Rainfall:**

The West Coast Study Area was mapped according to its rainfall characteristics using the five categories identified in Table 3.8, listed below. The percent of land in each category is given in column three.

Table 3.8 Rainfall statistics

| Mapping Symbol | Rainfall Category | Percent Area Coverage |
|---|---|---|
| A | 40 - 50 ins (102 - 127 cms) mean annual rainfall with a very marked dry season (in excess of five dry months) | 18.87 |
| B | 40 - 50 ins (102 - 127 cms) mean annual rainfall with a marked dry season (three to four dry months) | 6.33 |
| C | 50 - 60 ins (127 - 152 cms) mean annual rainfall with a marked dry season (three to four dry months) | 55.66 |
| D | 60 - 70 ins (152 - 178 cms) mean annual rainfall with a marked dry season (three to four dry months) | 11.40 |
| E | 60 - 70 ins (152 - 178 cms) mean annual rainfall with a weak dry season (one to two dry months) | 7.83 |
| | TOTAL: | 100.00 |

Given that other climatic factors such as incoming solar radiation and temperature are relatively constant throughout the study area, rainfall is the major climatic variable affecting sugar production. Its inclusion in the set of physical factors that influence land use change is based entirely on the importance of rainfall variations to sugar cane production potential. Land use changes in and out of plantation agriculture, peasant agriculture, grazing, and unused land are thought to be significantly influenced by this variable.

The importance of the amount of annual rainfall and the duration of the dry season relative to sugar production potential varies with the type of sugar cane, evapotranspiration rates, soil type, irrigation practices, fertilization, cane health, cane age, stage of growth, cloud cover, wind advection et cetera. The inter-relationships between all of these parameters could obviously lead one to the formulation of a complex series of equations designed to predict cane production potential. For the purposes of this study, however, only the more basic and best documented relationships between average annual rainfall, length of dry season and sugar production potential need be considered. These fundamental relationships have been identified by Oguntoyinbo and Rouse:

(1) The distribution of rainfall in Barbados is uneven both in time and space; the mean annual total is on the whole marginal for the cultivation of sugar cane. This

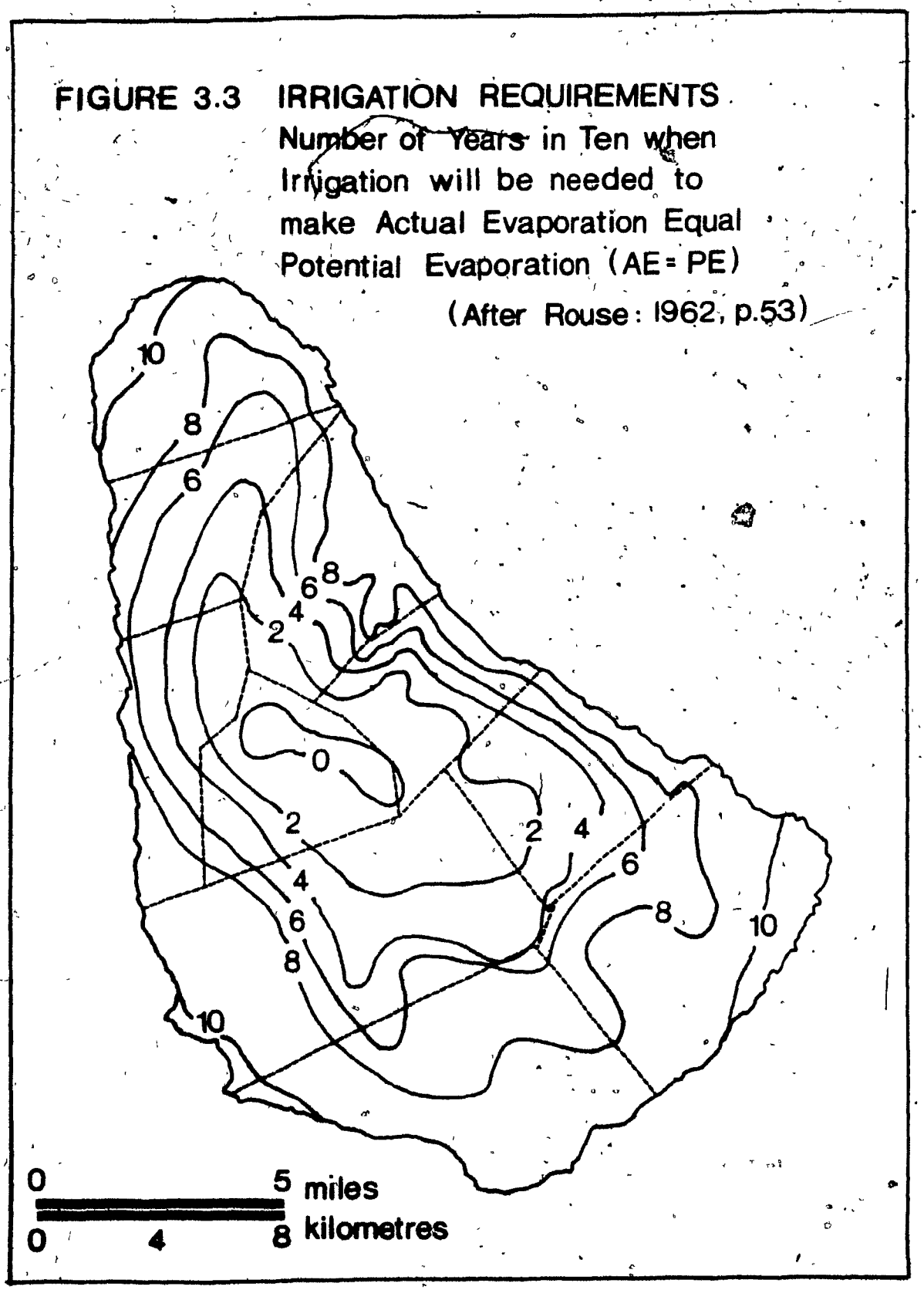
means that the varying rainfall amounts year to year will influence the yields to be expected. In addition, yields from the same soil type will vary from one part of the island to another (Oguntoyinbo: 1964, p.38).

(2) Generally speaking, the more rainfall an area receives annually, the greater will be its production potential. This is because the ratio of actual evapotranspiration to potential evapotranspiration (AE/PE), which is a measure of moisture deficiency, is found to be lowest in the low rainfall areas (Oguntoyinbo: 1964, p.51).

(3) The shorter the dry season, the higher the sugar production potential. This conclusion stems from Rouse's (1962, p. 58) observation that plant cane and ratoon yields will be high only if the actual evapotranspiration always equals the potential throughout the growing period of each. Long dry seasons, requiring usually unavailable irrigation thus reduce sugar cane production potential. The likelihood that irrigation will be required in a given year is presented in Figure 3.3.

The relationship between rainfall and land use change in the West Coast Study Area is examined in Chapter Five.

This concludes the review of physical factors affecting land use. The following section deals with economic influences on land use.


FIGURE 3.3 IRRIGATION REQUIREMENTS
Number of Years in Ten when Irrigation will be needed to make Actual Evaporation Equal Potential Evaporation (AE = PE)
(After Rouse: 1962, p.53)
10
8
6
8
6
4
2
0
2
2
4
4
6
6
8
8
10
10
0
5 miles
0
4
8 kilometres

## Section Four: Economic Factors Affecting Land Use

Land capability, as defined by the basic inherent physical qualities of the land, occasionally results in an absolute restriction on the type of land use with a corresponding effect on the options for land use change. More frequently, however, a number of options exist. In western Barbados, land use change in areas where a number of possibilities exist is always a product of economic and/or governmental impetus.

A complete examination of the complex set of economic and governmental inter-relationships that effect land use change in western Barbados would require a thesis in itself. Thus, for the purposes of this work, geo-economic considerations are restricted to two key concepts: (1) proximity, as originally modelled by Von Thunen, and (2) land scarcity, which is merely an extension of the concept of competition arising out of supply and demand.

Land scarcity is examined with reference to western Barbadian land use types in a later section. The following pages are devoted to a discussion of the effect of proximity on land use change.

Butler (1980, p. 56) states that "in the spatial approach to economic location, the principal variable is distance, or more accurately, the costs of overcoming distance". In this work, the emphasis is on land capability. Based on empirical evidence, the only distance

variable that could be realistically considered to be a land capability parameter in western Barbados is proximity to the coast.

It was originally intended to apply rural-urban location models, such as those developed to explain hinterland / market inter-relationships to the study of land use change in the West Coast Study Area. Upon closer review, however, it became evident that such modelling would be next to meaningless, given the unique character of land use in that area. In particular, the following characteristics of the West Coast Study Area serve to preclude the existence of a relationship between proximity to urban areas and land use change: (1) the very small distances involved, (2) the 'self-serving' urbanization of tourism development, (3) the small size of the only two urban centres (Holetown and Speightstown), (4) the existence of a totally dominant primate city (Bridgetown) outside of the study area, (5) the almost exclusive agricultural production of sugar cane, which is grown, milled and shipped without being influenced by the two towns in the West Coast Study Area, and (6) the relative uniformity of urbanization along the west coast highway (Highway 1) between Bridgetown and Speightstown.

As a result of these considerations, only one location variable is thought to have played a significant enough role in directing land use change to warrant independent examination. That variable is proximity to the

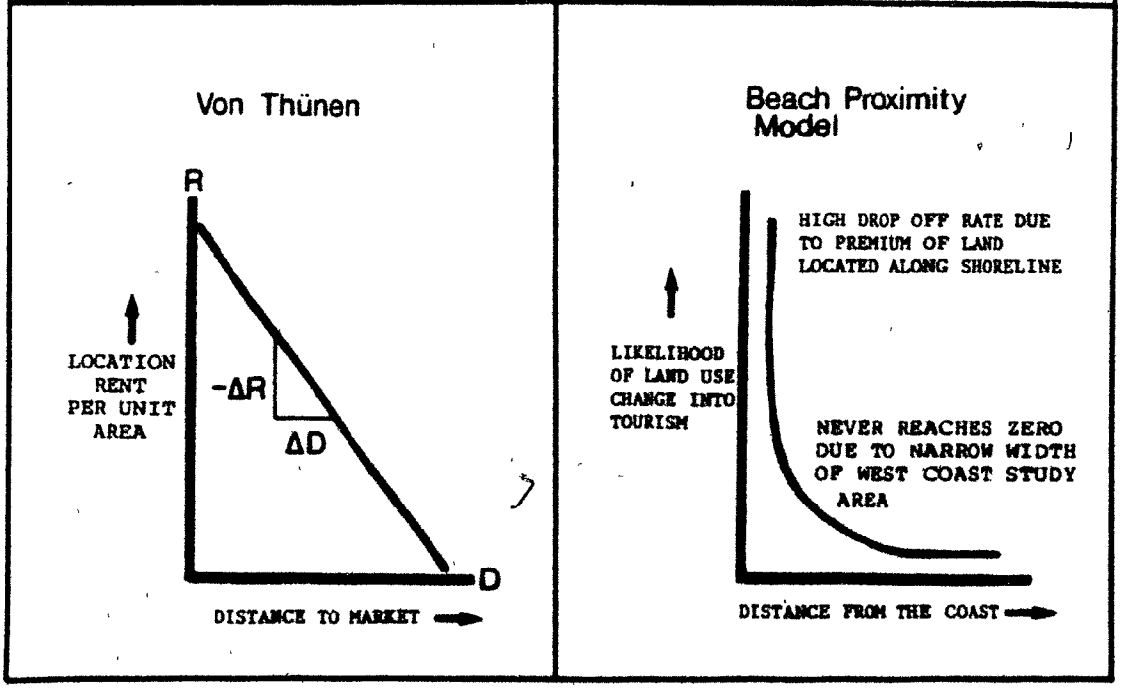
coast, because it is obvious that the distance between a parcel of land and the coast is the most important factor in determining the potential capability of that land to generate income through tourism.

The model employed here supposes that all land in the West Coast Study Area is identical in terms of building potential. This is in keeping with Von Thünen's basic supposition that "rent is generated by the distance factor even if the environment is assumed to be everywhere the same" (Butler: 1980, p.74). Von Thünen's model is more complex than the proximity index developed here, however. Von Thünen dealt with economic variables such as location rent, agricultural yield per acre, market price, unit production cost, shipping rate, and distance to market. By combining the effects of these parameters, Von Thünen concluded that the location rent of a parcel of land could be determined with reference to its proximity to the market place.

The proximity model used in this work differs from Von Thünen's in two significant respects. (1) It is not intended to correlate with location rent (although there is likely to be a relationship); rather, its purpose is to predict land use change into tourism as a function of proximity to the coast. (2) The slope of the graph is not expected to be linear; rather it is likely that the high premium placed on land located directly on the coast, combined with the relative closeness to the ocean of all

land in the West Coast Study Area will result in a slope similar to the one shown in Figure 3.4.

FIGURE 3.4 PROXIMITY MODELS




In order to test the model, all land in the West Coast Study Area was mapped according to its proximity to the coast using the legend presented in Table 3.9.

Table 3.9 Proximity to the coast

| Mapping Symbol | Distance to Coast (Kilometers) | Percent Area Coverage |
|---|---|---|
| A | < 0.5 | 20 |
| B | 0.5 - 1.0 | 20 |
| C | 1.0 - 1.5 | 20 |
| D | 1.5 - 2.0 | 20 |
| E | 2.0 - 2.5 | 15 |
| F | > 2.5 | 5 |
| | | TOTAL: 100 |

The relationships between the proximity index and land use changes are examined in Chapter Six.

Land Scarcity

Vink (1975, p.3), in discussing the anthropological, historical and institutional aspects of land use, reaches the conclusion that "land use is the result of a scarcity of land". He defines scarcity in terms of the amount of land available that is capable of "providing sufficient fruits of nature for human sustenance" (1975, p.3). While this definition is suitable for either a global interpretation, or for the study of local agricultural land use, it is too narrow to be applied to the overall Barbadian land use situation.

For our purposes, the term 'land scarcity' will be defined as a perceived shortage of land suitable for an intended use. In a geographic sense, the likelihood of Barbados experiencing land scarcity is directly proportional to its population density and state of development, and inversely proportional to its total available land area. These concepts are logically unquestionable, but they address only the quantitative nature of land scarcity. The fact that land scarcity is defined here in terms of an intended use is an indication that it is dependent upon qualitative as well as quantitative variables.

The two most important qualitative variables to which land scarcity is related in Barbados are (1) the expectation of a certain standard of living, and (2) the potential to achieve that standard through land use change. Stated as a simple example, if the Barbadian people were satisfied with an agricultural economy that was capable of providing a subsistence level existence, they would perceive no land scarcity unless food shortages developed. This is the basis of Vink's definition of land scarcity. The same people, offered the opportunity to develop a tourist industry and an improved standard of living, would soon perceive land scarcities if beach-front sites were already occupied and controlled by agricultural or other interests. At this point, an economic response - the changing of land use from agriculture to hotel development, in order to attain increased financial benefit from the land - would likely be

provoked.

It is contended that there are three major types of land scarcity that induce changes in land use in Barbados in a manner similar to that described in the example above. These are (1) agricultural land scarcity, (2) income land scarcity, and (3) community land scarcity. All three of these types of scarcity are determined by the availability of land that meets the specific site and physical characteristics necessary for the successful application of one of these three categories of intended use.

The three major types of land scarcity on Barbados may be defined as follows.

Agricultural land scarcity is said to exist on Barbados when there is insufficient land available to produce the tonnage of sugar cane and/or other cash crops required to yield an acceptable or necessary amount of foreign exchange. At first glance, this definition may seem somewhat awkward, but this is due to the highly specific situation to which it applies. When taken a phrase at a time, the rationale for its wording becomes apparent. The definition is intended to imply that both capability and availability are absolute determinants of agricultural land scarcity in Barbados. Just as it is meaningless to ask whether the height or the base of a triangle contributes more to its area, so, too is it futile to wonder whether capability or availability are more important in causing agricultural land scarcity. Thus, neither the availability

of land that is unsuitable, nor the suitability of land that is unavailable, to meet the criteria outlined above, will alleviate an agricultural land scarcity.

Income land scarcity is defined as a perceived shortage of land that is capable of providing non-agricultural income to the people of Barbados. Thus, a shortage of land for industrial or tourism development would be classified as an income land scarcity. As with agricultural land scarcity, the perception of income land scarcity is related to a number of qualitative variables such as standard of living expectations and, in this case, appeal to tourists.

Community land scarcity differs from agricultural land scarcity and income land scarcity in that the intended use of the land does not involve the production of goods or services in return for food or income. Community land scarcity is nonetheless very strongly related to the common variable of standard of living expectation. A community land scarcity is said to exist on Barbados when there is a perceived shortage of land for the development of native housing or community facilities such as schools, hospitals or recreation areas.

The optimum sites and physical characteristics of land required for agricultural, tourism/industry, and community development are not mutually exclusive. Thus, competition between these three types of land use is possible, even probable. Examples of competition between the

three sectors are found in the Physical Development Plan for Barbados. Several examples are cited below.

(1) Income Land vs. Community Land: In the discussion of land availability and location, there is a clear statement of the kind of competition created by the demand for tourist accommodation.

> The brunt of the demand for tourist accommodation will fall on whatever land is available that is contiguous with or adjacent to safe bathing beaches... Competition between permanant residents and tourists for these areas of high amenity has been resolved in favour of the dollar with the highest value (1970, pgf. 3.213).

(2) Community Land vs. Agricultural Land: The Physical Development Plan provides a good example of competition between these two land use needs in reviewing the problem of low density sprawl. This is the unplanned, haphazard growth of rural housing which results "in the loss of substantial acreage of prime agricultural land on which the Island's prosperity depends" (1970, p. vii).

(3) Income Land vs. Agricultural Land: Perceived scarcities of income land often result in land speculation. The Physical Development Plan describes the adverse effects that result from uncontrolled competition between these two sectors. The authors state that "the result is a reduction in agricultural productivity and the proliferation of disorganized building development to satisfy what is anticipated as the demands of tourism" (1970, pgf. 3.215).

Given the inter-relationships between the land scarcity types described above, it is clear that land use change on Barbados can occur in one of two ways: (1) as an uncontrolled system of open competition for land, or (2) following planned and regulated land use policies that will ensure maximum long term benefit to the Island by guaranteeing optimum relationships between all three sectors. The choice between these two options was finally made in favour of the latter in the mid-1960's with the commissioning of the Physical Development Plan for Barbados.

## Section Five: Physical Development Strategy and Land Use Change Hypotheses (1950-1980)

In planning land use, the Barbadian government's three major objectives are: (1) the achievement of maximum financial benefit for the national economy, (2) the maintenance of a high standard of living, and, (3) the protection of the country's resources and natural beauty. As a result, the subject of the scarcity of Barbadian land relative to its ability to provide capital for the island's large population is an important theme in the planning of land use policy.

A review of the Physical Development Plan for Barbados, which was prepared, with United Nations technical assistance, by the Barbadian Town and Country Development Planning Office, is a worthwhile exercise. The plan was prepared at the mid-point of the 1950-1980 study period considered in this work. It is a valuable reference in that it outlines, in general terms, the land use changes that had occurred between 1950 and 1965. Evaluation of the nature and, to a lesser degree, the extent of these changes formed the basis for the most comprehensive land use planning proposals ever made for the Island. All of the specific proposals made in the report were designed to bring about three major objectives. These were (pgf. 1.02)

> (a) to conserve arable land for more intensive food production and a diversified agriculture since the resources of the country are mainly agricultural, ensuring holdings are of optimum economic size for

> mechanical cultivation, irrigation and diversification of crops;
>
> (b) to provide suitable sites for the development of a variety of manufacturing industries which would be essential for diversification of the island as a whole;
>
> (c) to create and maintain an environment which would attract visitors and encourage the development of tourism.

The specific proposals based on these three objectives have been incorporated, in one form or another, in all subsequent development plans regarding land use change on Barbados. It can be fairly stated that the Physical Development Plan, more than any other work, was responsible for the recognition and curtailment of unfavourable trends in land use change. When viewed in conjunction with the government legislation that enforces its recommendations, it is the most important document ever prepared on the subject of Barbadian land use. The formulation of hypotheses regarding land use change in Barbados between 1950 and 1980 thus necessitates a review of its observations and recommendations. Both the evaluation of land use change up to 1965 and the development proposals recommended in the plan are considered below according to the land use type to which they relate. The format of this review provides a convenient forum for the articulation of specific hypotheses related to the anticipated findings of this research. Hypotheses are developed under five headings, each relating to a specific land use category. The five headings are: (1)

Plantation Agriculture, (2) Peasant Agriculture, (3) Marginal Land, (4) Urban Land, and (5) Tourism and Recreation Land. In some cases the hypotheses agree with the observations, predictions and recommendations of the plan, in other instances they do not. In either case, the inclusion of the plan's findings provides a valuable reference. Hypotheses concerning land tenure / land capability relationships (a subject which is not adequately addressed in the Physical Development Plan) are formulated with reference to the findings of Henshall (1964), Prescott (1967), and Persaud and Persaud (1968).

Plantation Agriculture

Protection: It was a clearly stated objective of the Physical Development Plan to keep all 70,000 acres of arable land in agricultural production (pgf. 5.208). The assertion was made that "apart from areas zoned as urban centres, such as Bridgetown, Oistins, Speightstown, no agricultural land with potential for sugar, dairy, market gardens or food crop production should be utilised for purposes other than agriculture" (pgf. 5.111). This recommendation likely resulted in a curtailment of the use of agricultural lands for urbanization and tourism development. The Physical Development Plan was published in 1970. Thus, its effect on land use change during the 1964-1972 study period was negligible. However, the same general increase in awareness concerning land use / land

capability relationships that prompted the government to commission the Physical Development Plan in the mid-1960's was reflected in government legislation a few years before 1970. A slight reduction in the rate of loss of plantation land to other uses may, therefore, be observed for the 1964-1972 time period.

Zoning: It was recommended in the Physical Development Plan that "sugar should be zoned in the high and intermediate rainfall areas of the island and on good deep soil regardless of the irrigation potential" (pgf. 5.106). This recommendation was little more than a statement of the obvious, however, rather than a serious attempt to save prime agricultural land from development. Very little conflict has ever existed between 'strong' plantations and tourist development and urbanization. The high and intermediate rainfall areas of good soil in Barbados are located inland, away from the coastal zone of tourism and urban pressures on land use. Thus, plantations that are located in the 'sugar belt', as defined in the Physical Development Plan, are expected to emerge as one of the most stable land use types throughout the three study periods.

Subdivision: It is probable that there was a significant amount of subdivision of plantations to form peasant plots during the 1950-1964 study period. This conclusion stems mainly from the trend toward plantation subdivision that was described in Chapter Two. By the

mid-1960's, however, three factors that had the power to diminish or eliminate this trend came into play. First, mechanization benefited large plantations, both in absolute and relative terms. Weak plantations could be strengthened by mechanization, making them less likely to fall into subdivision. Furthermore, peasant plots could not make effective use of large scale, cost-reducing mechanization, thus giving the plantations a competitive advantage over them on the sugar market. Second, the movement of labour away from peasant agriculture, in favour of employment in the tourist industry must have contributed to a reduction in plantation subdivision. Third, the authors of the Physical Development Plan considered plantations of 100 acres in size to be the most efficient in terms of crop diversity and mechanization (pgf. 1.02). Fragmentation of plantations was thus discouraged (pgf. 5.104).

Hypotheses: Three hypotheses relating to plantation agriculture, listed below, will be examined in this work. (1) There was significantly less development of plantations for urbanization and tourism during the 1972-1980 study period than during either of the two previous study periods. (2) Plantations in the 'sugar belt' will be found to have been the most stable land use type throughout the three study periods. (3) Mechanization, the movement of labour away from peasant agriculture in favour of employment in the tourist industry, and the discouragement of subdivision by

the government are expected to have effectively ended subdivision of plantations by the mid-1960's.

Peasant Agriculture

Protection: As mentioned in the previous section, a clearly stated planning objective to keep all 70,000 acres of arable land in production was outlined in the Physical Development Plan for Barbados (pgf. 3.208). In order to achieve this, an affirmative action programme designed to protect agricultural lands was recommended (pgf. 5.111).

Subdivision: It was also mentioned earlier that further fragmentation of plantations was discouraged by the Physical Development Plan (pgf 5.104). The end of the expansion of peasant agriculture as it had evolved since emancipation was suggested. In fact, the plan called for a reversal of the trend, recommending the "consolidation of agricultural smallholdings through Co-operative Societies and credit unions for more efficient and economical exploitation of marginal land" (pgf. 5.313). This consolidation would have to have occurred on a vast scale if it were to manifest itself statistically in this work. At least ten contiguous one acre peasant plots would have to have become spatially amalgamated before this change would be recognized in the air photo interpretation. This is a most unlikely prospect, especially considering the massive trend in the opposite direction that has existed on the Island since emancipation. It is therefore unlikely that

any land will be found to have changed in use from peasant agriculture to plantation agriculture during any of the three time periods.

Tenure / Capability: It was stated in Chapter Two that the period between emancipation and 1950 saw the failure and subsequent subdivision of many large plantations. A point that was not elaborated upon, however, was that it was mainly plantations located in areas of marginal productivity that were failing. The peasants of the time were thus spending considerable amounts of money to purchase poor agricultural land. This process was studied by Prescott in 1967, and his findings are quite revealing. He noted (p. 2) that between 1851 and 1915, the number of peasant holdings in Barbados increased from 3,537 to 14,000. When thirteen representative plantations that had been subdivided during that period were examined, many were found to be located on marginal land. Prescott (1967, p. 3) states that "it will be noticed that the majority of these plantations are located in areas least favourable for cane growing as far as relief, rainfall and soil conditions are concerned...". Six of these thirteen plantations were located in the West Coast Study Area. Persaud and Persaud (1968, p. 17) also commented on the consequences of the subdivision of marginal land, noting that "most small farms are in the coastal areas where rainfall is low", and that "these areas also have the heavy alkaline soils which are more difficult to manage". Their findings are substantiated

by Henshall, who studied 116 peasant farms in Barbados and concluded that

> ...55% had soil considered too shallow for successful plant growth whilst 33% had land which was excessively stony or had large areas of rock outcrop. An unfortunate 29% of the sample had holdings which had both the above disadvantages... 23% of the farms sampled had land which was either steep enough to be subject to erosion, or land which was broken by the depressions typical of a limestone landscape (1964, p.33).

Hypotheses: Three hypotheses relating to peasant agriculture will be examined in this work. (1) The rate at which peasant-held agricultural land was being developed for tourism and urban purposes will diminish through the three study periods, becoming insignificant by the 1972-1980 study period. (2) The rate of increase in peasant holdings will be highest in the 1950-1964 study period and lower in the 1964-1972 study period. No increase in the number of peasant holdings will be observed for the 1972-1980 study period. In fact, the area of peasant holdings should remain essentially constant in the 1972-1980 period, in response to the recommendations for consolidation of peasant holdings presented in the Physical Development Plan. (3) Statistical analysis of land tenure / land capability relationships for the West Coast Study Area will show a disproportionately high correlation between peasant agriculture and marginal farming land for all four study years.

Marginal Land

Pasture Improvement: The major recommendation of the Physical Development Plan with regard to this land use type was the suggested utilisation of "12,000 acres of marginal arable and grassland or permanent pasture for the diversification of agriculture through the provision for livestock breeding and dairy farming" (pgf. 3.208). It was considered especially necessary "to intensify production in the dry coastal belts through improved pastures for dairying" (pgf 5.107). The growing of Pangola and Bermuda Coastal grasses was suggested as a means of achieving this goal (pgf. 5.110). The mere improvement of marginal land does not represent a change in its use and will therefore not be documented in this research.

Afforestation: Another suggestion was the establishment of a small forestry industry. The 1965-1968 Economic Development Plan, published by the Barbados government noted that "forestry is not yet an economic activity in the island, but during the period of the Plan it is expected that some capital formation in this section will occur as schemes for afforestation are implemented" (1964, p.27). Despite these plans, it is unlikely that the amount of forested land in the West Coast Study Area changed significantly during the thirty year period studied in this work. It was noted in Chapter Two that the island's flat lands had been almost completely cleared of their forest cover by 1650. No significant re-growth is thought to have

taken place over the next three centuries, because aerial photographs for 1950, 1964, 1972 and 1980 all show an almost complete lack of forest cover on flat land. There remains an extremely strong correlation between steep slopes and the incidence of forest cover. As no use has been found for the forests in which the trees grow, it is unlikely that either the spatial distribution or amount of forest cover in the West Coast Study Area has changed much over the past thirty years.

Urban Development: The plan's intended protection of agricultural land restricted urbanization in most regions to marginal land. It was recognized, however, that not all marginal land was in a suitable location for urban development.

> The reserve of urban land therefore dwindles to 12,000 acres for the accommodation of a projected population of 350,000 at a gross residential density of 29 persons per acre. Once again the problem of restricted urban development is not supply but the distribution and location of suitable land (pgf. 3.208).

Compounding this problem was the fact that much marginal land that was suitable for development was lying idle.

The plan noted that

> the available stock of housing land does not meet the real needs of the majority of the population to be housed. This is illustrated by the fact that 80% of all plots in approved subdivisions are more than 3,000 square feet in area - of which 67% are undeveloped. On the other hand, only 26% of remaining plots, i.e. less than 3,000 square feet are undeveloped (pgf. 7.107).

The plan cited land speculation as the cause of this problem and recommended both (1) "the imposition of higher taxation on unused land to encourage their development or redevelopment for more marketable purposes", and (2) the "revokation of past permissions for subdivision in cases where redevelopment to higher densities is desirable" (pgf. 7.108).

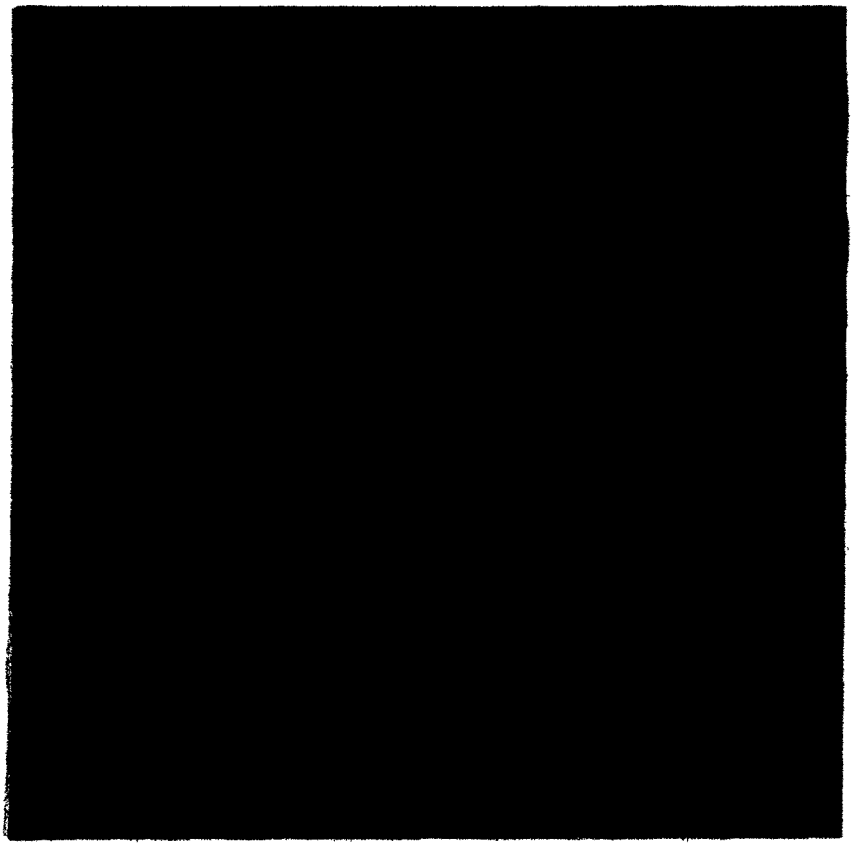


Figure 3.5 Aerial photograph illustrating a largely undeveloped low density subdivision on marginal land

Protection on the Basis of Slope: It was observed by the authors of the Physical Development Plan that mechanization favours flat land. They speculated that marginal areas of flat land might become economically viable productive areas with further mechanization. It was therefore recommended that "care be taken to protect contiguous areas of flat land against the fragmentation which would make them valueless when mechanised cultivation

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assumes dominance" (pgf. 5.110). This recognition that flat areas of marginal land have more potential in terms of agricultural production than do hilly areas of marginal land is a sign that correlations between slope and rate of development may exist. It is possible that areas of flat marginal land will be found to be less prone to subdivision than areas of hilly marginal land. This pattern, if it was in fact induced by the government policy articulated above, will only be in evidence for the third study period. The previous two study periods should demonstrate the opposite trend, because, in an unregulated situation, subdivision and development will naturally occur in the more practical, flatter areas.

Hypotheses: Two hypotheses emerge from the observations and conclusions concerning marginal land that were presented above. (1) Urban development of marginal land will be found to have increased dramatically from one study period to the next. (2) Most development of marginal land in the 1950-1964 and 1964-1972 study periods probably occurred in flat areas. If government policy had any effect, development of marginal land in the final (1972-1980) study period would have occurred primarily in areas with higher slope factors.

Urban Land

Objectives: With regard to urban land, the Physical Development Plan had as its underlying theme the planning for "the land needs of, and proper spatial relationship between Housing, Commerce, Industry, Education, Health, Public Administration, Religion, Entertainment and Recreation" (pgf. 1.03). As a result, it viewed with alarm a trend toward "uncontrolled low density sprawl" (p. vii) and the associated problems of "the loss of substantial acreage of prime agricultural land" (p. vii), the "serious lack of land made available for community facilities" (pgf. 7.104), housing densities that were too low to be efficiently serviced (pgf. 7.104), and insufficient housing lands, due primarily to speculation (pgf. 7.107).

Urban Development Strategy: A major part of the proposed solution to these problems was the implementation of a hierarchical urban development strategy. That strategy included the recommendation that "selected villages be designated as growth points with an optimum population of 1,500" (pgf. 9.106). In order to reduce "low density sprawl", the planners indicated that "isolated families and those whose homes are located on unstable ground would be resettled in such villages" (pgf. 9.106). These villages of 1,500 people were to form the lowest level of a settlement

hierarchy that also included "District Centres", which would be chosen "by virtue of their location and ease of communication with other settlements" (pgf. 9.106). District Centres would have the necessary facilities to serve a population of between 15,000 and 30,000 within a three mile (five kilometer) radius. The penultimate of the four hieracrhical levels, in ascending order, was the "Regional Centre". Two Regional Centres, Oistins and Speightstown, were designated. It was recommended that these towns be equipped to serve populations of 100,000 people within a nine mile (14 km) radius. Bridgetown alone, being the primate and capital city of Barbados, was assigned the top hierarchical level. Given the implementation of this urban development strategy, urbanization throughout the 1972-1980 study period would be concentrated in the following regions of the West Coast Study Area: (1) Speightstown (Regional Centre), (2) Holetown (District Centre), (3) Mile and a Quarter, (4) Carlton, (5) Sion Hill, (6) Redmans, (7) Cave Hill (north), (8) Oxnards (proposed government housing project), and (9) Husbands (proposed government housing project).

Housing Land: There was a recognized need for the provision of more housing land. In all, 12,000 acres of unproductive land was designated as being suitable for urban development. Of this total, 1,200 acres were to be used for the construction of low density accommodation (10 persons per acre), 9,600 acres were to be used for medium density

accommodation (30 persons per acre), and the remaining 1,200 acres were to be made available for high density accomodation (42 persons per acre) (pgf. 3.212). As mentioned earlier, the problem of land that was sitting idle due to speculation was to be solved by the "imposition of higher taxation on unused land to encourage their development, or redevelopment for more marketable purposes", and the "revokation of past permissions for subdivision in cases where redevelopment to higher densities is desirable" (pgf. 7.108).

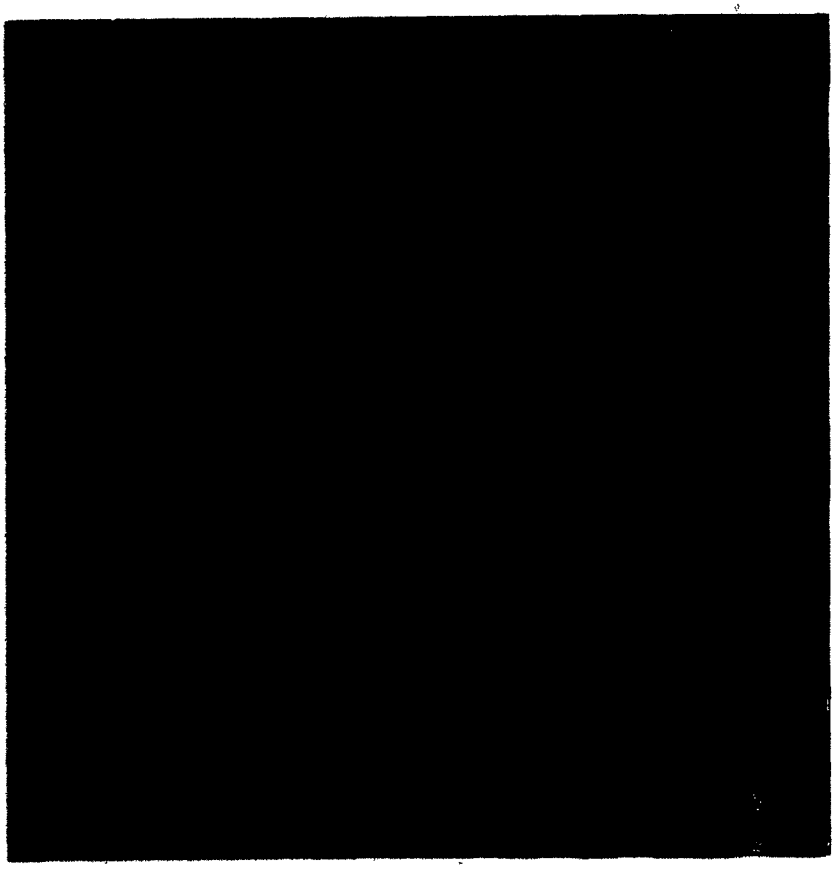


**Figure 3.6 Aerial photograph illustrating ribbon of urbanization along Highway 1**

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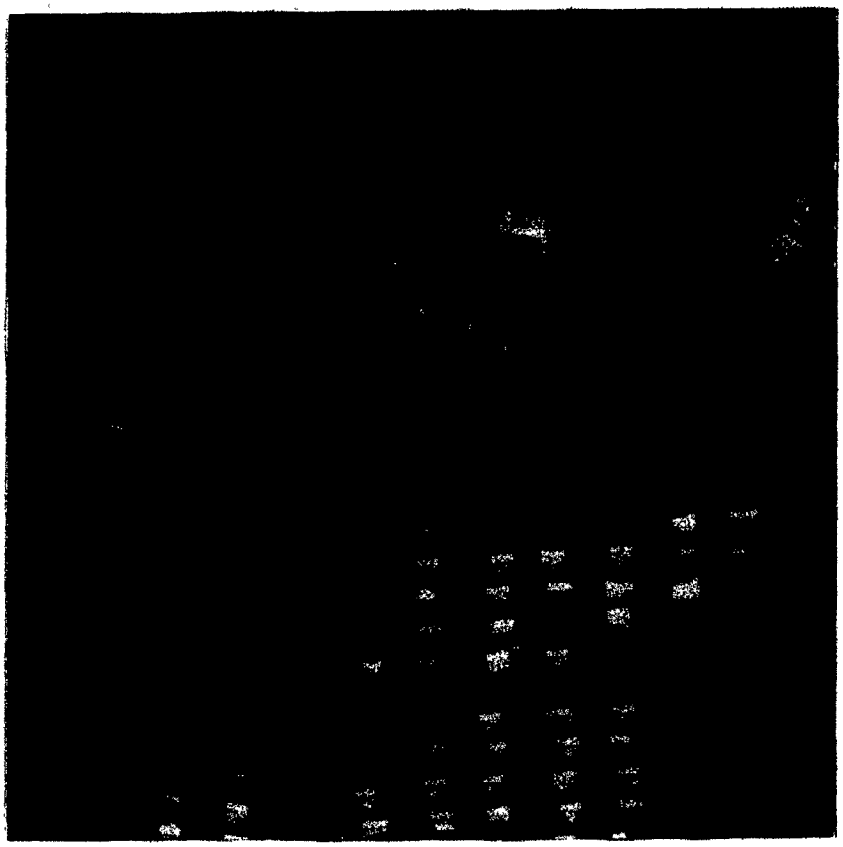


Figure 3.7 Aerial photograph illustrating different housing densities

Industrial Sites: It was a stated government objective to develop industry on the Island. Provision was therefore made in the Physical Development Plan for the designation of more industrial sites. The authors of the plan noted (pgf. 5.312) that "the basic requirements of industrial sites and estates are that they should be on reasonably flat and well-drained land which can be conveniently supplied with essential services...". Proximity to transportation facilities and sources of labour

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were also deemed essential. Despite these good intentions, however, the lack of raw materials, shortage of risk capital and prohibitive distances to world markets has made the development of industry a slow task in Barbados. Therefore, it is unlikely that the process of industrial urbanization caused significant land use change in the West Coast Study Area during any of the three study periods. On the other hand, the construction of tourist facilities, native housing and infrastucture, all urbanizing forces in their own right, probably necessitated the opening of quarries for rock and cement. These quarries themselves represent an increase in the amount of urban land in the West Coast Study Area.

Hypotheses: Three hypotheses have been formulated regarding urbanization. (1) Urbanization that occurred before 1972 took place without regard to land capability or previously established land uses. This is a predictable outcome of unregulated open competition for housing and industrial land. (2) Urban development that occurred after 1972 took place in designated growth areas. In particular the Speightstown, Sunset Crest and Prospect sub-units of the West Coast Study Area are anticipated zones of high urbanization for the third study period. (3) Urban development that occurred during the third study period (1972-1980) likely involved land that was unused during the previous (1964-1972) study period. While most of this development probably took place on marginal land, some development of land of high capability may also have

occurred. Such development would be restricted to cases in which land had been taken out of agriculture for the purpose of speculation before the publication of the Physical Development Plan. Thus, land of high capability that was developed for urban uses during the 1972-1980 study period probably evolved through the following series of land use changes: (i) 1950-1964, agriculture, (ii) 1964-1972, unused / speculation, (iii) 1972-1980, development.

Tourism and Recreation Land

Competition with Agriculture: The Physical Development Plan noted that tourism had increased in its contribution to the national economy from eight million dollars worth of gross receipts in 1957 to twenty-six million dollars worth in 1965. The further encouragement of tourism was seen as being of potential economic benefit to the Island. One of the plan's objectives was thus to "create and maintain an environment which would attract visitors and encourage the development of tourism" (pgf. 1.02). This recommendation supported further dramatic increases in the amount of land devoted to the tourist industry on the west coast of Barbados. Certain restrictions had to be imposed on tourism development, however, because in the 1950's and 1960's, competition with the agricultural sector for land had been eroding the potential economic benefits of tourism. The authors of the Physical Development Plan noted that

> ...the uncertainty of the potential of land for building development give(s) rise to higher living costs and speculation in land prices. The latter danger is the chief hazard to orderly planning of the development of the island's basic resources as evidenced in the growing tendency to alienate agricultural land for purposes of speculative trading. The result is a reduction in agricultural productivity and the proliferation of disorganized building development to satisfy what is anticipated as the demands of tourism (pgf. 3.215).

Prescott (1967, p. 12) substantiated the plan's claim when he wrote "the west coast, especially, is feeling the impact of the tourist industry, and sub-divisions occur at Paynes Bay and Sandy Lane". What Prescott did not mention is that the Sandy Lane Plantation, one of the few irrigated plantations on the island, and one of the most productive on the west coast, was turned into a golf course in the early 1960's. It was this sort of wasteful, unregulated land use change that prompted the government to commission the formulation of a development stratgey for the Island.

Competition with Housing: The authors of the Physical Development Plan noted (pgf. 3.213) that competition between residents, who needed land for housing, and the tourist industry, which was seeking land for hotels and recreational facilities, was also being resolved "in favour of the dollar with the highest value".

Development Strategy: In light of these problems, the planners recommended that tourist accommodation be

incorporated in the development strategy that had been designed to control urban sprawl and protect agricultural land. Land areas zoned for low density accommodation would include 'A' class hotels. Guest houses, tourist apartments and cottages were to be built in medium density areas along with apartment buildings and other native housing of medium density. 'B' class hotels would be restricted to areas zoned for high density development (pgf. 3.212). The location relationships between land use types for any single study period are not examined in this work. Thus, the success or failure of plans to mix native housing and tourist accommodation cannot be guaged.

Proximity: Tourism facilities cannot be integrated easily into an urban development plan designed primarily to control housing "sprawl" because, to be successful, tourist facilities must be located close to beaches. As a result, the vast majority of tourism development in the West Coast Study Area is expected to have occurred within a thin band close to the shore. A factor responsible for the modification of this 'hotel to beach distance' relationship is the establishment of secondary proximity relationships with other types of tourism-related land uses. For example, the development of tourist housing (villas) inland of existing beach-front facilities is a trend that has been observed in the Sandy Lane Area since 1964. In most cases,

the appeal of the building sites upon which these villas were constructed was their proximity to the Sandy Lane Golf Course. A secondary proximity relationship is said to exist here because the villas were situated adjacent to the golf course, which was itself intentionally built in close proximity to the beach.

Hypotheses: Three hypotheses related to tourism development are tested in this thesis. (1) Land use statistics for 1964 should show considerably more land devoted to tourism than the 1950 statistics. The lack of regulations protecting prime agricultural land during the 1950-1964 study period and the resultant use of land with high agricultural capability for the building of hotels, golf courses and recreational facilities is expected to emerge quite clearly in the analysis of land use change between 1950 and 1964. (2) The 1972-1980 time period should exhibit by far the greatest rate of increase in tourism development. The dangerous trend toward alienation of agricultural land will probably show signs of slackening-off in this study period, however. If land of high capability is found to have been developed for tourism in the 1972-1980 study period, it will be necessary to examine the evolution of the particular parcels involved from 1950. In such cases, it is likely that land that was being used for the growing of crops in the first time period, was bought

for speculation and taken out of production in the second time period, and was finally developed in the third time period. This sequence, which is also anticipated with respect to land speculation for urban development is a likely possibility when considering speculation leading to the development of land for tourism. (3) The comparison of a proximity index with land use change information will almost certainly prove that distance to the beach has had a greater impact on decisions regarding the location of tourist facilities than has any other variable. It is expected that this relationship will be equally strong for all three time periods. Secondary proximity indices will also be examined. It is anticipated that this phenomenon will be most prevelant in the 1972-1980 study period.

Having formulated hypotheses relating to the significant physical, economic and legislative controls on land use change in the West Coast Study Area, it now becomes necessary to develop a land use classification that will enable both (1) accurate measurement and mapping of land use change, and (2) the guaging of correlations between land use change and land capability and site parameters. The development of such a land use classification for western Barbados is performed in Chapter Four.

# CHAPTER FOUR: LAND USE CLASSIFICATION

This chapter begins with a review of the principles of land use classification and an analysis of some of the general systems in use at the present time. The factors affecting the levels of classification that can be achieved are then examined in order to provide a background to the development of a classification system at a scale that is appropriate to the study of land use change in western Barbados. A six category land use classification is then developed, with complimentary and other anomalous land use types being explained in some detail. The chapter concludes with a discussion of the scale at which the classification ia applied to the study of land use change in western Barbados.

## Types of Land Use Classification

The undirected description, classification or documentation of land use is seldom practiced. Rather, almost all land use surveys are performed with a clearly stated intention in mind. Wood (1973, p.170) believes that

> ...a land use classification must have a clearly defined purpose and that it should be possible to determine the success of the classification by evaluating its achievements in relation to that purpose.

This is not to imply that a broadly defined land use classification is any less scientifically valid than a less specific one. General purpose land use classes mapped over

large areas are invaluable in national planning and in providing an overview for researchers who intend to perform more specific studies at later dates. The national Land Use and Land Cover Classification System developed by Anderson (1976) is an example of such a work. Anderson recognized the need for a hierarchical reference system which could be used at different levels of generalization. His system was intentionally designed to be open-ended

> ...so that Federal, regional, State and local agencies can have flexibility in developing more detailed land use classifications at the third and fourth levels in order to meet their particular needs and at the same time remain compatible with each other and the national system (Anderson: 1976, p.1).

Anderson's Land Use and Land Cover Classification System is unusual, however, in that the great majority of land use systems are designed to be employed in much more specific situations. It follows that the types of land use surveys are as numerous and varied as the physical, social or economic variables to which they relate. For example, land use classifications have been developed to study the relationships between land use and soil, crop disease, economic output, field patterns, land systems, and land ownership.

Regardless of the nature or scope of a land use classification, the first rule of land use study is always the statement of, and adherence to, a clearly defined intention for the work. This statement of intention must

include not only the parameters to be studied, but also the size and location of the study area and the scale at which the classification is designed to be applied.

## Classification Resolution

Four factors combine to limit the potential resolution of a land use classification, as outlined below. (Mapping scale is in each case inversely proportional to the classification resolution chosen).

(1) The diversity of land use within the study area is the prime determinant of potential classification resolution. The greater the land use variability, the more essential is a fine resolution.

(2) The size of the land use components (SLC) relative to the mapping scale (MSC) is a second factor that controls potential classification resolution (PCR). PCR increases as the ratio of SLC to MSC approaches unity. It is apparent that very small areas devoted to specific land uses may fail to be documented by large scale land use mapping.

(3) The detail and accuracy of land use information is obviously crucial in determining potential classification resolution. The inability to recognize small land use components on aerial photographs or to derive information about them from field surveys will reduce the potential resolution of the analysis. Conversely, it is possible to increase the resolution of a land use classification by

including very small land use components. This temptation must be resisted, however, when the accuracy of detail is insufficient to ensure correct representation of the most specific land use types.

(4) Land use surveys are often performed in order to compare land use with some other variable, such as land capability. In such cases, the potential classification resolution of land use is technically unrelated to the accuracy and detail of the parameters to which land use will later be compared. The degree of detail employed in a land use classification should, however, be geared towards the illustration of the most meaningful relationships between land use and the second group of parameters being considered. Too much land use detail tends to obscure the relationships, whereas insufficient detail does not allow an adequate correlation.

Once all of the considerations mentioned above have been taken into account, it is normal for a land use researcher to attempt to classify land use with as much detail as possible. Clawson (1965, p.5) considered that "in field enumeration or other data assembly at the basic stage, activities as observed or reported should be recorded with the maximum detail and with the minimum of preclassification or grouping ... (because) ... this leads to more accurate recording of activity, and, more importantly, the data so obtained and coded may be either grouped into broader

classes by any one of several grouping arrangements or used in any detail desired".

As desirable as it is to apply this general principle to land use classifications which will later be re-aggregated to fill geographically or thematically specialized requirements, it should be kept in mind that many land use researchers are able to determine the specific degree of classification detail required at the outset of their work, by considering both the limiting factors outlined above and the focus of the study.

(5) The focus of a land use study is the major determinant of the classification resolution to be employed. A recreational land use study, for example, would differentiate between tennis courts, golf courses, beaches and parks. An agricultural land use study would use different symbols to represent corn, potatoes and livestock. A general land use study might group the first four categories under the single heading 'recreational land', satisfactorily differentiating these areas from 'agricultural land', which could include the latter three categories. It will become apparent, once the land use classification to be employed in this work is outlined, that consideration of greater land use detail would have been both superfluous to the needs of the research and unnecessarily time consuming in this case.

In this study the requirement is for a land use classification scheme appropriate for detecting the changes

associated with development. It is a general land use classification in that it comprises six land use classes.

As with most general land use schemes, the classification employed here recognizes three main categories of land use: (1) Agricultural Land, (2) Developed Land, and (3) Unused Land. Each of these three categories is further subdivided into two land use types, resulting in a six element land use classification, as outlined on the following pages.

Land Use Type 'A' ('Grazing and Unused Land'):

This category includes all grasslands and scrublands, including those with a covering of sourgrass or small bushes. Designated pastures, areas of rough grazing land and all peasant or plantation holdings not in agricultural production also fall into this category. Sink holes, ponds and swamps, although comprising only a very small percentage of the land in the West Coast Study Area, are also considered to be part of Land Use Type 'A'.

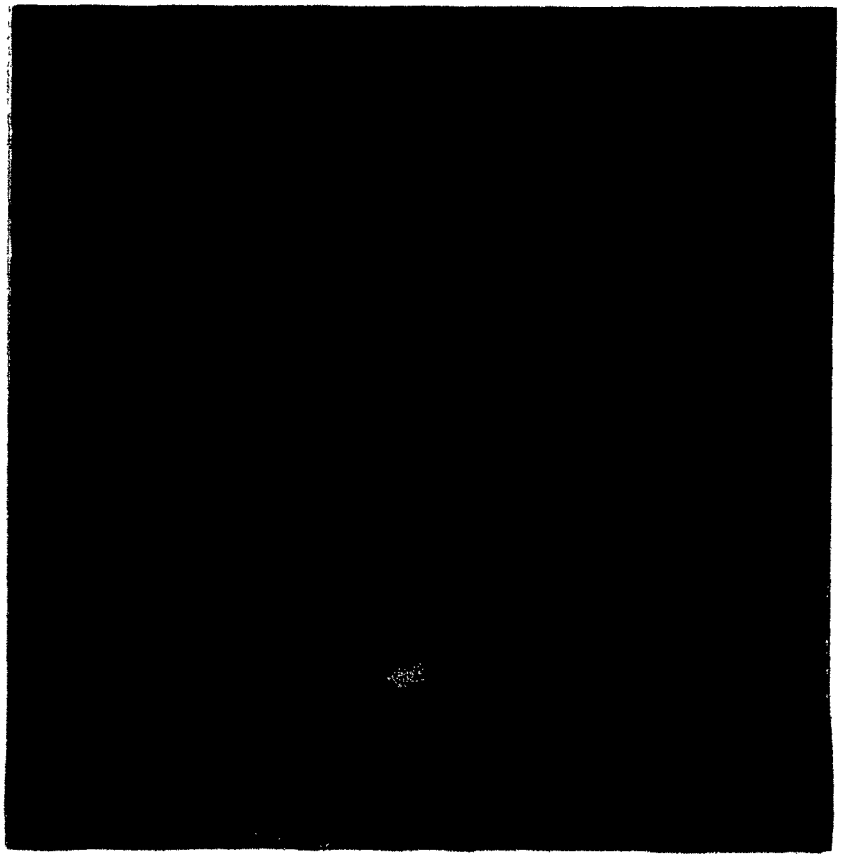


Figure 4.1 Aerial photograph illustrating Land Use Type 'A' ('Grazing and Unused Land')

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Land Use Type 'B' ('Plantation Agriculture'):

This category consists solely of plantation land that was in agricultural production during the year of interpretation. It does not include land in fallow.

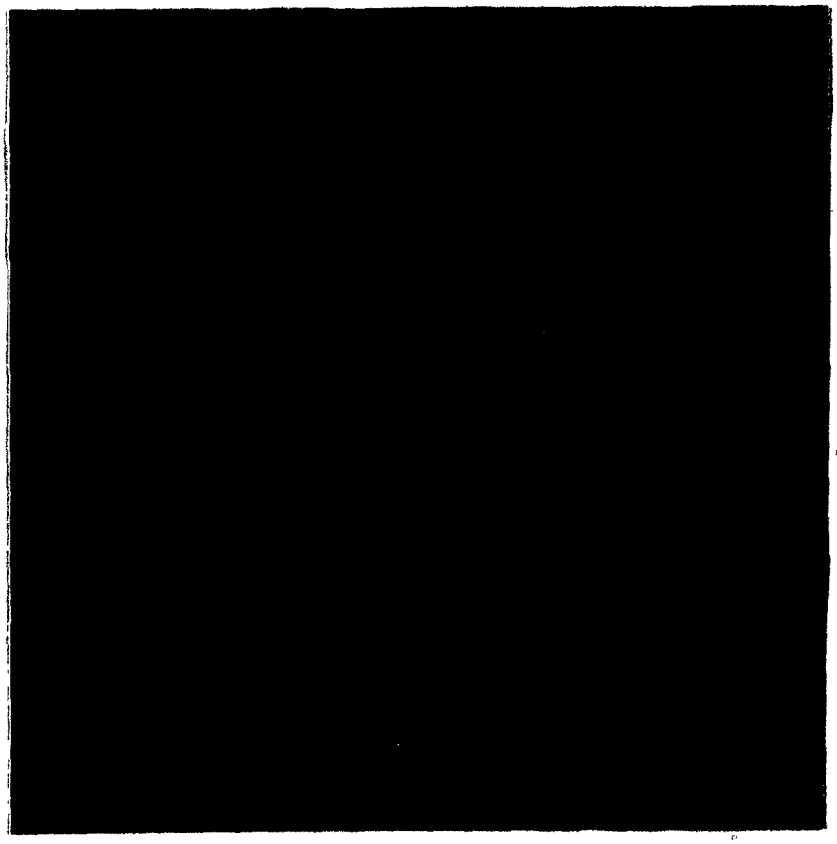


Figure 4.2 Aerial photograph illustrating Land Use Type 'B' ('Plantation Agriculture')

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Land Use Type 'C' ('Peasant Agriculture'):

This land use category includes all peasant lands that were in agricultural production during the year of interpretation. It does not include land in fallow. Individual or small groups of chattel houses and related infrastructure also fall under this heading where concentrations do not warrant interpretation as Land Use Type 'F' ('Urban and Industrial Land').

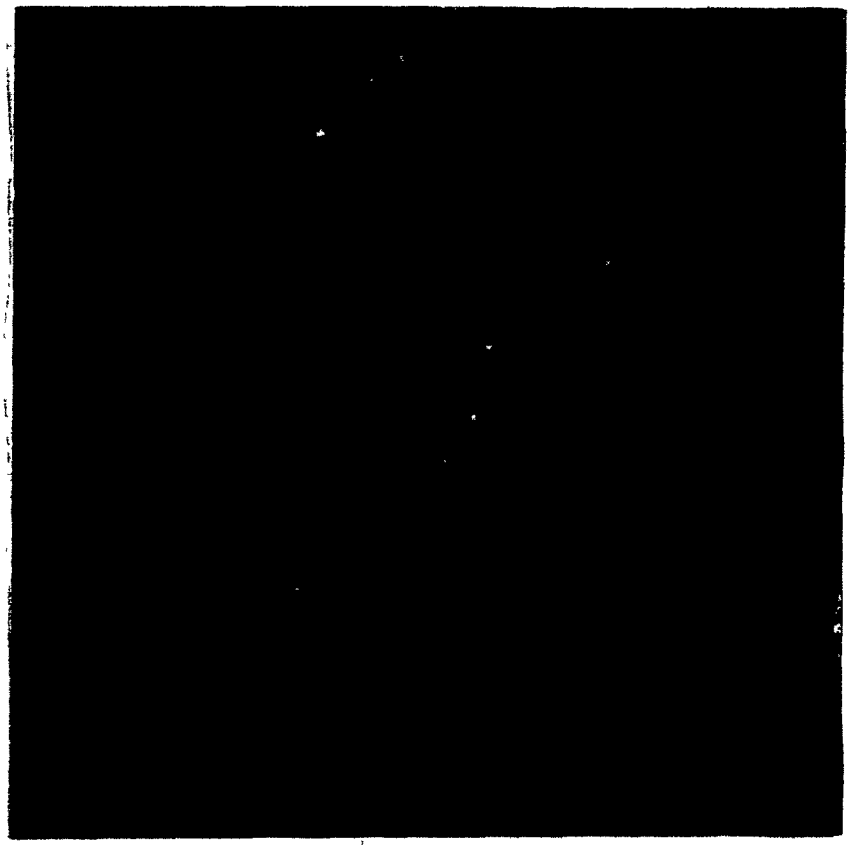


Figure 4.3 Aerial photograph illustrating Land Use Type 'C' ('Peasant Agriculture')

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Land Use Type 'D' ('Uncleared and Overgrown Land'):

This land use category consists of all unused land that is covered in trees or dense concentrations of small bushes.



Figure 4.4 Aerial photograph illustrating Land Use Type 'D' ('Uncleared and Overgrown Land')

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Land Use Type 'E' ('Tourism and Recreation Land'):

This land use category includes all land that is used for recreational purposes by either tourists or natives. Thus golf courses, tennis courts, beaches and playing fields all fall under this heading. All forms of housing and other accommodation designed to house tourists are also included in this category. This includes hotels, guest 'villas' (and their associated property) and all non-native housing (and its associated property).

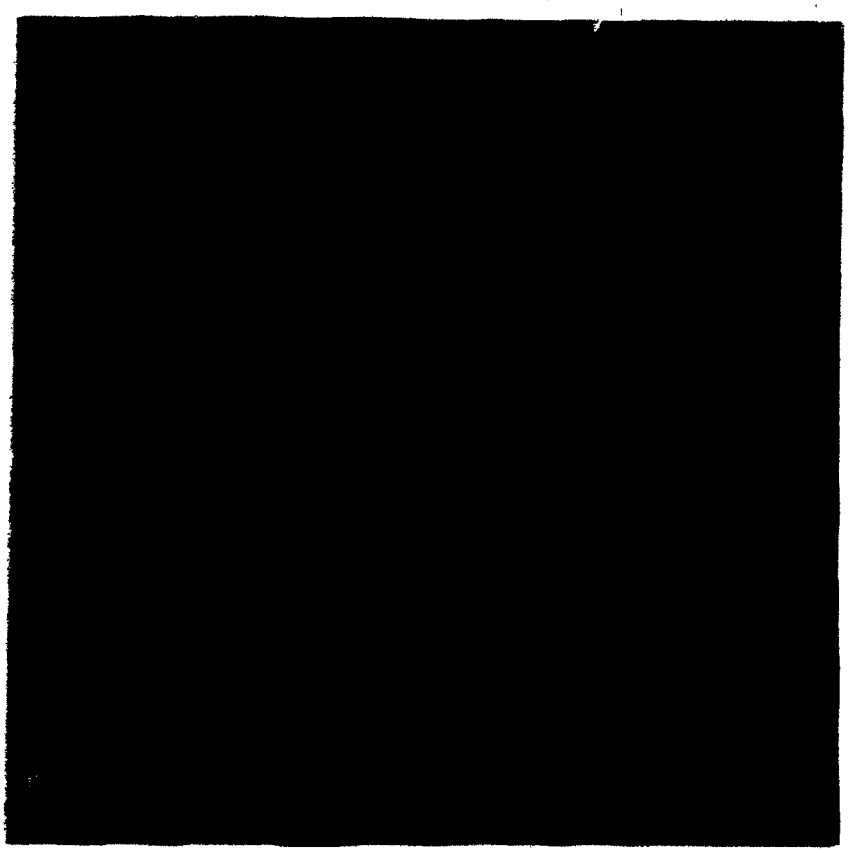


Figure 4.5 Aerial photograph illustrating non-native housing adjacent to a recreation field - both Land Use Type 'E', ('Tourism and Recreation Land')

COLOURED PICTURES
Images en couleur

Land Use Type 'F' ('Urban and Industrial Land'):

This category is comprised of urban and industrial infrastructure and housing. Urban infrastructure includes shopping complexes, offices, schools, churches, hospitals and other service oriented buildings and land. Industrial infrastructure includes mines, mills and factories, whether located in urban or rural areas. Housing includes chattel houses in villages or hamlets, as well as plantation houses and their associated infrastructure (including small, non-productive lots surrounding these buildings).

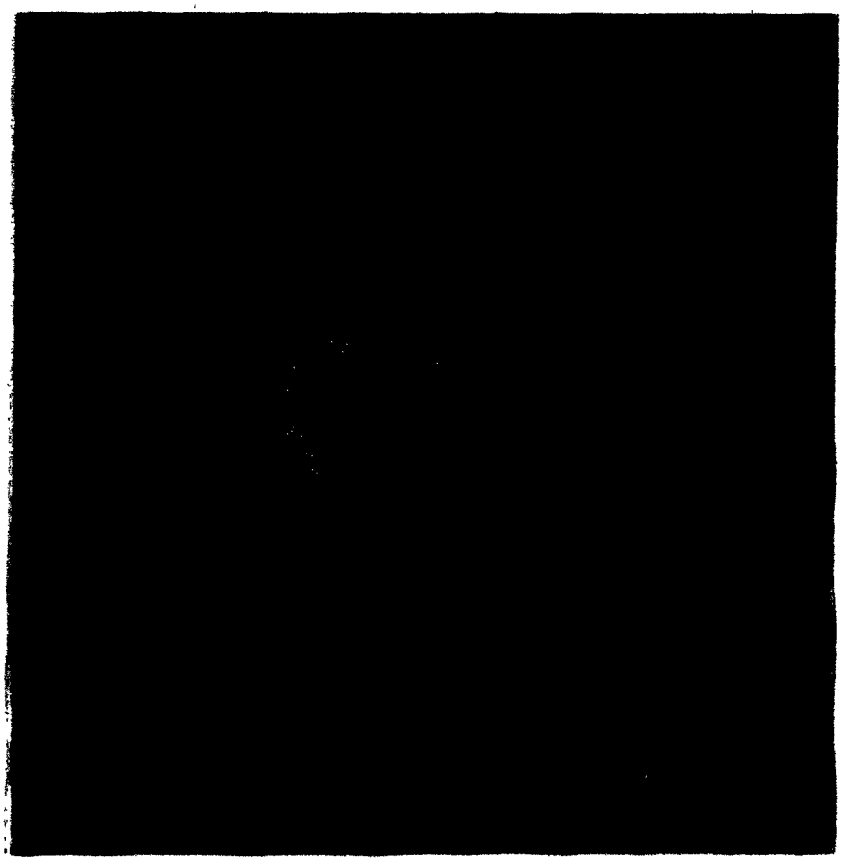


Figure 4.6 Aerial photograph of Porter's Sugar Factory - Land Use Type 'F', (Urban and Industrial Land')

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Figure 4.7 Aerial photograph illustrating quarrying. Land Use Type 'F', ('Urban and Industrial Land')

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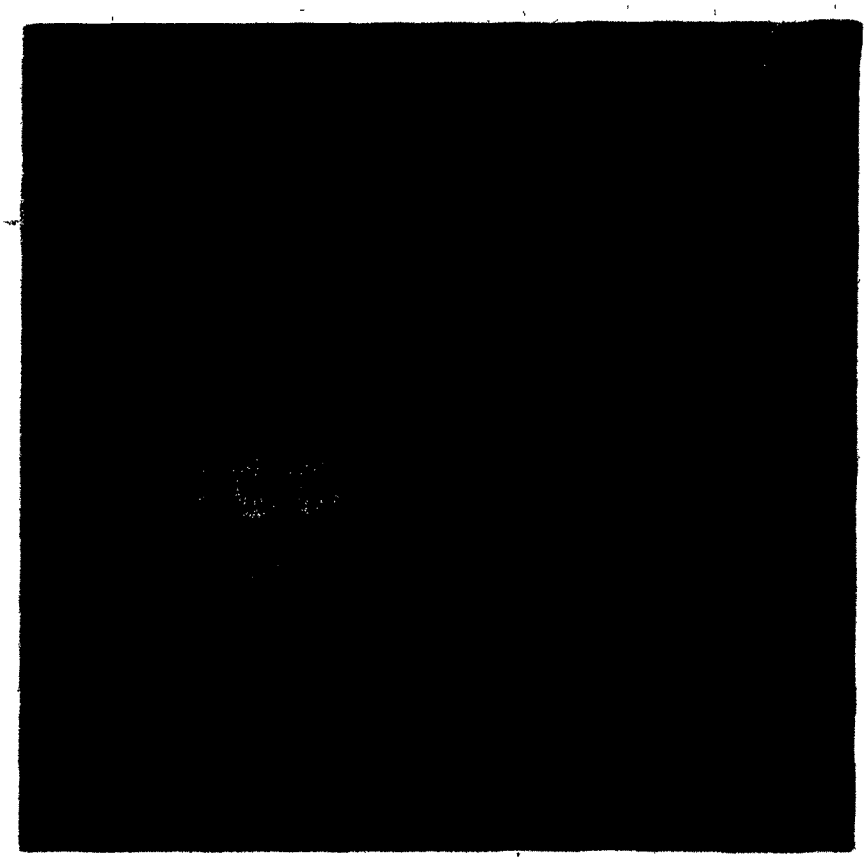


Figure 4.8: Aerial photograph of St. James Secondary School (white roof) and St. James Mixed School (red roof) - Land Use Type 'F', ('Urban and Industrial Land').

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## Comments on the Classification System

The classification employed was intentionally limited to six land use types in order to simplify the interpretation and mapping of land use and land use / land capability relationships. Given the historical nature of this land use study, it was especially important to restrict the classification to clearly recognizable land use types, as the interpretation could not rely on field verification.

The reader will, by this point, have observed that this 'land use classification' is perhaps more properly referred to as a 'land use / land cover / land tenure classification' in that its six categories are equally divided between representation of these three parameters. Land 'use' technically refers only to categories 'E' ('Tourism and Recreation Land') and 'F' ('Urban and Industrial Land'). Categories 'B' ('Plantation Agriculture') and 'C' ('Peasant Agriculture') are distinguished from one another on the basis of their tenure, rather than their use. Categories 'A' ('Grazing and Unused Land') and 'D' ('Uncleared and Overgrown Land') both refer to land cover, rather than land use.

While it may seem contradictory to include 'unused land' in a land 'use' classification, convention allows for this slight anomaly, especially in lieu of the repeated use of an unnecessarily cumbersome name for the classification. The inclusion of land tenure characteristics within a land

use classification is justified on the following grounds: a change from plantation agriculture to peasant agriculture is considered to be a land use change in that it represents a change, not necessarily in how the land is used, but by whom it is used.

This land use classification was designed to document significant land use differences for the relatively small West Coast Study Area of Barbados. However, there exist in that area both 'hidden' and 'complimentary' land uses which should be elaborated upon, as the use of a six character legend precludes their regognition.

(1) In a very few cases, small roadside bars, restaurants and grocery stores may have been misrepresented as 'chattel' houses. Such small businesses are often operated out of buildings that are identical in size and shape to 'chattel' houses, making their accurate interpretation from aerial photographs impossible. It should be stressed that this misrepresentation is thought to be negligible, in that most of these businesses are found in areas of high housing concentrations, thus the overwhelming majority of them would be correctly grouped under heading 'F' ('Urban and Industrial Land Use'), rather than under heading 'C' ('Peasant Agriculture').

(2) The interpretation of 'non-native housing' and 'guest villas' (both Land Use Type 'E'), as distinct from 'native housing' (Land Use Type 'F') is another area where the impossibility of field verification presented a slight

problem. It is felt, however, that the writer's knowledge of the study area enabled accurate interpretation of these classes of housing based on house and lot size, site, and associated infrastructure. Some limited misinterpretation surely took place, but it is considered to be negligible, especially considering the extremely conservative interpretation guidelines which were adhered to in this case.

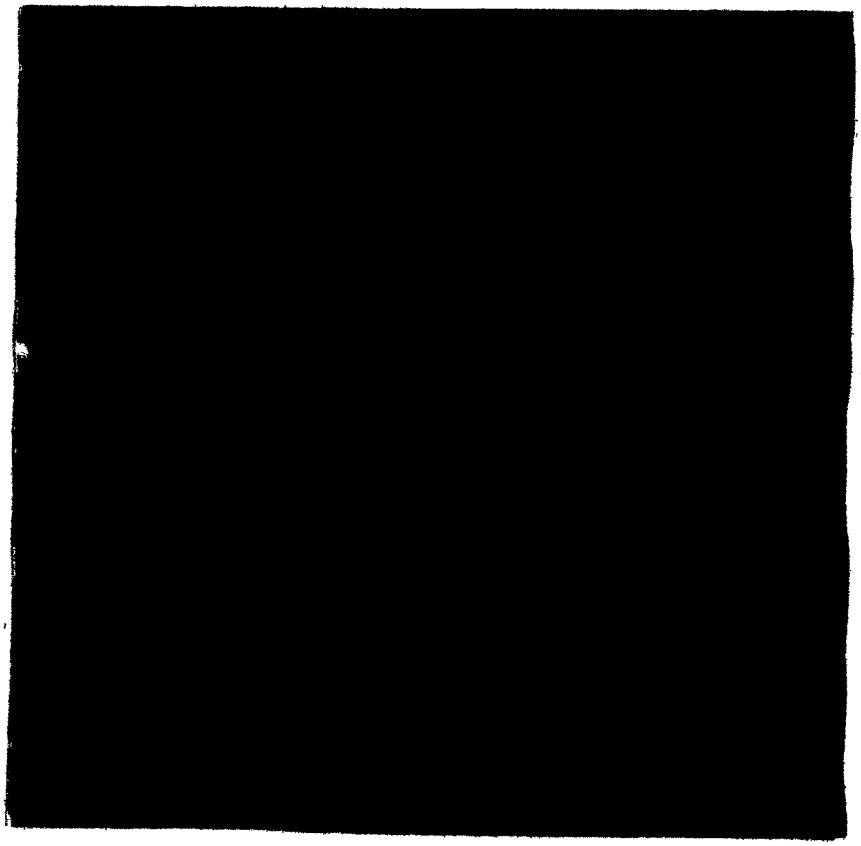


Figure 4.9 Aerial photograph illustrating native and non-native (above gully) housing

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(3) Some shopping complexes built to serve tourist areas are used extensively by the native population, while tourists obviously use shopping centres which were not built specifically to serve them. The result is that, while most shopping complexes are classed as Land Use Type 'F' ('Urban and Industrial Land Use'), a few have been labelled 'E' ('Tourism and Recreation Land Use'). The few that were labelled 'E' are those surrounded by, and clearly designed primarily to serve, tourist areas. Office buildings, churches and hospitals also serve both natives and tourists, but these are all classed as 'F' ('Urban and Indusrtial Land Use'), given that their primary purpose is to serve the native population.

(4) Land use category 'A' has as its major heading 'Grazing and Unused Land'. For the purpose of this work, all cleared, unused land is considered to be potential rough grazing land. Once again, familiarity with the study area supports this interpretation. The high population density, extensive livestock ownership, unrestricted access to unused land and the lack of defined grazing areas makes the practice of the rough grazing of animals a ubiquitous one throughout the West Coast Study Area.

(5) Golf courses and playing fields have all been classified as Land Use Type 'E' ('Tourism and Recreation Land'). It should be borne in mind, however, that rough grazing is also practiced in these areas. In most cases,

overgrown areas adjacent to golf course fairways or playing fields have been classified as Land Use Type 'A' ('Grazing and Unused Land').

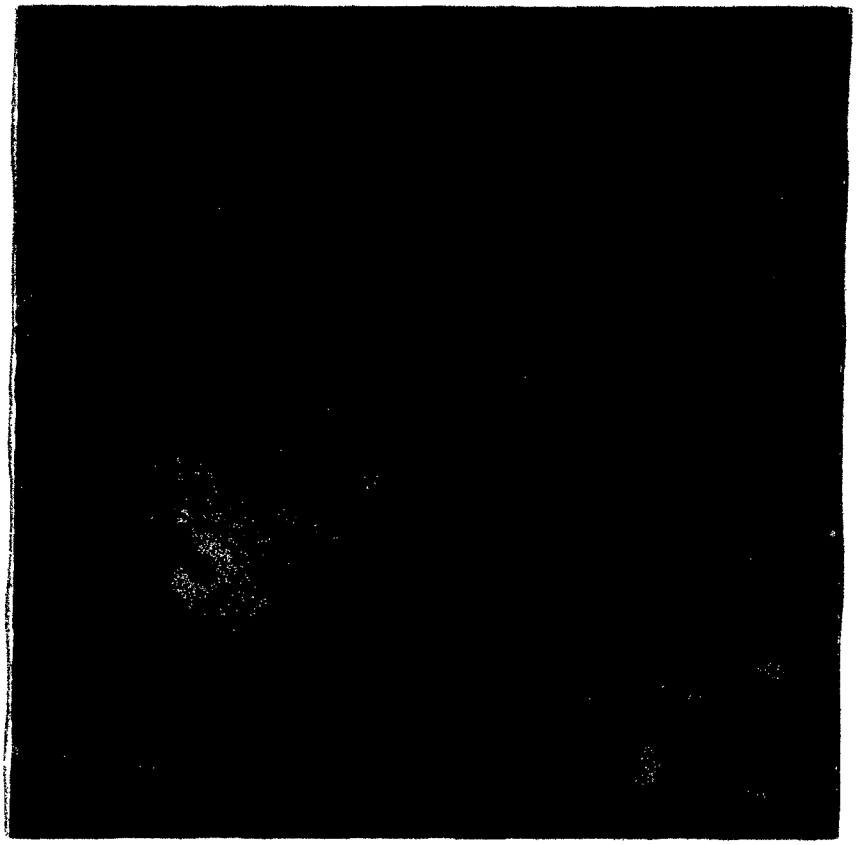


Figure 4.10 The shopping complex in the lower left-hand corner of this aerial photograph is surrounded by 'guest villas' and other tourist facilities. It is, therefore, classified, along with its surroundings, as Land Use Type 'E' ('Tourism and Recreation Land').

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Thematic Mapping of the West Coast Study Area

It was stated at the beginning of this chapter that a land use classification can be evaluated in terms of its effectiveness in meeting a particular requirement. The stated objective of this work is the study of relationships between land use change and land capability parameters for western Barbados. A defense of the classification system being applied towards this objective has already been presented. As good as the classification system may be in terms of distinguishing between land use types for a given period, its ultimate faithfulness to the stated objective of measuring land use change depends to a large extent on the geographic accuracy with which it is recorded. Clawson (1965, p.13) states that

> there is great value in historical comparisons of data relating to land, but this can best be accomplished by comparisons of observations taken at two defined points in time, each for the same area and each so clearly identified as to location that no confusion will arise. An attempt to record past changes in land use, except by such clear identification of the situation at specified points in time, will almost certainly lead to confusion.

A number of factors play key roles in determining the degree of difficulty in controlling the spatial accuracy of thematic mapping. The first factor is the relationship between the size of individual data points and the scale at which the data is mapped. For any given mapping scale, a

decrease in data point size results in an increase in the difficulty of achieving good geographic restitution. This complication must be weighed against the potential increase in detail and accuracy of comparison that also results from a decrease in data point size. In this work, all computer mapping is 'fitted' to the 1:10,000 scale of the topographic survey of Barbados. The 1:10,000 topographic sheets thus provide a controlled base to which all aerial photographs and thematic base maps are related. Each square inch (6.45 $cm^2$) of computer output map consists of 64 data points. The actual ground area represented by each data point is thus 1,008.06 square meters. It is felt that this ratio of mapping scale to data point size ensures accurate comparison of land use and land capability variables by providing a high degree of detail, while still ensuring near perfect restitution.

A second factor that influences the likelihood of achieving a high level of geographic accuracy is the relationship between air photo scale and mapping scale. The more detailed the aerial photography relative to the final map, the more likely it is that a high degree of geographic accuracy will be achieved.

In this work, four separate sets of aerial photographs were used, one set corresponding to each of the four study years. The 1950, 1964 and 1972 aerial photographs were all taken using black and white film in nine inch (22.86 cms) by nine inch format cameras. Lens

focal length was identical and flying height similar, resulting in comparable air photo scales. The 1980 aerial photographs were taken by the author using colour film in a 70mm format camera. Mission altitudes of between 2,000 feet (600 meters) and 5,000 feet (1,500 meters) and the use of an 80mm focal length lens produced a range in photo scale from 1:5,700 to 1:19,000. This range resulted primarily from weather problems which necessitated the selection of different altitudes. It should be noted, however, that the vast majority (>80 percent) of the 1980 photography ranges in scale from 1:5,000 to 1:10,000.

The slightly different scales, formats, film types and angles of view (tilt) of the photographs were insignificant in terms of their effect on the geographic accuracy of the recording of the land use data. This was ensured through the use of a Zoom Transfer Scope, an optical instrument which facilitates, within certain limits, the geographic restitution of information represented on distorted images. Anamorphic correction is achieved through the use of optics which stretch, tilt and rotate the aerial photograph relative to the base map. In this case the variations in scale, tilt and format did not even approach the limits of the instrument, despite the relatively high detail and geographic accuracy required in this work.

Using the Zoom Transfer Scope, the photographs were projected directly onto the 1:10,000 topographic sheets. Once a perfectly aligned overlay had been achieved, the land

use interpretation was performed on a piece of translucent drafting paper, which was itself registered with the topographic map. The graph paper was sub-divided into 96 data points along the X axis and 80 data points along the Y axis. This rectangular format was necessary in order to comply with the data entry restrictions of the computer. The shape of the map was defined by leaving blank the data points for which there was no information. The same procedure was used for the computer mapping of land capability and site variables, the only difference being that thematic maps, rather than aerial photographs were used as sources of information.

The method of geographic restitution described above ensured that a specific geographic location was always assigned the same set of coordinates, and, concomitantly that both inter-period comparisons of land use, and comparisons of land use with land capability and site variables, were meaningful.

Each data point was entered into the computer manually, using a video display terminal upon which the editing of the data base was possible.

# CHAPTER FIVE: LAND USE CHANGE (1950-64-72-80)

## Mapping and Measuring Land Use Change

### The Computer Program:

The study of changing land use over a three decade period and its relationship to land capability necessarily involves consideration of numerous interrelated variables. Both land capability and land use studies are multi-parametric in nature, the number of variables considered being a function of the nature and scope of the research.

In attempting to decide upon a system of comparing land capability and land use variables, a number of methods were considered. These included: (1) overlays, (2) manual comparison and redrawing of maps using grid references to generate 'composite' data sets, and (3) computer data set comparison. The former two options were rejected in favour of computer data set comparison due to the following advantages inherent in the computer system. (1) The ability to store, retrieve and compare both terrain factor and land use data sets, allowing the researcher to examine many more combinations of variables than would be practical had manual methods been used. (2) The ability to compare highly specific points representing small areas, thereby providing better spatial resolution than would be possible with manual techniques. An important factor in this regard is the

facility of the computer to assign clearly defined (unambiguous), geographically specific symbols to each point of comparison. This would simply not be practical at the scale employed if the researcher had to rely on manual comparison. (3) The ability to compare specific areas or variables while ignoring others. (4) The provision of accurate statistics on the percentage change or absolute area of change in land use or land use / terrain factor relationships. (5) The facility to generalize classifications in cases where the difference between two land use types or terrain factors is insufficiently significant for them to be independently represented. Very often this problem does not become apparent until after the data are compared, by which time it would be extremely time consuming to redefine the data classes using any method other than computer editing. (6) The ability to handle large amounts of data that would swamp conventional data set comparison procedures.

Having decided on the use of computer comparison, it was necessary to write a program that would 'overlay' any one data set on another and provide statistics for the two original data sets, as well as the 'composite' data set.

The Fortran program written for this application recognizes six possible characters in Data Set One - 'A', 'B', 'C', 'D', 'E', and 'F'.

Table 5.1: Character Generation Matrix

| | | Character in Data Set Two | | | | | |
|---|---|---|---|---|---|---|---|
| | | A | B | C | D | E | F |
| Character in Data Set One | A | A | B | C | D | E | F |
| | B | G | H | I | J | K | L |
| | C | M | N | O | P | Q | R |
| | D | S | T | U | V | W | X |
| | E | Y | Z | * | 1 | 2 | 3 |
| | F | 4 | 5 | 6 | 7 | 8 | 9 |

The same six characters are used in Data Set Two. The computer simply compares each co-ordinate as defined by the data entry format (described in Chapter Four) in the first set with its counterpart in the second set. A thirty-six character composite data set is then generated, with each output character representing a specific combination of letters from the first and second data sets. The composite data set a common structure according to the listing given in the matrix (Table 5.1).

The characters 'A' to 'F' can be assigned to any variable by simple redefinition of the legend to suit the subject of the thematic map being prepared. The legends used in the mapping of soil association, soil depth, terrain slope, rainfall and proximity to the ocean, are all listed

under the appropriate headings in Chapter Three. The land use legend employed for all four years of observation is listed in Chapter Four.

The statistics produced using the computer system described above are analysed in the following section.

## Analysis of Land Use Change: 1950-64-72-80

Land use statistics for the West Coast Study Area for each of the four years of analysis are presented in Table 5.2 Figure 5.1.

Table 5.2 Land use statistics (Percent of total area)

| Land Use Type | 1950 | 1964 | 1972 | 1980 |
|---|---|---|---|---|
| Grazing/Unused Land | 33.30 | 21.16 | 36.26 | 34.88 |
| Plantation Agric. | 37.75 | 42.12 | 28.09 | 25.03 |
| Peasant Agric. | 15.97 | 18.20 | 9.83 | 9.19 |
| Uncleared/Overgrown | 7.88 | 9.99 | 9.11 | 8.90 |
| Tourism/Recreation | 1.87 | 3.70 | 6.39 | 8.61 |
| Urban/Industrial | 3.23 | 4.83 | 10.32 | 13.39 |
| TOTAL: | 100.00 | 100.00 | 100.00 | 100.00 |

The nature and extent of detailed changes in land use are examined in the following pages under three sub-headings - (1) analysis of change relative to other study years, (2) analysis of change relative to other land use types, and (3) analysis of change relative to physical parameters. The chapter concludes with the testing of the hypotheses presented in Chapter Three, in the order in which they were originally formulated.

## CHANGE IN LAND USE TYPE A - GRAZING AND UNUSED LAND

### Change Relative to Other Study Years

A surprising statistic, given the land scarcities that exist in Barbados, is that more than one third of all cleared land in the West Coast Study Area was in the 'Grazing and Unused' category in 1950 (see Table 5.2). The area is significantly reduced in 1964, only to rebound to an even higher level by 1972. Of the 1,297 hectares of this land use type that existed in 1950, a mere 616 hectares (47.53%) remained as 'Grazing and Unused Land' in 1964. This is the lowest retention value recorded for any of the six land use types throughout any of the three change periods (1950-64, 1964-72, 1972-80).

It must be remembered that Land Use Type 'A' includes all cleared, 'unused' land, including land in fallow, rough grazing land, and pasture. It will be demonstrated in a later section that land in fallow comprised a substantial portion of the 'unused' land in the West Coast Study Area during all four study years, and that it was the moving of land into and out of fallow that caused the majority of the fluctuations in the amount of Land Use Type 'A' ('Grazing and Unused Land') during the three study periods.

Figure 5.1 Land use change in the West Coast Study Area (1950-1980)

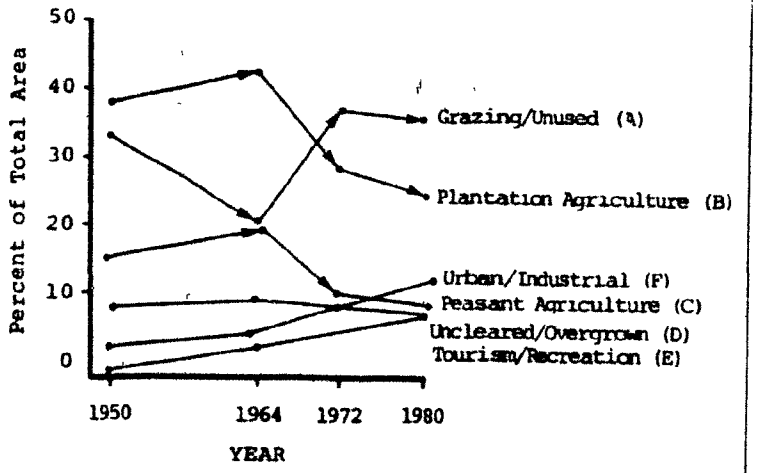



Table 5.3 Changes from 'Grazing and Unused Land' (1950-1980)

| LAND USE CHANGE INTO: | 1950-1964 | 1964-1972 | 1972-1980 |
|---|---|---|---|
| (A --> A) Unchanged | 616.43 (47.53) | 605.04 (73.41) | 1,150.50 (81.46) |
| (A --> B) Plantation Agriculture | 399.59 (30.81) | 39.72 (4.82) | 89.21 (6.32) |
| (A --> C) Peasant Agriculture | 95.36 (7.35) | 10.69 (1.30) | 15.93 (1.13) |
| (A --> D) Uncleared/ Overgrown | 126.61 (9.76) | 66.13 (8.02) | 18.35 (1.30) |
| (A --> E) Tourism/ Recreation | 19.76 (1.52) | 36.59 (4.44) | 60.99 (4.32) |
| (A --> F) Urban/ Industrial | 39.21 (3.02) | 66.03 (8.01) | 77.42 (5.48) |
| Total Hectares Total Percent | 1,296.97 (100.00) | 824.19 (100.00) | 1,412.39 (100.00) |

Figures in parentheses represent percent of total change

## Change Relative to Other Land Use Types

### 'Grazing and Unused Land' vs. 'Plantation Agriculture'

Nearly a third of the 'Grazing and Unused Land' that existed in 1950 was being farmed under the plantation system by the year 1964. This is the largest percentage shift from one land use type to another for any of the thirty possible land use change combinations and three change periods studied in this work.

At first glance, the land use shift from 'Grazing and Unused Land' to 'Plantation Agriculture' seems so extreme as to be a statistical error. Upon closer review, however, it becomes evident that the data are accurate and reflect a direct response to the international sugar market. Examination of the fourteen sub-units individually provides more detail concerning the relationship between sugar export statistics and this type of land use 'change'.

Twelve of the fourteen sub-units displayed reductions in the amount of 'Grazing and Unused Land' within their boundaries between 1950 and 1964. Only the Prospect (#13) and Sandy Lane (#11) sub-units showed increases. Of the twelve sub-units that showed decreases of 'Grazing and Unused Land', five exhibited unusually great declines, while the remaining seven changed at rates close to the average.

It is interesting to note that of the five sub-units where Land Use Type 'A' declined drastically between 1950 and 1964, four were in the top positions in terms of the

percentage of land devoted to plantation agriculture in 1964. This relationship is illustrated in Table 5.4. It can be seen that the sub-units showing the greatest decline in Land Use Type 'A' ('Grazing and Unused Land') between 1950 and 1964 were those where plantation agriculture predominated in 1964. This is an indication that a large part of the land use 'change' from 'Grazing and Unused Land' to 'Plantation Agriculture' was induced by the removal of land from fallow for the growing of sugar. Such changes are readily reversible and should not be interpreted as permanent land use change trends.

The massive shift from 'Grazing and Unused Land' to 'Plantation Agriculture' that occurred between 1950 and 1964 was completely reversed between 1964 and 1972. Fully 30.44 percent (499 hectares) of the plantation land that was being farmed in 1964 went out of agricultural production in 1972 and reverted to the 'Grazing and Unused' category. This trend continued between 1972 and 1980 with the change of a further 182 hectares of land from plantation agricultural production back into 'Grazing and Unused Land'.

The relationship between 'Grazing and Unused Land' and 'Plantation Agriculture' is illustrated for three sub-units in Figures 5.2, 5.3 and 5.4.

It is safe to assume from the statistics and graphs presented in this section that the movement of land into and out of the 'Grazing and Unused' category is induced by the economics of the world sugar market. This relationship is

examined in more detail in the section entitled "Change in Land Use Type 'B': 'Plantation Agriculture'".

Figure 5.2 'Grazing / Unused Land' and 'Plantation Agriculture' in the Six Men's (801) sub-unit (1950-1980). Percent area coverage.

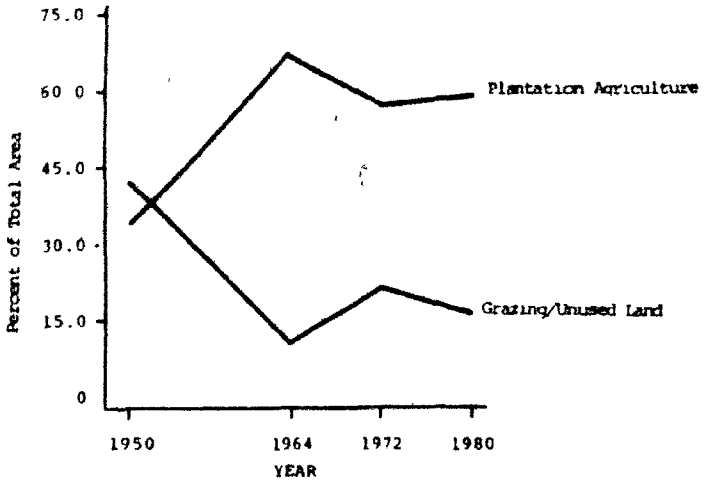
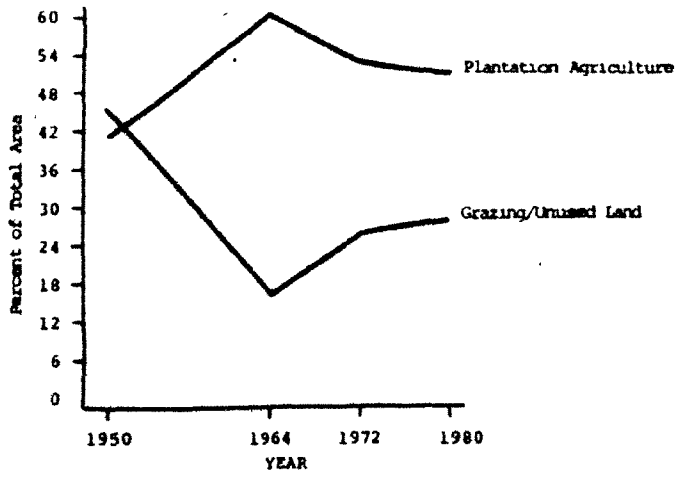



Figure 5.3 'Grazing / Unused Land' and 'Plantation Agriculture' in the Eastry (804) sub-unit (1950-1980). Percent area coverage.



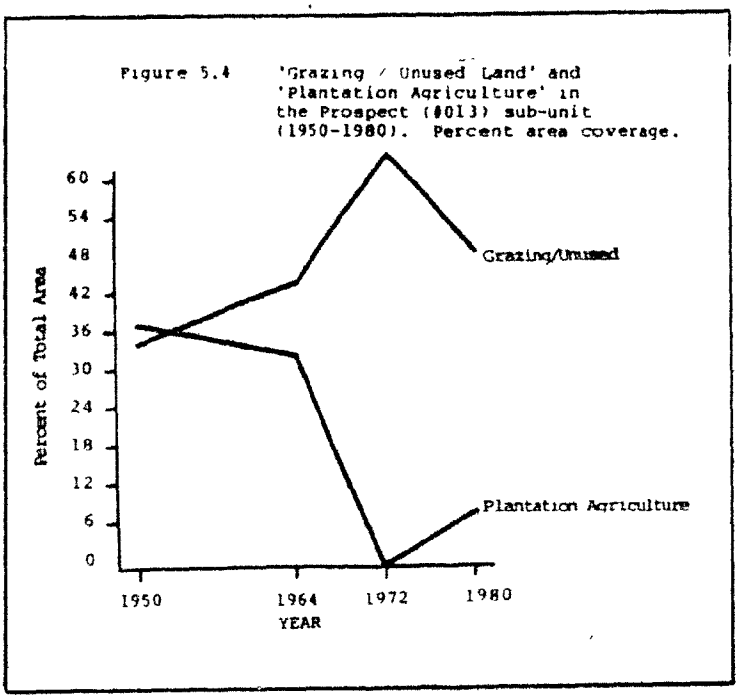



Figure 5.4 'Grazing / Unused Land' and 'Plantation Agriculture' in the Prospect (#013) sub-unit (1950-1980). Percent area coverage.

Table 5.4 'Grazing / Unused Land' vs. 'Plantation Agriculture' (1950-1964)

| SUB-UNIT | Percent Decrease in Grazing/Unused Land ---- 1950-1964 ---- | Percent Area Coverage Plantation Agriculture -------- 1964 -------- |
|---|---|---|
| 01 | 75.39 * | 67.30 * |
| 02 | 30.54 | 16.34 |
| 03 | 56.05 * | 30.14 |
| 04 | 67.74 * | 61.42 * |
| 05 | 28.34 | 27.06 |
| 06 | 33.71 | 24.74 |
| 07 | 31.92 | 48.89 |
| 08 | 53.63 * | 51.44 * |
| 09 | 44.28 * | 55.54 * |
| 10 | 27.99 | 50.76 |
| 11 | 0.00 | 38.59 |
| 12 | 23.61 | 11.39 |
| 13 | 0.00 | 32.16 |
| 14 | 30.97 | 64.29 * |

* Asterisks indicate top five positions in category.

'Grazing and Unused Land' vs. 'Peasant Agriculture'

In contrast to the 400 hectares of 'Grazing and Unused Land' that was put into 'Plantation Agriculture' between 1950 and 1964, a mere 95 hectares of this land use type passed into 'Peasant Agriculture' during the same period. Even when expressed as a percentage, the change toward agriculture from 'Grazing and Unused Land' is less significant for peasant farms than for plantations. Of the 1,640 hectares of plantation land being farmed in 1964, 400 hectares (24.39%) came from 'Grazing and Unused Land' in 1950. In contrast, only 95 of 709 hectares (13.40%) of the peasant land being farmed in 1964 was unused in 1950. This difference suggests that the major concern of peasant agriculture is with cash and subsistence crops, rather than sugar cane, and that of those peasant plots that do grow sugar, fewer are fallowed in response to external pressures.

Very little 'Grazing and Unused Land' was put into peasant agricultural production between 1964 and 1972. Just under 11 hectares were so converted. This represents a drop of almost 90% in the rate of conversion of 'Grazing and Unused Land' to 'Peasant Agriculture' when compared with the previous time period. Between 1972 and 1980, this figure stabilized at about 16 hectares.

The rate of change of 'Grazing and Unused Land' to 'Peasant Agriculture' followed exactly the same trend throughout the three study periods as did conversions to 'Plantation Agriculture'. The absolute magnitude of the

shifts was smaller due to the smaller land area devoted to 'Peasant Agriculture' than to 'Plantation Agriculture'. The percentage shifts were also somewhat less pronounced due to greater crop diversity and less flexibility to respond to external pressures.

'Grazing / Unused Land' vs. 'Uncleared / Overgrown Land'

Approximately ten percent of the 'Grazing and Unused Land' that existed in 1950 was overgrown in 1964. A further eight percent changed from 'Grazing and Unused Land' to 'Uncleared and Overgrown Land' in the second study period. The least significant shift from Land Use Type 'A' to Land Use Type 'D' took place between 1972 and 1980. In those eight years, only 1.3 percent of the 'Grazing and Unused Land' in the West Coast Study Area was allowed to become overgrown. It appears that the demands of grazing have remained relatively constant throughout the study period and that very little land has been allowed to revert to scrub.

'Grazing / Unused Land' vs. 'Tourism / Recreation Land'

Between 1950 and 1980, 118 hectares of 'Grazing and Unused Land' were developed for tourism or recreation purposes. 20 hectares were developed between 1950 and 1964, a further 37 between 1964 and 1972, and the final 61 hectares changed land use type in this way between 1972 and 1980.

These figures are consistent with both the trend towards the establishment of more 'Tourism and Recreation Land', and the emphasis placed on the conversion of 'Grazing and Unused Land' for this purpose, especially in the third study period.

'Grazing and Unused Land' vs. 'Urban / Industrial Land'

A similar trend is observed with the conversion of 'Grazing and Unused Land' for urban and industrial applications. A total of 182 hectares were converted from Land Use Type 'A' to Land Use Type 'F' between 1950 and 1980. Of these, 39 hectares were developed between 1950 and 1964, a further 66 between 1964 and 1972, and the final 77 between 1972 and 1980.

As with 'Tourism and Recreation Land', the figures for conversion of 'Grazing and Unused Land' to 'Urban / Industrial Land' are consistent with both the trend towards the establishment of urban and industrial areas, as well as the emphasis placed on the protection of agricultural areas by using 'Grazing and Unused Land' for this purpose.

## Change Relative to Physical Parameters

### 'Grazing and Unused Land' vs Proximity to the Coast

The procedure for establishing proximity zones has already been discussed, in Section Three. It was shown that proximity zones A, B and C each encompassed 20 percent of the total area, while zones E and F accounted for 15 percent and five percent respectively.

The statistics for 'Grazing and Unused Land' vary only slightly from these general figures. On average, between 1950 and 1980, 17.05 percent of the 'Grazing and Unused Land' in the West Coast Study Area is found in proximity zone A (within 0.5 kilometers of the coast). This is very close to the 20 percent figure that would be expected if there was no relationship between this land use type and coastal proximity. In the 0.5 to 1.0 kilometer swath (proximity zone B), the figure is nearly steady at 25 percent for each year of analysis - 1950 (25.48%), 1964 (24.08% , 1972 (24.92%), and 1980 (24.26%). Greater fluctuations are observed in the 1.0 to 1.5 kilometer strip (proximity zone C), however. On average 23 percent of the 'Grazing and Unused Land' is found in this area. The same consistent relationship occurs in proximity zone D (1.5 - 2.0 kilometer distance from the coast), where approximately 20 percent of the 'Grazing and Unused Land' is located in each study period - 1950 (21.39%), 1964 (21.12%), 1972 (18.90%), and 1980 (20.68%). Only in the final proximity

bands is there any major discrepancy between the expected occurrence of 'Grazing and Unused Land' and the actual occurrence. Twenty percent of the actual land area lies within these zones. However the percent of land in Type 'A' land use is significantly below this expected value - 1950 (14.18%), 1964 (12.45%), 1972 (14.68%), and 1980 (19.14%).

In summary it can be seen that slightly more 'Grazing and Unused Land' is found in the central strip (0.5 - 2.0 kilometers) than along the coast or along the east side of the study area. The fact that less than 20 percent of the unused land is found along the coast is likely explained by the premium placed on this land for development. The reason for the below average figure in proximity zones E and F is due to the fact that these zones, being in a higher rainfall area and having the most productive soils, are the most agriculturally developed. The central strip, where the highest percentage of 'Grazing and Unused Land' is found, is a region of both relatively poor soils (including the extremely unproductive Red Sand Association) and low rainfall.

'Grazing and Unused Land' vs. Rainfall

The areas of minimum rainfall (40 - 50 ins., 102 - 127 cms.) with a very marked dry season constitute approximately 19 percent of the total area of the West Coast Study Area. It can be predicted, given the relationship between rainfall, duration of the dry season, and sugar cane yields, and the fact that irrigation is all but unknown in western Barbados, that significantly more than 19 percent of the 'Grazing and Unused Land' will be found in this low rainfall category. In fact, an average of almost 25 percent of the 'Grazing and Unused Land' in the West Coast Study Area is found in the driest rainfall class.

6.33 percent of the land in the West Coast Study Area falls into the second lowest rainfall category (40 - 50 inches / 102 - 127 cms, with a marked dry season). The figures for 'Grazing and Unused Land' show a somewhat higher percentage in this rainfall class, averaging 7.15 percent for the four study years.

An increase of ten inches of rainfall per year results in significantly less agricultural restriction, as evidenced by the relative significance of Land Use Type 'A' in rainfall zone 'C' (50 - 60 inches / 127 - 152 cms of rain annually. Significantly more than half of the land in the West Coast Study Area (55.66%) falls into this rainfall zone, yet less than half of the unused land (48.96%) is in areas with this rainfall regime.

The remaining 19.23 percent of the West Coast Study Area receives between 60 and 70 inches (152 - 178 cms) of rain per year with or without a marked dry season. On average, the exact same percentage (19.23%) of 'Grazing and Unused Land' is found in this rainfall category for the four study years.

'Grazing and Unused Land' vs. Slope

Table 5.5 illustrates the relationship between the location of 'Grazing and Unused Land' and degree of terrain slope, for the West Coast Study Area.

It is apparent from Table 5.5 that a relationship exists between 'Grazing and Unused Land' and terrain slope. On average, between 1950 and 1980, only 64 percent of Land Use Type 'A' was on land with slopes of ten degrees or less. This compares with 74.35 percent for all land uses combined during the same period. 36 percent of the 'Grazing and Unused Land' in the West Coast Study Area was found on slopes in excess of ten degrees. This compares with less than 26 percent for all land uses combined.

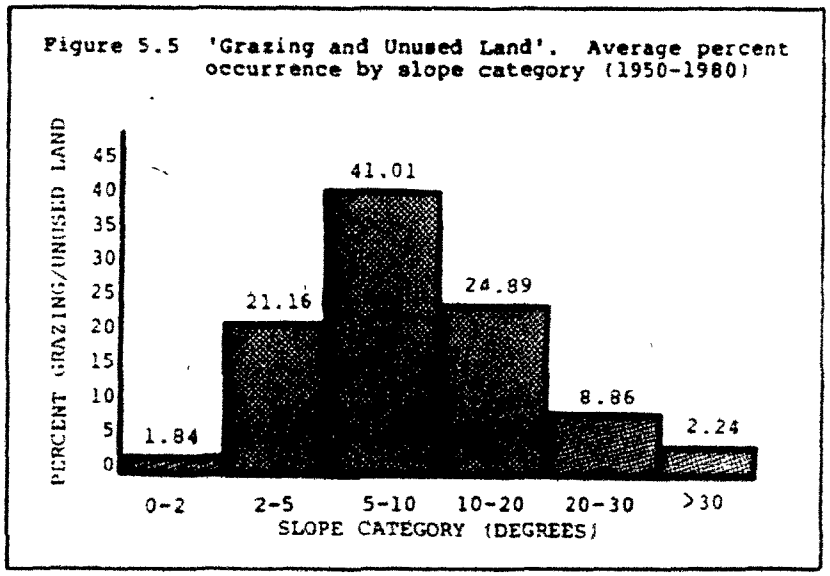



Table 5.5 'Grazing and Unused Land' vs. slope

| Slope Class (Degrees) | Percent Area Occupance in the West Coast Study Area. | | Percent Occurrence in Each Slope Category (1950 - 1980 average) | |
|---|---|---|---|---|
| 0 - 2 | 4.57 | | 1.84 | |
| 2 - 5 | 20.60 | 74.35 | 21.16 | 64.00 |
| 5 - 10 | 49.18 | | 41.01 | |
| 10 - 20 | 18.09 | | 24.89 | |
| 20 - 30 | 5.84 | 26.00 | 8.86 | 36.00 |
| >30 | 1.72 | | 2.24 | |
| TOTAL: | 100.00 | | 100.00 | |

'Grazing and Unused Land' vs. Soil Depth

As with the other physical parameters reviewed so far, there are no surprises when the relationships between soil depth and 'Grazing and Unused Land' are examined.

61.27 percent of the West Coast Study Area is covered in soils of normal depth. On average, between 1950 and 1980, only 50.23 percent of the 'Grazing and Unused Land' in western Barbados was on soils of normal depth.

21.15 percent of the land in the study area has shallow soils. This figure corresponds almost perfectly with the percentage of 'Grazing and Unused Land' found on shallow soils: 1950 - 20.51%, 1964 - 21.15%, 1972 - 20.35%, and 1980 - 20.70%.

Only 17.58 percent of the West Coast Study Area has very shallow soils, whereas 29.09 percent (average 1950-1980) of land in the 'Grazing and Unused' category occurs on this soil depth class.

'Grazing and Unused Land' vs. Soil Type

The relationship between the presence of Land Use Type 'A' and soil type appears to be very weak.

14.29 percent of the West Coast Study Area is covered by soils of the Black Association. On average, 19.08 percent of the 'Grazing and Unused Land' in western Barbados is found on these Black soils. This average figure is somewhat misleading, however, as the actual value ranges from a low of 13.48 percent in 1950 to a high of 22.55

percent in 1972. The fallowing of large tracts of land for periods of more than a year has probably contributed to these fluctuations.

About three quarters (75.49%) of the West Coast Study Area is covered by soils of the Grey-Brown Association. The percentage of Land Use Type 'A' that was present on this soil type between 1950 and 1980 was very close to this figure, and remained so for all four study years. In 1950, 72.10 percent of the 'Grazing and Unused Land' in the West Coast Study Area was on Grey-Brown soils. This figure remained essentially unchanged in 1964, at 72.47 percent. A slight drop to 69.22 percent in 1972 was followed by a rebound to 73.62 percent in 1980.

The soils of the Red Sand Association cover 7.67 percent of the West Coast Study Area. Not surprisingly, these extremely unproductive soils accounted for 12.61 percent of the 'Grazing and Unused Land' in 1950. This figure then declines significantly to a mere 3.12 percent in 1964. The fact that an average of only 4.33 percent of the 'Grazing and Unused Land' was found on the Red Sands during the final three study years indicates that some other (non-agricultural) development may have taken place on these unproductive soils.

The soils of the Coastal Association make up only 2.55 percent of the West Coast Study Area. They make up a similar percentage of the 'Grazing and Unused Land', averaging 2.67 percent between 1950 and 1980.

## CHANGE IN LAND USE TYPE B - PLANTATION AGRICULTURE

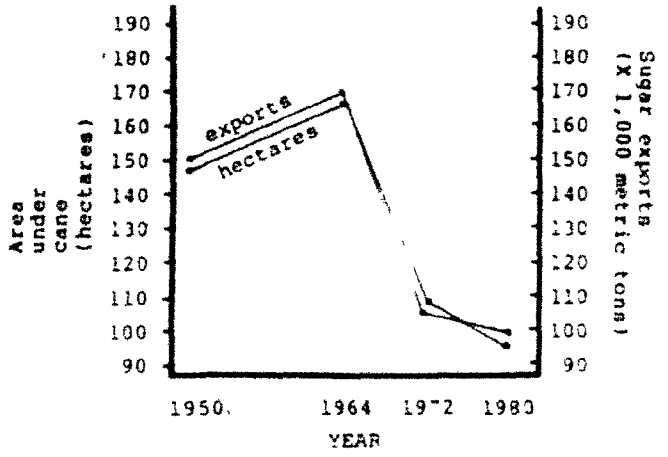
### Change Relative to Other Study Years

The amount of land in agricultural production under the plantation system was found to vary quite drastically from one study year to another. This is attributable mainly to the practice of fallowing large tracts of plantation land, thus converting them temporarily to Land Use Type 'A', 'Grazing and Unused Land'. This phenomenon was documented in the previous section, and is graphically represented in Figures 5.2, 5.3 and 5.4.

Not mentioned in the earlier analysis, however, was the possible motivation for fallowing such large percentages of the plantation land in western Barbados. The reason becomes immediately apparent when the sugar export statistics for the period are compared with the amount of plantation land in production. As indicated in the discussion of the results of the air photo interpretation, it seems clear that variations in the total volume of sugar exports were determined not by variations in the per hectare productivity of plantations, but rather by the intentional fallowing of parts of the plantation in response to fluctuations of the world sugar market.

Analysis of other changes in plantation agriculture is presented in the following sections.

Figure 5.6 Hectares of 'Plantation Agriculture' versus sugar exports (1950-1980 *)




* Sugar export statistics are three year averages for the year previous to the study year, the study year itself and the year following the study year. All data were derived from United Nations Yearbooks of Food and Agriculture Statistics.

## Change Relative to Other Land Use Types

### 'Plantation Agriculture' vs. 'Grazing and Unused Land'

This change is primarily a function of the fallowing of large tracts of plantation land in response to international sugar market fluctuations, and has been analysed in previous sections.

### 'Plantation Agriculture' vs. 'Peasant Agriculture'

This type of land use change is reviewed in detail in the section on changes in 'Peasant Agriculture'.

'Plantation Agriculture' vs. 'Uncleared / Overgrown Land'

No significant areas of 'Plantation Agriculture' were allowed to become overgrown in any of the three study periods. The 1.01 percent (1950 - 1964), 1.21 percent (1964 - 1972), and 0.03 percent (1972 - 1980) of 'Plantation Agriculture' that are represented in the statistics as having become overgrown are considered to be insignificant.

'Plantation Agriculture' vs. 'Tourism and Recreation Land'

A total of 80.54 hectares of 'Plantation Agriculture' was developed for tourism and recreation uses between 1950 and 1980. 29 percent of this development took place between 1950 and 1964, 67 percent occurred between 1964 and 1972, and a mere four percent was developed in the final (1972 - 1980) study period. This preliminary finding indicates that government involvement in the protection of agricultural land, which began in the early 1970's was extremely effective in curtailing this unwanted type of development.

'Plantation Agriculture' vs. 'Urban / Industrial Land'

A total of 56.25 hectares of plantation land was developed for urban and industrial purposes between 1950 and 1980. Urbanization for non-tourism / recreational purposes accounted for approximately 40 percent of the total development of 'Plantation Agriculture' over the thirty year period between 1950 and 1980. The higher percentage shift to 'Tourism and Recreation Land' (approximately 60 percent) is largely accounted for by a single development - the eighteen hole golf course in the Sandy Lane and Sunset Crest sub-units.

Of the 56.25 hectares of plantation land that were developed for urban / industrial purposes between 1950 and 1980, 11.29 hectares (20.07%) were developed between 1950 and 1964, 29.54 hectares (52.52%) were urbanized in the second study period, and 15.42 hectares (27.41%) were changed from 'Plantation Agriculture' to 'Urban / Industrial Land' between 1972 and 1980.

This pattern of accelerated then diminished change is similar to that identified in the shift of plantation land into tourism and recreation use. Over half the development took place between 1964 and 1972, and development was reduced significantly between the second and third study periods.

## Change Relative to Physical Parameters

### 'Plantation Agriculture' vs. Proximity to the Coast

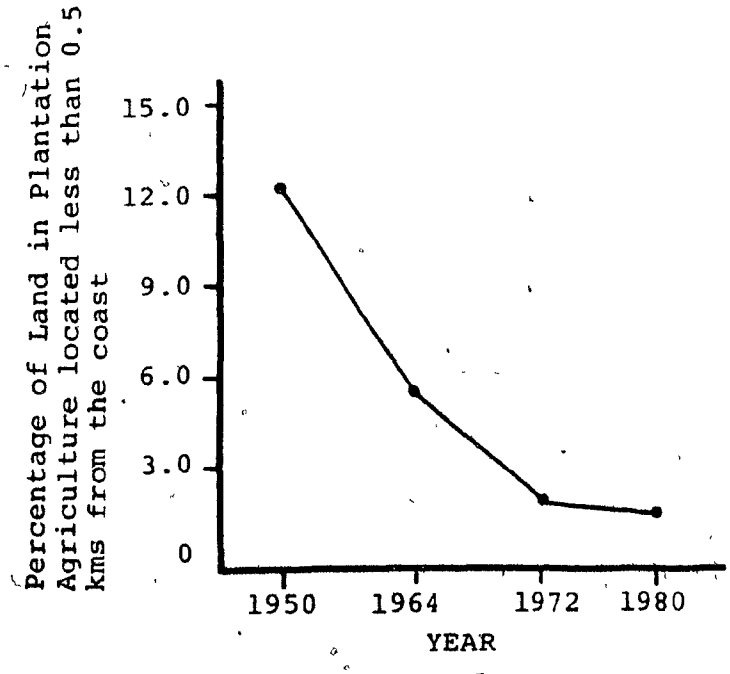
The extensive road network and lack of industrialized urban areas on Barbados' west coast makes a relationship between 'Plantation Agriculture' and proximity to any variable highly unlikely. The only anticipated relationship between 'Plantation Agriculture' and coastal proximity is a secondary one, based on the fact that the better agricultural soils and rainfall areas are furthest inland. Furthermore, competition from other land use types that place a premium on coastal proximity are likely to force 'Plantation Agriculture' away from the coast.

These patterns are observed in the 'Plantation Agriculture' vs. ocean proximity statistics. Instead of the 20 percent occurrence of 'Plantation Agriculture' that is to be expected in terms of area equivalence in the first proximity zone (0.5 - 1.0 kilometer from the coast), the figure is a mere 5.33 percent on average for the study period. The figures for each study year taken separately are more informative, however. They illustrate the fact that 'Plantation Agriculture' has been pushed out of the coastal zone. This is especially evident for the period 1950 - 1972, as represented by Figure 5.7. The building of the Sandy Lane Golf Course on plantation land during the first study period, combined with its expansion during the

1964 - 1972 study period, must have been a major contributor to this shift.

Significantly more 'Plantation Agriculture' is found at a distance in exgess of two kilometers from the coast than would be the case should no relationship exist between location and the presence of this land use type. Instead of the expected 20 percent, an average of 31.04 percent of the 'Plantation Agriculture' in the West Coast Study Area is located more than 2.0 kilometers from the coast. This relationship is of no significance, however, because it is the presence of better soils and higher rainfall inland, rather than proximity factors, which account for the higher percentages.

Figure 5.7 Percentage of 'Plantation Agriculture' occurring less than 0.5 kilometers from the coast (1950-1980)



'Plantation Agriculture' vs. Rainfall

Sugar plantation agriculture requires abundant water. On the west coast of Barbados, where irrigation is all but non-existent, the high rainfall areas are best suited to the growing of sugar. This relationship is evident from the statistics presented in Table 5.6, which shows that, on average, only 17.47 percent of the plantation land in the West Coast Study Area is found in the driest rainfall zone (40 - 50 inches). This figure is clearly markedly below the 25 percent figure which would be expected in terms of proportional correspondence.

The moderately wet regions (50 - 60 inches average annual rainfall) make up 55.06 percent of the West Coast Study Area. This figure compares with an average of 54.93 for the percentage of the area of plantation crop land located in this rainfall zone between 1950 and 1980.

**Table 5.6** Percent area of 'Plantation Agriculture' according to rainfall zone (1950-1980)

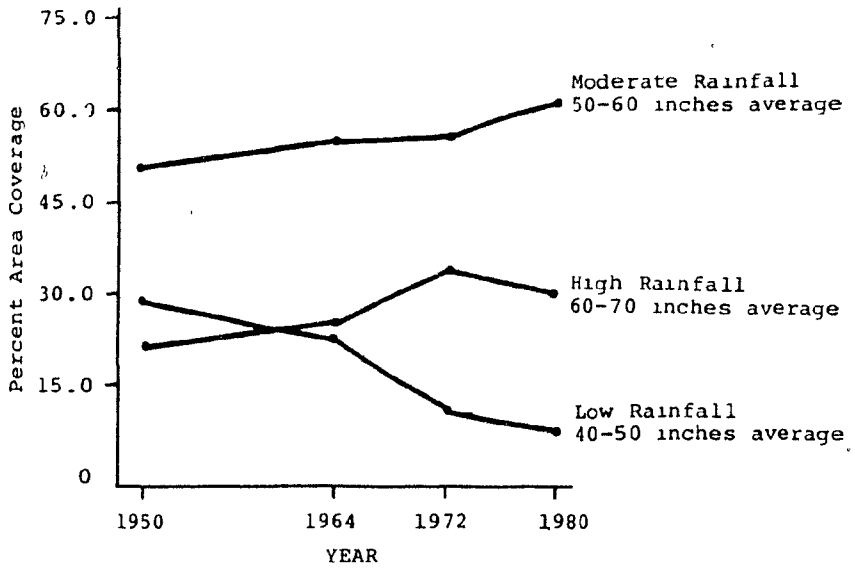
| Rainfall Zone (Mean Annual Total) | Area of Rainfall Zone as a Percentage of Total Study Area. | Percentage of Total Area of Plantation Agriculture Occurring in the Rainfall Zone |
|---|---|---|
| 40 - 50 inches<br>102 - 127 cms | 25.11 | 1950 - 28.04<br>1964 - 21.58<br>1972 - 11.03<br>1980 - 9.25<br>Average: 17.47 |
| 50 - 60 inches<br>127 - 152 cms | 55.66 | 1950 - 49.68<br>1964 - 54.32<br>1972 - 55.39<br>1980 - 60.31<br>Average: 54.93 |
| 60 - 70 inches<br>152 - 178 cms | 19.23 | 1950 - 22.28<br>1964 - 24.10<br>1972 - 33.58<br>1980 - 30.45<br>Average: 27.60 |

19.23 percent of the West Coast Study Area falls into the high rainfall category (60 - 70 inches average annual rainfall). A disproportionately high 27.60 percent of the 'Plantation Agriculture' in the West Coast Study Area was located in these high rainfall areas, between 1950 and 1980.

These figures clearly show a positive relationship between 'Plantation Agriculture' and high rainfall. Perhaps even more interesting, however, is the fact that this relationship has become considerably more pronounced over the past thirty years. When we look beyond the average statistics, and review the relationship between average annual rainfall and 'Plantation Agriculture' for the four study years separately, we observe the following trend. In 1950, over 28 percent of the 'Plantation Agriculture' in the West Coast Study Area was located on land in the lowest rainfall zone (40 - 50 ins.). This figure had dropped to a mere 9.25 percent by 1980, a decrease that was paralleled by an increase in the percentage of plantation land occurring in the highest rainfall zone from approximately 22 percent in 1950 to over 30 percent in 1980. The moderate rainfall zone, which receives between 50 and 60 inches of precipitation per year, accounted for almost 11 percent more 'Plantation Agriculture' in 1980 than in 1950, increasing from under 50 percent to over 60 percent during that time period. These statistics are presented graphically in Figure 5.8.

It is safe to conclude from these figures that the more marginal plantations, particularly those in low rainfall areas, were the primary ones lost to the forces of urbanization and development for tourism and recreation land uses during the past three decades.

Figure 5.8 Percent of total area of 'Plantation Agriculture' occurring in each rainfall zone (1950-1980)



'Plantation Agriculture' vs. Slope

Slopes in excess of ten degrees are infrequent in the West Coast Study Area. Gentle slopes of ten degrees and less are encountered in approximately three quarters (74.35%) of the study area. Over 85 percent of the total area of 'Plantation Agriculture' occurs on slopes of ten degrees and less. This is a clear indication that plantations tend to be on 'preferred' land. This relationship remained essentially unchanged for each of the four study years: (1950 - 87.26%, 1964 - 86.27%, 1972 - 83.85%, and 1980 - 83.11%). The slight decline in each successive study year is attributable to the concentration of plantations in the higher, more hilly, regions of the West Coast Study Area.

'Plantation Agriculture' vs. Soil Depth

Just over 61 percent of the West Coast Study Area is covered by soils of normal depth (profiles in excess of 18 ins. - 46 cms.). However, a considerably higher percentage of the total area of plantation land was found to occur on these soils - 1950 (77.97%), 1964 (77.08%), 1972 (75.91%), and 1980 (76.88%). The pattern here is very similar to that observed for the relationship between 'Plantation Agriculture' and slope statistics, i.e. plantations are consistently located on preferred land, and the percentage shift is very slight from one year to another.

'Plantation Agriculture' vs. Soil Type

A number of interesting patterns are observed when 'Plantation Agriculture' is compared with soil type. First, the amount of 'Plantation Agriculture' on soils of the Black Association progressively declined between 1950 and 1980. Over 200 hectares of plantation land were located on soils of the Black Association in 1950. By 1964 this figure had dropped to 187 hectares. A drastic decline (from 187 hectares to 52 hectares) occurred between 1964 and 1972. By 1980, a mere 43 hectares of plantation land remained on the Black Association soils. This represents a decline from almost 14 percent of the total plantation land in 1950 to just over four percent in 1980.

Soils of the Black Association, though less mature than those of the Grey-Brown Association, are, nonetheless, good cane producers. The reason for this marked decline must be sought in the location of these soils, rather than in their fertility. The soils of the Black Association are restricted to the coastal zone of the West Coast Study Area, and, as a result, are subject to tremendous development pressure.

The soils of the Coastal Association have experienced similar pressure from development because of their proximity to the ocean. However, the soils of this association were never significant for cane production because of their low fertility. Nonetheless, a pattern of elimination of these soils in plantation areas is documented by the statistics.

In 1950, 3.20 percent of the plantation land in the West Coast Study Area was on coastal soils. By 1980, after two successive declines, no 'Plantation Agriculture' was located on soils of the Coastal Association.

The Red Sands, being composed of almost 63 percent sand, and less than 25 percent clay, are extremely inefficient cane producers. It is surprising, given this fact, combined with the occurrence of these soils along the coastal zone, that their significance as cane producers has steadily increased. In 1950, just over six percent of the plantation land in the West Coast Study Area was found on this soil type. In 1964 and 1972, the figures were 13.48 percent and 13.80 percent respectively. By 1980, over 17 percent of the 'Plantation Agriculture' in the West Coast Study Area was found on soils of the Red Sand Association. An agricultural development, such as a strain of sugar cane grown specifically for sandy soil, provides a possible explanation as to how the soils of the Coastal Association could survive the development pressure and concomitant eastward migration of 'Plantation Agriculture' over the past thirty years.

The soils of the Grey-Brown Association - the predominant sugar producing soils in the West Coast Study Area - are seen to have remained stable in their contribution to 'Plantation Agriculture' since 1950. On average, about 78 percent of the 'Plantation Agriculture' in the West Coast Study Area has been located on soils of this

association over the past three decades. The actual statistics are: 1950 - 77.05%, 1964 - 73.68%, 1972 - 81.40%, and 1980 - 78.41%.

## CHANGE IN LAND USE TYPE C - 'PEASANT AGRICULTURE'

### Change Relative to Other Study Years

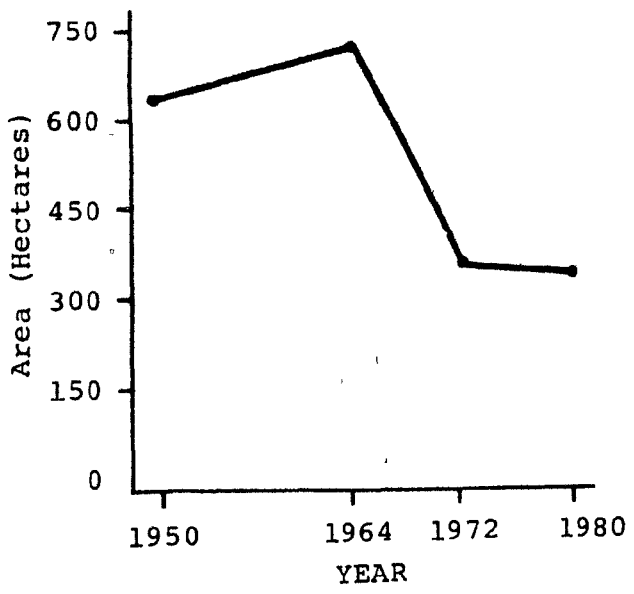
'Peasant Agriculture', while the third most common land use type in 1950, only occupied about 16 out of every 100 hectares in the West Coast Study Area. There were more than twice as many hectares left unused during the same year. Plantations occupied more than twice as much land as did peasant holdings.

When examined more closely, it is observed that there was tremendous variation in the amount of land devoted to 'Peasant Agriculture' in each of the fourteen sub-units in 1950. For example, in the Eastry sub-unit (#04), only 3.29 percent of the land was being used by peasants in 1950. In the Trent sub-unit (#09), a mere 2.05 percent was in this category. On the other hand, over 34 percent of the land in the Porters sub-unit (#06), and almost 33 percent of the land in the Speightstown sub-unit (#03) was being worked in the same year by peasants.

Another interesting feature of the pattern of Peasant Agriculture is the very uneven distribution from sub-unit to sub-unit with relatively high or relatively low percentages and very few intermediate values. In ten sub-units, less than 15 percent of the land was occupied by 'Peasant Agriculture'. The remaining four sub-units each show values in excess of 26 percent for this land use type. These four sub-units, Carlton (#05), Porters (#06), Speightstown (#03)

and Thorpe (#12) made up 54.74 percent of the 'Peasant Agriculture' on the west coast in 1950. The remaining ten sub-units combined contributed only 45.26 percent of the total 'Peasant Agriculture' in the West Coast Study Area.

Figure 5.9 Changes in the total area of 'Peasant Agriculture' (1950-1980)



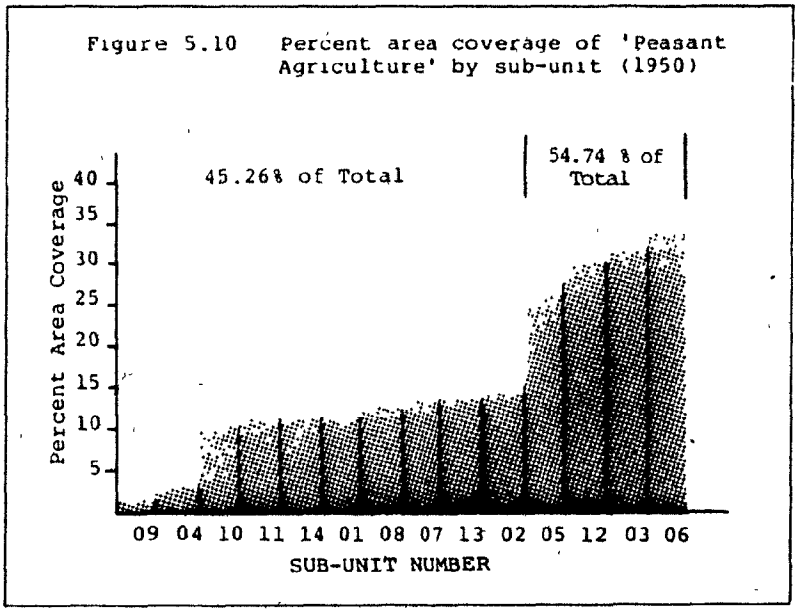



Figure 5.10 Percent area coverage of 'Peasant Agriculture' by sub-unit (1950)

Table 5.7 Percentage area of 'Peasant Agriculture' per sub-unit of the West Coast Study Area (1950-1980)

| SUB-UNIT | 1950 | 1964 | 1972 | 1980 |
|---|---|---|---|---|
| 09 | 2.05 | 3.02 | 3.36 | 7.84 |
| 04 | 3.29 | 8.42 | 2.47 | 1.52 |
| 10 | 10.42 | 12.37 | 7.87 | 7.30 |
| 11 | 10.59 | 11.85 | 1.01 | 1.04 |
| 14 | 11.04 | 15.98 | 2.40 | 2.54 |
| 01 | 11.52 | 11.78 | 7.50 | 7.43 |
| 08 | 12.62 | 5.24 | 3.18 | 1.49 |
| 07 | 13.54 | 14.68 | 9.08 | 8.70 |
| 13 | 13.61 | 5.85 | 0.00 | 0.00 |
| 02 | 14.50 | 27.77 | 15.68 | 16.43 |
| 05 | 26.47 | 34.48 | 26.78 | 21.02 |
| 12 | 30.18 | 23.55 | 2.11 | 1.99 |
| 03 | 32.82 | 39.44 | 24.34 | 0.00 |
| 06 | 34.22 | 38.52 | 2.40 | 2.54 |

As with Land Use Type 'B' ('Plantation Agriculture'), the amount of 'Peasant Agriculture' generally increased in the West Coast Study Area between 1950 and 1964. Of the fourteen sub-units, all but three had a higher percent area coverage statistic for 'Peasant Agriculture' in 1964 than in 1950. Interestingly, these three sub-units (#08, #12 and #13), all continued to show a decline in the amount of 'Peasant Agriculture' within their borders over the remaining two study periods.

These three sub-units can be considered the first of three groups of peasant agriculture land use change types. This first group is characterized by a rapid decline in the 1950 - 1964 study period, followed by a second significant drop between 1964 and 1972. By 1980, none of the sub-units in this group displayed significant amounts of 'Peasant Agriculture'.

The second group of sub-units is representative of the general trend in this land use type. Six of the fourteen sub-units displayed slight increases in 'Peasant Agriculture' between 1950 and 1964, only to have these values either taper off or increase slightly during the last two study years. The sub-units in this category include #01, #02, #05, #07, #09, and #10.

The final group consists of five sub-units (#3, #4, #6, #11, and #14), and is perhaps the most interesting. For some reason, each of the sub-units in this group displayed increases in the amount of Land Use Type 'C' within their

borders between 1950 and 1964, only to have this land use type decline to insignificance by 1980. Even more surprising is the fact that, in 1964, two of these sub-units (#03 and #06) displayed the highest percentage of land devoted to 'Peasant Agriculture' - almost 40 percent - for any sub-unit or study year considered in this work. By 1980, sub-unit #06 had a mere 2.54 percent of its land devoted to 'Peasant Agriculture', while sub-unit #03 was without a single hectare of this land use type.

These declines are examined relative to other land use types in the following section.

## Change Relative to Other Land Use Types

### 'Peasant Agriculture' vs. 'Grazing and Unused Land'

As observed in the previous section, the amount of 'Peasant Agriculture' in the West Coast Study Area increased between 1950 and 1964. 70 percent of this increase can be accounted for by the farming of 95.36 hectares of land in 1964 that had been left for grazing and unused purposes in 1950. In contrast, only 34.27 hectares of 1950 peasant agricultural land was left idle for rough grazing in 1964. This represents a net shift of over 61 hectares towards 'Peasant Agriculture' between 1950 and 1964.

Between 1964 and 1972, the amount of 'Peasant Agriculture' in the West Coast Study Area had dropped from 18.20 percent (708.77 hectares) to a mere 9.83 percent (383.06 hectares). As with the decline in 'Plantation Agriculture' during the same period, the greater part of this reduction can be attributed to the fallowing of land. Between 1964 and 1972, 184.07 hectares of 'Peasant Agriculture' was converted to 'Grazing and Unused Land'. During the same period, a mere 10.69 hectares of 'Grazing and Unused Land' was put into agricultural production by peasants. Thus there is a net shift away from 'Peasant Agriculture' of 173.38 hectares. This figure accounts for over 53 percent of the loss of 'Peasant Agriculture' during the second study period.

It was mentioned in an earlier section that international sugar markets seem to have been responsible for the tremendous decline in 'Plantation Agriculture' during the 1964 - 1972 study period. It was also suggested that peasant plots would be unlikely to respond to the same degree. This view is substantiated by the data presented, which show that the shift into land use category 'A' ('Grazing and Unused Land') accounted for over 84 percent of the 1964 - 1972 reduction in 'Plantation Agriculture', but only 53.23 percent of the decline in 'Peasant Agriculture' over the same period.

Between 1972 and 1980, the amount of land reverting from 'Peasant Agriculture' to the 'Grazing and Unused'

category was very small, accounting for only 22.78 hectares. In fact, the net loss to 'Grazing and Unused Land' was only 6.85 hectares, because 15.93 hectares of land that was in category 'A' in 1972 was being farmed by peasants in 1980. This 6.85 hectare reduction accounted for only 27 percent of the total decline in 'Peasant Agriculture' during this period.

Table 5.8 **Loss of agricultural land to Land Use Type 'A' - 'Grazing and Unused Land' (1964-1972)**

| | PLANTATION AGRICULTURE Land Use Type B (Hectares) | PEASANT AGRICULTURE Land Use Type C (Hectares) |
|---|---|---|
| Total Area in 1964 | 1,640.32 | 708.77 |
| Total Area in 1972 | 1,093.75 | 383.06 |
| Area Reduction 1964 - 1972 | 546.57 | 325.71 |
| Loss to Land Use Type A | 499.39 | 184.07 |
| Gain from Land Use Type A | 39.72 | 10.69 |
| Net Loss to Land Use Type A | 459.67 | 173.38 |
| Percentage of Net Loss resulting from shift from Land Use Types B and C to Land Use Type A | 84.10 % | 53.23 % |

## 'Peasant Agriculture' vs. 'Plantation Agriculture'

Table 5.9 'Peasant Agriculture' vs. 'Plantation Agriculture' (1950-1980)

| PERIOD / CHANGE | 1950-1964 (HECTARES) | 1964-1972 (HECTARES) | 1972-1980 (HECTARES) |
|---|---|---|---|
| Peasant to Plantation | 26.01 | 24.19 | 11.90 |
| Plantation to Peasant | 84.48 | 22.28 | 19.25 |
| Net Change for 'Peasant Agriculture' | + 58.47 | - 1.91 | + 7.35 |

The figures for change from 'Peasant Agriculture' to 'Plantation Agriculture' are presented in Table 5.9.

The process of sub-division of plantations into peasant holdings declined markedly in the 1960's as a result of the government's declared policy of reducing the amount of sub-division and encouraging the amalgamation of small plots. However, the amalgamation scheme did not achieve any great success during either the 1964 to 1972 or 1972 to 1980 study periods.

'Peasant Agriculture' vs. 'Uncleared and Overgrown Land'

The amount of peasant land allowed to become overgrown during the three study periods was very slight. Between 1950 and 1964, 10.99 hectares became overgrown and 5.65 were cleared, for a net loss to 'Peasant Agriculture' of only 5.34 hectares. Between 1964 and 1972, the net loss was greater than for the previous study period, at 11.49 hectares, with 16.53 becoming overgrown and 5.04 having been cleared during this period. Between 1972 and 1980, less than one hectare of peasant land became overgrown. Similarly, less than one hectare was cut back.

'Peasant Agriculture' vs. 'Tourism and Recreation Land'

Almost no 'Peasant Agriculture' has been developed for tourist purposes in any of the fourteen sub-units over the past three decades. The statistics area as follows: 1950-1964: 3.53 hectares, 1964-1972: 7.26 hectares, 1972-1980: 0.10 hectares. This is not surprising, considering that no 'Peasant Agriculture' was located on beach front property, even in 1950.

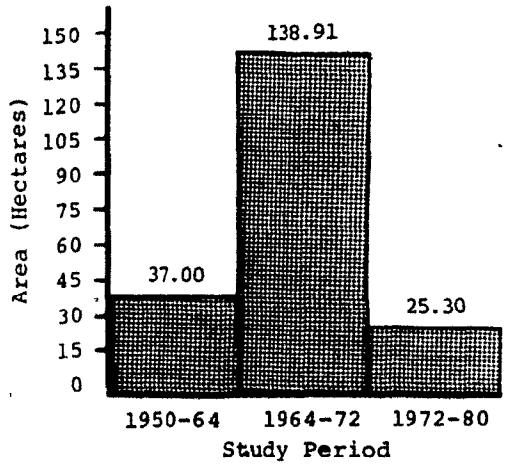
It is interesting to note, despite the very small amounts of peasant land converted to 'Tourism and Recreation Land', that increasing development pressure in the 1964-1972 period did in fact double the amount of peasant land lost to tourism and recreation. However, between 1972 and 1980, in spite of even greater pressures for tourism development, not a single peasant plot was lost to tourism

or recreation land uses. Although the actual areas involved are very small, it is interseting to find that the anticipated trend of a slight loss of agricultural land to development in the first study period, followed by a greater loss in the second period, and concluding with no loss in the 1972 - 1980 study period, is actually confirmed by the data.

'Peasant Agriculture' vs. 'Urban / Industrial Land'

Much more significant losses of 'Peasant Agriculture' occurred as a result of urban / industrial pressures than as a result of pressures from tourism and recreation. The pattern of these losses in the three study periods is similar to that already described for 'Tourism and Recreation Land'. Reference to Figure 5.1 shows that between 1950 and 1964, 37 hectares of 'Peasant Agriculture' were lost to Land Use Type 'F'. Under increased pressure from urbanization, this figure increased by 275 percent during the next study period to 139 hectares. Once again, despite increased development pressure, the amount of peasant land lost to urbanization between 1972 and 1980 declined to the lowest value for any of the three study periods, at slightly over 25 percent. This decline is directly attributable to the government controls on land use.

Figure 5.11 Conversion of 'Peasant Agriculture' to 'Urban / Industrial Land' (1950-1980)




The success of the government's policy in curtailing the urbanization of land previously in 'Peasant Agriculture' is even more apparent when the amount of peasant agricultural land lost is viewed as a percentage of the total urban area for the three periods.

Between 1950 and 1964, the amount of 'Urban / Industrial Land' in the West Coast Study Area increased by 62 hectares, from 126 to 188 hectares. Of this, 37 hectares (60 percent) came from 'Peasant Agriculture'. Between 1964 and 1972, the area of 'Urban / Industrial Land' increased by another 214 hectares, to 402 hectares. During this study period, 139 hectares of this urbanized land (65 percent) came from 'Peasant Agriculture'.

Between 1972 and 1980, 119 hectares of land were urbanized in the West Coast Study Area. Of this total, only 25 hectares (21 percent) came from 'Peasant Agriculture'.

## Change Relative to Physical Parameters

### 'Peasant Agriculture' vs. Proximity

Because of the economic pressures exerted by the high financial returns from plantation agriculture, tourism / recreation, and urbanization, it is logical to expect that peasant agricultural land will be under-represented in both the coastal zone (because of pressure from tourism and urbanization) and the zone of prime cane production. A disproportionately greater occurrence of land in 'Peasant Agriculture' can be anticipated in the intermediate proximity zones between 0.5 and 1.5 kilometers from the coast.

In 1950, the percent of land in 'Peasant Agriculture' located in the first coastal proximity zone was considerably higher than might have been expected. Rather than the pro rata 20 percent of land in this area, 'Peasant Agriculture' occupied 33.27 percent of this zone.

Competition from tourism and recreation and urbanization / industrialization systematically forced 'Peasant Agriculture' out of this zone over the next three decades. By 1964, only 29.33 percent of the 'Peasant Agriculture' was located within 0.5 kilometers of the coast. By 1972, this figure had dropped to 21.45 percent. In 1980, thirty years of development pressure had caused a reduction of almost 15 percentage points, and only 18.33

percent of the 'Peasant Agriculture' in the West Coast Study Area was found in the coastal zone.

This movement away from the coast was not compensated by movement into the prime agricultural areas beyond 2.0 kilometers from the coast. Although a progressively higher percentage of the 'Peasant Agriculture' in the West Coast Study Area was recorded for this zone, (1950 - 14.04%, 1964 - 14.55%, 1972 - 14.76%, 1980 - 20.78%), the increase was not as significant as for the middle (0.5 km - 2.0 km) zone.

The percentage of 'Peasant Agriculture' occurring in the intermediate zone increased from 52.69 percent in 1950 to 63.80 percent in 1972. By 1980, with a greater percentage now located more than 2.0 kilometers from the coast, the figure declined slightly to 60.88 percent for the central strip.

'Peasant Agriculture' vs. Rainfall

It was demonstrated in Figure 5.8 that there is a high correlation between areas of high average annual rainfall and the proportion of land in 'Plantation Agriculture'. When the figures for 'Peasant Agriculture' are stratified in the same manner, the relationships are found to be quite different.

Table 5.10 Percent area of 'Peasant Agriculture' according to rainfall zone (1950-1980)

| Rainfall Zone (Mean Annual Total) | Area of Rainfall Zone as a Percentage of Total Study Area. | Percentage of Total Area of Peasant Agriculture Occurring in the Rainfall Zone |
|---|---|---|
| 40 - 50 ins.<br>102 - 127 cms | 25.11 | 1950 - 23.99<br>1964 - 19.25<br>1972 - 3.39<br>1980 - 2.76<br><br>Average: 12.35 |
| 50 - 60 ins.<br>127 - 152 cms | 55.66 | 1950 - 59.94<br>1964 - 66.40<br>1972 - 79.00<br>1980 - 75.84<br><br>Average: 70.30 |
| 60 - 70 ins.<br>152 - 178 cms | 19.23 | 1950 - 16.07<br>1964 - 14.35<br>1972 - 17.61<br>1980 - 21.40<br><br>Average: 17.36 |

Two positive trends are observed in the statistics presented in Table 5.10. First, the percentage of 'Peasant Agriculture' in the low rainfall areas has declined steadily from 24 percent in 1950 to a mere 2.76 percent in 1980. This movement is primarily a function of competition for coastal access by tourism and recreation land uses. Second, there is an increase of over five percentage points in the amount of peasant agricultural land found in the highest rainfall area between 1950 and 1980. This does not represent a major increase in actual area, but rather a shift in the relative proportions as a result of the declining percentage in the central section.

The highest rainfall class has always been the domain of 'Plantation Agriculture'. Despite a steady increase in the percentage of 'Peasant Agriculture' in the most productive wet zone, the percentage of 'Plantation Agriculture' found in these areas has been increasing at a faster rate. In 1980, over 30 percent of the 'Plantation Agriculture' in the West Coast Study Area was found in areas with 60 to 70 inches average rainfall. The figure for 'Peasant Agriculture' in the same year was 21.40 percent.

'Peasant Agriculture' vs. Slope

Slopes in excess of ten degrees are infrequent in the West Coast Study Area. Gentle slopes of ten degrees and less are encountered in approximately three quarters (74.35%) of the study area. Approximately 77 percent of the total area of 'Peasant Agriculture' occurs on slopes of ten degrees and less. This is a clear indication that a significantly lower percentage of 'Peasant Agriculture' than 'Plantation Agriculture' is located on 'preferred' land. The occurrence of 'Peasant Agriculture' on slopes of less than ten degrees remained essentially constant for each of the four study years, with a slight reduction observed in each successive period - 1950 (78.52%), 1964 (77.18%), 1972 (75.69%), 1980 (74.68%).

'Peasant Agriculture' vs. Soil Depth

Just over 61 percent of the West Coast Study Area is covered by soils of normal depth (profiles in excess of 18 ins. - 46 cms.). Surprisingly, the percentage of 'Peasant Agriculture' on these soils was consistently below the 60 percent level. On average between 1950 and 1980, 56.87 percent of the 'Peasant Agriculture' in the West Coast Study Area was located on soils of depth class 'A'.

Shallow soils cover 21 percent of the West Coast Study Area. A much higher percentage - over 35 percent - of the 'Peasant Agriculture' in the West Coast Study Area was located on shallow soils between 1950 and 1980.

Very shallow soils cover almost 18 percent of the West Coast Study Area. The average figure for 'Peasant Agriculture' on very shallow soils is just under half this value, at eight percent.

Comparisons between the relative areas of 'Peasant Agriculture' and 'Plantation Agriculture' found on each soil class are presented in a later section.

'Peasant Agriculture' vs. Soil Type

14.29 percent of the West Coast Study Area is covered by soils of the Black Association. Because these soils are generally restricted to the coastal lowlands, the percentage of 'Peasant Agriculture' found on this soil association declined in direct proportion to the shift in land use toward tourism / recreation and urbanization / industrialization. Thus in 1950, over 16 percent of the 'Peasant Agriculture' in the West Coast Study Area was found on soils of the Black Association. By 1980, after declines of 4.62 and 10.17 percentage points in 1964 and 1972 respectively, the percentage of 'Peasant Agriculture' found on soils of the Black Association was a mere 1.55 percent. This eastward 'migration' of 'Peasant Agriculture' caused concomitant increases in the percentage of peasant lands found on soils of the Grey-Brown Association. The figures show a steady increase over the study period: 1950 (76.75%), 1964 (81.15%), 1972 (89.89%), and 1980 (90.43%). These figures are considerably higher than would be expected in

view of the fact that the soils belonging to the Grey-Brown Association only occupy 75 percent of the West Coast Study Area.

Soils of the Red Sand Association cover 7.67 percent of the West Coast Study Area. A slightly lower proportion of 'Peasant Agriculture' is found on this soil type - averaging 6.21 percent between 1950 and 1980.

A similar pattern is observed with the unproductive soils of the Coastal Association, which cover 2.55 percent of the study area. On average between 1950 and 1980, just under two percent of the 'Peasant Agriculture' in the West Coast Study Area was located on these soils.

## CHANGE IN LAND USE TYPE 'D - 'UNCLEARED AND OVERGROWN LAND'

### Change Relative to Other Study Years

The amount of 'Uncleared and Overgrown Land' in the West Coast Study Area has remained steady at approximately nine percent for all four study years. Rounded to the nearest percentage point, the figures are: 1950 - 8 percent, 1964 - 10 percent, 1972 - 9 percent, 1980 - 9 percent.

### Change Relative to Other Land Use Types

Because the forests were cleared by the 1600's, and the great majority of the remaining cover is in the gullies, this land use type is one of the most stable in the West Coast Study Area. Each study period shows small amounts of land put into and taken out of this land use type, but these changes are insignificant. As a result, no detailed analysis of change in 'Uncleared and Overgrown Land' relative to other land uses was undertaken.

### Change Relative to Physical Parameters

Due to the static nature of this land use type, the amount of 'Uncleared and Overgrown Land' in the West Coast Study Area has remained essentially constant. 'Uncleared and Overgrown Land' occurs to a very large extent along the sides of gullies and so the frequency of gullying determines the relative significance of this land use category.

## CHANGE IN LAND USE TYPE E - 'TOURISM AND RECREATION LAND'

### Change Relative to Other Study Years

The amount of 'Tourism and Recreation Land' in the West Coast Study Area increased by over four and a half times between 1950 and 1980, as evidenced by the figures in Table 5.11.

Table 5.11 'Tourism and Recreation Land' in the West Coast Study Area (1950 - 1980)

| Study Year | Tourism and Recreation Land as a Percentage of the Total Area | Area of Tourism and Recreation Land (Hectares) | Percent Increase from Previous Study Year |
|---|---|---|---|
| 1950 | 1.87 | 72.98 | -.- |
| 1964 | 3.70 | 143.95 | 97.26 |
| 1972 | 6.39 | 248.79 | 72.83 |
| 1980 | 8.61 | 335.18 | 34.72 |

The greatest rate of increase occurred between 1950 and 1964, but the greatest absolute increase in land used for tourism and recreation purposes took place betwen 1964 and 1972, when 105 hectares were developed. The next eight year period saw a further 86 hectares developed. Considerably more land was developed for tourism and recreation purposes in each of the last two study periods

than the total that was being used for this purpose in 1950.

## Change Relative to Other Land Use Types

Once land is developed for tourism or recreation purposes, its use very seldom reverts to other land uses. As a result, no analysis of change into other land use types is presented in this section. The following section deals with the relationship between Land Use Type 'E' and physical parameters.

## Change Relative to Physical Parameters

### 'Tourism and Recreation Land' vs. Proximity to the Coast

As expected, the vast majority (99.17 percent) of the 'Tourism and Recreation Land' in the West Coast Study Area was located within 0.5 kilometers of the ocean in 1950. This percentage figure declined in each of the next three study years, as tourism developments grew bigger and expanded inland. In particular, the building of golf courses and 'villas' contributed to the eastward shift of 'Tourism and Recreation Land'. The actual figures are listed in Table 5.12.

Table 5.12 Percentage occurrence of Land Use Type 'E' ('Tourism and Recreation Land') vs. proximity to the ocean (1950-1980)

| YEAR | PROXIMITY ZONE | | |
|---|---|---|---|
| | < 0.5 km | 0.5 - 2.0 km | > 2.0 km |
| 1950 | 99.17 | 0.83 | 0.00 |
| 1964 | 80.39 | 19.61 | 0.00 |
| 1972 | 73.98 | 26.02 | 0.00 |
| 1980 | 65.49 | 34.51 | 0.00 |

Tourism and Recreation Land vs. Rainfall:

Almost no 'Tourism and Recreation Land' is found in the wettest areas of the West Coast Study Area. Less than five percent fell into the 60-70 inch average annual rainfall category in 1980. Prior to this, no 'Tourism and Recreation Land' whatsoever was found in the wettest regions of the study area. The fact that most 'Tourism and Recreation Land' is located in the drier areas of the West Coast Study Area does not indicate that a direct relationship exists between rainfall and location of tourist facilities. The relationship is insignificant because most 'Tourism and Recreation Land' is located in the coastal zone, which is coincidentally the driest part of the West Coast Study Area.

'Tourism and Recreation Land' vs. Slope

The greatest extent of 'Tourism and Recreation Land' in the West Coast Study Area has always been located on terrain that slopes less than ten degrees. The figures show relatively little change over the study period: 1950 (99.58%), 1964 (96.00%), 1972 (94.76%), and 1980 (91.88%). The reason for this high correlation stems from the fact that most tourism land is located on the flat coastal lowlands. However, eastward development of 'Tourism and Recreation Land' has brought about steady reduction in this percentage during each of the four study years.

'Tourism and Recreation Land' vs. Soil Depth

Although only 61 percent of the West Coast Study Area is covered by soils of normal depth (profiles in excess of 18 ins. - 46 cms.), an average of 80 percent of the 'Tourism and Recreation Land' was located in this soil zone between 1950 and 1980. In no study year does the value deviate by as much as five percentage points from this average. This is due to the fact that the majority of shallow and very shallow soils in the West Coast Study Area are located along gullies or in other areas with high slope factors. These landscape types are all but non-existent in the coastal lowlands, where 'Tourism and Recreation Land' predominates.

On average between 1950 and 1980, 12 percent of the 'Tourism and Recreation Land' was located on shallow soils, despite the fact that over 21 percent of the West Coast

Study Area is covered in soils of this type. The same pattern is observed for very shallow soils, which cover 18 percent of the West Coast Study Area, but accounted for an average of only 8.15 percent of the 'Tourism and Recreation Land' between 1950 and 1980.

'Tourism and Recreation Land' vs. Soil Type

Due to the eastward spread of tourism development, the amount of land devoted to 'Tourism and Recreation' occurring on soils of the Black Association declined steadily from 24.72 percent in 1950 to only 10.80 percent in 1980.

This reduction was paralleled by increases in the percentage of 'Tourism and Recreation Land' located on all three of the other soil types in the West Coast Study Area. Between 1950 and 1980, the amount of Land Use Type 'E' on soils of the Grey-Brown Association increased from 67.40 percent to 71.54 percent. The increased correlation with soils of the Red Sand Association during the same period was 6.33 percentage points, from 0.41 percent in 1950 to 6.74 percent in 1980. A 3.46 percentage point increase - from 7.46 percent in 1950 to 10.92 percent in 1980 - is observed for the Coastal Association.

## CHANGE IN LAND USE TYPE F - 'URBAN / INDUSTRIAL LAND'

### Change Relative to Other Study Years

The amount of 'Urban / Industrial Land' in the West Coast Study Area increased by 315 percent between 1950 and 1980. In doing so, the percent area coverage of this land use type increased from a mere 3.23 percent of the total in 1950 to over 13 percent in 1980. These figures are listed in Table 5.13.

Table 5.13 'Urban / Industrial Land' in the West Coast Study Area (1950 - 1980)

| Study Year | Urban / Industrial Land as a Percentage of the Total Area | Area of Urban / Industrial Land (Hectares) | Percent Increase from Previous Study Year |
|---|---|---|---|
| 1950 | 3.23 | 125.71 | -.- |
| 1964 | 4.83 | 188.31 | 49.80 |
| 1972 | 10.32 | 402.12 | 113.54 |
| 1980 | 13.39 | 521.37 | 29.66 |

Both the greatest percentage increase and the greatest absolute increase in the amount of 'Urban / Industrial Land' in the West Coast Study Area took place between 1964 and 1972. In these eight years, 214 hectares of land was developed for urban or industrial purposes,

representing a 114 percent increase in the total amount of land devoted to these uses.

Change Relative to Other Land Use Types

As with 'Tourism and Recreation Land', once land is developed for urban or industrial purposes, its use very seldom reverts to agriculture or any other land use. As a result, no analysis of change into other land use types is presented in this section. The following section deals with the relationship between Land Use Type 'F' and physical parameters.

Change Relative to Physical Parameters

'Urban / Industrial Land' vs. Proximity to the Coast

'Ribbon' development along Highway 1 parallel to the west coast of the island had already begun before 1950. The statistics for 'Urban / Industrial Land' use vs. ocean proximity indicate that nearly two thirds (64.77%) of the urbanized land in the West Coast Study Area was already located within one kilometer of the coast in 1950. This figure then increased slightly, to 67.29 percent in 1964. Following the tourism development boom of the 1960's, the percentage of 'Urban / Industrial Land' located within one kilometer of the coast dropped to 54.64 percent in 1972 and to an even lower 53.44 percent by 1980.

The amount of 'Urban / Industrial Land' located more than 2.0 kilometers from the coast also declined during this thirty year period. In 1950, just under 19 percent of this land use type was found more than two kilometers from the beach, but by 1980 this figure had dropped to about 15 percent. Thus, the movement of 'Peasant Agriculture' into the central strip, as documented in an earlier section, was paralleled by a similar shift in 'Urban / Industrial Land'. The central one kilometer wide east-west strip of the West Coast Study Area accounted for just over 16 percent of the 'Urban / Industrial Land' in 1950, but almost double this percentage (31.08 percent) in 1980.

'Urban / Industrial Land' vs. Rainfall

The narrow 'ribbon' of urban development that existed in the dry coastal lowlands in 1950 resulted in a slightly higher than expected percentage occurrence of this type of land use in the two lowest rainfall classes. Instead of the pro rata 25.11 percent of land that would be expected in the lowest rainfall zone, the actual 1950 figure was 27.13 percent. The building of Husbands and Oxnards housing projects in an area where the lowest rainfall zone extends unusually far east, resulted in increases in this figure for the next three study periods. By 1964, 33.67 percent of the 'Urban / Industrial Land' in western Barbados received an average of 40 - 50 inches of rainfall annually. Further development in this unusually dry inland area increased this figure to 40.35 percent by 1972.

By 1980, the percentage of 'Urban / Industrial Land' in low rainfall areas had reached 45.43 percent. This represents an increase of over 18 percentage points and demonstrates the effectiveness of plans to protect higher rainfall agricultural land from this sort of development.

The percentage of 'Urban / Industrial Land' in the West Coast Study Area found to be located in areas that receive an average of 50 - 60 inches of rainfall annually, declined by almost 20 percentage points from 64.53 percent in 1950 to only 45.11 percent in 1980. This means that, in this zone in 1950, 'Urban / Industrial Land' accounted for about ten percent more than the average for all land uses combined, whereas in 1980 'Urban / Industrial Land' ranked ten percent less than average for all land uses combined in these agriculturally favourable rainfall zones.

An average of about nine percent of the 'Urban / Industrial Land' in the West Coast Study Area has always been located in the wettest regions of the study area.

'Urban / Industrial Land' vs. Slope

The premium placed on level terrain for construction, combined with the early urbanization of the Coastal Lowlands, resulted in a disproportionately high correlation between the location of 'Urban / Industrial Land' and areas with slopes of ten degrees or less. Between 1950 and 1980, an average of over 81 percent of the 'Urban / Industrial Land' was located on land that slopes ten degrees or less.

This relationship remained essentially constant throughout the thirty year study period, despite the noted eastward movement of this land use type.

'Urban / Industrial Land' vs. Soil Depth

The percentage of urban and industrial development located on soils of normal depth (profiles in excess of 18 ins. - 46 cms) decreased between 1950 and 1980. This trend probably occurred in response to government initiatives and legislation designed to protect agricultural land. In 1950, over 65 percent of Land Use Type 'F' in the West Coast Study Area was on soils of average depth. By 1980, this figure had dropped to 57 percent. In the same time period, the percentage of urban and industrial development on shallow soils increased from 22.47 percent to 28.29 percent. On very shallow soils, the increase was from 12.20 percent to 14.54 percent.

'Urban / Industrial Land' vs. Soil Type

It was shown earlier that the eastward shift in the concentration of tourism and recreation between 1950 and 1980 resulted in significant declines in the percentage of this type of land use on soils of the Black Association. A similar trend might be expected for 'Urban / Industrial Land', given the same eastward shift of this land use type. In fact, precisely the opposite trend is observed.

The percentage of 'Urban / Industrial Land' found on soils of the Black Association increased steadily and quite dramatically, from 19.66 percent in 1950, to 31.96 percent by 1980. A concomitant decline in the number of hectares per hundred located on soils of the Grey-Brown Association is also observed. In 1950, 72.23 percent of the 'Urban / Industrial Land' in the West Coast Study Area was located on soils of the Grey-Brown Association. By 1980, after three successive declines of about three percent each, the figure dropped to 62.12 percent.

The increase in the percentage of Land Use Type 'F' on soils of the Black Association is due to the development and expansion of two large scale housing projects, Oxnards and Husbands, commencing in the 1960's. All of this development has taken place in sub-unit #13 (Prospect), which is the only sub-unit to have 100 percent of its terrain covered by soil of the Black Association.

The percentage of 'Urban / Industrial Land' located on soils of the Red Sand and Coastal Associations remained essentially unchanged throughout the three decades. On average, 3.36 percent of the 'Urban / Industrial Land' in the West Coast Study Area was located on the Red Sands, and about 3.62 percent was found on Coastal soils.

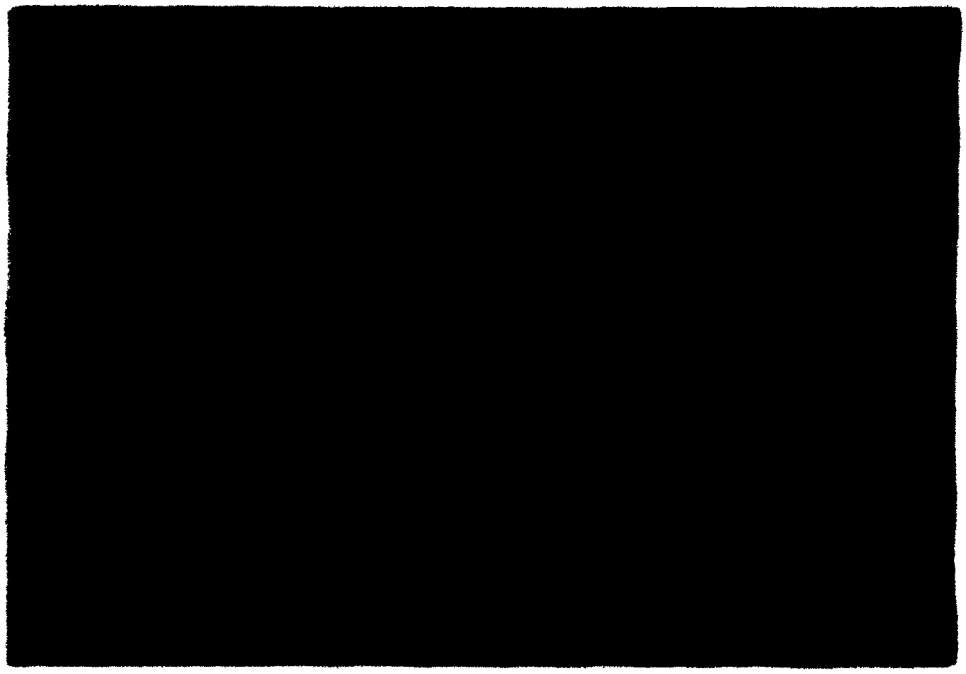


Figure 5.12 'Urban / Industrial Land' at Husbands and Oxnards in sub-unit #13, on soil of the Black Association

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Images en couleur

## TESTING OF HYPOTHESES -- PLANTATION AGRICULTURE

Hypothesis 1: Significantly less development of plantations for urbanization and tourism occurred during the 1972-1980 study period than during either of the two previous study periods.

Analysis: It is clear that the amounts of both 'Tourism and Recreation Land' and 'Urban / Industrial Land' increased dramatically in the West Coast Study Area during all three study periods.

Between 1950 and 1964, a total of 11.29 hectares of 'Plantation Agriculture' was converted to 'Urban / Industrial Land'. A further 23.49 hectares of 'Plantation Agriculture' was developed for tourism and recreation purposes, bringing total development of 'Plantation Agriculture' in the first study period to 34.78 hectares. Of the 23.49 hectares converted to 'Tourism and Recreation Land', 21.57 hectares (91.83.%) were located in the Sandy Lane (#11) and Sunset Crest (#10) sub-units, the site of the Sandy Lane Golf Course.

Between 1964 and 1972, even more 'Plantation Agriculture' was converted to 'Urban / Industrial Land' and 'Tourism and Recreation Land' uses. 53.93 hectares were taken over by 'Tourism and Recreation Land' use, while 29.54 hectares were developed for urban / industrial pruposes. A total of 83.47 hectares of plantation land was thus converted to these two land use types. This is a 240

Figure 5.13 Increases in the area devoted to tourism and recreation uses (1972-1980)

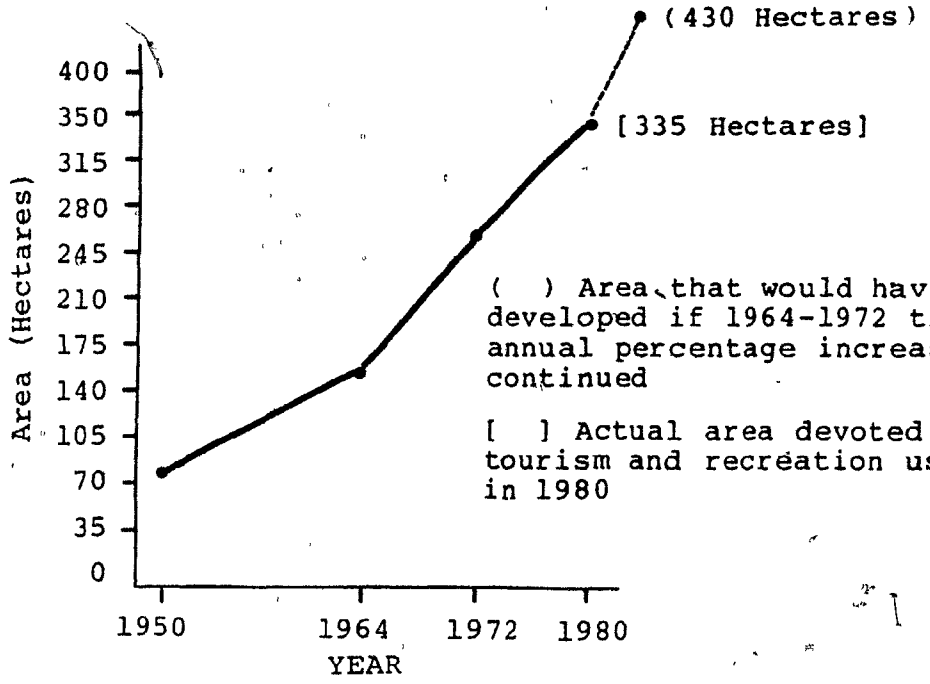
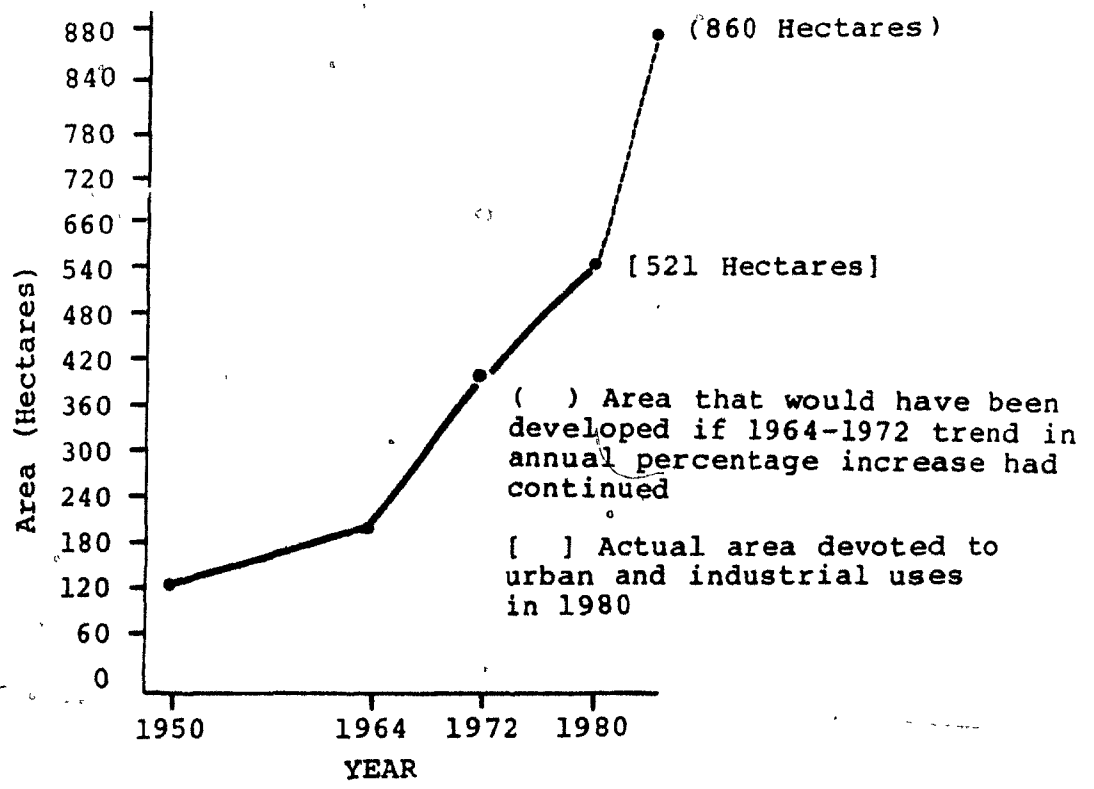



Figure 5.14 Increases in the area devoted to urban and industrial uses (1972-1980)



percent increase compared with the first study period. Once again, the Sandy Lane and Sunset Crest sub-units accounted for the majority (93.46%) of the land converted from 'Plantation Agriculture' to 'Tourism and Recreation Land'.

As predicted in the hypothesis outlined above, the third study period saw a significant decrease in the amount of 'Plantation Agriculture' converted to 'Urban / Industrial Land' and 'Tourism and Recreation Land'. 15.42 hectares of plantation land were developed for urban / industrial purposes between 1972 and 1980. Another 3.12 hectares were converted to tourism / recreation land use. In all, only 18.54 hectares of plantation land were lost to these two urbanizing forces in the third study period. This is a 78 percent decrease from the previous study period. The figures for all three study periods are presented in Table 5.14 and Figure 5.15.

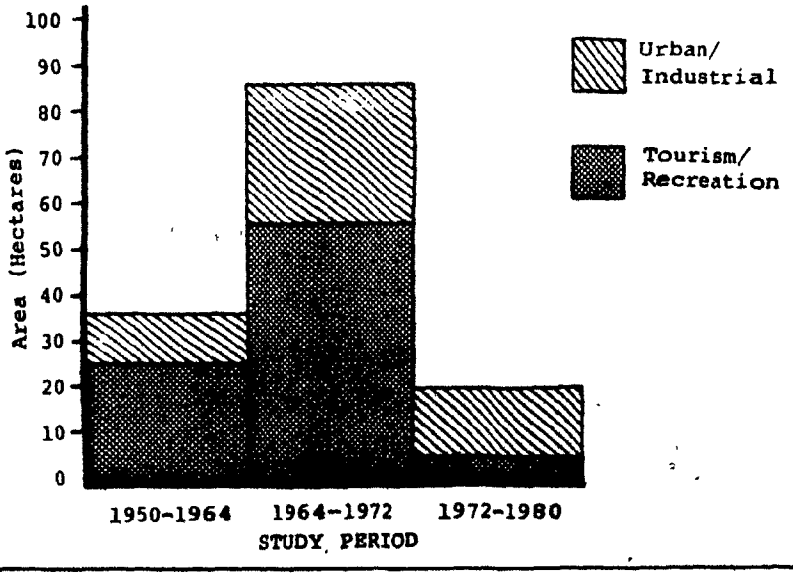
Of particular significance is the fact that the decrease in the rate of conversion of 'Plantation Agriculture' into 'Urban / Industrial Land' and 'Tourism and Recreation Land' took place at a time of greatly increased demand for land for these two purposes. See Figures 5.13 and 5.14.

Thus, despite continued high demand for land to develop for tourism / recreation and urban / industrial purposes, the amount of plantation land lost to these forces during the 1972-1980 study period was drastically reduced. Hypothesis One is, therefore, accepted.

Table 5.14 Areas of 'Plantation Agriculture' lost to other land uses (1950-1980)

| Time Period | Area lost to Tourism and Recreation Development (Hectares) | Area lost to Urban and Industrial Development (Hectares) | Total Loss Sustained by Plantation Agriculture (Hectares) |
|---|---|---|---|
| 1950-64 | 23.49 | 11.29 | - 34.78 |
| 1964-72 | 53.93 | 29.54 | - 83.47 |
| 1972-80 | 3.12 | 15.42 | - 18.54 |
| TOTAL: | 80.54 | 56.25 | - 136.79 |

Figure 5.15 Histogram illustrating the amount of 'Plantation Agriculture' diverted to other land uses during the three study periods (1950-64, 1964-72, 1972-80)



Hypothesis 2: Plantations in the 'sugar belt' will be found to have been the most stable land use type throughout the three study periods.

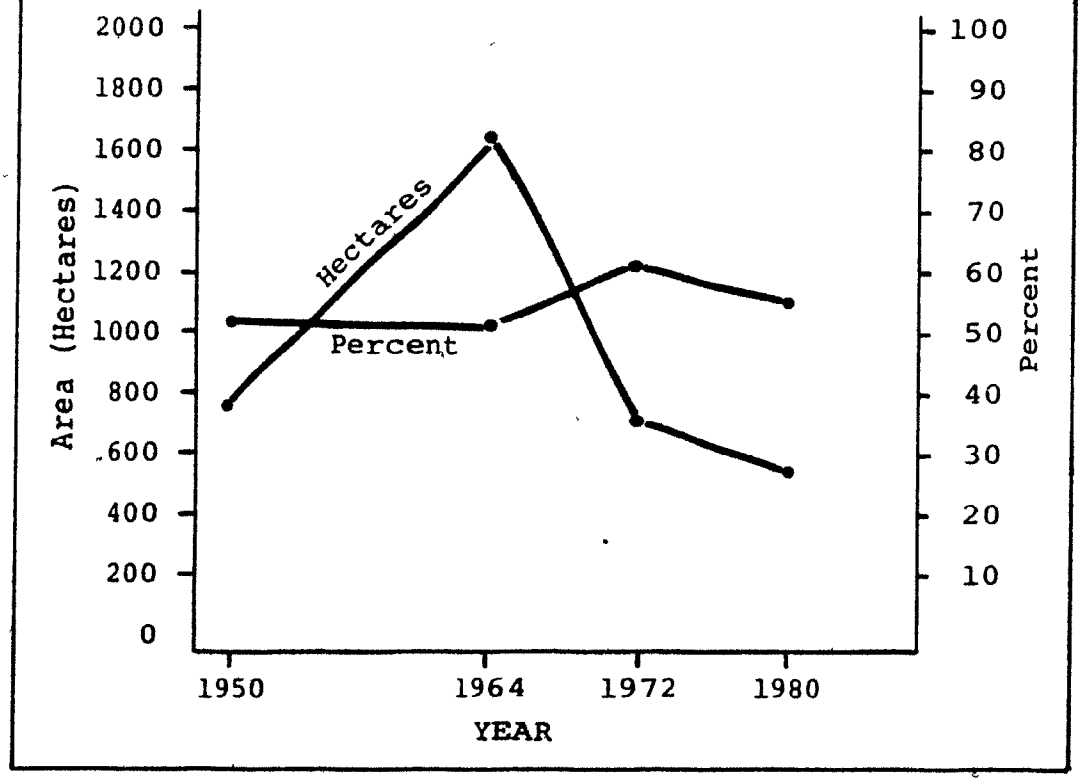
Analysis: For the purposes of this study, the 'sugar belt' is considered to be all land that is more than 1.5 kilometers from the coast. Aside from gullies and terrace fronts (which are common to most parts of the West Coast Study Area) this eastern section of the study site is generally characterized by Grey-Brown soils of average depth, slopes of less than ten degrees, and higher than average rainfall.

Upon initial examination, it appears that the plantation land in the sugar belt has been anything but stable. For the area located more than 1.5 kilometers from the coast, the range in the recorded area of sugar cane is in excess of 1,000 hectares. This is an amazing statistic, given that the entire 'sugar belt', as defined in this work, is a mere 1,548 hectares in area. The obvious conclusion is that many of the apparent increases and decreases in the amount of land in 'Plantation Agriculture' in this region are a function of both the practice of fallowing, and the criteria that were employed in the air photo interpretation of this land use type. Field verification of the details shown on aerial photographs is impossible in an historical study such as this, and so the only areas classified as agricultural land were those in which sugar cane was seen to be growing.

When the percentage figures for 'Plantation Agriculture' located in the sugar belt are considered, the stability of plantation land in this region becomes more apparent (Figure 5.16).

Clearly, an increase in the percentage of 'Plantation Agriculture' located in the sugar belt, from 51.24 percent in 1950, to 57.26 percent in 1980, is an indication of the stability of this location for sugar production relative to other areas. Hypothesis Two is thus accepted.

Figure 5.16 Changes in the area and percentage of 'Plantation Agriculture' located in the 'sugar belt' (1950-1980)



Hypothesis 3: Mechanization, the movement of labour away from peasant agriculture in favor of employment in the tourist industry, and the discouragement of subdivision by the government are expected to have effectively ended subdivision of plantations by the mid-1960's.

Analysis: The period 1950-1964 saw 84.48 hectares of plantation land subdivided into peasant holdings. Between 1964 and 1972, this figure had been reduced by almost 75 percent. A mere 22.28 hectares were subdivided during this second study period. This figure was further reduced in the 1972-1980 study period, during which only 19.25 hectares of plantation land were converted to peasant agriculture. When the number of hectares converted from peasant agriculture back to the plantation system is taken into account, the net shift to peasant agriculture is seen to have been curtailed to an even greater extent in the second and third study periods.

Conversions both into and out of 'Peasant Agriculture' relative to 'Plantation Agriculture' declined steadily throughout the three decade study period. Between 1972 and 1980, less than 20 of almost 1,100 hectares of plantation land were subdivided into peasant plots. This represents a mere 1.76 percent of the 'Plantation Agriculture' in the West Coast Study Area in 1972, and compares with a 5.75 percent conversion rate between 1950 and 1964. The hypothesis is thus accepted.

Table 5.15 'Peasant Agriculture' vs. 'Plantation Agriculture' (1950-1980)

| PERIOD / CHANGE | 1950-1964 (HECTARES) | 1964-1972 (HECTARES) | 1972-1980 (HECTARES) |
|---|---|---|---|
| Peasant to Plantation | 26.01 | 24.19 | 11.90 |
| Plantation to Peasant | 84.48 | 22.28 | 19.25 |
| Net Change in 'Peasant Agriculture' | + 58.47 | - 1.91 | + 7.35 |

## TESTING OF HYPOTHESES -- PEASANT AGRICULTURE

Hypothesis 4: The rate at which peasant held agricultural land is being developed for tourism and urban purposes will diminish through the three study periods, becoming insignificant by the 1972 - 1980 study period.

Analysis: As mentioned earlier, the amounts of both 'Tourism and Recreation Land' and 'Urban / Industrial Land' increased dramatically in the West Coast Study Area during all three study periods. 'Tourism and Recreation Land' increased from under 75 hectares in 1950 to over 335 hectares in 1980, (a 359 percent increase). 'Urban / Industrial Land' increased by almost as much, from about 125 hectares in 1950 to over 520 hectares in 1980 (a 315 percent increase).

It has already been demonstrated that much less plantation land was sacrificed for these two types of development in the 1972 - 1980 study period than during the previous two study periods. A similar trend is observed in the development of peasant holdings for tourism / recreation and urban / industrial purposes.

Between 1950 and 1964, a total of 3.53 hectares of peasant land was converted to tourism / recreation use. More than ten times this amount (37.00 hectares) was changed to 'Urban / Industrial Land' use.

As was the case with plantation land, the 1964 - 1972 study period saw even more peasant land developed for urban

/ industrial and tourism / recreation purposes. In fact, the amount of peasant land sacrificed for tourism development more than doubled (from 3.53 hectares to 7.26 hectares), while losses to 'Urban / Industrial Land' increased by over 275 percent (from 37.00 hectares to 138.91 hectares) in the 1964 - 1972 study period, as compared with the 1950 - 1964 study period.

Despite an ever-increasing demand for both 'Tourism and Recreation Land' and 'Urban / Industrial Land' in the 1972 to 1980 study period (see Figures 5.13 and 5.14), the amount of peasant land converted to these two uses was reduced dramatically in the 1972 - 1980 study period. Only 0.10 hectares of 'Peasant Agriculture' was turned into 'Tourism and Recreation Land' between 1972 and 1980. This is a 99 percent decrease from the previous study period. 25.30 hectares of peasant land were developed for urban or industrial purposes between 1972 and 1980. This is an 82 percent reduction from the 1964 - 1972 figure. In all, only 25.40 hectares of peasant land were lost to these two urbanizing forces in the third study period. This represents an 83 percent decrease as compared with the second study period, and corresponds quite closely with the 78 percent reduction in the amount of 'Plantation Agriculture' converted to 'Tourism and Recreation Land' and 'Urban / Industrial Land' over the same time span. Hypothesis Four is thus accepted.

Table 5.16 Development of 'Peasant Agriculture' (1950-1980)

| Time Period | Tourism and Recreation Development (Hectares) | Urban / Industrial Development (Hectares) | Total Conversion of Peasant Land (Hectares) |
|---|---|---|---|
| 1950-64 | 3.53 | 37.00 | 40.53 |
| 1964-72 | 7.26 | 138.91 | 146.17 |
| 1972-80 | 0.10 | 25.30 | 25.40 |
| TOTAL: | 10.89 | 201.21 | 212.10 |

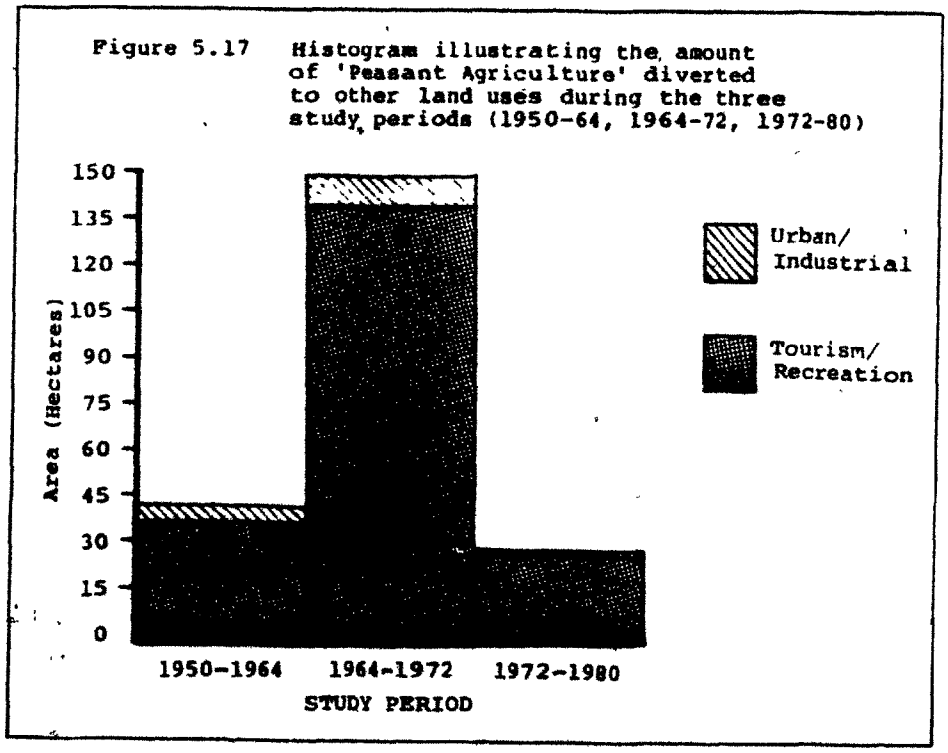



Figure 5.17 Histogram illustrating the amount of 'Peasant Agriculture' diverted to other land uses during the three study periods (1950-64, 1964-72, 1972-80)

Hypothesis 5: The rate of increase in peasant holdings will be highest in the 1950 - 1964 study period, and lower in the 1964 - 1972 study period. No increase in the number of peasant holdings will be observed for the 1972 - 1980 study period. In fact, the area of 'Peasant Agriculture' should remain essentially constant in the 1972 - 1980 study period, in response to the recommendations for consolidation of peasant holdings presented in the Physical Development Plan.

Analysis: The area of 'Peasant Agriculture' in the West Coast Study Area increased from 621.87 hectares in 1950 to 708.77 hectares in 1964. This is a 14 percent increase. By 1972, there were only 383.06 hectares of 'Peasant Agriculture' in the West Coast Study Area. This figure had dropped even further to 357.96 hectares, by 1980. Thus, the second and third study periods saw decreases in the amount of 'Peasant Agriculture' in the West Coast Study Area of 46 percent and 7 percent respectively. Hypothesis Five is thus accepted, but further examination provides interesting insight into the losses of 'Peasant Agriculture' in the second and third study periods.

Not all of the loss of 'Peasant Agriculture' can be accounted for by government policy discouraging sub-division and encouraging amalgamation. The loss of peasant lands was the result of competition from a number of sectors. As discussed in the previous section, over 170 hectares of 'Peasant Agriculture' were lost to tourism / recreation and urban / industrial uses between 1964 and 1980.

Figure 5.18 Changes in the area of 'Peasant Agriculture' in the West Coast Study Area (1950-1980)

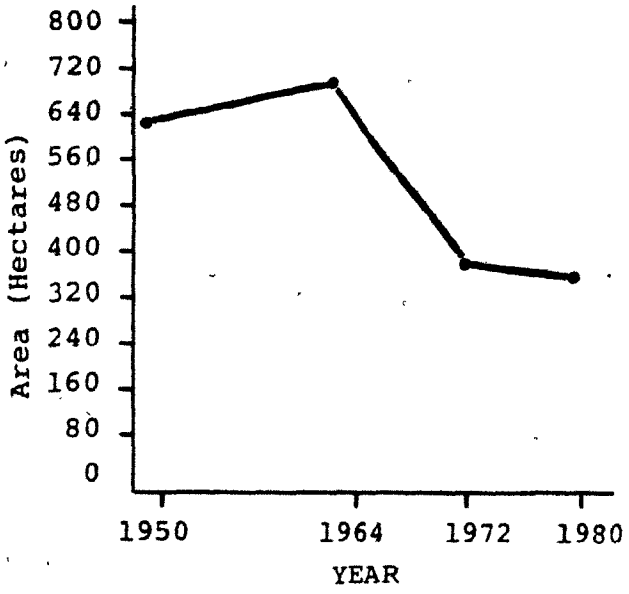



Figure 5.19 Net conversion of 'Plantation Agriculture to 'Peasant Agriculture' (1950-1980)

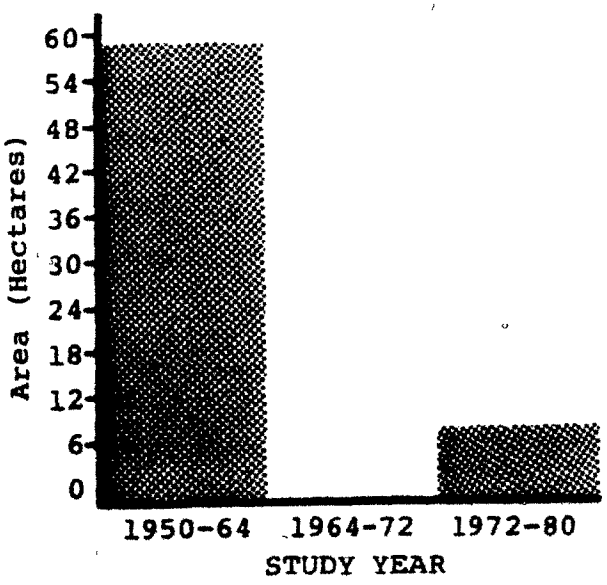


Table 5.17 Losses of Land Use Type 'C' - 'Peasant Agriculture' (1964-1980)

| Change Type \ Period | 1964-1972 (Hectares) | 1972-1980 (Hectares) |
|---|---|---|
| Peasant Agriculture to Grazing / Unused | 184.07 | 22.78 |
| Grazing / Unused to Peasant Agriculture | 10.69 | 15.93 |
| Net Change | - 173.38 | - 6.58 |
| Peasant Agriculture to Plantation Agriculture | 24.19 | 11.90 |
| Plantation Agriculture to Peasant Agriculture | 22.28 | 19.25 |
| Net Change | - 1.91 | + 7.35 |
| Peasant Agriculture to Uncleared / Overgrown | 16.53 | 0.71 |
| Uncleared / Overgrown to Peasant Agriculture | 5.04 | 0.30 |
| Net Change | - 11.49 | - 0.41 |
| Peasant Agriculture to Tourism / Recreation | 7.26 | 0.10 |
| Tourism / Recreation to 'Peasant Agriculture | 0.20 | 0.00 |
| Net Change | - 7.06 | - 0.10 |
| Peasant Agriculture to Urban / Industrial | 138.91 | 25.30 |
| Urban / Industrial Land to Peasant Agriculture | 7.06 | 0.20 |
| Net Change | - 131.85 | - 25.10 |
| Net Loss Sustained by 'Peasant Agriculture' | 325.69 | 25.01 |

Figure 5.20 Net losses of 'Peasant Agriculture' to other land use types (1964-1972)

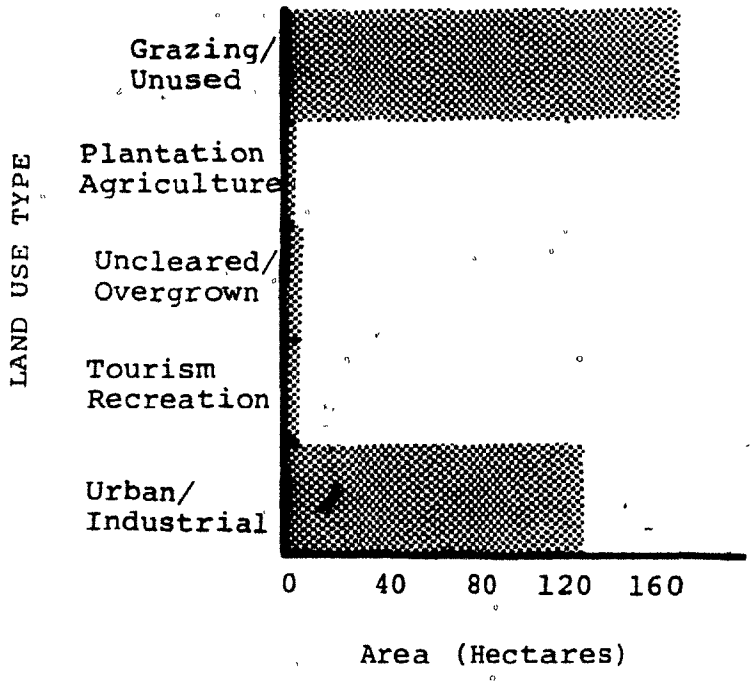
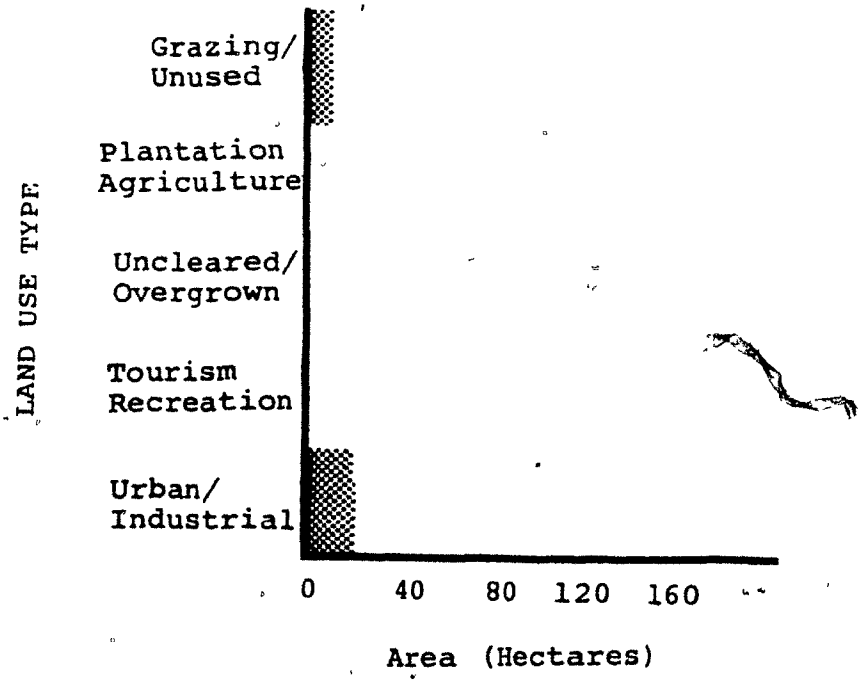



Figure 5.21 Net losses of 'Peasant Agriculture' to other land use types (1972-1980)



Hypothesis 6: Statistical analysis of land tenure / land capability relationships for the West Coast Study Area will show a disproportiontely high correlation between 'Peasant Agriculture' and marginal farming land for all four study years.

Analysis: In testing this hypothesis, the percent area coverage of 'Plantation Agriculture' and 'Peasant Agriculture' by slope class, soil type, soil depth and rainfall are compared individually.

Table 5.18 Percentage of 'Peasant Agriculture' and 'Plantation Agriculture', according to slope class (1950 - 1980)

| YEAR | SLOPE CATEGORY <10 degrees | | SLOPE CATEGORY >10 degrees | |
|---|---|---|---|---|
| | Percentage of Peasant Agriculture | Percentage of Plantation Agriculture | Percentage of Peasant Agriculture | Percentage of Plantation Agriculture |
| 1950 | 78.53 | 87.26 | 21.47 | 12.74 |
| 1964 | 77.18 | 86.27 | 22.82 | 13.73 |
| 1972 | 75.69 | 83.85 | 24.31 | 16.15 |
| 1980 | 74.68 | 83.11 | 25.32 | 16.89 |
| AVG: | 76.52 | 85.12 | 23.48 | 14.88 |
| CHANGE 1950-80 | DECREASE | DECREASE | INCREASE | INCREASE |

Figure 5.22 Percentage of 'Peasant Agriculture' and 'Plantation Agriculture' on slopes of less than 10 degrees (1950-1980)

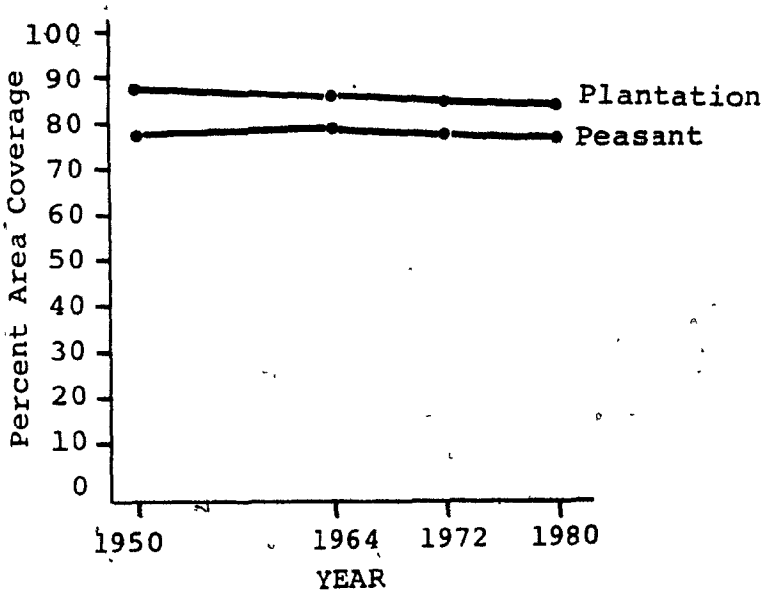
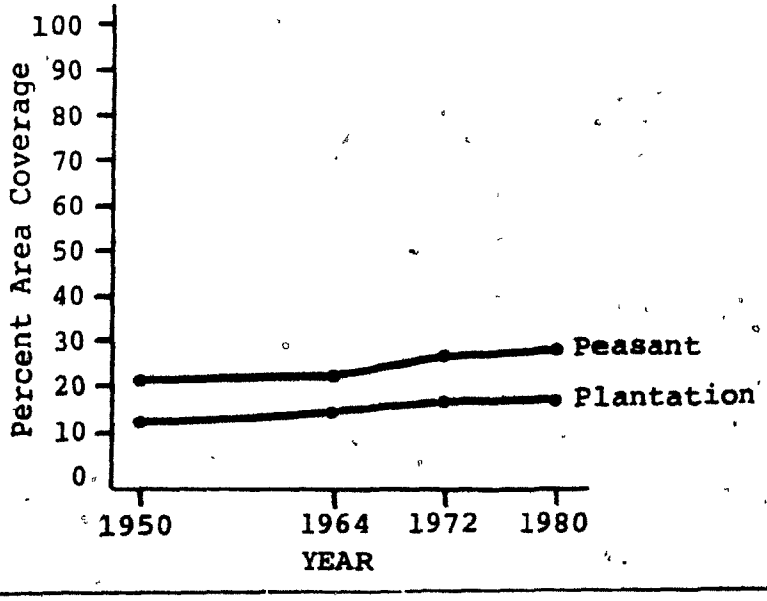



Figure 5.23 Percentage of 'Peasant Agriculture' and 'Plantation Agriculture' on slopes of more than 10 degrees (1950-1980)



Figures 5.22 and 5.23 graphically represent a number of interesting relationships and trends, including the following.

(1) The great majority of agricultural land is found on slopes of ten degrees or less.

(2) A higher percentage of 'Plantation Agriculture' than 'Peasant Agriculture' is located in areas with slope factors of ten degrees or less. An average of 85.12 percent of the 'Plantation Agriculture' in the West Coast Study Area had slopes of ten degrees or less during the four study years. Significantly less - 76.51 percent - of the 'Peasant Agriculture' in the West Coast Study Area was found to be located on land with these favorable slopes.

(3) A higher percentage of 'Peasant Agriculture' than 'Plantation Agriculture' was found to be located in areas with high slope factors. An average of 23.48 percent of the 'Peasant Agriculture' in the West Coast Study Area occurred on slopes of more than ten degrees. Only 14.88 percent of plantation agricultural land fits into this same category.

(4) A higher percentage of both 'Peasant Agriculture' and 'Plantation Agriculture' was located in areas with slopes of ten degrees or less in 1950 than in 1980. In fact, each of the three study years following 1950 saw a decrease in the percentage of agricultural land located on favorable slopes. The concomitant increase in the percentage of agricultural land in areas with slopes exceeding ten degrees is also observed. This is attributed

to the eastward migration of both of these agricultural land use types, due to pressure from 'Tourism / Recreation Land' and 'Urban / Industrial Land' along the coast.

The analysis presented above clearly indicates that a significantly higher percentage of plantation land than peasant land is located on terrain with slopes favorable to agriculture.

Soil Type: For the purpose of this analysis, the four soil types of the West Coast Study Area have been placed in two categories - agriculturally favorable and agriculturally unfavorable. Agriculturally favorable soils include those of the Black and Grey-Brown associations. Soils of the Red Sand and Coastal associations fall into the agriculturally unfavorable category.

Table 5.19 Percentage of 'Peasant Agriculture' and 'Plantation Agriculture' according to soil quality (1950-1980)

| YEAR | FAVORABLE SOILS | | UNFAVORABLE SOILS | |
|---|---|---|---|---|
| | % of Total Peasant Agriculture | % of Total Plantation Agriculture | % of Total Peasant Agriculture | % of Total Agriculture Agriculture |
| 1950 | 92.88 | 90.68 | 7.12 | 9.32 |
| 1964 | 92.66 | 85.07 | 7.34 | 14.93 |
| 1972 | 91.23 | 86.14 | 8.77 | 13.86 |
| 1980 | 91.98 | 82.80 | 8.02 | 17.20 |
| AVERAGE | 92.19 | 86.17 | 7.81 | 13.83 |
| CHANGE (1950-80) | SLIGHT DECREASE | DECREASE | INCREASE | INCREASE |

It is surprising to note from the figures in Table 5.20 that significantly more 'Peasant Agriculture' than 'Plantation Agriculture' was located on favorable soils during all four years of analysis.

Another unexpected finding is that the percentage of both agricultural land use types located on unfavorable soils increased steadily over the thirty year study period. Between 1950 and 1980, the percentage of plantation land occurring on unfavorable soils almost doubled - from 9.32 percent to 17.20 percent. The increase noted for peasant land is not as dramatic - from 7.12 percent in 1950 to 8.02 percent in 1980.

We can conclude from these figures that soil type is not a limiting factor to 'Peasant Agriculture' when compared with 'Plantation Agriclture'.

Figure 5.24 Percentage of 'Peasant Agriculture' and 'Plantation Agriculture' on favorable soils (1950-1980)

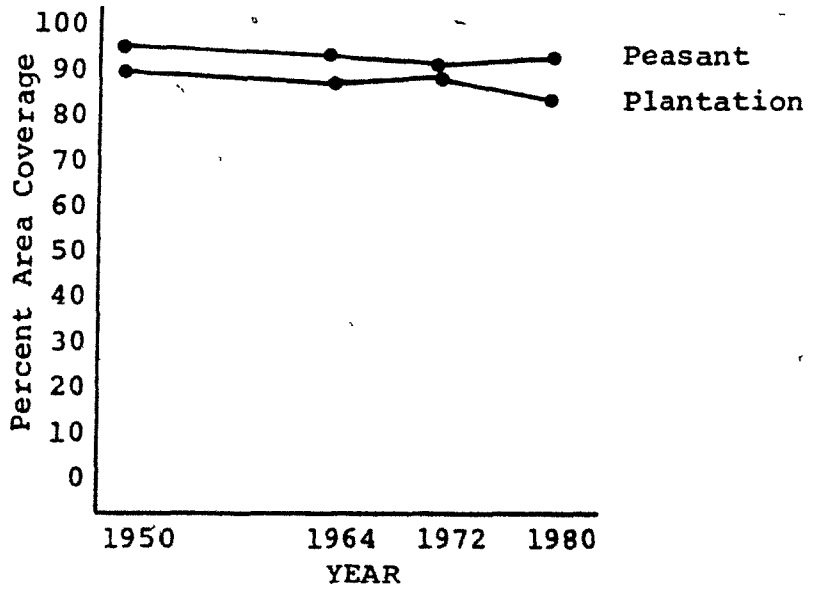
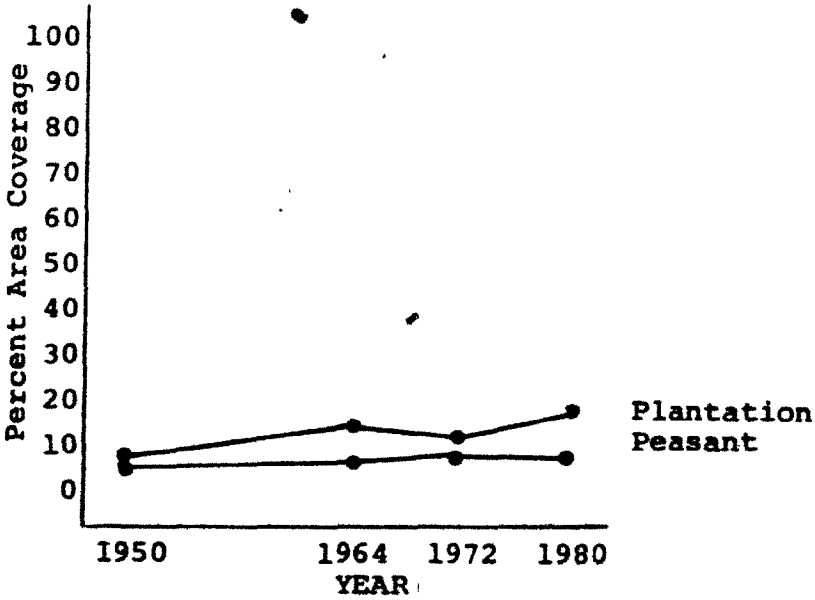



Figure 5.25 Percentage of 'Peasant Agriculture' and 'Plantation Agriculture' on unfavorable soils (1950-1980)



Soil Depth: Table 5.21 and Figures 5.26 and 5.27 illustrate a very strong correlation between soil depth class and land tenure. For the 1950 - 1980 study period, an average of 56.87 percent of the 'Peasant Agriculture' in the West Coast Study Area was located on soils of normal depth (profiles in excess of 18 inches - 46 cms). This compares with 76.96 percent for 'Plantation Agriculture'. This twenty percentage point differential is obviously also reflected in the statistics for land tenure versus shallow soils. 43.13 percent of 'Peasant Agriculture' - but only 23.04 percent of 'Plantation Agriculture' - occurred on shallow or very shallow soils between 1950 and 1980.

As with all other physical parameters examined so far, the percentage of both peasant and plantation land located on soils of favorable depth decreased over the thirty year study period.

Table 5.20 Percentage of 'Peasant Agriculture' and 'Plantation Agriculture' according to soil depth (1950-1980)

| YEAR | NORMAL (Profiles >18 ins - 46 cms) | | SHALLOW AND VERY SHALLOW (Profiles <18 ins - 46 cms) | |
|---|---|---|---|---|
| | % of Peasant Agriculture | % of Plantation Agriculture | % of Peasant Agriculture | % of Plantation Agriculture |
| 1950 | 58.21 | 77.97 | 41.79 | 22.03 |
| 1964 | 56.36 | 77.08 | 43.64 | 22.92 |
| 1972 | 57.60 | 75.91 | 42.40 | 24.09 |
| 1980 | 55.31 | 76.88 | 44.69 | 23.12 |
| AVERAGE | 56.87 | 76.96 | 43.13 | 23.04 |
| CHANGE (1950-80) | DECREASE | DECREASE | INCREASE | INCREASE |

Figure 5.26 Percentage of 'Peasant Agriculture' and 'Plantation Agriculture' according to normal soil depth (1950-1980)

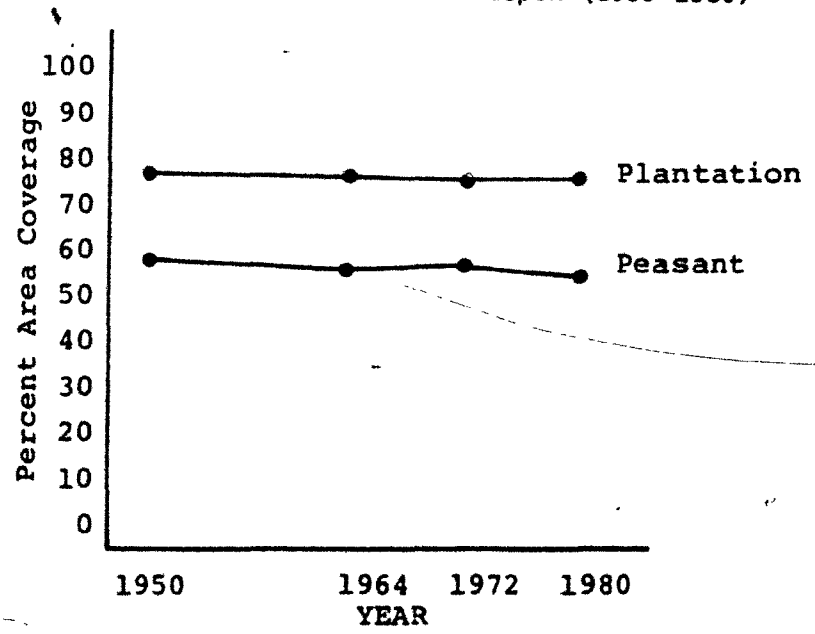
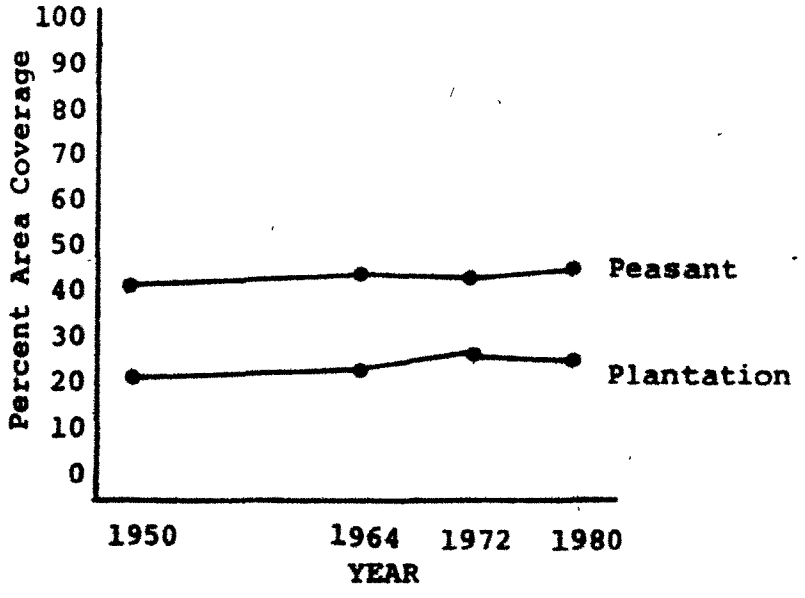



Figure 5.27 Percentage of 'Peasant Agriculture' and 'Plantation Agriculture' according to shallow and very shallow soil depth (1950-1980)



Rainfall: For the purpose of this analysis, the West Coast Study Area has been divided into two rainfall categories. The 'most favorable' zone receives in excess of sixty inches of precipitation per year. The 'less favorable' zone receives less than sixty inches of rain annually.

Table 5.21 Percentage of 'Peasant Agriculture' and 'Plantation Agriculture' according to rainfall class (1950-1980)

| | LESS FAVOURABLE ZONE <60 Inches Average Annual Rainfall | | MORE FAVOURABLE ZONE >60 Inches Average Annual Rainfall | |
|---|---|---|---|---|
| YEAR | % of Peasant Agriculture | % of Plantation Agriculture | % of Peasant Agriculture | % of Plantation Agriculture |
| 1950 | 83.93 | 77.72 | 16.07 | 22.28 |
| 1964 | 85.65 | 75.90 | 14.35 | 24.10 |
| 1972 | 82.39 | 66.42 | 17.61 | 33.58 |
| 1980 | 78.60 | 69.55 | 21.40 | 30.45 |
| AVERAGE | 82.64 | 72.39 | 17.36 | 27.61 |
| CHANGE (1950-80) | DECREASE | DECREASE | INCREASE | INCREASE |

An average of approximately 28 percent of the 'Plantation Agriculture' in the West Coast Study Area was located in the favorable rainfall zone between 1950 and 1980. This compares with a mere 17 percent for 'Peasant Agriculture'. A clear correlation thus exists between land tenure and average annual rainfall.

Figure 5.28 Percentage of 'Peasant Agriculture' and 'Plantation Agriculture' according to less favorable rainfall class (1950-1980)

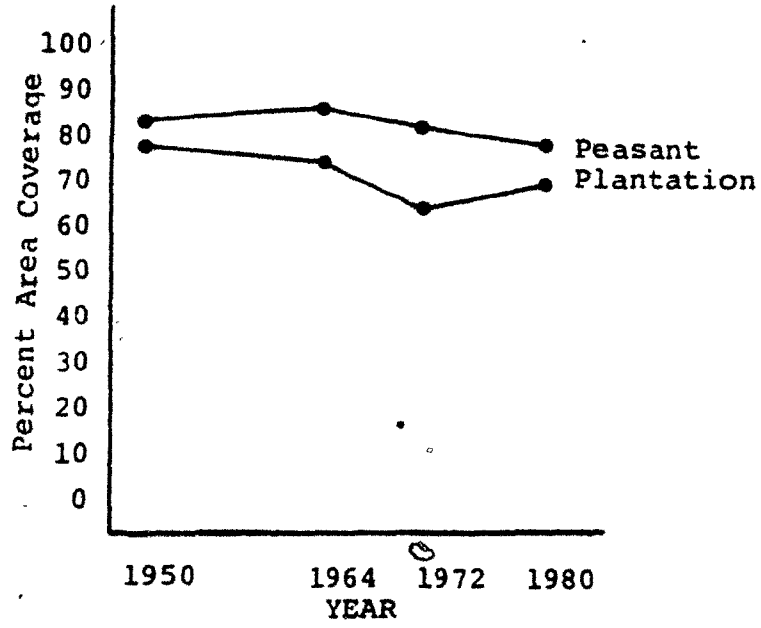
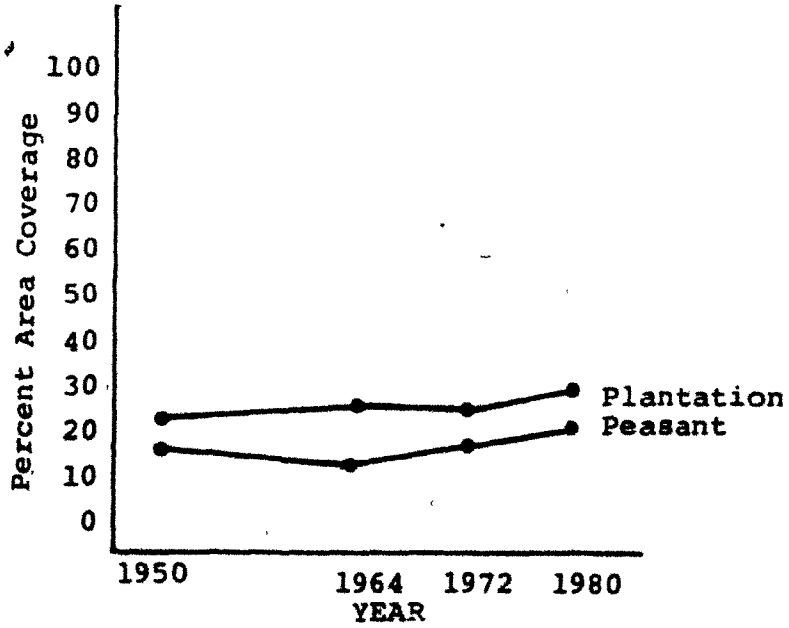



Figure 5.29 Percentage of 'Peasant Agriculture' and 'Plantation Agriculture' according favorable rainfall class (1950-1980)



The eastward migration of both peasant and plantation agriculture resulted in a steady decrease in the percentage of these land use types located in the dry coastal belt. The proportion of 'Peasant Agriculture' located in the favorable rainfall zone (>60 inches average annual rainfall) increased from 16.07 percent in 1950 to 21.40 percent in 1980 (a 33 percent increase). A similar shift of 36 percent (from 22.28 percent in 1950 to 30.45 percent in 1980) is observed for 'Plantation Agriculture'.

Conclusion: Strong correlations exist between land tenure and terrain slope, soil depth and rainfall. When land tenure is compared with each of these variables, a significantly higher percentage of 'Plantation Agriculture' than 'Peasant Agriculture' is found to be located in favorable zones. The only land capability parameter for which this pattern is not observed is soil type. The hypothesis is thus accepted.

## TESTING OF HYPOTHESES -- MARGINAL LAND

Hypothesis 7: Urban development of marginal land will be found to have increased dramatically from one study year to the next.

Analysis: For the purpose of this analysis, marginal land is defined as land with any or all of the following characteristics: terrain slopes in excess of ten degrees, average annual rainfall in the 40-50 inch range, shallow or very shallow soil profiles (less than 18 ins / 46 cms), or soil belonging to the Coastal or Red Sand Associations.

In testing this hypothesis, the net increase in urbanized land was calculated for each study period. The figures indicate that both the greatest relative and absolute change in the amount of urban land occurred in the 1964 - 1972 study period, when 213.81 hectares were converted to this land use type. This compares with 62.60 hectares between 1950 and 1964, and 119.25 hectares between 1972 and 1980.

In the second phase of the analysis, the area and percentage of the newly urbanized / industrialized land is compared with the occurrence of each of the marginal land types.

Slope: Approximately 26 percent of the land in the West Coast Study Area has slopes in excess of ten degrees. Table 5.22 indicates that the percentage of land converted to urban or industrial uses did not reach this level for any of the three development periods studied (1950-64, 1964-72, 1972-80).

This finding is not an indication that government policy to encourage the use of marginal land for urbanization / industrialization has been unsuccessful. Two factors - the premium placed on level land for the construction of buildings, and the concentration of development in the flat coastal lowlands - are responsible for the low correlation between terrain with high slope factors and the development of urban / industrial areas.

Table 5.22 Urbanization of terrain with slopes of more than 10 degrees (1950-1980)

| STUDY YEAR | Net increase in urban land since previous study year (hectares) | Total Urban Industrial Land occurring on slopes > 10° (hectares) | Total newly urbanized land on slopes > 10° (hectares) | Percentage of newly urbanized land on slopes > 10 |
|---|---|---|---|---|
| 1950 | --- | 23.89 | --- | --- |
| 1964 | 62.60 | 34.37 | 10.48 | 16.74 |
| 1972 | 213.81 | 82.67 | 48.30 | 22.59 |
| 1980 | 119.25 | 105.35 | 22.68 | 19.02 |

Rainfall: Table 5.23 indicates that 46.85 percent of the urbanization / industrialization that occurred between 1950 and 1964 took place in the lowest (<50 inches) average annual rainfall zone. Between 1964 and 1972, almost the exact same percentage - 46.20 percent - of the urban and industral development occurred in the driest rainfall zone. Between 1972 and 1980, 78 of a total of 119 hectares of urban / industrial development (66 percent) took place in the driest regions of the West Coast Study Area.

All of these figures are significantly higher than the 25 percent of land in the West Coast Study Area that falls into the marginal (<50 inches) average annual rainfall zone. Although encouraging in terms of the appropriate development of urban infrastructure in areas of low agricultural potential, the statistics do not represent as strong a cause / effect relationship between development and rainfall as first appears.

Proximity to the coastal highway is a major determinant of the location of urban development. Because this highway runs through the dry coastal plain, all development that was actually induced by proximity considerations is equally represented in the development / rainfall correlation statistics.

Table 5.23 Urbanization of land areas receiving more than 50 inches (127 cms) of rainfall annually (1950-1980)

| STUDY YEAR | Net increase in urbanized land area since previous study year (hectares) | Total urban/ industrial land located in rainfall with zones > 50 inches (hectares) | Total newly urbanized land occuring in rainfall zones with > 50 inches (hectares) | Percentage of urbanized land occuring in rainfall zones with > 50 inches |
|---|---|---|---|---|
| 1950 | --- | 34.08 | --- | --- |
| 1964 | 62.60 | 63.41 | 29.33 | 46.85 |
| 1972 | 213.81 | 162.20 | 98.79 | 46.20 |
| 1980 | 119.25 | 240.62 | 78.42 | 65.76 |

Only the 1972 - 1980 rainfall/development correlation statistic is considered to be significant. The decision to expand the Oxnards and Husbands housing projects (both of which are located inland of Highway 1, but in an area that is agriculturally marginal due to low rainfall), was apparently based on a land use / land capability decision. The expansion of these two projects accounts for the majority of the increase in 'Urban / Industrial Land' between 1972 and 1980.

Soil Depth: 39 percent of the West Coast Study Area is covered by shallow or very shallow soils (profiles less than 18 ins - 46 cms). The percentages of urban and industrial development occurring on these soils for the three study periods are close to this figure - 1950-64 (38.64%), 1964-72 (52.80%), and 1972-80 (35.77%).

In the first and last study periods, no cause / effect relationship existed between choice of development location and the occurrence of shallow soils. A significant correlation is, however, observed in the statistics for the 1964 - 1972 study period, during which 52.80 percent of the urban and industrial expansion took place on shallow and very shallow soils. This is particularly significant, given that more development occurred during this study period than during the first and third study periods combined.

Table 5.24 Urbanization of land with shallow and very shallow soils (profiles <18 ins - 46 cms ) (1950-1980)

| STUDY YEAR | Net increase in area of urbanized land since last study year | Total Urban/ Industrial Land occurring on shallow and very shallow soils | Total newly urbanized land occurring on shallow and very shallow soils (hectares) | Percentage of newly urbanized land occurring on shallow and very shallow soils |
|---|---|---|---|---|
| 1950 | — | 43.55 | — | — |
| 1964 | 62.60 | 67.74 | 24.19 | 38.64 |
| 1972 | 213.81 | 180.64 | 112.90 | 52.80 |
| 1980 | 119.25 | 223.29 | 42.65 | 35.77 |

Soil Type: The soils of the Red Sand and Coastal Associations comprise only 10.23 percent of the land in the West Coast Study Area. Table 5.25 indicates that areas covered by soils of the Red Sand or Coastal Associations were not specifically selected as sites for urban or industrial development during any of the three study periods.

Conclusion: The unsuitability of land with high slope factors for urban or industrial development, combined with the premium placed on land in the flat coastal plain, negated the establishment of a correlation between land of marginal capability due to slope and urban development.

A high correlation is observed between land of low agricultural capability due to inadequate rainfall and urban / industrial development. This relationship is likely explained by a secondary (ocean proximity) variable, however. Only in the 1964 - 1972 study period is the correlation between marginal land due to low average annual rainfall and selection of development sites considered to be significant.

The selection of land for urbanization / industrialization that is marginal due to shallow or very shallow soils is deemed to be significant for the second study period only. No correlation was found to exist between agriculturally marginal soil types and selection of urban / industrial sites.

Table 5.25 Urbanization of land with agriculturally marginal soil (1950-1980)

| YEAR | Net increase in area of urbanized land since last study year | Total Urban / Industrial Land occurring on shallow and very shallow soils (hectares) | Total Urban / Industrial Land occurring on Coastal or Red Sand Association soils (hectares) | Percentage of newly urbanized land on soils of the Red Sand or Coastal Associations |
|---|---|---|---|---|
| 1950 | — | 10.18 | — | — |
| 1964 | 62.60 | 14.41 | 4.23 | 6.76 |
| 1972 | 213.81 | 25.00 | 10.59 | 4.95 |
| 1980 | 119.25 | 30.85 | 5.85 | 4.91 |

The hypothesis that urban development of marginal land will be found to have increased dramatically from one year to the next cannot be accepted based on the data. Although strong correlations do exist in many instances between the location of agriculturally marginal land and development, most correlations are coincidental and no cause / effect relationship can be established.

Hypothesis 8: Most development of marginal land in the 1950 - 1964 and 1964 - 1972 study periods probably occurred in flat areas. If government policy had any effect, development of marginal land in the final (1972 - 1980) study period would have occurred primarily in areas with higher slope factors.

Analysis: A six phase analysis was performed to test this hypothesis. (1) In the first phase, marginal land areas were identified as those receiving less than 50 inches (127 cms) of precipitation annually (rainfall classes 'A' or 'B'); with Coastal or Red Sand soil associations (soil zones 'C' or 'D'); or with shallow or very shallow soil (soil depth classes 'B' or 'C'). (2) A composite data set including only marginal land was then prepared for each of the fourteen sub-units. (3) Developed land was defined as land being used for either tourism / recreation or urban / industrial purposes (Land Use Types 'E' or 'F'). (4) A series of separate data sets, including only developed land, was then prepared for each of the fourteen sub-units and four study years. (5) In the fifth phase, the data sets of marginal land were compared with the data sets of developed land for each of the four study years. The result of this comparison is a set of fourteen data sets for areas of developed marginal land in each study year. (6) The sixth, and final, phase of the analysis involved the comparison of these 'Developed Marginal Land' data sets with the slope data set.

The analysis described above yielded the following statistics for developed marginal land according to slope class.

Table 5.26 Developed marginal land according to terrain slope (1950-1980)

| Terrain Slope Class (Degrees) | Developed Marginal Land (Hectares) | | | |
|---|---|---|---|---|
| | 1950 | 1964 | 1972 | 1980 |
| 0-2 | 16.63 | 22.68 | 52.12 | 53.33 |
| 2-5 | 44.05 | 86.09 | 117.64 | 162.70 |
| 5-10 | 35.99 | 66.13 | 186.29 | 251.91 |
| 10-20 | 13.81 | 24.90 | 71.57 | 103.43 |
| 20-30 | 5.54 | 9.17 | 15.12 | 16.43 |
| >30 | 0.30 | 0.50 | 0.91 | 1.11 |
| TOTAL: | 116.32 | 209.47 | 443.65 | 588.91 |

The percentage and absolute increases in the amount of developed marginal land, according to slope class, are presented in Table 5.27.

Table 5.27 Development of marginal land according to terrain slope (1950-1980)

| TERRAIN SLOPE CLASS (DEGREES) | DEVELOPMENT OF MARGINAL LAND | | | | | |
|---|---|---|---|---|---|---|
| | 1950-64 | | 1964-72 | | 1972-80 | |
| | HA | Percent Increase | HA | Percent Increase | HA | Percent Increase |
| 0-2 | 6.05 | 36.38 | 29.44 | 129.81 | 1.21 | 2.32 |
| 2-5 | 42.04 | 95.44 | 31.55 | 36.65 | 45.06 | 38.30 |
| 5-10 | 30.14 | 83.75 | 120.16 | 181.70 | 65.62 | 35.22 |
| 10-20 | 11.09 | 80.30 | 46.67 | 187.43 | 31.86 | 44.50 |
| 20-30 | 3.63 | 65.52 | 5.95 | 64.89 | 1.31 | 8.66 |
| 30 + | 0.20 | 66.67 | 0.41 | 82.00 | 0.20 | 21.98 |
| TOTAL: | 93.15 | -.- | 234.18 | -.- | 145.26 | -.- |

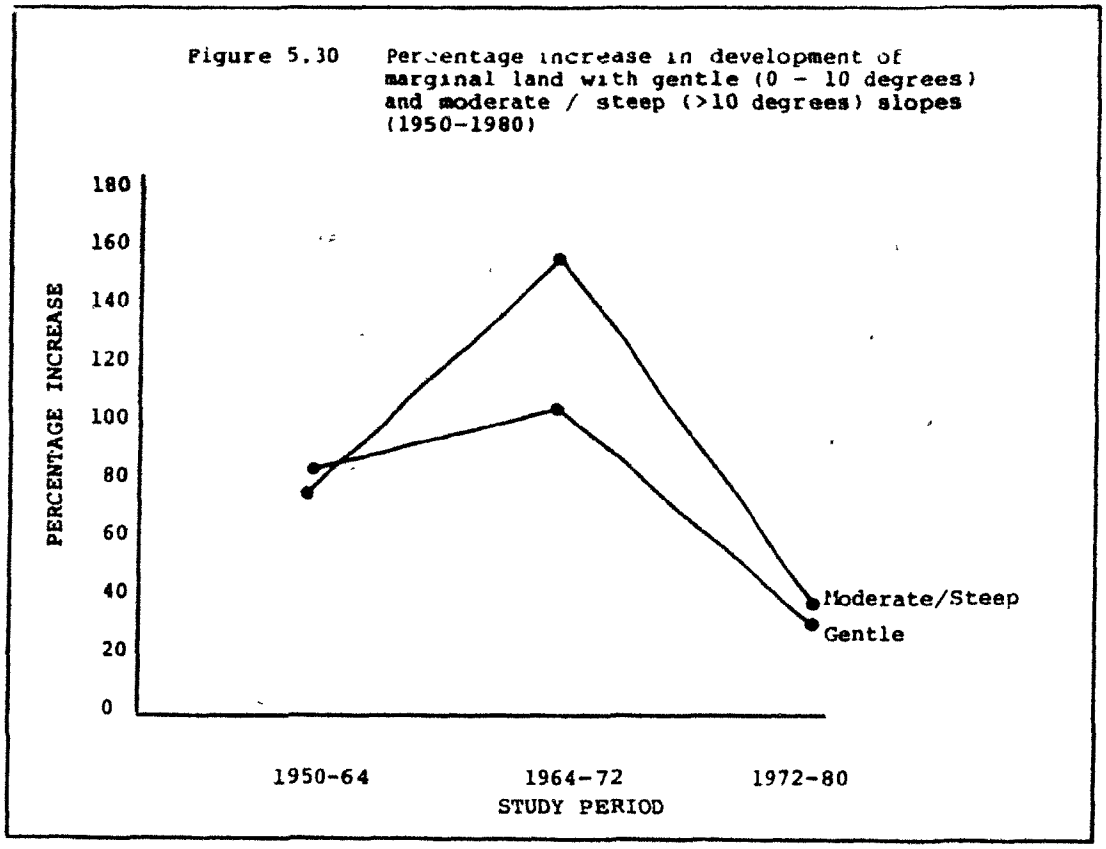



Figure 5.30 illustrates the percentage increase in development of marginal land for gentle and moderate/steep slope classes. It is clear that the rate of development of marginal land with gentle slope factors decreased significantly during the third study period. The same trend is, however, observed for marginal land with moderate or steep slope factors. The hypothesis that marginal land with gentle slopes would be protected to a greater degree from development during the third study period than would marginal land with moderate or steep slopes cannot, therefore, be accepted.

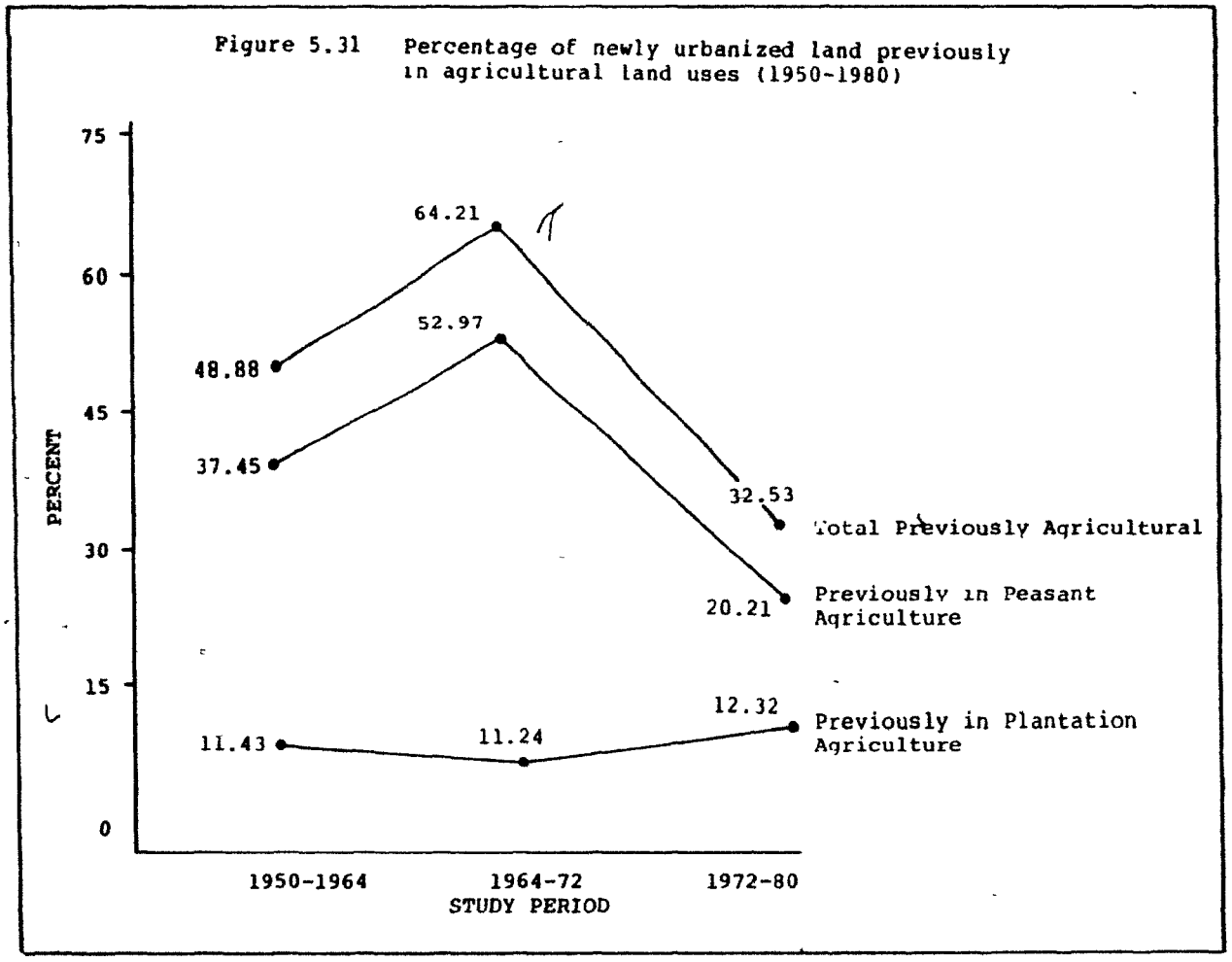
## TESTING OF HYPOTHESES -- URBANIZATION

Hypothesis 9: Urbanization that occurred before 1972 took place without regard to land capability or previously established land uses. This is a predictable outcome of unregulated open competition for housing and industrial land.

Analysis: For the purposes of this analysis, the percentage of newly urbanized land that was previously in agricultural production is calculated for each study period. These values are then compared, in order to determine whether or not a significantly higher percentage of agriculturally productive land was developed between 1950 and 1964 than during the latter two study periods.

Figure 5.31 clearly illustrates that the greatest development of agricultural land for urban / industrial purposes occurred in the 1964 - 1972 study period, rather than in the 1950 - 1964 study period as suggested by the hypothesis. Nonetheless, the hypothesis is accepted, given that almost half of the land developed for urban / industrial purposes had been agriculturally productive at the beginning of the study period. The legislation introduced as a result of the Physical Development Plan was successful in reducing this figure by more than 67 percent by the final study period.

Figure 5.31 Percentage of newly urbanized land previously in agricultural land uses (1950-1980)



Hypothesis 10: Urban development that occurred after 1972 took place in designated growth areas. In particular the Speightstown, Sunset Crest and Prospect sub-units of the West Coast Study Area are anticipated zones of high urbanization for the third study period.

Analysis: For the purpose of this analysis, the term 'urban development' is considered to mean any increase in the amount of land devoted to Land Use Type 'F' (Urban / Industrial). Table 5.28 presents a breakdown of the urban development that occurred in the West Coast Study Area between 1972 and 1980.

The average 1972 - 1980 increase in urban land, expressed as a percentage of sub-unit area, was 3.57 percent. Although the actual figures ranged from a low of 0.48 percent (sub-unit #06) to a high of 15.00 percent (sub-unit #12), the great majority of sub-units experienced urban development of between 0.5 percent and 5.0 percent of their respective land areas between 1972 and 1980. In only two sub-units (#12 and #13) did urban development occur on more than five percent of the land area. These two sub-units (Thorpe and Prospect) are geographically contiguous and are located in one of the anticipated zones of high urban development.

Table 5.28 Urbanization of the West Coast Study Area (1972-1980)

| SUB-UNIT | TOTAL AREA (HECTARES) | URBAN DEVELOP-MENT (HECTARES) | INCREASE IN URBAN LAND (1972-80) AS PERCENTAGE OF TOTAL AREA |
|---|---|---|---|
| 01 | 301.21 | 2.42 | 0.80 |
| 02 | 230.14 | 8.37 | 3.64 |
| 03 | 330.44 | 7.66 | 2.32 |
| 04 | 245.36 | 3.93 | 1.60 |
| 05 | 357.26 | 9.68 | 2.71 |
| 06 | 253.93 | 1.21 | 0.48 |
| 07 | 264.31 | 2.32 | 0.88 |
| 08 | 244.35 | 6.96 | 2.85 |
| 09 | 323.89 | 2.11 | 0.65 |
| 10 | 320.36 | 4.04 | 1.26 |
| 11 | 398.89 | 10.59 | 2.65 |
| 12 | 167.34 | 25.10 | 15.00 |
| 13 | 231.05 | 24.29 | 10.51 |
| 14 | 226.41 | 10.58 | 4.67 |
| TOTAL: | 3,894.94 | 119.26 | AVG: 3.57 |

An average of 12.75 percent of the land in these two sub-units was converted to urban / industrial uses during the final study period. Together, they accounted for 50 of the 119 hectares of urban development that took place over the eight year period. Thus, over 40 percent of the total urban development in the West Coast Study Area was concentrated in only two sub-units between 1972 and 1980.

Hypothesis 10 is accepted, although it must be noted that two of the three specific sub-units that were expected to experience the greatest rate of urban development between 1972 and 1980 were incorrectly predicted. This, in turn, is an indication that the hierarchical Urban Development Strategy described in Chapter Three was less than effective in terms of encouraging housing development in Holetown and Speightstown. Only the Oxnards and Husbands housing developments (located in the Thorpe and Prospect sub-units) were correctly forecast as being high growth areas.

Hypothesis 11: Urban development that occurred during the third study period (1972-1980) likely involved land that was unused during the previous (1964-1972) study period. While most of this development probably took place on marginal land, some development of land of high capability may also have occurred. Such development would be restricted to cases in which land had been taken out of agriculture for the purpose of speculation before the publication of the Physical Development Plan. Thus, land of high capability that was developed for urban uses during the 1972-1980 study period probably evolved through the following series of land use changes: (i) 1950-1964, agriculture, (ii) 1964-1972, unused / speculation, (iii) 1972-1980, development.

Analysis: As with the testing of Hypothesis 10, the term 'urban development' is used here to mean any increase in the amount of land devoted to Land Use Type 'F' (Urban / Industrial).

A total of 125 hectares of land in the West Coast Study Area was developed for urban purposes between 1972 and 1980. Of this total, 84 hectares (67 percent) had been unused in 1972. 77 of the 84 hectares of unused land in 1972 were in the 'Grazing and Unused Land' category. The remaining 7 hectares belonged to the 'Uncleared and Overgrown' land use type.

By comparison, 41 hectares of the land that was developed for urban purposes between 1972 and 1980 had been in agricultural production in 1972. This means that at least one third of the urban development that occurred

during the final study period resulted in the loss of agricultural land.

It was predicted in Hypothesis 11 that virtually all land developed between 1972 and 1980 would have come from land that was unused in 1972, due to either low productivity or speculation. The in-depth analysis of the evolution of individual parcels of land that were developed in the final study period was designed to find 'hidden' abuses of the intention of the Physical Development Plan. The analysis presented above indicates, however, that urban development of agricultural land - although made more difficult by the recommendations contained in the Physical Development Plan - did not require pre-planned transition periods of disuse.

Conclusion: Although it is encouraging to note that two out of every three hectares of land developed for urban purposes between 1972 and 1980 did not come from agriculture, the optimistic hypothesis that only unused land would be developed in the third study period cannot be accepted.

## TESTING OF HYPOTHESES -- TOURISM AND RECREATION LAND

Hypothesis 12: Land use statistics for 1964 should show considerably more land devoted to tourism than the 1950 statistics. The lack of regulations protecting prime agricultural land during the 1950-1964 study period and the resultant use of land with high agricultural capability for the building of hotels, golf courses and recreational facilities is expected to emerge quite clearly in the analysis of land use change between 1950 and 1964.

Analysis: In this analysis, the amount of land developed for tourism / reccreation purposes between 1950 and 1964 is first documented. This developed land is then compared with slope, soil type, soil depth and rainfall data to determine the percentage of the developement that took place on land with good agricultural potential.

The amount of land devoted to tourism and recreation in the West Coast Study Area almost doubled in the first study period - from 73 hectares in 1950, to 144 hectares in 1964. 92 percent of this development occurred on land that sloped 10 degrees or less, 97 percent was on the productive soils of the Black and Grey-Brown Associations, and 81 percent of the development was on soils of normal depth. Only the tourism / recreation land versus average annual rainfall correlation varies from this pattern of development of agriculturally productive land. Due to the premium placed on land in the dry coastal plain for the building of

tourism facilities, only 36 percent of the tourism / recreation development that occurred between 1950 and 1964 was in areas that receive more than 50 inches of rain annually. Hypothesis 12 is thus accepted.

Hypothesis 13: The 1972-1980 time period should exhibit by far the greatest rate of increase in tourism development. The dangerous trend toward alienation of agricultural land will probably show signs of slackening-off in this study period. If land of high capability is found to have been developed for tourism in the 1972-1980 study period, it will be necessary to examine the evolution of the particular parcels involved from 1950. In such cases, it is likely that land that was being used for the growing of crops in the first time period, was bought for speculation and taken out of production in the second time period, and was finally developed in the third time period. This sequence, which is also anticipated with respect to land speculation for urban development is a likely possibility when considering speculation leading to the development of land for tourism.

Analysis: Figure 5.32 clearly refutes the hypothesis that the 1972 - 1980 time period should exhibit by far the greatest rate of increase in tourism development.

It should be emphasized, however, that the amount of land developed for tourism and recreation purposes between 1972 and 1980 was still very significant.

Of the 87 hectares converted to Tourism / Recreation land use between 1972 and 1980, fully 78 hecares (90 percent) were in either the 'Grazing and Unused Land' category (61 hectares) or the 'Uncleared / Overgrown Land' category (17 hectares) in 1972. A mere 3 hectares of agricultural land from 1972 had been developed for tourism or recreation purposes by 1980.

Figure 5.32 Increases in 'Tourism / Recreation Land' (1950-1980)

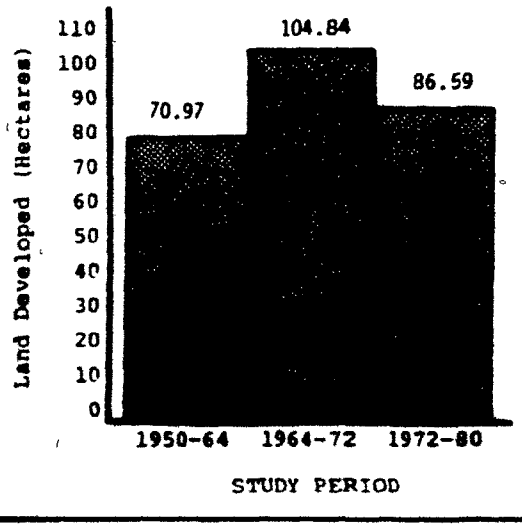
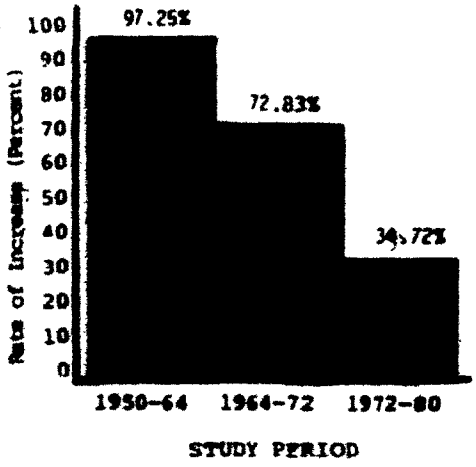



Figure 5.33 Rate of increase in Tourism development (1950-1980)



Figures 5.34 and 5.35 illustrate how well these statistics compare with the two previous study periods in terms of protection of agricultural land.

46 percent of the 'Tourism / Recreation Land' that was developed between 1964 and 1972 had been in agricultural production at the outset of the study period. By the final study period, the equivalent figure had been reduced to a mere three percent. The hypothesis, that the dangerous trend toward alienation of agricultural land will probably show sign of slackening off, is therefore accepted.

Figure 5.34 Percentage of land converted to tourism and recreation uses that was unused in the previous study period (1950-1980)

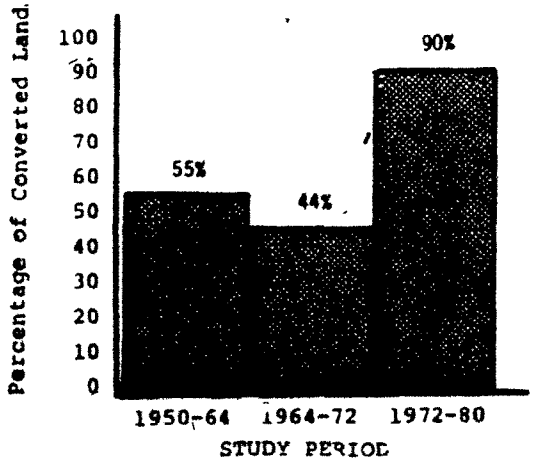
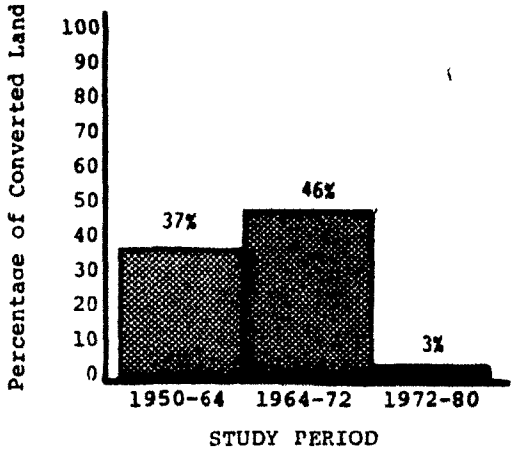



Figure 5.35 Percentage of land converted to tourism and recreation uses that was in agricultural production during the previous study year (1950-1980)



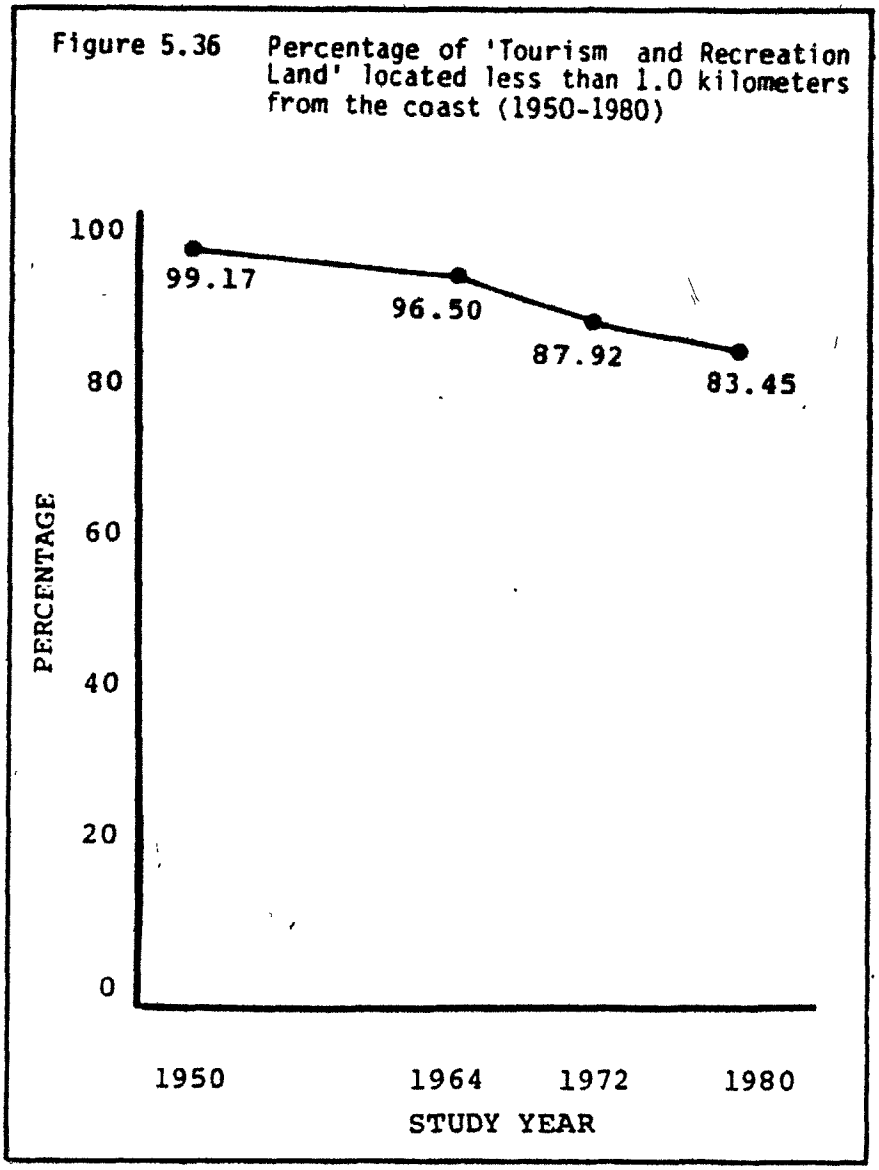
Hypothesis 14: The comparison of an ocean proximity index with land use change information will almost certainly prove that distance to the beach has had a greater impact on decisions regarding the location of tourist facilities than has any other variable. It is expected that this relationship will be equally strong for all three time periods. Secondary proximity indices will also be examined. It is anticipated that this phenomenon will be most prevelant in the 1972-1980 study period.

Analysis: The percentage of 'Tourism and Recreation Land' located less than 1.0 kilometers from the coast is in excess of 80 percent for each of the four study years. This finding substantiates the hypothesis that distance to the beach has had a greater impact on decisions regarding the location of tourist facilities than has any other variable.

The hypothesis that this relationship will remain equally strong for all three time periods is, however, refuted by Figure 5.36, which indicates that the percentage of Land Use Type 'E' ('Tourism and Recreation Land') located less than 1.0 kilometer from the coast declined steadily in each successive study year.

This finding lends support to the theory that secondary proximity relationships were established in the second and third study periods with the building of tourist infrastructure around the Sandy Lane Golf Course. The hypothesis is thus accepted.

Figure 5.36 Percentage of 'Tourism and Recreation Land' located less than 1.0 kilometers from the coast (1950-1980)



# SUMMARY AND CONCLUSION

The island of Barbados is a mere 430 square kilometers in area, yet supports a population of a quarter of a million people. The success or failure of land use planning thus has significant social and economic implications.

## Geological Evolution

The island, as we know it today, began to take shape 600,000 years ago when coral reefs started to form over sedimentary deposits that were being tectonically uplifted. 85 percent of Barbados is today covered by the resulting Quaternary limestone "cap".

## History of Land Use Change

The complete lack of mineral wealth on Barbados resulted in it being largely overlooked by European settlers until the early 1600's. Colonization began with British settlement in 1627. Over the next ten years, patches of the dense indigenous forest were randomly cleared for the growing of subsistence crops. The successful introduction of sugar by the Dutch in 1637 resulted in the rapid transformation of the landscape from one of thick woods to one of large sugar plantations. By 1650, the dense forests had been cleared from almost all of the flat land, in order to enable the growing of sugar.

The next 300 years saw numerous problems confront the plantation owners. Foreign wars, overseas competition, loss of soil fertility, environmental disasters and the emancipation of slaves all reduced the profitability of the monocrop sugar economy. Of all of these setbacks, however, it was only the emancipation of the slaves in 1834 that led to a significant change in the landscape of the island. Over the next century, numerous plantations (mainly the least productive ones) were subdivided and sold to peasants.

In 1950, Barbados appeared ready to enter its fourth century supported by an agricultural economy based almost entirely upon sugar cane. The introduction and immediate success of large scale tourism in the 1950's were to drastically change both the economy and land use patterns over the next 30 years, however. For the first time in 300 years, sugar plantation agriculture began to feel the effects of competition for land from a potentially more lucrative industry.

## Study Area

Tourism and sugar cane have been competing for land in Barbados for over three decades. This study was designed to document that land use competition, and to study its effects on land use change. In order to accomplish this, a study area was outlined on the west coast of the island. The study area defined averages 15.5 kilometers in length and 2.6 kilometers in width. It was selected primarily for its

dynamic land use change history, simple pattern of physical and landscape features and extremely diverse land capability. The study area was subdivided into 14 sub-units to facilitate computer data entry.

## Physical Factors Affecting Land Use

Soil Type and Depth: Four soil associations were identified and their relative coverage percentages noted.

Each of the four soil associations found in the West Coast Study Area was formed by a combination of the erosion of the limestone cap and the deposition of ash from volcanic eruptions on neighbouring islands. Differences in soil genesis relate mainly to the age of the soil, which determines the degree of weathering and the amount of volcanic dust in its composition. Soils found at higher elevations are more mature and contain more volcaninc ash than lower soils, due to the slow tectonic emergence of the island.

Soils of the **Black Association** have a uniformly dark profile which is likely the result of the sorption of organic matter on montmorillonitic clay. Soils of this association consist mainly of clay with relatively low sand and silt content. Soil depth and drainage characteristics are strongly related and combine to significantly alter the productivity of this soil type. Where well drained and of adequate depth, these soils are suitable for cane or other agricultural production.

The soils of the **Grey-Brown Association** are similar to those of the Black Association in that they are composed of over 60 percent clay and relatively little sand or silt. They are found at higher elevations than are the soils of the Black Association and have, as a result, been exposed to greater weathering and deposition of volcanic ash. When of adequate depth and well drained, these soils are good cane producers.

The soils of the **Red Sand Association** have extremely low agricultural potential due to their sandy (>65 percent) composition, low levels of organic material and poor hydrological properties.

The soils of the **Coastal Association** are also extremely unproductive. They are generally shallow and rocky and are restricted to the driest section of the West Coast Study Area.

Terrain Slope: Cane production is impossible on land of any soil type with high slope factors, due to the concomitant problems of stoniness, high erosion, poor drainage, shallow depth and overall low fertility. Generally, the flatter the terrain, the higher its agricultural potential.

Rainfall: Complex inter-relationships exist between cane growth and average annual rainfall, length of the dry season, potential versus actual evapotranspiration, et cetera. Review of the findings of Oguntoyinbo (1964) and Rouse (1962) indicates, however, that these relationships

can be reduced to three common principles applying to sugar cane potential in Barbados: (1) Rainfall distribution is spatially and temporally inconsistent, with the mean annual total being, on the whole, marginal for cane cultivation; (2) As a rule, the higher the average annual rainfall in an area, the greater its cane production potential; (3) The shorter the dry season ,the higher the sugar production potential.

## Spatial-Economic Factors Affecting Land Use

Proximity: A number of spatial - economic factors that are unique to the west coast of Barbados precluded the application of traditional rural/urban or market/hinterland location models to the study area. Instead, a unique proximity model was developed for this work to test relationships between beach proximity and land use change. Fundamental differences between the beach proximity model and Von Thünen's market / location rent model were reviewed in order to emphasize: (1) the premium of shoreline property for tourism development, and (2) the effect on the model of a narrow study area which produces no significant time or economic hinderence to movement between the coast and inland areas.

Land Scarcity: As a basis for the formulation of hypotheses regarding land use change, the term "land scarcity" was defined in this work to mean "a perceived shortage of land suitable for an intended use". Land

scarcity is directly dependent on an expectation of maximum social or economic benefit from a parcel of land. Three categories of land scarcity were defined: (1) agricultural land scarcity, (2) income land scarcity, and (3) community land scarcity.

Government Influence on Land Use: The Physical Development Plan, which was commissioned by the Government of Barbados in the mid-1960's, recognized that competition for land was intensifying as a result of increased land scarcity in all three of the categories listed above. The purpose of the Physical Development Plan was to ensure maximum social and economic benefit to the island by guaranteeing optimum relationships between all three sectors. More specifically, its three major objectives were: (1) to conserve arable land holdings of efficient size for agricultural production, (2) to provide suitable sites for industrial development, in order to diversify the economy and, (3) to create and maintain an environment which would attract visitors and encourage the development of tourism. The Physical Development Plan was more important in terms of recognizing unfavorable land use change trends and potential than was any other work.

## Formulation of Hypotheses

As a result of extensive review of the land use recommendations contained in the Physical Development

Plan, a number of hypotheses were developed in this work to test the impact of government policy on land use change.

Testing the hypotheses necessitated development of a land use classification that could be applied to the interpretation of aerial photographs at scales of between 1:5,000 and 1:19,000 from four years of observation. This classification was then entered into a computer in order to generate 'composite' data sets representing comparison of land use from one study year to the next or comparisons of land use with terrain factor variables. The following conclusions apply to the classification system developed and to the methodology employed: (1) The diversity of land use / land tenure / land cover / within the study area was adequately represented with the six key classification that recognized (i) plantation agriculture, (ii) peasant agriculture, (iii) grazing and unused land, (iv) uncleared and overgrown land, (v) tourism / recreation land and (vi) urban / industrial land. (2) The accurate representation of each land use type and land capability variable was successfully achieved using a mapping scale of 1:10,000 with 64 pixels per square inch. (3) The restriction of the land use classification to six elements and the limiting of the physical and proximity land characteristic descriptors to six or less elements ensured that relationships between these two groups of variables were not statistically obscured by excessive detail. (4) Only minor 'hidden' and 'complimentary' land uses were potentially overlooked as a

result of the interpretation of historical aerial photographs as a method of data acquisition for use with this land use classification. (5) Geographic restitution of aerial photgraphs and thematic maps was guaranteed at the relative scales employed through the use of a Zoom Transfer Scope. (6) Manual (keyboard) entry of the 350,000 land information points took months to complete. Much more efficient data entry could be achieved using modern map digitizing equipment.

Land Use Change and Its Relationship to Land Capability

'Grazing and Unused Land': Large oscillations were observed in the percent area coverage statistic for 'Grazing and Unused Land' between 1950 and 1980. These fluctuations were found to 'mirror' changes in the area of land devoted to 'Plantation Agriculture', thus demonstrating the significance of field fallowing. Correlations between the number of hectares fallowed and sugar export statistics are extremely high, thus confirming the data sets derived from air photo interpretation. Percentage shifts in the amount of 'Peasant Agriculture' relative to 'Grazing and Unused Land' were far less pronounced. Moreover, they were not found to mirror shifts in the area coverage of 'Grazing and Unused Land' to the same extent as for 'Plantation Agriculture'.

An insignificant number of hectares of 'Grazing and Unused Land' was allowed to become overgrown or was cut back

during the study period. This is an indication of the stability of this land use type relative to 'Uncleared and Overgrown Land'.

The amount of 'Grazing and Unused Land' developed for both tourism / recreation and urban / industrial purposes increased steadily throughout the study period. This finding suggests that government pressure to encourage development of marginal land was effective.

Slightly more 'Grazing and Unused Land' is found in the central part of the West Coast Study Area than along either the coast or the upland terraces. This is due to (i) the premium placed on coastal land for tourism development, and (ii) the location of agriculturally favourable land in the more humid upland zones. The latter relationship is substantiated by correlation statistics for the occurrence of 'Grazing and Unused Land' according to rainfall zone. A significantly lower percentage of the 'Grazing and Unused Land' was located in the higher rainfall zones than elsewhere in the West Coast Study Area in all four study years.

As expected, relationships between 'Grazing and Unused Land' and both terrain slope and soil depth prove that these land capability factors are important determinants of land use.

Soil types of low agricultural potential were not found to correlate very strongly with the occurrence of Land Use Type 'A'. This is attributed to urban and tourist

facility development on marginal soils, which are concentrated in the coastal belt.

Plantation Agriculture: Major fluctuations in the amount of this land use type were found to result from the practice of fallowing fields in response to the international sugar market.

No significant abandonment of plantations to 'Uncleared and Overgrown Land' was observed.

Mechanization, movement of labour away from the agricultural sector, and government discouragement of subdivision significantly curtailed fragmentation of plantations by the third study period.

Significant declines were noted in the amount of 'Plantation Agriculture' developed for both tourism / recreation and urban / industrial land uses in the third study period. This is an indication of the adoption and success of the recommendations contained in the Physical Development Plan.

Plantation agriculture was found to have been 'pushed out' of the coastal strip in successive study years. This is attributed to competition from 'Tourism / Recreation Land'. The highest relative percentage of 'Plantation Agriculture' for any of the four study years was found more than 2.0 kilometers from the coast. Land capability variables, such as better soils and higher rainfall, rather than time or distance of travel to the coast, are responsible for this relationship. These two findings

indicate that the more marginal plantations, particularly those in low rainfall areas, were the primary ones lost to the forces of development. Plantations located in the wet 'sugar belt' were found to have strong land use stability.

Plantations were found to be consistently located on gentle slopes with productive soils of normal depth. Significant movement of this land use type away from soils of the Black Association is attributed to the location, rather than productivity, of this soil type.

An anomalous increase in the amount of 'Plantation Agriculture' on soils of the Red Sand Association was observed.

Peasant Agriculture: The amount of 'Peasant Agriculture' was found to vary significantly from year to year and from one sub-unit to another. The fallowing of fields in response to the international sugar market was responsible for some of these shifts, but was not as significant a factor as with shifts in 'Plantation Agriculture', due to less financial flexibility and greater crop diversity.

Subdivision of plantations declined markedly between 1964 and 1972 and remained at a low level until 1980. Government policy to discourage fragmentation of plantations was largely responsible for this decline.

Insignificant amounts of peasant land became overgrown or were expanded into areas of 'Uncleared and Overgrown Land' between 1950 and 1980.

Almost no 'Peasant Agriculture' was lost to tourism development between 1950 and 1980. Nonetheless, a pattern of increased loss between 1964 and 1972, followed by curtailment of this unwanted type of development in the third study period, is apparent from the statistics.

Significant development of 'Peasant Agriculture' for urban and industrial purposes occurred during the first and second study periods. Government controls introduced before the third study period were successful in drastically reducing this undesirable type of development.

As with 'Plantation Agriculture', 'Peasant Agriculture' was successively forced out of the coastal strip by urban development between 1950 and 1980. This shift was not compensated by movement into prime agricultural areas, however. Competition from 'Plantation Agriculture' in the fertile uplands resulted in a concentration of 'Peasant Agriculture' in the central section of the West Coast Study Area.

The amount of 'Peasant Agriculture' located in high rainfall zones has always been below the equivalent figure for 'Plantation Agriculture'. Slight increases were observed in the percentage of 'Peasant Agriculture' located in the highest rainfall zone over the 30 year study period. The percentage of 'Plantation Agriculture' located in this zone increased at a greater rate over the same period, however.

A significantly higher percentage of 'Plantation Agriculture' than 'Peasant Agriculture' was located in agriculturally favourable areas between 1950 and 1980. 'Plantation Agriculture' was consistently located in higher rainfall areas, on gentler slopes and on deeper soils than was 'Peasant Agriculture'. Only the soil type versus land tenure correlation statistic deviated from this pattern.

'Uncleared and Overgrown Land': The amount of 'Uncleared and Overgrown Land' in the West Coast Study Area was found to have remained steady throughout the three decades. This land use type is located almost exclusively in gullies, which are have no sugar or development potential.

'Tourism / Recreation Land': The amount of 'Tourism / Recreation Land' in the West Coast Study Area increased by over four and a half times between 1950 and 1980, with the greatest relative increase occurring between 1950 and 1964, and the greatest absolute increase happening between 1964 and 1972. Much of the 1950 - 1964 development occurred on agriculturally productive land.

This land use type was located exclusively in the zone between 0.0 and 0.5 kilometers from the coast in 1950, but was observed, in the data for each successive study year, to have migrated eastward.

Relationships between the occurrence of 'Tourism / Recreation Land' and average annual rainfall, terrain slope, soil depth and soil type are induced by the predominance of

this land use type in the dry, flat coastal zone. Changes in the relative occurrence of 'Tourism / Recreation Land' and each of the above mentioned terrain factors were the result of the eastward expansion of tourist facilities.

Proximity to the coast was a major determinant of tourism / recreation development throughout the study period.

'Urban / Industrial Land': The amount of 'Urban / Industrial Land' in the West Coast Study Area increased by 315 percent between 1950 and 1980. Nearly two thirds of this development was located less that one kilometer from the coast in 1950. Competition from tourism over the next thirty years resulted in only half of the 'Urban / Industrial Land' being located less than one kilometer from the coast by 1980. As with 'Peasant Agriculture', a trend toward concentration of this land use type in the central strip of the West Coast Study Area was observed.

Despite an eastward migration of 'Urban / Industrial Land', the amount of this land use type located in low rainfall areas increased by 18 percentage points between 1950 and 1980. This demonstrates the effectiveness of plans to protect areas suitable for agriculture, due to their high average annual rainfall, from development for urban or industrial purposes.

An equally encouraging trend that occurred over the study period was a decrease in the percentage of 'Urban / Industrial Land' located on soils of normal depth.

No significant changes were observed for the percentages of 'Urban / Industrial Land' located on soils of low agricultural capability due to high slope factors or unproductive soil type.

Agricultural developement that took place between 1972 and 1980, although concentrated in specific areas, did not occur in the growth areas designated in the Physical Development Plan.

## Conclusion

The people of Barbados are well aware of the perils of an economy based on a single industry. As a result, government intervention in land use change was used to ensure a beneficial balance between agriculture and tourism. Government plans to curb the loss of agricultural land to development, although optimistic in some cases, have been very successful in many others.

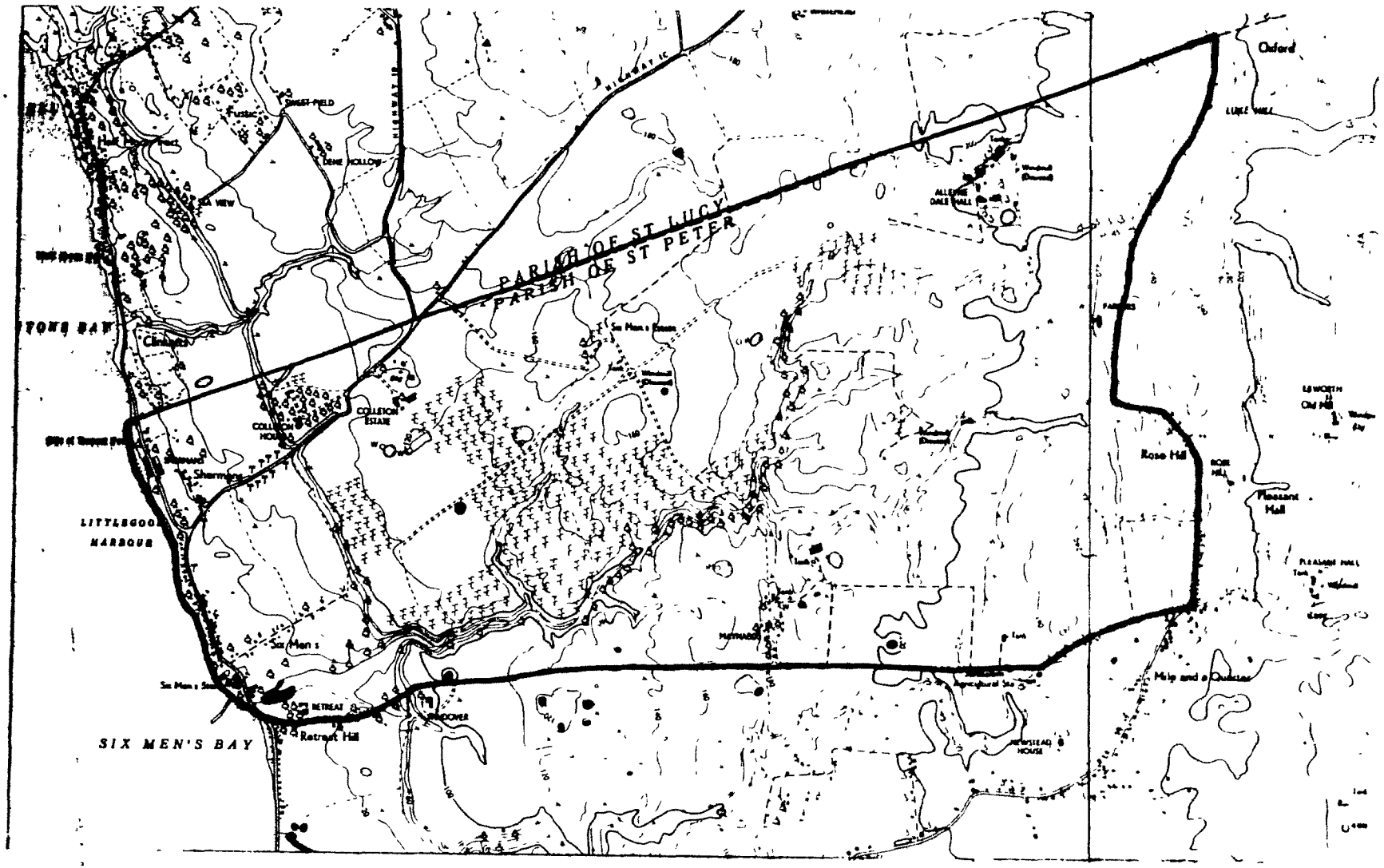
It is hoped that this work provides insight into the type of land use competition that can, if left unchecked, adversely affect both the environment and economy of a small country such as Barbados. By understanding these conflicts, and by studying and taking encouragement from other peoples' successes in controlling them, we can learn a lot about land use planning.

## APPENDIX: THE SUB-UNITS OF THE WEST COAST STUDY AREA

(01) The Six Men's sub-unit is the northernmost of the fourteen areas. It has as its northern border the St. Lucy / St. Peter parish line. On the west, the Six Men's sub-unit is bounded by the coast, on the east by Highway 2A. The common border between the Six Men's and Heywoods (#02) sub-unit is the east-west oriented highway which intersects the beach at Six Men's Bay on the west. It then passes south of Maynard's Plantation and north of the Jerusalem Agricultural Station, meeting Highway 2A near the town of Mile and a Quarter.

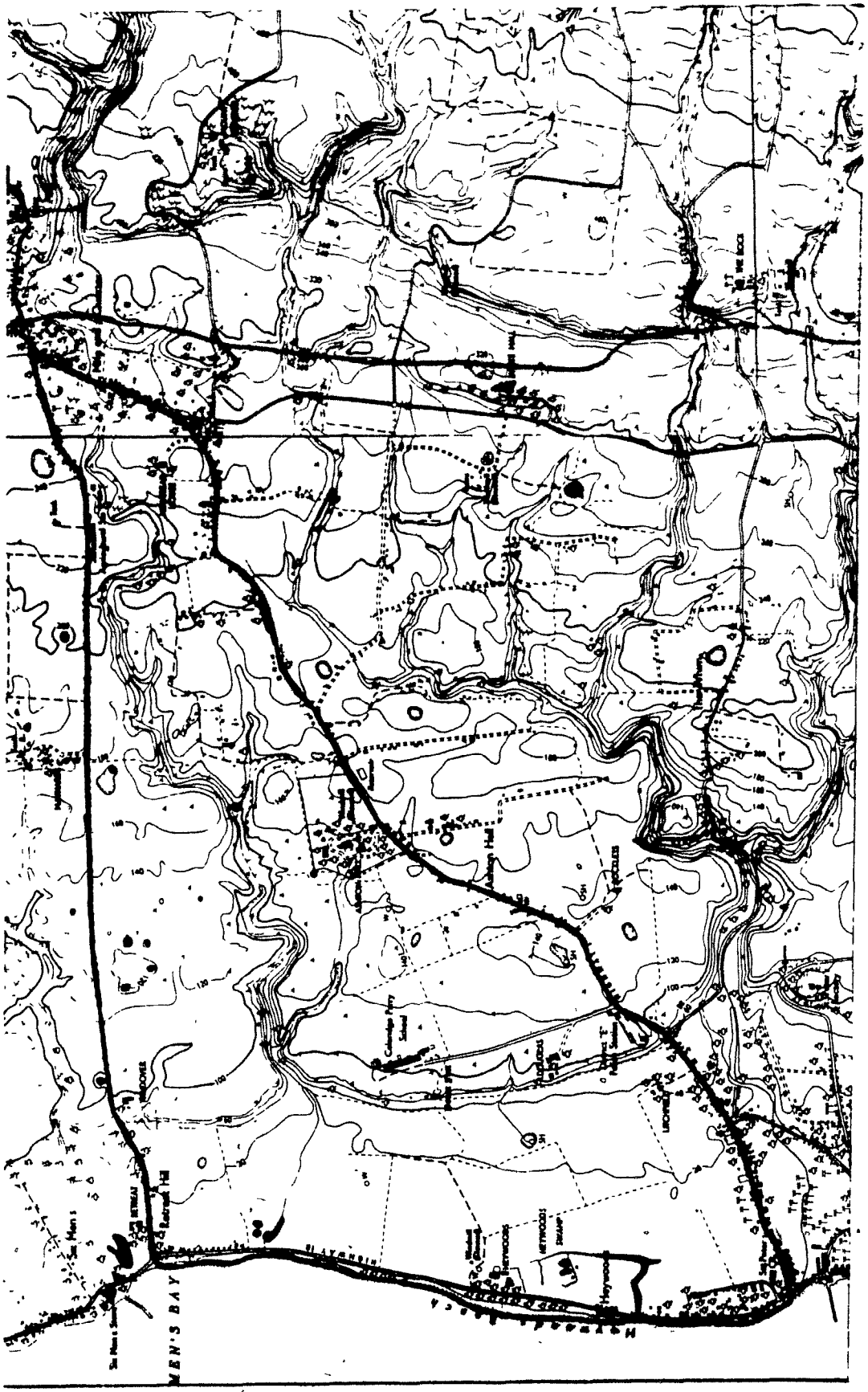
The Six Men's sub-unit is 3.01 square kilometers (301 hectares) in size.

(02) The Heywoods sub-unit is approximately triangular in shape. Its western edge is a long stretch of beach running from just north of the town of Speightstown to Six Men's Bay. Its eastern border, on the other hand, is a very short stretch of Highway 2A. This 450 meters of road joins the northern and southern borders of the sub-unit, which intersect it on either side of the town of Mile and a Quarter. The Heywoods sub-unit borders the Speightstown sub-unit (#03) on its southern side, their common boundary running in a northeasterly direction from the beach adjacent to St. Peter's Church, along Highway 1, for its full extent to an intersection with Highway 2A just south of the town of




SUB-UNIT 01: SIX MEN'S

SCALE: 1:15,000



SUB-UNIT 02: HEYWOODS

SCALE: 1:15,000

Mile and a Quarter. The northern border of the Heywoods sub-unit runs almost due east from the beach at Six Men's Bay, along the Retreat - Mile and a Quarter road, intersecting Highway 2A near the town of Mile and a Quarter.

The Heywoods sub-unit is 2.30 square kilometers (230 hectares) in size.

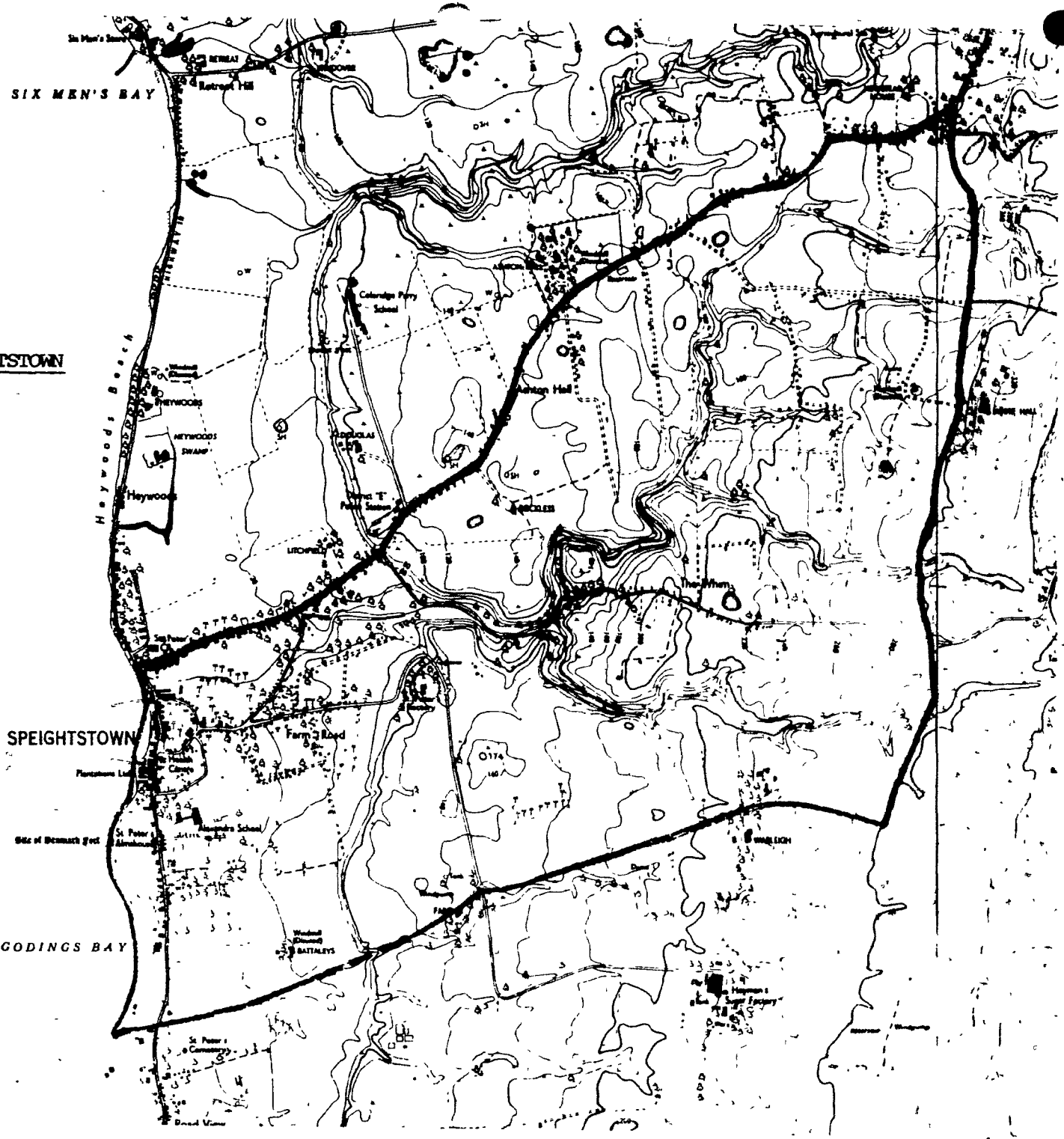
(03) The Speightstown sub-unit extends from the ocean on the west to Highway 2A on the east. The southern border runs east along the gully through Battaley's Plantation to a point half way between the coast and Highway 2A. At this point it follows the road through Warleigh Plantation to an intersection with Highway 2A, 400 meters east of the Warleigh Plantation House. The northern border of the Speightstown sub-unit runs in a northeasterly direction from the beach adjacent to St. Peter's Church, along the highway, through Ashton Hall, and for its full extent to an intersection with Highway 2A just south of the town of Mile and a Quarter.

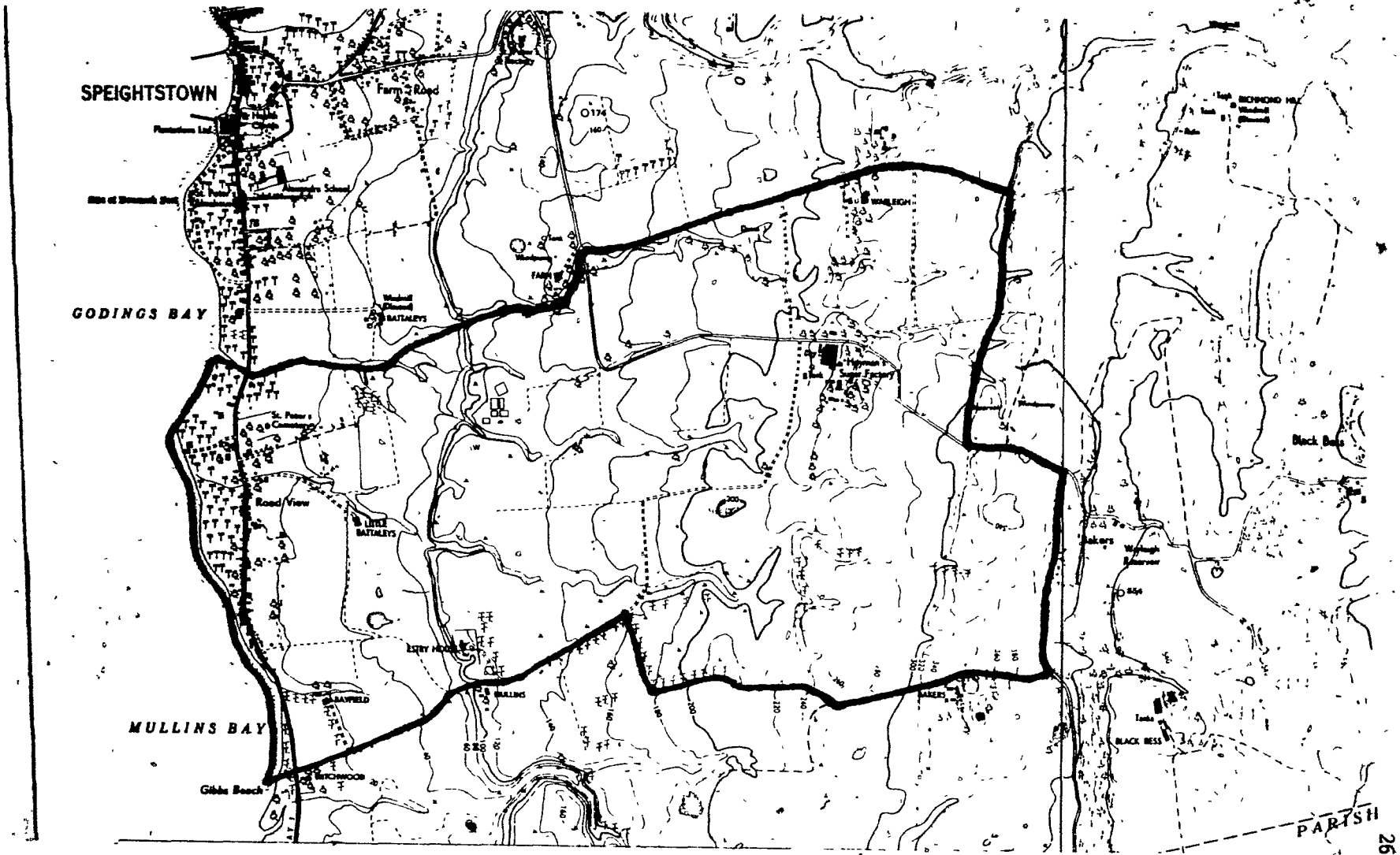
The Speightstown sub-unit is 3.30 square kilometers (330 hectares) in size.

(04) The Eastry sub-unit is approximately rectangular in shape, running between the ocean on its west and Highway 2A, its eastern border. On the south, the Eastry sub-unit is bounded by the Witchwod - Bakers road, which separates it from the Carlton sub-unit (#05). The

SUB-UNIT 03: SPEIGHTSTOWN

SCALE: 1: 15,000






SUB-UNIT 04: EASTRY

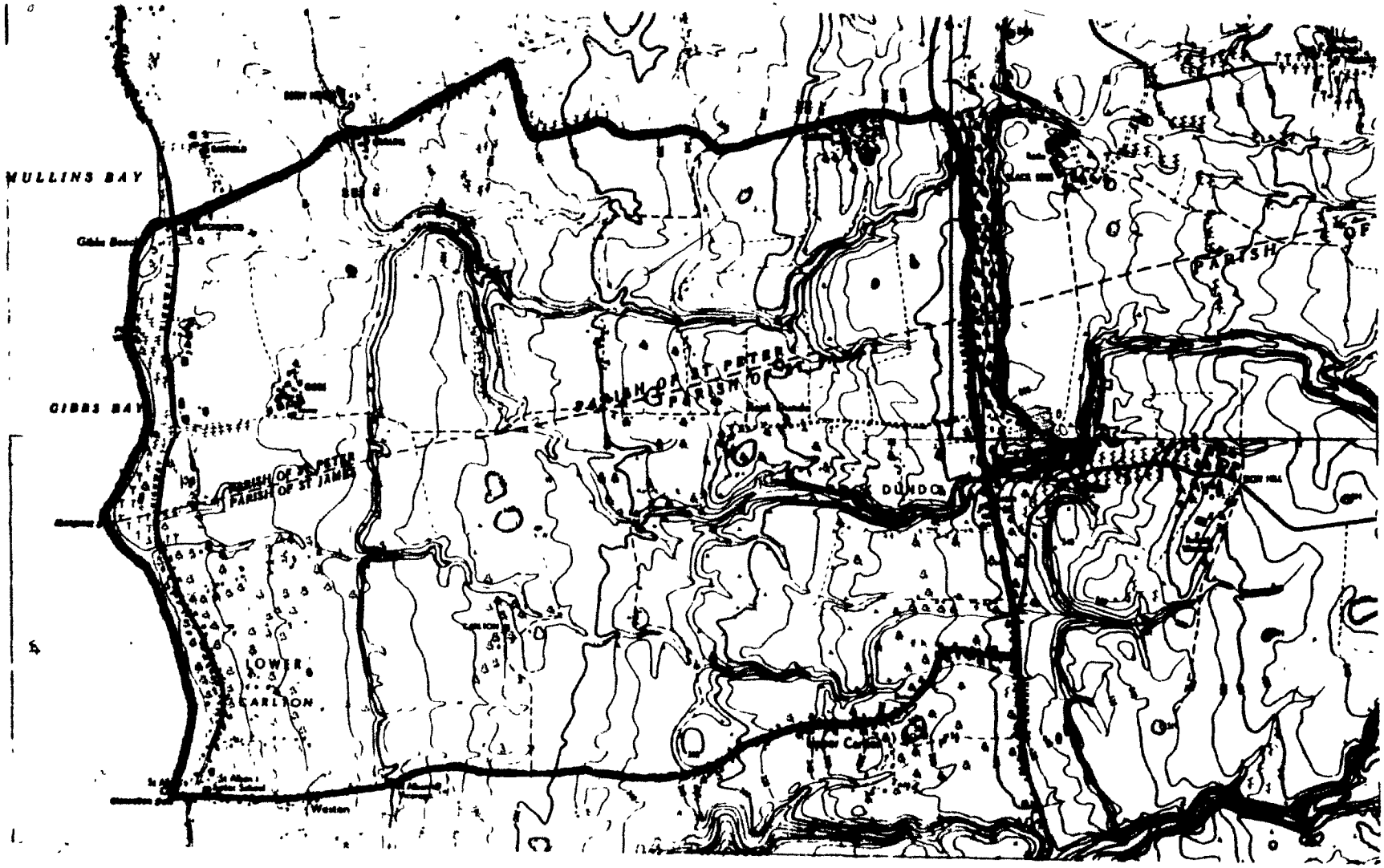
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Witchwood - Bakers road runs for all but 50 meters of the border, extending from Highway 2A in the east to the town of Witchwood in the west, where it intersects Highway 1. From this point, the border follows a heading of 255° to its termination point at the coast. The northern border of the Eastry sub-unit has as its eastern section the Warleigh road, which intersects Highway 2A 375 meters east of Warleigh. The Warleigh Road acts as the northern border of the Eastry sub-unit until a point half way between the ocean and Highway 2A. It is here that the border follows the gully which runs from Battaley's Plantation to its mouth at Goding's Bay.

The Eastry sub-unit is 2.45 square kilometers (245 hectares) in size.

(05) The Carlton sub-unit is almost square in shape. It is bordered on the west by the ocean, on the east by Highway 2A, on the north by the Witchwood - Bakers road, and on the south by Carlton Road. Neither of the two roads intersect the coast, however. In the case of the northern boundary, the border follows a heading of 255°, from the intersection of the Witchwood - Bakers road and Highway 1, to the coast. The westernmost section of the southern border follows an east-west line that runs the final 50 meters between Highway 1 and the coast.

The Carlton sub-unit is 3.57 square kilometers (357 hectares) in size.




SUB-UNIT 05: CARLTON

SCALE: 1:15,000

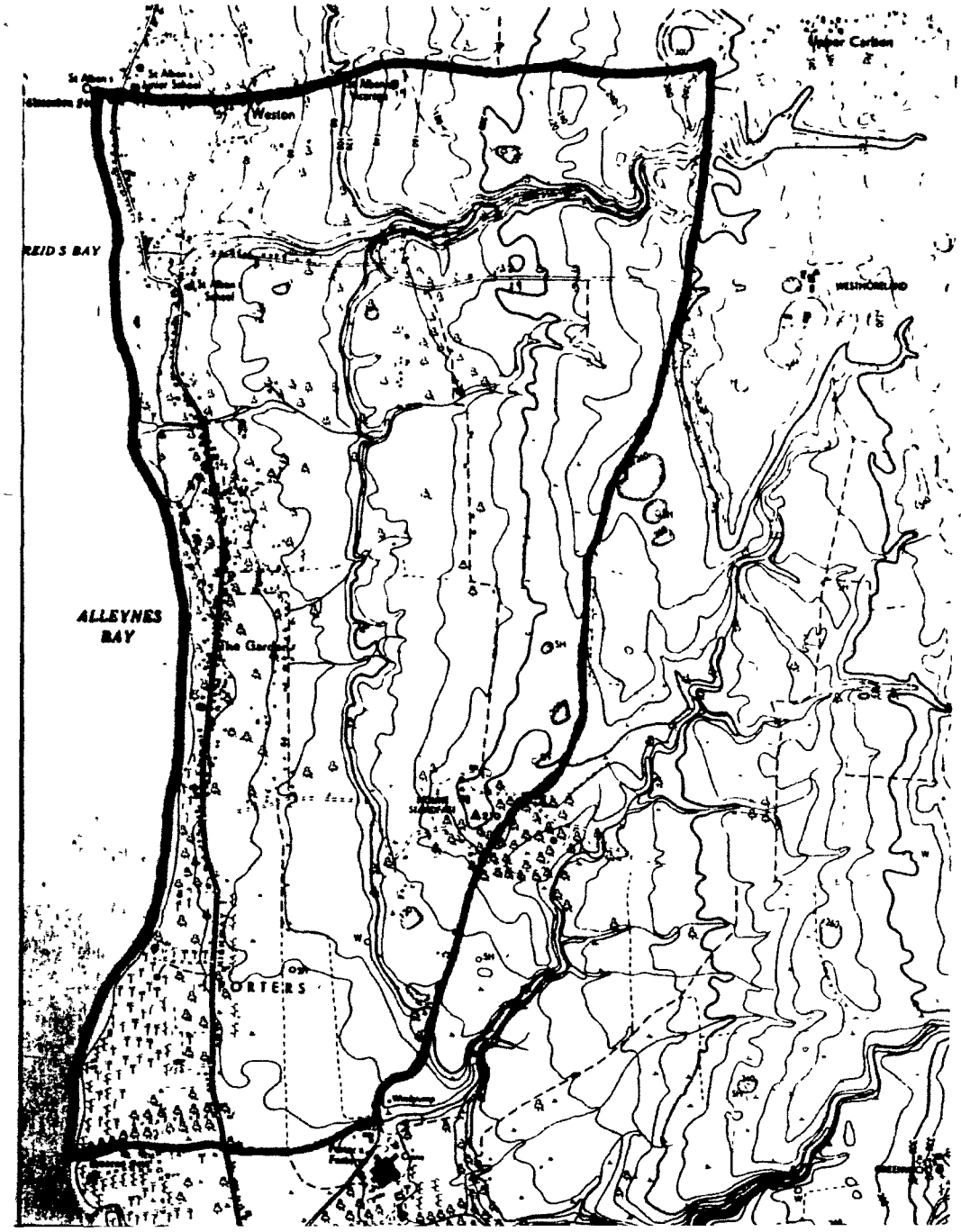
(06) The Porters sub-unit is approximately rectangular in shape, running north-south between the coast on its west and the Westmore sub-unit (#07) on its east. The southern border of this area is the periodic stream that runs between a bridge under the Porters - Upper Carlton road, located just north of the Porter's Sugar Factory, to its mouth, adjacent to Queens Fort. The eastern border of the Porters sub-unit is a section of the Porters - Upper Carlton road that runs from the Porter's Sugar Factory in the south to an intersection with Carlton Road, 200 meters west of the town of Upper Carlton. The northern border of the Porters sub-unit tracks Carlton Road from its intersection with the Porters - Upper Carlton road, almost due west to a 90° meeting with Highway 1 at St. Alban's Junior School. From this point the border extends due west a short distance (approximately 50 meters) to the coast.

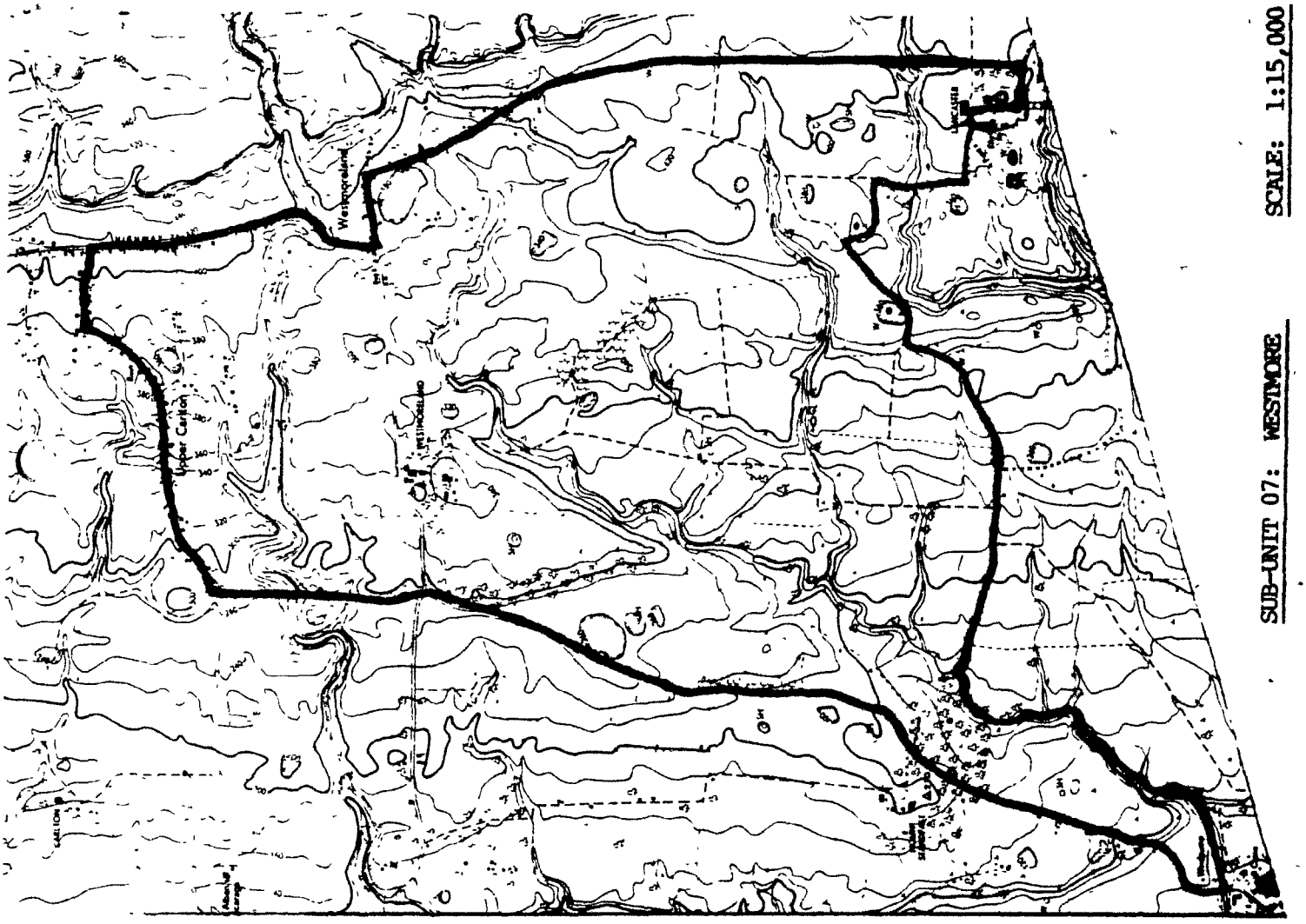
The Porters sub-unit is 2.54 square kilometers (254 hectares) in size.

(07) The Westmore sub-unit has the most irregular shape of the fourteen sub-units. It is also one of only two sub-units that are land-locked, the Prior sub-unit (#14) being the other. The Westmore sub-unit borders the Porters sub-unit (#06) for almost the full length of its western side. The border follows the Porters - Upper Carlton road north from Porter's Sugar Factory to an intersection with

**SUB-UNIT 06: PORTERS**

**SCALE: 1:15,000**






SUB-UNIT 07: WESTMORE

SCALE: 1:15,000

Carlton Road at a point 200 meters west of the town of Upper Carlton. The northern border of the Westmore sub-unit is its shortest, running one kilometer along Carlton Road between Highway 2 on the east and an intersection with the Porters - Upper Carlton road on the west. Highway 2 forms the entire eastern border of the Westmore sub-unit, running from the Lancaster Sugar Factory, north to an intersection with Carlton Road, approximately 500 meters east of the town of Upper Carlton. The southern border of the Westmore sub-unit separates it from the Greenwich sub-unit (#08). This is its longest and most complicated border, having as its easternmost section a road that runs due west through Lancaster Plantation from an intersection with Highway 2. Following a 90° jog to the north, this road heads northwest to a second 90° turn. From here, the southern border of the Westmore sub-unit follows the same road southwest for a further 1.3 kilometers until it crosses a gully at a point 300 meters east-southeast of Mount Standfast. At the intersection of the road and the gully, the border begins to follow the gully. It does so for the full extent of the gully's southwesterly trek to its mouth, near Queen's Fort.

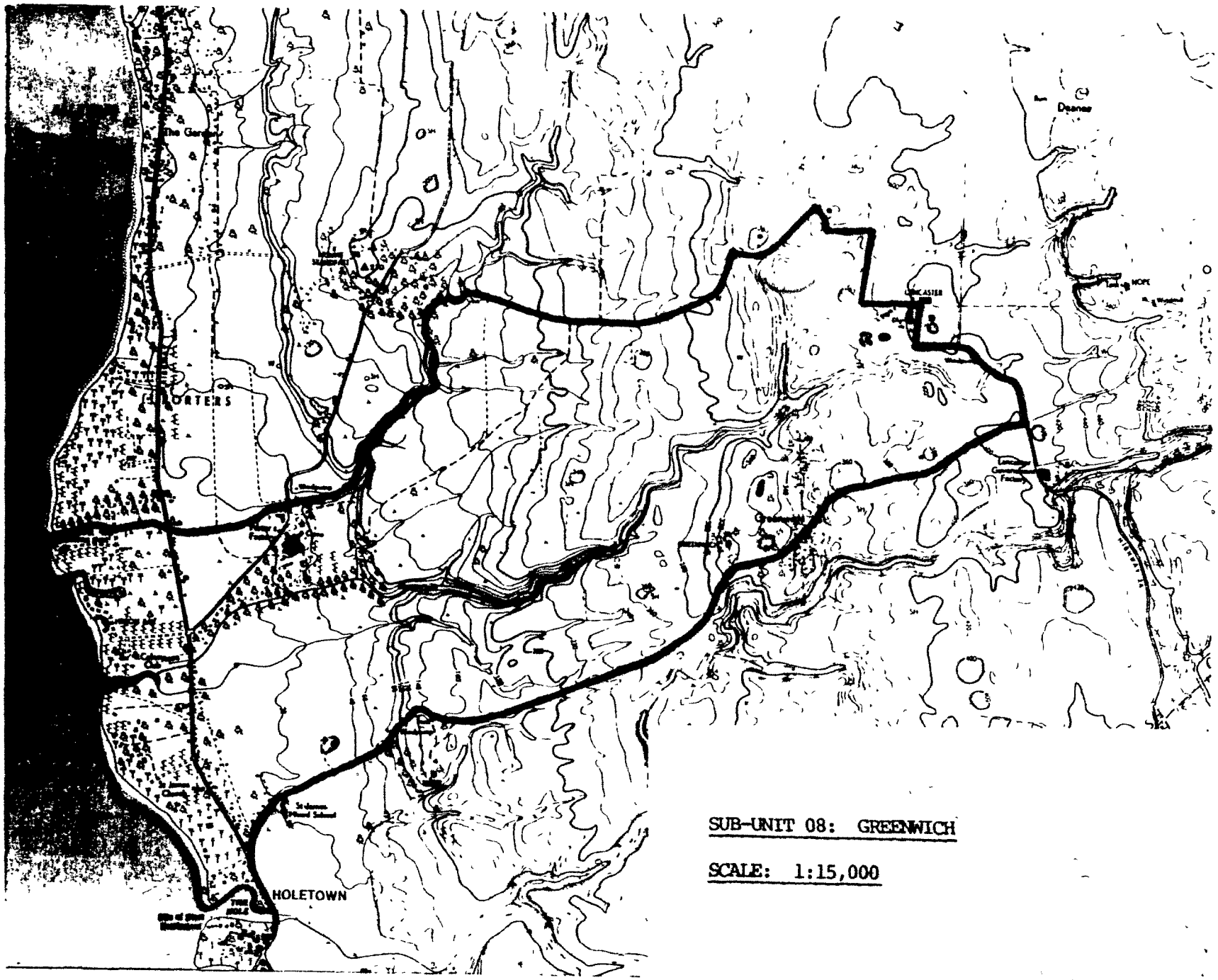
The Westmore sub-unit is 2.64 square kilometers (264 hectares) in size.

(08) The Greenwich sub-unit is approximately rectangular in shape, running from the coast on the west to

Highway 2 on its eastern border. The southern border of the Greenwich sub-unit follows the Holetown - Lancaster road from an intersection with Highway 2, just north of the Lancaster Government Factory, west - southwest for approximately three kilometers to a 45° intersection with Highway 1, just north of Holetown. The southern border then tracks Highway 1 south - southwest to the southern edge of the Hole. From this point it follows the southern shore of the Hole to the ocean. The northern border of the Greenwich sub-unit has as its easternmost section a road that runs due west through Lancaster Plantation from an intersection with Highway 2. Following a 90° jog to the north, this road proceeds northwest to a second 90° intersection. From here the border follows the same road southwest for a further 1.3 kilometers until it crosses a gully at a point 300 meters east - southeast of Mount Standfast. From the intersection of the road and the gully, the border follows the gully for the full extent of its southwesterly trek to its mouth, near Queen's Fort.

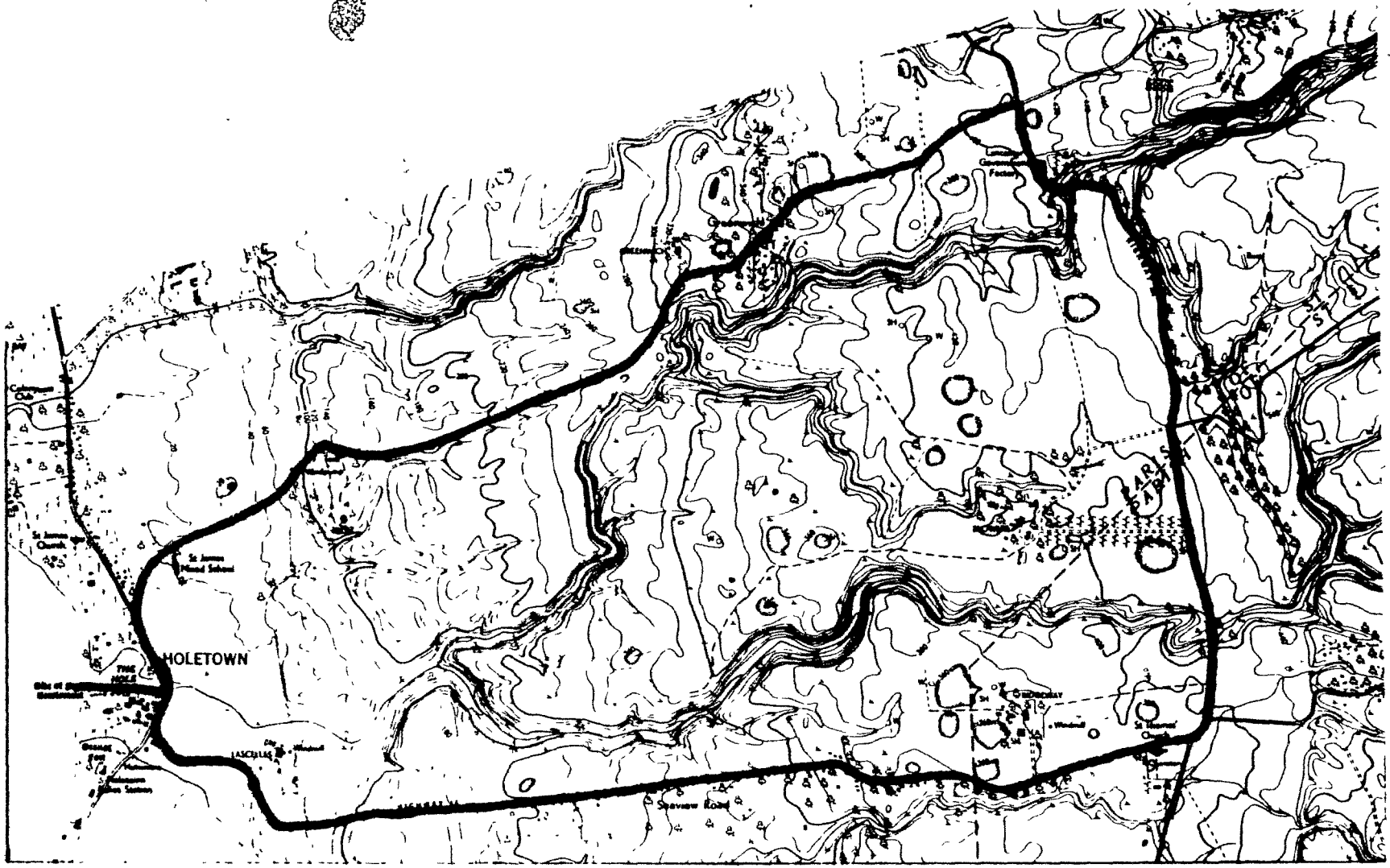
The Greenwich sub-unit is 2.44 square kilometers (244 hectares) in size.

(09) The Trent sub-unit is nearly triangular in shape. It borders the coast on its western flank, and Highway 2A on its eastern side. Its southern border follows Highway 1A from an intersection with Highway 2 near St. Thomas' Church, west for approximately three kilometers to




SUB-UNIT 08: GREENWICH

SCALE: 1:15,000



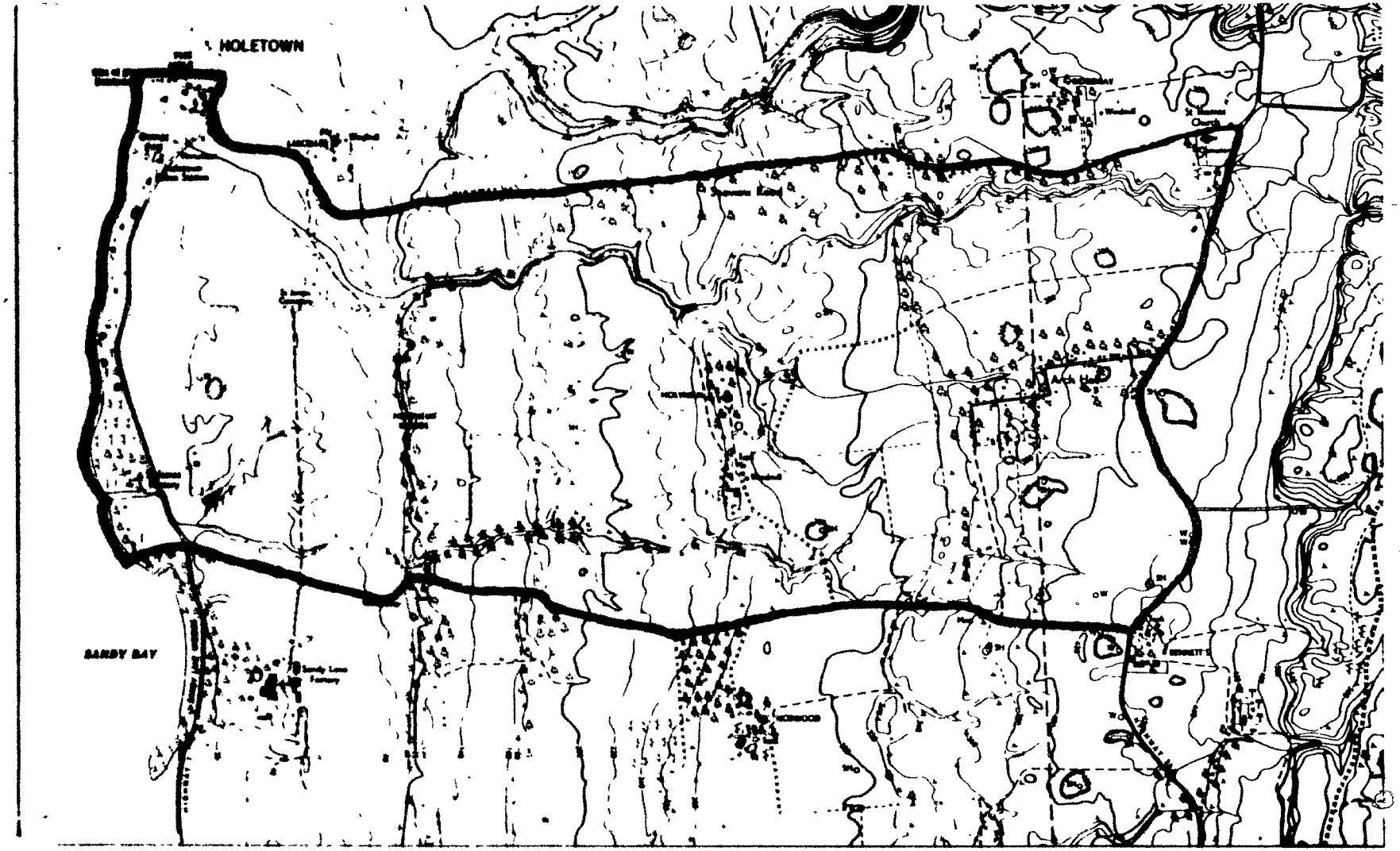

SUB-UNIT 09: TRENT

SCALE: 1:15,000

an intersection with Highway 1 near Holetown. The final 220 meters of the southern border follows a heading of 290° to an intersection with the coastline. The northern border of the Trent sub-unit follows the Holetown - Lancaster road from an intersection with Highway 2 just north of the Lancaster Government Factory, west - southwset for just under three kilometers to a 45° intersection with Highway 1 north of Holetown. The northern border then tracks Highway 1 south - southwest to the intersection of the southern edge of the Hole and Highway 1. From this point it follows the southern shore of the Hole to the ocean.

The Trent sub-unit is 3.24 square kilometers (324 hectares) in size.

(10) The Sunset Crest sub-unit is similar to the Sandy Lane sub-unit (#11) in that it extends with approximately uniform width from the coast to Highway 2A. It is bounded on the south by the Sandy Bay - Bennetts road, which runs from Bennett's Plantation in the east to an intersection with Highway 1 in the west. The westernmost 180 meters of the border follows a right-of-way from Highway 1 to the coast. The northern border of the Sunset Crest sub-unit follows Highway 1A from an intersection with Highway 2 near St. Thomas' Church, east for approximately three kilometers to an intersection with Highway 1 near Holetown. The final 220 meters of the northern border




**SUB-UNIT 10: SUNSET CREST** **SCALE: 1:15,000**

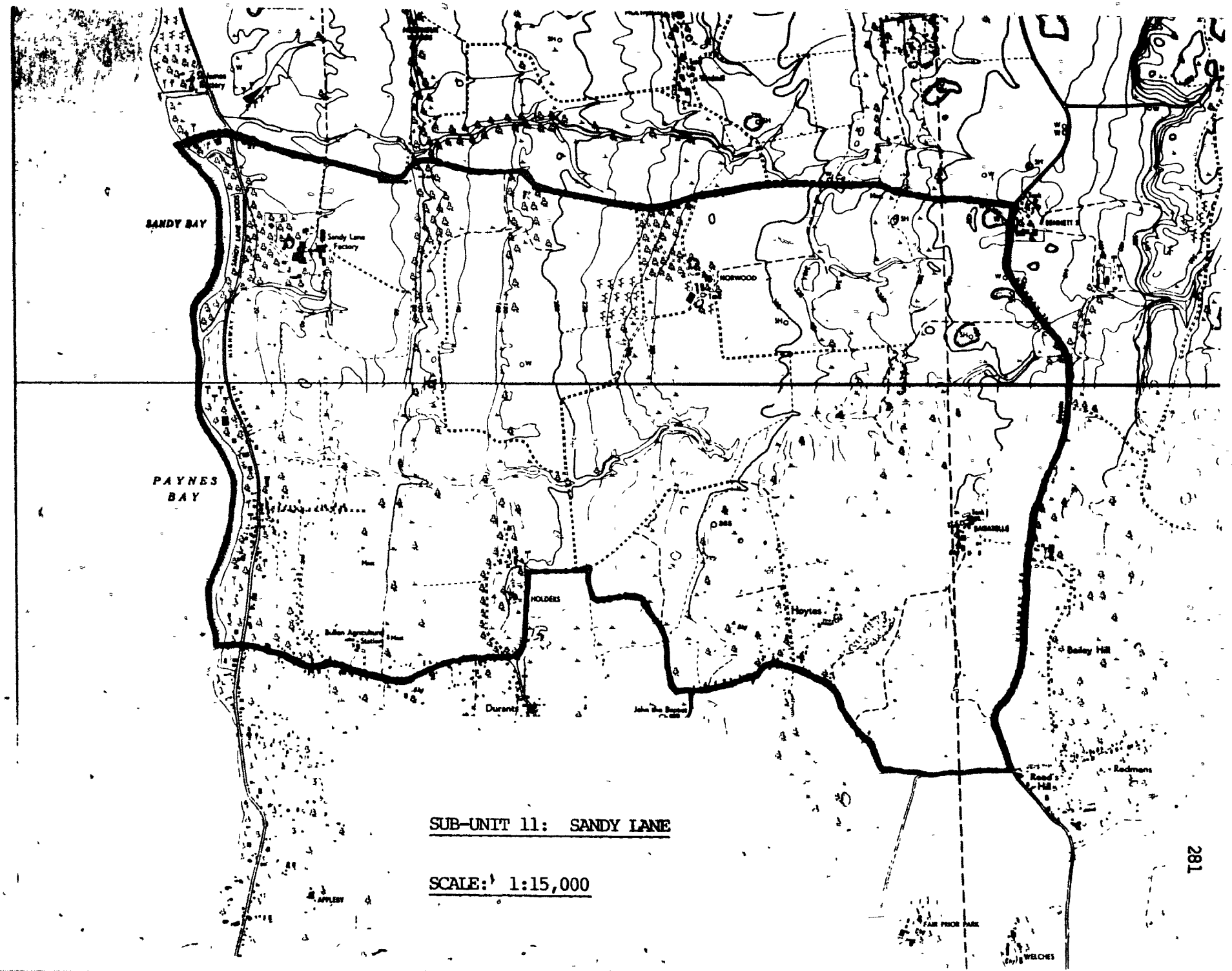
follows a heading of 290° to an intersection with the shoreline.

The Sunset Crest sub-unit is 3.20 square kilometers (320 hectares) in size.

(11) The large Sandy Lane sub-unit extends from the west coast to Highway 2A, on its eastern border. The Sandy Lane sub-unit is bounded on the south by the Thorpe (#12) and Prior (#14) sub-units. The dividing line is the Paynes Bay - Reed's Hill road. The Sandy Lane sub-unit is bounded on the north by the Sandy Bay - Bennetts road, which separates it from the Sunset Crest sub-unit (#10). Neither road forms a complete border to the western extremity of the sub-unit. The northern border has as its final 180 meters, a right-of-way that runs from Highway 1 to the coast. The westernmost 50 meters of the southern border is a line running due west to the coast from the intersection of the Paynes Bay - Reed's Hill road with Highway 1.

The Sandy Lane sub-unit is 3.99 square kilometers (399 hectares) in size, making it the largest of the fourteen sub-units.

(12) The Thorpe sub-unit lies north of the Prospect sub-unit (#13) and south of the western half of the Sandy Lane sub-unit (#11). It is bounded on the south by an irregular border with the Prospect sub-unit (#13) which follows an abandoned road for its full length between a

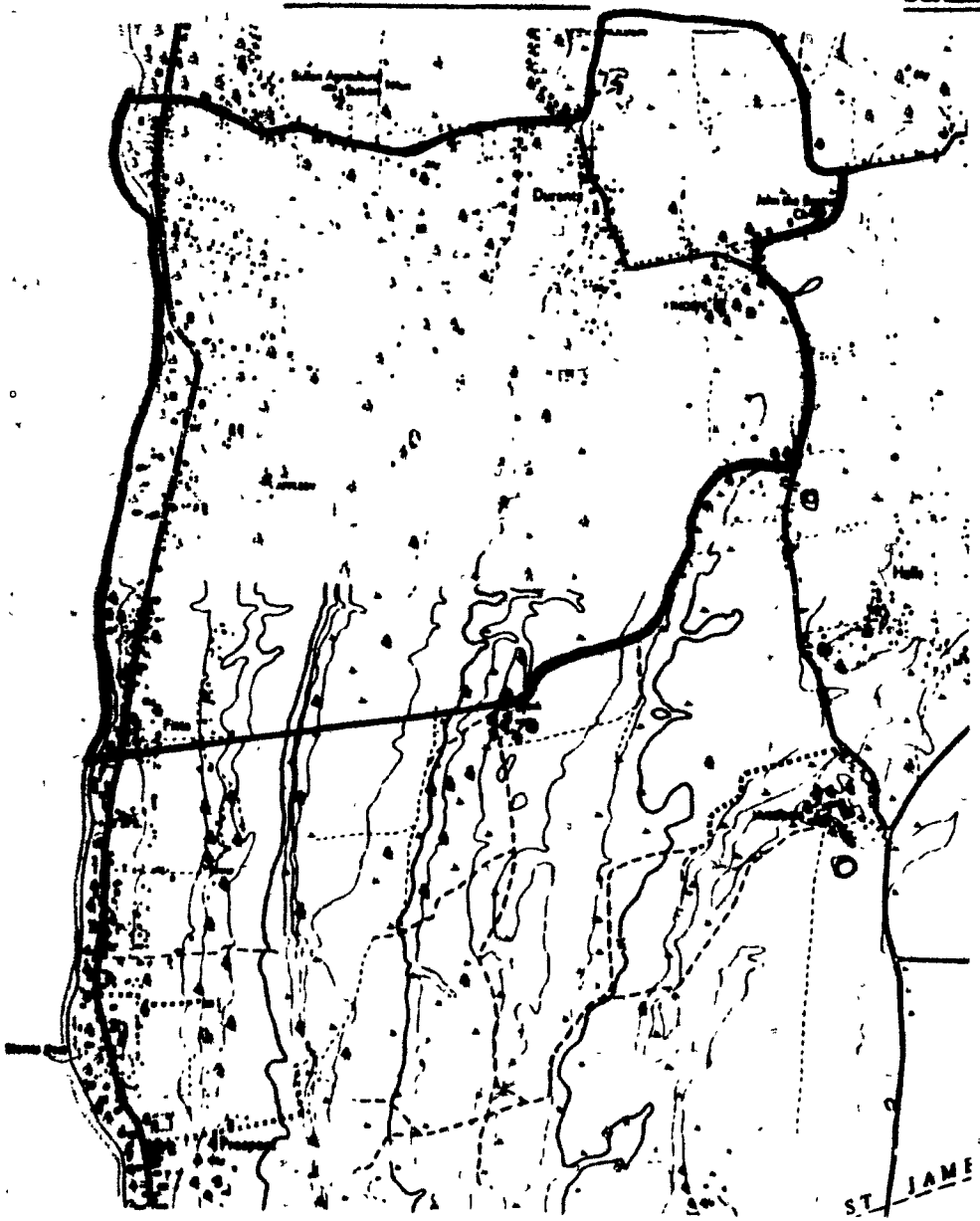



SUB-UNIT 11: SANDY LANE

SCALE: 1:15,000

SUB-UNIT 12: THORPE

SCALE: 1:15,000



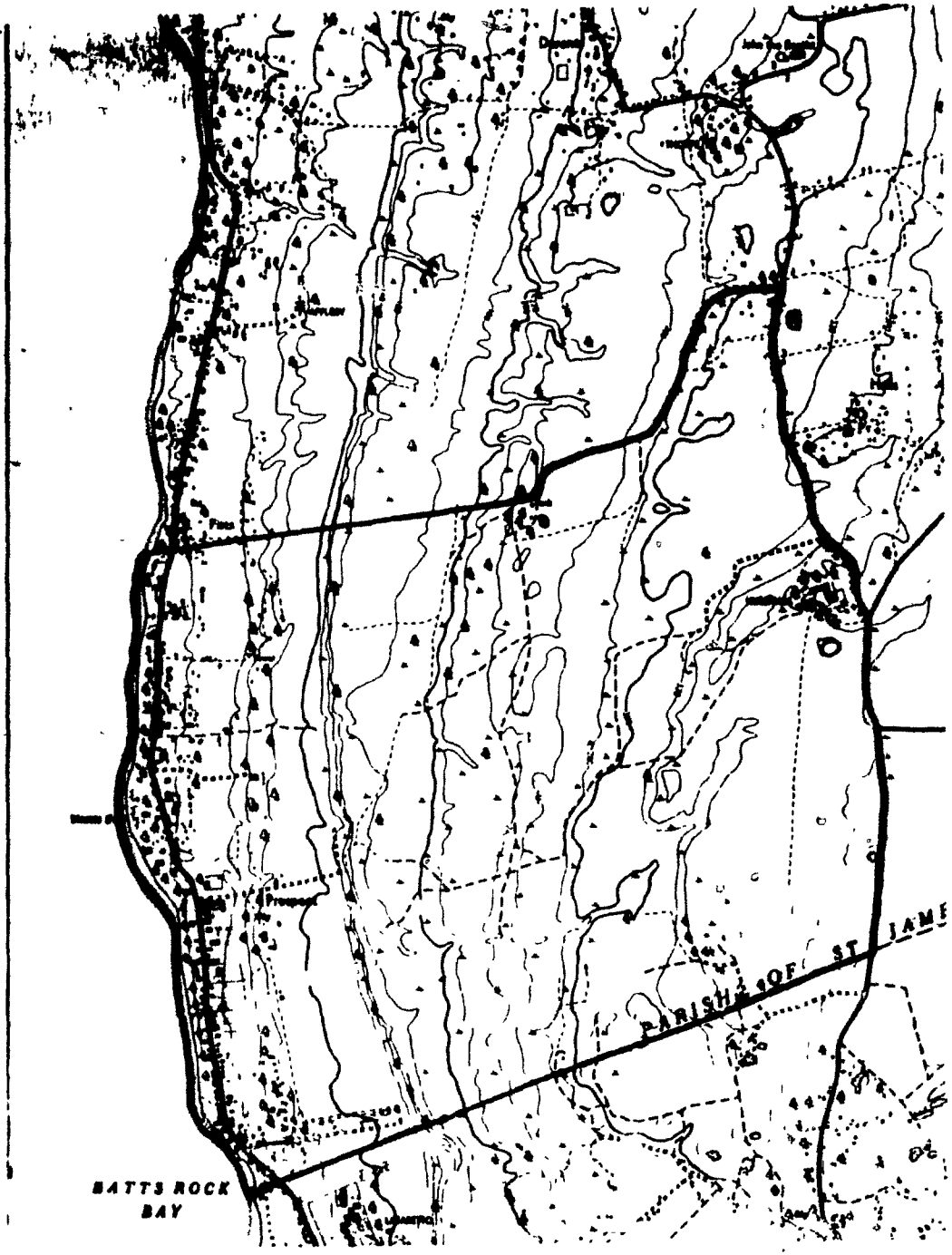
point exactly 1.1 kilometers east of Appleby and its termination point, 0.7 kilometers southeast of Appleby. From here it runs independently of landmarks on a heading of 263° to an intersection with the coast 150 meters south of the town of Fitts. The Thorpe sub-unit is bordered on the east by the road that runs between John the Baptist Church and the Husband's Plantation House. On the north, the Thorpe sub-unit is bounded by the western half of the Paynes Bay - Reed's Hill road. This road makes up all but the westernmost 50 meters of the northern border of this area. The remaining 50 meters of the border follows a line that runs west to the coast from the intersection of the Paynes Bay - Reed's Hill road and Highway 1.

The Thorpe sub-unit is 1.67 square kilometers (167 hectares) in size, making it the smallest of the fourteen sub-units.

(13) The Prospect sub-unit occupies the extreme southwest corner of the West Coast Study Area. It is bounded on the west by the sea, on the south by the St. James / St. Michael parish border, on the east by the Prior sub-unit (#14), and on the north by the Thorpe sub-unit (#12). The Prospect sub-unit / Prior sub-unit (#14) border is the road that runs between John the Baptist Church and Husbands, as well as its southern extension. The border between the Prospect and Thorpe (#12) sub-units is an irregular line following an abandoned road for its full

**SUB-UNIT 13: PROSPECT**

**SCALE: 1:15,000**



length between a point exactly 1.1 kilometers east of Appleby, and its termination point, 0.7 kilometers southwest of Appleby. From here the border runs independently of landmarks on a heading of 263° to an intersection with the coast 150 meters south of the town of Fitts.

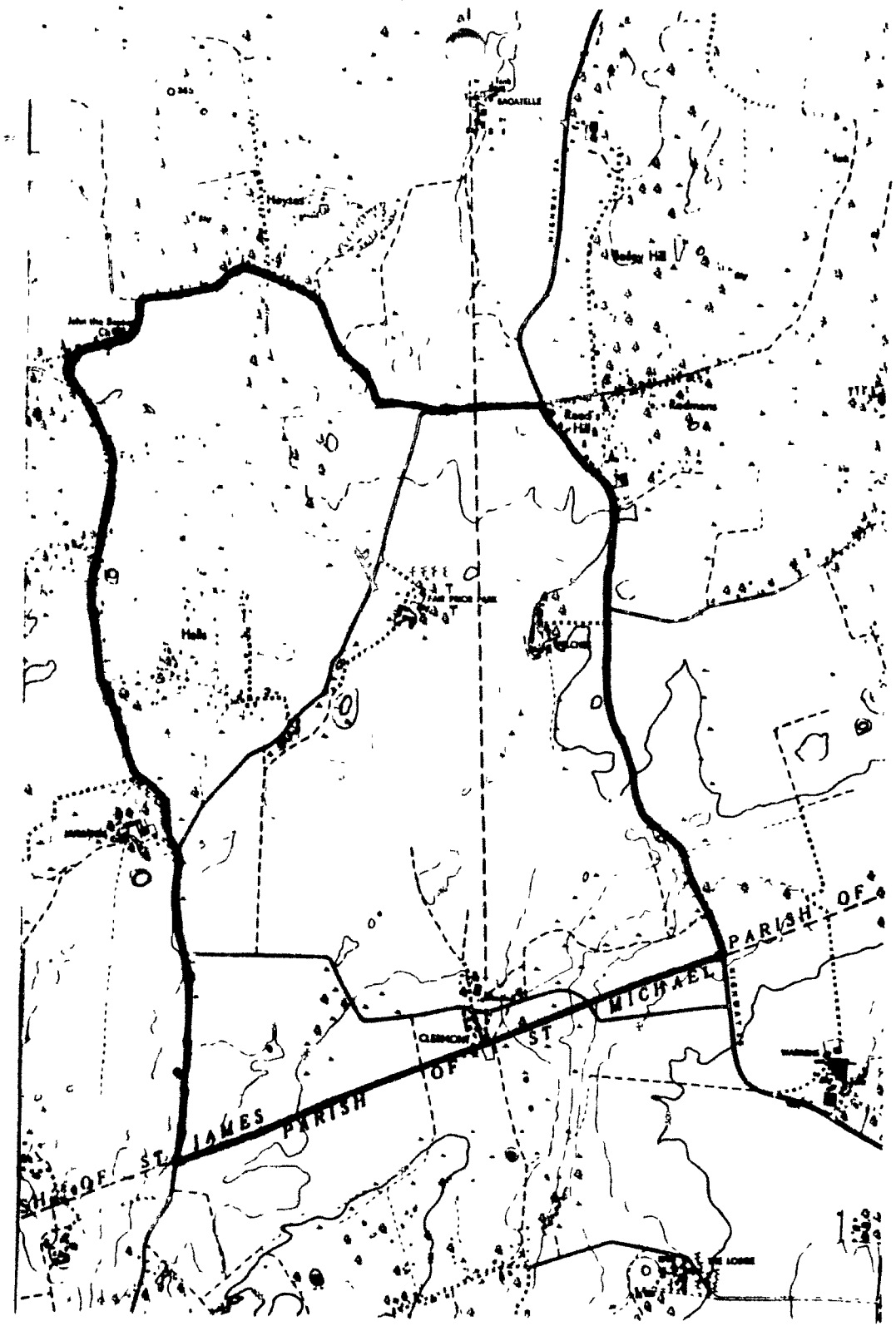
The Prospect sub-unit is 2.31 square kilometers (231 hectares) in size.

(14) The Prior sub-unit occupies the extreme southeast corner of the West Coast Study Area. It is bounded on the east by Highway 2A, on the west by the Prospect (#13) and Thorpe (#12) sub-units, on the north by the Sandy Lane sub-unit (#11), and on the south by the St. James / St. Michael parish border. The western border of the Prior sub-unit is a road that intersects the parish line halfway between the coast and Highway 2A. From here it proceeds north past the Husband's and Thorpe Plantation Houses, then northeast to its termination point slightly beyond John the Baptist Church. The northern border of the Prior sub-unit is the eastern half of the Paynes Bay - Reed's Hill road. More specifically, the northern border runs from the 'T' intersection adjacent to John the Baptist Church east to an intersection with Highway 2A at the town of Reed's Hill.

The Prior sub-unit is 2.26 square kilometers (226 hectares) in size.

**SUB-UNIT 14: PRIOR**

**SCALE: 1:15,000**



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