5-1999

Me island have mighty fine jungle' : contentions over the cloud forest of Montserrat

Ella Christina Newton

To the Graduate Council:

I am submitting herewith a thesis written by Ella Christina Newton entitled "Me island have mighty fine jungle' : contentions over the cloud forest of Montserrat." I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Geography.

Lydia Mihelic Pulsipher, Major Professor

We have read this thesis and recommend its acceptance:

Carol P. Harden, Faye Harrison

Accepted for the Council:
Carolyn R. Hodges

Vice Provost and Dean of the Graduate School

(Original signatures are on file with official student records.)

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Carol P. Harden

Roger V. Hansen

Accepted for the Council:

Anne Mayhew

Associate Vice Chancellor and
Dean of The Graduate School

"ME ISLAND HAVE MIGHTY FINE JUNGLE":

CONTENTIONS OVER THE CLOUD FOREST OF MONTSERRAT

A Thesis

Presented for the

Master of Science

Degree

The University of Tennessee, Knoxville

Ella C. Newton

May, 1999

DEDICATION

This thesis is dedicated to my parents,

Travis and Carol Newton,

for their love and patience.

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The people of Montserrat deserve much credit for their willingness to aide in my research. In particular, I would like to thank Jennifer Knowles and Henderson "Quincy" Davis, for climbing Chances Peak and aiding me in fieldwork, and Winston Thomas, who fixed my broken equipment. I am grateful to the staff at Groves Agriculture Station for the use of their scales. Keith Thomas of the Montserrat Water Authority, Venus Garcia of Cable and Wireless, and the entire staff of the Montserrat National Trust were invaluable sources of information. Marie Bramble must be noted for her enduring hospitality. James "Mr. Nice" Bradshaw and Ederson "Tyre" Daly, two very special friends, are thanked for their intangible contributions during my stay on Montserrat. I am also indebted to Christiana Smith, of St. Lucia, for teaching me.

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I would like to acknowledge my parents, Travis and Carol Newton, and my friends, Amy Arcadi, Scott Anthony, and Steve Hixson. Their support, encouragement, and unwavering belief in me made this thesis possible.

The title of this thesis contains a quote from Ederson "Trye" Daly, a native of Montserrat. In May of 1994, I asked Trye if he wished to accompany me on a hike to Chances Peak, as he had never been to the top of the mountain. Upon seeing the cloud forest for the first time, he turned to me and exclaimed, "Hey Tina, me island have mighty fine jungle, eh?"

ABSTRACT

A place, or space, is often required to fulfill more than one role for a community. Often, a community's desired uses of a space conflict with one another. This creates the dilemma of wishing to protect one aspect of a place while wanting to benefit from the exploitation of other aspects. Montserrat, an island in the British West Indies, was such a community. Montserrat's Chances Peak was covered with cloud forest, an ecosystem that very likely played a significant role in supplying groundwater to the island. The site was also the most suitable location on the island for telecommunications facilities and media transmitting stations. Furthermore, because of its unique beauty, the cloud forest was also a potential ecotourism site, important to the island in terms of economic development. Each of these uses of the cloud forest was critical to certain segments within Montserrat's society. However, the latter two uses threatened the ecological integrity of the cloud forest and possibly Montserrat's supply of fresh water. Here I have studied both the physical and social roles of Montserrat's cloud forest. I examined the hydrological aspects of the cloud forest, as it was in 1994, in order to assess its water procurement role. Then I placed the results of my investigation in the context of the community's social and economic needs. This case study, which uses a multi-method strategy of research is presented as an example of a holistic approach to resource management practices,

one that combines the physical and social sciences, in order to best serve the public interest.

FOREWORD

In the summer of 1994, I went to Montserrat to conduct fieldwork for this thesis. During my time on the island, I observed active sulphuric fumeroles and experienced several small-scale earthquakes. Both of these phenomena indicated I was in a volcanic region, yet it was considered a dormant situation, and I unquestioningly accepted that evaluation. Neither I nor the inhabitants of Montserrat were prepared for what lay ahead. On July 18, 1995, Montserrat entered a phase of clearly intense cyclic volcanic activity that has changed the island drastically, altering its physical aspects and disrupting the lives of its inhabitants. This activity continues today. The center of this activity is the Soufriere Hills in the southern portion of the island. In these mountains is Chances Peak, my study site (see Figure 1-2).

The first series of steam-driven eruptions in the summer of 1995 brought scientists to assess the situation. Shelters were set up in churches and schools to accommodate temporary evacuees from the southern portion of the island. Throughout the following autumn, the volcano sporadically showed activity, with magma eventually breaching the surface. By the spring of 1996, the volcano began to generate dangerous pyroclastic flows, extremely hot mixtures of volcanic debris that travel down the slopes of the mountain at high speeds. It became obvious that the southern two-thirds of the island lay in an extremely dangerous zone, and piece by piece the area was declared off-limits to all residents and visitors. This decision turned out to be critical, because within the last two years, the southern portion of Montserrat has endured numerous pyroclastic flows, several of which destroyed the capital, Plymouth (see Figure 1-2), and numerous other villages.

The main crater of the volcano lies just meters to the east of Chances Peak, and after the first eruption, I was told via e-mail by a friend in Montserrat that the cloud forest no longer existed. A charred, gray landscape now stands atop the mountain (Figure A).

After much deliberation and consultation with advisors and friends, I decided to continue the research I had begun and write this thesis. There are several reasons for this. First, my work is relevant to other cloud forest environments and may one day be relevant in Montserrat again. Second, my research accomplishes the goal of examining the environmental management strategies of Montserrat through physical and cultural research, and is still viable as an example of the holistic and multi-method approaches in geography. Third, when a place is changed as drastically and suddenly as Montserrat was, records of the past become of paramount importance. This thesis will serve as a benchmark for how Montserrat was in 1994, before the recent activity of the volcano.

Of course it must be noted that the site of my study, Chances Peak, underwent an unexpected and highly significant change, and that the Montserratian community

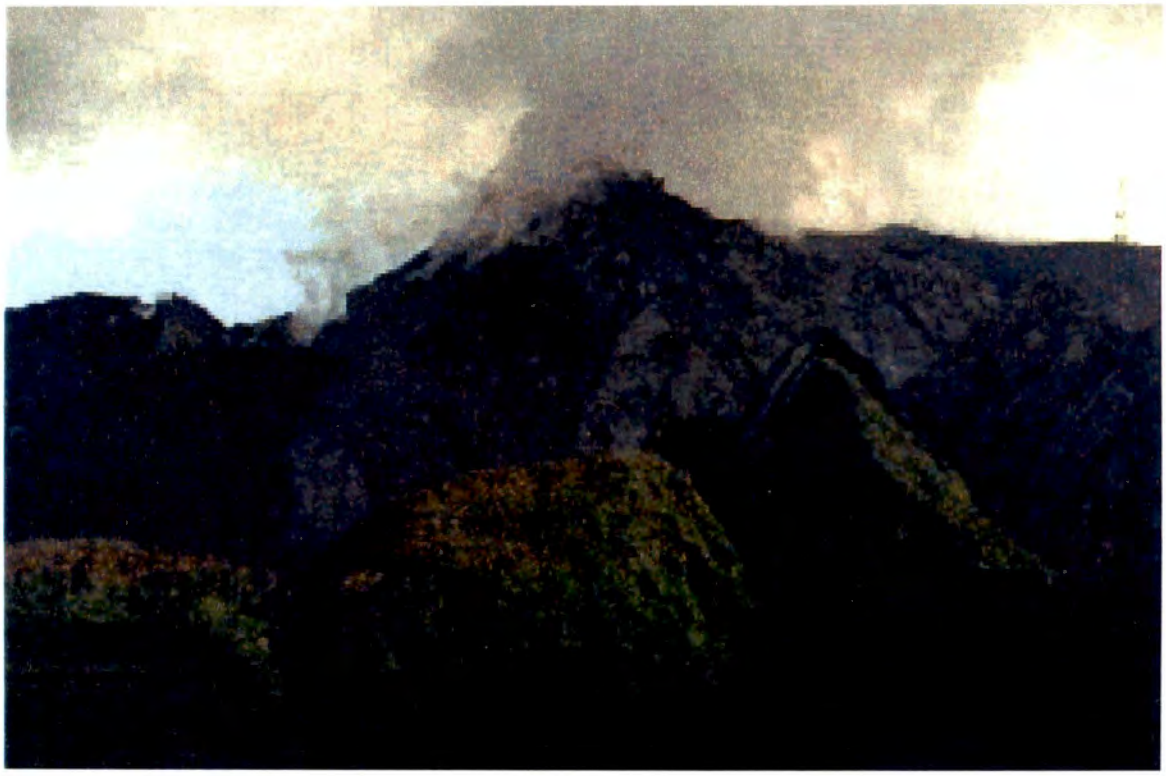

Figure A. Chances Peak, Montserrat, in January 1997. Volcanic activity has completely denuded the top portion of the mountain of its cloud forest. At the far right, the Cable and Wireless tower (referred to in this thesis) can be seen. The smokey haze is sulfur emissions from the crater of the volcano. The brown vegetation is probably the result of acid rain.

Source: Sustainable Ecosystems Institute. 1997, March 1. "Emissions from Montserrat volcano Jan '97." http://sei.org/impactsTN.html.

at large is vastly different from the one I encountered at the time of my study. For convenience and ease of reading, I have written much of this thesis in the present tense. As a result, the descriptions of my fieldwork and of Montserrat's then policy positions towards the cloud forest contradict the present state of affairs on the island. Mainly, the reader should be aware that in 1999, there is no cloud forest, the community is focused primarily on re-development issues in the north of the island, and ecotourism now centers around the splendor of an active volcano, instead of the once-lush forests of the island.

No one knows how long this period of volcanic activity will last. Many residents of Montserrat have fled to England under a voluntary evacuation plan. Those who have chosen to stay are concentrating on developing the northern third of the island, a zone deemed safe by scientists. Plans for a new capitl city and permanent jetty are being considered and debated publicly. Ironically, as we are reminded that no one can control nature, Montserratians have been granted an unique opportunity in which they can control the development of their "new" island at an unprecedented level. This opportunity serves to continue Montserrat's tradition of formulating development strategies with careful thought, much research, and considerable public participation. Already Montserratians are taking full advantage of the situation, moving slowly but steadfastly into the future.

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CHAPTER 1

INTRODUCTION

Research Objectives

This thesis chronicles the components within and surrounding the Montserratian cloud forest, the physical properties of the forest and the potential uses of the forest by Montserratians, focusing on the forest's hydrological role, its suitability as a telecommunication facility and media transmitting station site, and its allure as a destination for ecotourists. The thesis will examine the potential impact those three uses might have on the forest and the population, and the possibility of each use becoming the primary function of the forest through policy making. Thus, this thesis explores some of the issues related to the intersection of human needs and sustainable natural resource management. The specific focus is on human use of a tropical cloud forest environment and the resulting social and physical ramifications. My goal is to add to the existing research on cloud forest, while also contributing to the discussion on how best to formulate environmental policies that integrate human needs with environmental protection plans, showcasing the positive aspects of synthesizing physical and cultural research methods in order to reach a better understanding of how an environment is and might be managed.

Informing Environmental Policy through Multi-Method Research

The concept of ecosystem management has been described by the ecologist Grumbine (1994) as "integrating scientific knowledge of ecological relationships within a complex sociopolitical and values framework." Ecosystem management should recognize that humans are part of ecosystems and that human values influence management goals. Ecosystem management should also recognize the need to do scientific research within an ecosystem and should encourage the use of data in aiding land use decisions. As Reuben Meade (1997), former Chief Minister of Montserrat, commented about the cloud forest on Chances Peak, "To manage it, one has got to know it from close up." I call this two-sided approach to ecosystem management holistic environmental management. This form of management promotes land use decisions based on both environmental and cultural considerations in order to fit regulations and management strategies to reality. My case study of a small island in the Caribbean explored such a holistic approach to environmental policy.

The holistic approach must also be used in the research that supports policy. In examining the hydrological properties of the Chances Peak cloud forest, I needed quantitative data for the purpose of numerical comparison and analysis. However, when I began to examine what direction policy might follow concerning the cloud forest, the very nature of the questions that I wanted to answer required qualitative data. These questions were directly related to individual perceptions about the cloud forest, and my methodology relied heavily on interviews and interpersonal communications, such as letters and contracts.

In many disciplines, this combination of using both quantitative and qualitative data, or any type of mixed methodology to address a particular research problem is known as multi-method research (McKendrick 1999). In geography, multi-method research is only just being recognized as an important research strategy, though multiple methods have actually long been used by most geographers (Winchester 1999). The multi-method strategy gives voice to the fact that within geography there are physical and human components. I have exploited that connection in this thesis. In certain situations, physical geographers need to examine points that are not precise and technical, such as those garnered through quantitative data collection, but rather ideas generally more suited to the human geographer. This gives their research context, as it put my hydrological research into context. At the same time, human geographers need to be able to provide a natural science framework for their more qualitative work. This allows them to assess and reflect upon the consequences of human activity in the biological world, as I was able to do on the cloud forest.

In my research on Montserrat, a multi-method approach was necessary in order to obtain a complete picture of the situation. McKendrick (1999) says multi-method research should involve "...situations where one method is applied with reference to another to address a research agenda." Each method should not stand alone, but rather should support and provide insights to the other throughout the research project.

Thesis Organization

This chapter introduces the concepts of holistic environmental management and multi-method research, and provides the geographical place setting for the case study. Chapter 2 presents a broad review of the physical aspects of tropical cloud forest, concentrating on watershed issues related to increasing groundwater through horizontal precipitation, and the effects of vegetation loss on groundwater supplies. In Chapter 3, I discuss research I did in the Summer of 1994 on the physical properties of the Montserrat cloud forest and the effects of clearing vegetation in that forest. Chapter 3 answers four questions: Is the area atop Chances Peak in Montserrat comparable to other tropical ecosystems known as cloud forest? How large is the area and how much of it has been cleared for telecommunications equipment installation? Is the area a potential water source for the island of Montserrat? How has the clearing of vegetation within the area affected the physical properties of the space, e.g., vegetation type, soil penetrability, soil compaction, and water content of the soil, and thus potentially compromised the integrity of the cloud forest's hydrological benefits?

Chapter 4 examines the three possible uses of Chances Peak, its hydrological role, its role as a telecommunications site, and its role in ecotourism. Each of the three uses requires differing and sometimes conflicting management strategies for the cloud forest. In Chapter 4, I describe the distinct social and physical consequences of each use. I examine the key players and land use decision-makers involved with Chances Peak by providing a synopsis of the agencies that hold direct control over Chances Peak, including governmental departments, non-governmental organizations (NGOs), and certain members of the business sector. I analyze the central policy direction of these agencies, namely the formation of a national park system. In Chapter 5, I look at the future of Chances Peak in light of the recent volcanic activity on Montserrat. Finally, in Chapter 6, I make suggestions for cloud forest management and summarize my conclusions from this case study in terms of holistic environmental management practice.

The Setting

The Eastern Caribbean, A Description of the Physical Geography

The Caribbean region encompasses a broad arc of islands stretching approximately 4000 km (2485 mi), from Cuba in the north, to Trinidad and Tobago in the south. Eastern Caribbean refers to those islands lying east of 65° W. The islands mark the border between the Atlantic Ocean to the east and the Caribbean Sea to the west, and they were formed by tectonic forces at the boundary of the Caribbean crustal plate and the North American plate. The Lesser Antilles (Figure 1-1) comprise the double arc of islands between Puerto Rico and Trinidad. The inner arc, which includes Montserrat, is composed of emerged volcanic cones, creating islands with mountainous terrain and peaks surfacing over 1470 m (4800 ft). The outer arc is composed of coral limestone, sitting upon a submerged volcanic base and rendering a mostly flat and hilly terrain. Although most of the spectacular tectonic activity that produced the basic structures seen today took place during the Late Cretaceous Period, changes in climate and sea levels during the Miocene and Pliocene epochs also have affected the terrain and the flora and fauna (Watts 1987; Cox and Moore 1993). Currently, tectonic activity is ongoing, with active volcanoes producing new deltas, peaks, and various other forms of sedimentary deposits on a number of islands, especially Montserrat.

The present climate of the Caribbean is derivative of its location within the tropics. The warming Northeast Trade winds bring moisture from the Atlantic as they flow toward the west. As this moist air moves up the eastern mountain slopes through the process of orographic lifting, precipitation occurs in the higher eastern elevations, theoretically leaving the western sides drier. However, since most of these mountain peaks only reach about 1000 m (3300 ft) on average, not nearly high enough to allow for the release of all of the moisture available, the lifting process often produces instability waves, which pass over peaks and carry moisture down the western slopes,

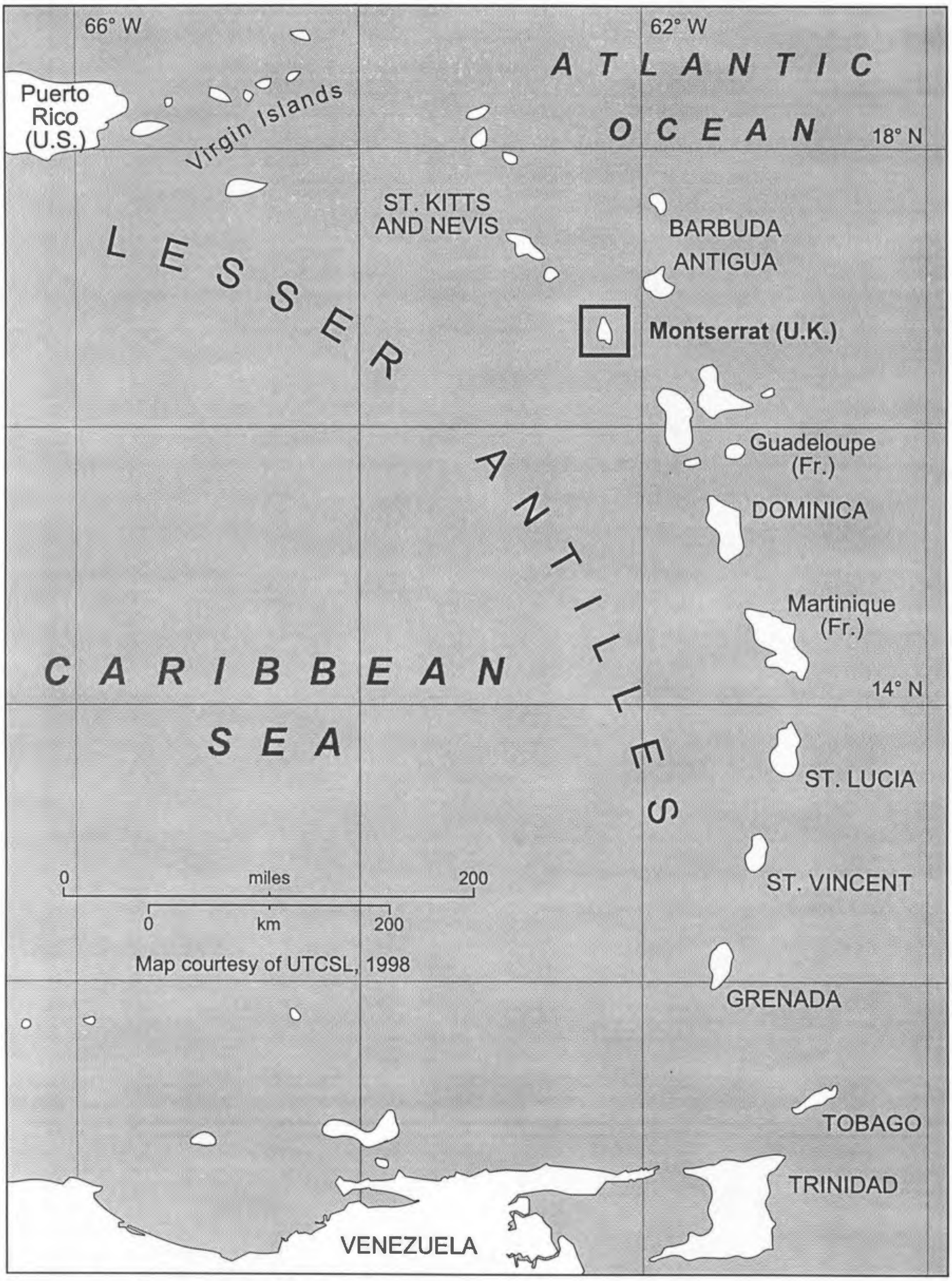

Figure 1-1. Eastern Caribbean: location map.

and sometimes out to sea (Watts 1987; Meditz and Hanratty 1989). This moisture regime creates lush mountain top environments surrounded in mist on all sides, as is the situation on Montserrat's Chances Peak. Islands with a flatter terrain depend upon convection, the rising of warm air, for precipitation. Hence, the amounts of rainfall measured on the lower islands are considerably smaller than on their mountainous neighbors. The track of the Northeast Trade winds varies seasonally. When the Trade winds are situated in the Caribbean during the summer, the result is a wet season. During the winter, when the Trade winds travel south of the Equator, a dry season occurs. It is during the warm wet season, approximately June to November, that hurricanes occur in the region, generating high velocity winds and heavy rainfalls.

Temperatures over the course of a year vary within a fairly narrow range because of the proximity of the region to the Equator. In the Lesser Antilles, average temperatures range from 21° C (70° F) to 32° C (90° F), with a mean of 25° C (78° F) (Beard 1949; Meditz and Hanratty 1989; Epenshade 1995). But the narrowness of this range masks a good deal of seasonal and spatial variation. On mountainous islands, micro-climatic conditions are strongly connected to elevation (Beard 1949; Grubb 1971). At sea level, the air is usually relatively drier and quite warm. With increasing height above sea level, the temperature drops and the air is more moisture-laden. While the actual change in temperature with regard to elevation is slight in real terms, only a few degrees, the effect on sensible temperature is acute, reflected in very distinctive vegetation gradients (Beard 1949; Price 1981).

Montserrat

Montserrat (Figure 1-2) is located at 16° 45' N, 62° 12' W, with neighbors Antigua and Barbuda to the northeast, St. Kitts and Nevis to the northwest, and Guadeloupe to the southeast. In 1994, the island's total area was 102 sq km (39.5 sq mi) (Island Resources Foundation 1993). Montserrat is mountainous, with three groups of central forested peaks and foothills flanked by coastal lowlands. Deep ravines, known as ghauts, have been cut into the sides of the mountains by Montserrat's many streams, resulting in a steep, irregular landscape.

Montserrat has three mountain ranges: the Silver Hills in the north, the Centre Hills in the island's midsection, and the Soufriere Hills in the south. The Soufriere Hills have been for many years the location of active fumaroles and sulphurous steams. Today, the Soufriere formation is the scene of continual volcanic activity consisting of the formation of successive magmatic domes followed by periodic explosions and pyroclastic flows. The present volcanic activity sheds light on the formations of the Soufriere Hills, including the pre-1996 landscape of Chances Peak.

Montserrat's humid tropical marine location, its variable topography, and its

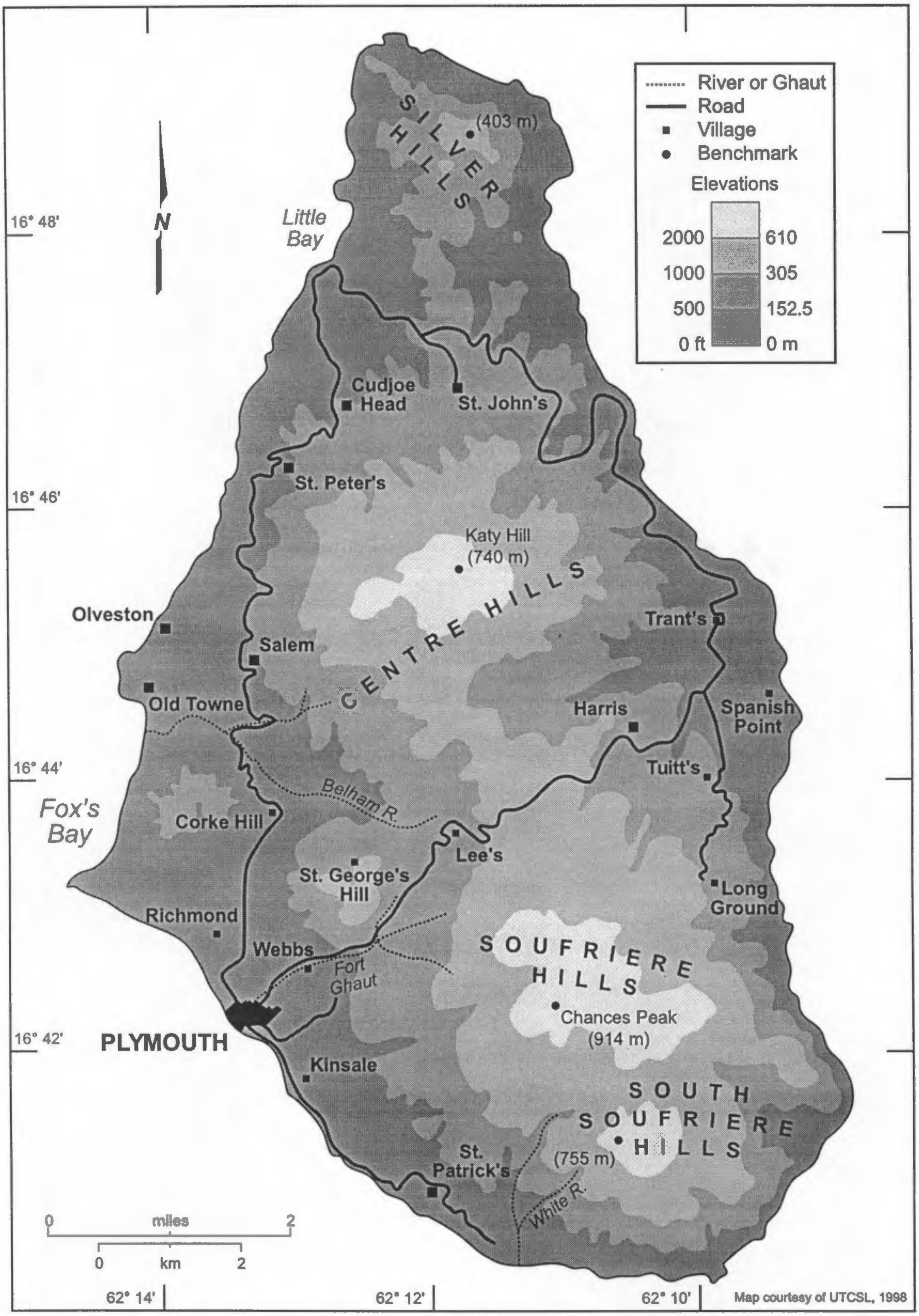

Figure 1-2. Montserrat: map of major villages, roads and physical features, circa 1994.

seasonal patterns of temperature and precipitation result in a complex pattern of microclimates and vegetation types, including semi-arid coastal scrubland, mangrove, shoreline forest, semi-evergreen seasonal forest, deciduous seasonal forest, lower montane rain forest, rain forest, and elfin woodland or cloud forest (Figure 1-3) (Beard 1949; Island Resources Foundation 1993). Lower to middle elevations on Montserrat also include grasslands and fields, created by human use dating from 1632 (Pulsipher 1986).

The Eastern Caribbean, A Description of Cultural Geography

Every island within the Eastern Caribbean has a distinct cultural history which distinguishes it from its neighbors. In fact, travelers are often surprised and impressed at the uniqueness of islands lying so close together. Nonetheless, there are a few common regional themes that emerge from three historical periods: pre-Columbian, colonial, and post-colonial.

Prior to 1492, and the arrival of Christopher Columbus, three groups of aboriginal peoples inhabited the various islands, having migrated northwards from the coastline of South America. These groups were the Arawaks[1] and the Caribs (Watts

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[1]I have chosen to use the broad language-based distinctions for the Native Americans of the Caribbean, although this might confuse some readers who are familiar with other popular terms. For example, in recent years "Tainos" has been applied to a group of Arawakan-language speakers in the Greater Antilles at the time of European contact, and is often confused with the Arawak group as a whole. It is believed that the Tainos never inhabited the Lesser Antilles or Montserrat(Watts 1987; Watters 1998).

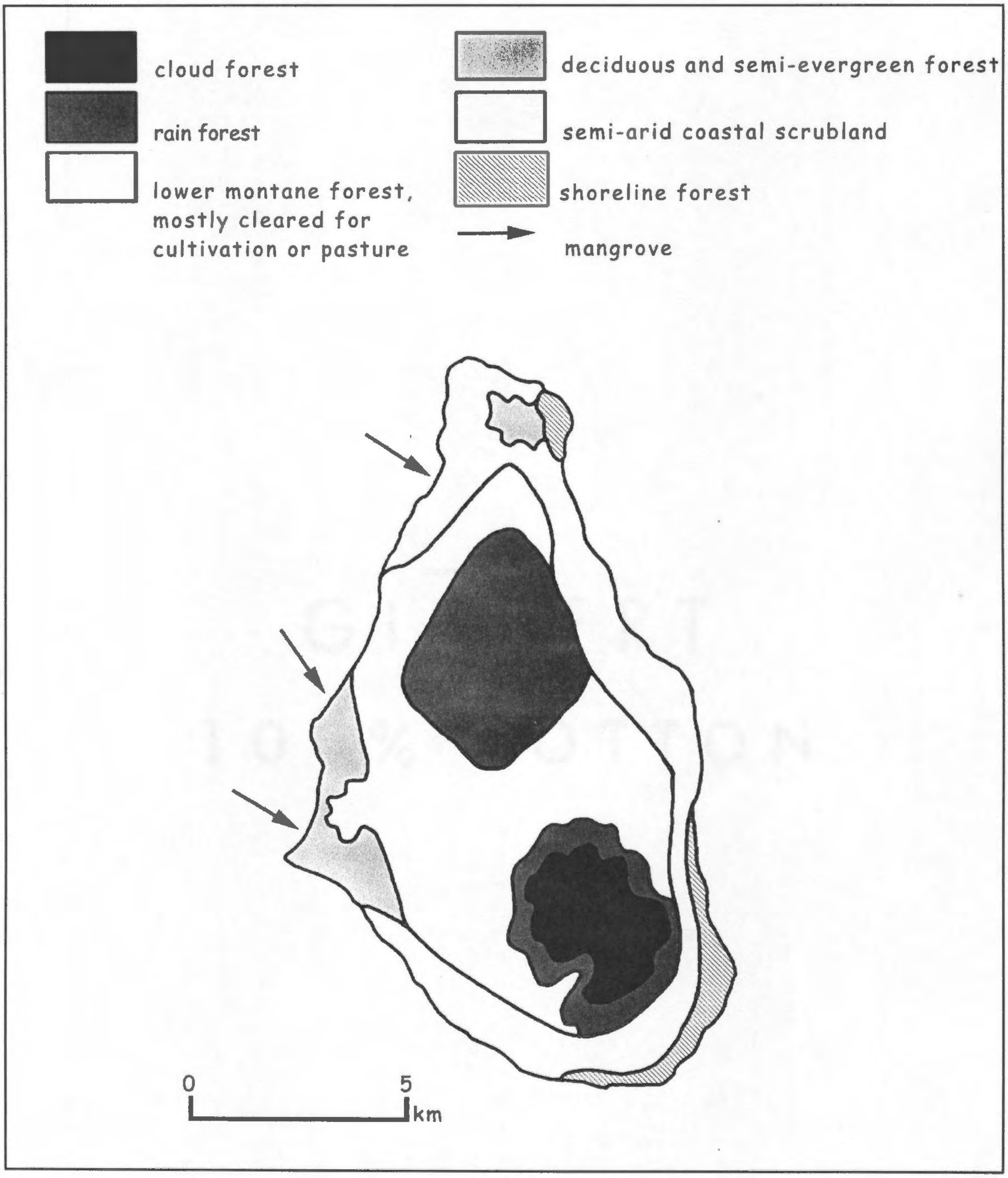

Figure 1-3. Generalized distribution of vegetation types in Montserrat, circa 1994.

Adapted from: Island Resource Foundation. 1993. *Montserrat Environmental Profile* (p. 8). St. Thomas, U.S. Virgin Islands.

1987; Meditz and Hanratty 1989). It is believed that most of these aboriginal peoples were annihilated by European forces, as a result of more sophisticated weaponry, cultural clashes, and the introduction of communicable diseases, against which the indigenous population had no immunity (Watts 1987; Watters 1998).

After the incursion by Christopher Columbus, immigrants linked to Europe, Africa, and Asia began to shape the cultural landscape in what is known as the colonial period. These immigrants first arrived as conquistadors and then as colonial officials, planters, settlers, slaves, indentured servants, and traders. Affecting the region most was the advent of the sugar plantation society based on slave labor, first introduced into the Eastern Caribbean by the Dutch in 1640, and elaborated on by the French and British (Watts 1987). The greatest proportion of Eastern Caribbean people today have some ancestors who arrived as slaves from Africa during the slave trade period from 1640 to 1807 (Watts 1987; Meditz and Hanratty 1989). After emancipation, which occurred individually for each island and was marked by the 1833 British Abolition Act, indentured servants from South Asia provided another wave of immigration, but only a relative few settled in the Eastern Caribbean, most of them in St. Lucia (Watts 1987; Meditz and Hanratty 1989).

The social systems in place today in the region are closely related to those established during colonial times by Holland, France, and Britain. While many islands have declared their independence from these powers, their political, educational, and economic systems, as well as their language and some of their customs, still reflect the hegemony of the colonial period (Watts 1987; Meditz and Hanratty 1989). In this post-colonial period, economic dependency continues, through trade with European nations and a burgeoning tourist industry that relies on visitors from Europe and North America.

Montserrat

Archaeological investigations, based on excavations, radiocarbon dates, and ceramic styles at the Trants and Radio Antilles sites on the island, indicate that Montserrat was settled at least by 500 B.C. (Watters 1998). These original settlers, termed Saladoid peoples after their distinctive pottery[2], were most likely Arawakan-language speakers and the ancestral populations of the Tainos, the people who occupied the Greater Antilles at the time of European contact (Watts 1987; Watters 1998). Although the Spanish never attempted to settle Montserrat, or any other Lesser Antilles island, it is likely that they contributed to the demise of the aboriginal peoples on the island by exposing them to communicable diseases via trading, and through slave raids (Watts 1987; Watters 1998). By the time other Europeans began to settle on Montserrat, there were no aboriginal peoples living on the island, and none

[2]The Saladoid pottery style was first discovered at the Saladero site in Venezuela (Watters 1998).

of their descendants live there today. Montserrat may have been abandoned by its first settlers before the Europeans arrived as a result of volcanic activity, but that possibility has not been verified (Watters 1998).

The name "Montserrat" was bestowed upon the island by Christopher Columbus as he sailed by in 1493, because the land reminded him of the site of a similarly named monastery in Spain. In 1632 or 1633, the island was colonized by English and Irish settlers, with Irish indentured servants acting as the primary labor force (Pulsipher 1986). It is this wave of Irish immigrants that gave rise to Montserrat's Irish cultural heritage[3] and the moniker "The Emerald Isle of the Caribbean." The first cultivated cash crops included cotton, indigo, and tobacco. In the mid-seventeenth century, sugar was introduced as the primary cash crop, and the importation of African slaves began. By 1730, Africans slaves made up the majority of the population, far outnumbering the plantation owners and Irish laborers (Pulsipher 1986). Today's population reflects this period in the island's history, with most Montserratians claiming some African as well as European biological and cultural heritage.

As sugar's marketability declined in the early 1800s, Montserrat turned to lime juice production on a few old sugar plantations, and later to cotton production under

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[3]Signs of Montserrat's Irish influence can be seen everywhere, from place names to family names. Recently, as a result of tourism promotion seeking to enhance Montserrat's distinctiveness as a tourist destination, St. Patrick's day was made a national holiday. It was not a traditional Montserrat holiday (Lydia Pulsipher, personal communication, March 1999).

a sharecropping system, though some sugar cane production persisted to the mid-twentieth century (Pulsipher 1986). By the early 1900s cotton had ascended to become the island's number one crop, and it remained so until 1950, when an international market surplus and a cotton workers strike depleted profits (Irish 1991; Island Resources Foundation 1993). At this juncture, soil depletion and erosion had greatly decreased land productivity and profitability for large-scale agricultural endeavors, though subsistence and market gardening was, and still is, quite feasible (Island Resources Foundation 1993). It was then, in the early 1960s, that the island began to turn its economic focus to tourism, with much employment coming through construction of villas by the 1970s (Island Resources Foundation 1993).

Tourism was gaining popularity throughout the Caribbean region at this time, with the tangibles of sun, surf, and sea as a hard selling point. However, the local Montserratian government took a different approach in its development scheme than did the neighboring islands. A policy of enticing residential and retirement visitors (rather than embracing resort or cruise tourism), was adopted because it was thought this would offer the potential for more sustainable development (McElroy and DeAlbuquerque 1992). It was hoped that a small number of visitors would stay longer, spend more money, and make less environmental and cultural impact than resort or cruise tourists, and that they could be enticed to return year after year. Statistics indicate that the government's plan has been effective. In 1992, 52 percent of visitors stayed in private second homes or with family and friends and 13 percent of visitors were retirees (McElroy and DeAlbuquerque 1992). From 1967 to 1987, the average length of stay at a hotel in Montserrat was eight days, one of the highest and most stable for all Caribbean destinations (McElroy and DeAlbuquerque 1992). My own observations regarding tourism on Montserrat, St. Lucia, and Antigua confirm the idea that when the islands use different methods of marketing, a strikingly different type of visitor comes calling. In Montserrat, a tourist feels like she is staying with friends who are sharing their homeland, while in St. Lucia and Antigua tourists either stay at a foreign-owned, all-inclusive grand resort hotel or step off a cruise ship for an afternoon shopping jaunt about the port. By 1999, overnight visitors were still encouraged to come to Montserrat, provided they were aware of the unique volcanic situation that they would encounter.

Tourism directly and indirectly employed 25 percent of the labor force on Montserrat in 1994, providing roughly 25 percent of the national income (U.S. Central Intelligence Agency (CIA) 1997). In all, the multiple effects of tourism were thought in 1994 to affect some 65 percent of the economy (Lydia Pulsipher, personal communication, 1997). The rest of the economy was based on small assembly-type manufacturing, a rice processing plant, grants in aid from the British (Montserrat has remained a British Crown Colony), and remittances from migrants working abroad (Island Resources Foundation 1993). Independence from Britain has been a recurring issue, but natural devastations, such as Hurricane Hugo in 1989, and the present volcanic activity have postponed any serious movements toward that goal. Montserrat is internally self-governing, with an elected Chief Minister and Parliament who work in conjunction with a local Governor appointed by the British Monarch. This tie with Britain provides another opportunity for individual prosperity: migration. Although a head count in November, 1997, showed 4,084 people remained on the island, the population of Montserrat had been a stable 10,000 to 12,000 in the early 1990s and had exhibited a very low growth rate of about 0.3 percent per annum this decade, largely due to a high rate of emigration (Island Resources Foundation 1993; U.S. CIA 1997; Information and Education Unit 1997). Many Montserratians spend several decades in the United Kingdom, Canada, or the United States, all countries where they can obtain work permits fairly easily based upon their status as British territorial citizens. They are lured by higher wages and lower unemployment rates. These emigrants remain close to their families, however, sending cash and goods back to the island and often returning when they reach retirement age. This influx of additional income has helped provide Montserrat with an annual per capita income of US$4,500 in 1997. This amount is sufficient to provide a high level of well being when compared to the global scale, especially given Montserrat's low cost of living (high purchasing power), made possible by local reciprocal exchange customs, a hospitable physical environment, and various aid programs that have funded a modern infrastructure of roads, schools, communications facilities and health care (United Nations Development Programme 1994; U.S. CIA 1997).

Although some Montserratians appear to barely scrape by, a shared sense of community responsibility ensures that no one truly suffers the throes of poverty. The health care system, including both public and private sectors, is adequate and affordable, resulting in a life expectancy of seventy-five years, and a low and shrinking infant mortality rate of less than nine per thousand (Island Resources Foundation 1993; U.S. CIA 1997).

Education is extremely important to Montserratians. Many travel to the various branches of the University of the West Indies in Jamaica, Barbados, and Trinidad. Others go abroad to the United Kingdom and United States to attend a college, a significant majority returning after their studies to work on the island. The literacy rate is 97 percent, and Montserratians keep themselves informed with two local newspapers and imported papers and magazines from the United Kingdom and United States (U.S. CIA 1997). Other mass communication outlets include two radio stations and one television station originating on the island, with other broadcasts, especially from North America, received via satellite. Computers and the Internet are familiar to many Montserratians, a fact made obvious by the daily conversations Montserratians hold with people around the globe on a listserver known as "The Electronic Evergreen." In fact, modern conveniences are familiar to all

Montserratians, with almost every home possessing a refrigerator, telephone, television, and a car.

To the casual observer, this island may seem quaint and simple, with its small homes, narrow winding roads, and lack of a bustling metropolis. Careful thought and some ingenuity has resulted in a settlement that never seems crowded or overrun. Houseyards, a type of domestic commons area, are often large and filled with fruit trees, gardens, small livestock, and a space in which to do chores (Thomasson 1992; Pulsipher 1993, 1994). Villages contain an elementary school, a few churches, perhaps a few family-run businesses, and a rum shop at which to play dominos and "lime"[4]. Major purchases were made in the capital city of Plymouth, until it was destroyed in 1996 by the volcano. These shops, businesses, and governmental offices have now moved to the north. While all of the varied name brands available in some other countries are missing, the necessities and many luxuries are plentiful.

Montserratians make decisions based on the obstacles and opportunities island life provides them, and their choices often present a contradictory picture. A house might have an outdoor shower, but have access to 50-plus satellite television stations inside. Well-paying jobs are scarce at times, but subsistence farming and houseyard gardens ease the amount of money budgeted to food stuffs (Thomasson 1992). Montserrat is a country that does not fit tightly into the paradigm of "development".

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[4]To "lime": to hang out.

Its situation is more complex. In some aspects (life expectancy, infant mortality, attainment of higher education, literacy, number of cars per capita), it is on a par with the most developed nations. Per capita income, on the other hand, places it among countries of medium development. A far more accurate description of Montserrat is that it is a culture blessed with a solid foundation of local tradition, and the citizens are savvy about the merits and limitations of their society.

CHAPTER 2

CLOUD FOREST: AN OVERVIEW

Introduction to Cloud Forest

"Cloud forest" generally refers to any forest that is frequently covered in clouds, fog, or mist. Used loosely, the term can be applied to many diverse locations. On the northwestern coast of the United States, for example, I have witnessed fog travel inland from the Pacific Ocean, bathing stands of redwoods and Douglas firs in moisture. I have also seen wisps of clouds float amongst the trees in the Great Smoky Mountains of Appalachia. Research on such mist-laden forests has usually been divided into temperate and tropical zones. Although the term "cloud forest" can denote any forest in any region of the world that reveals the impact of clouds, fog, or mist, the phrase is usually reserved for forests found in the humid tropics (Hamilton et al. 1995a). The name "cloud forest" in this thesis applies to those of the humid tropics, unless otherwise noted.

"Cloud forest" is not a scientific term, even though it is frequently used in scientific literature to describe the strong influence clouds and mist have on the forest's ecological properties. The phrase reached its acceptance in academia with the publication of Stadtmuller's definitive bibliographic review, *Cloud Forests in the Humid Tropics* (1987). Previous to this publication, the treatment of cloud forest in scientific literature was limited. Beebe and Crane (1947) and Beard (1949) were the first to do key studies of the ecological properties of specific cloud forests, but both concentrated mainly on floristic composition, merely noting hydrological properties. Subsequent works were written throughout the following decades, until the late 1980s and early 1990s, when publications became more frequent. A quest to document threats to the ecosystem's survival, stemming from the realization that its rate of loss in many regions exceeds that of lowland tropical rainforests, fueled this recent surge in research (Wuethrich 1993; Hamilton 1995). Picking up where Stadtmuller left off, a symposium was held in the summer of 1993, in San Juan, Puerto Rico, to assess the status of cloud forests globally and to survey cloud forest research. The product of this workshop, *Tropical Montane Cloud Forests* (Hamilton et al. 1995a), provides a current comprehensive review of cloud forest, and articulates the need for further research on this timely subject. In this chapter, I examine what is presently known about the physical characteristics of cloud forest.

As scholars refine the definition and categorization of cloud forest, one discussion centers on whether cloud forest is a subdivision of currently defined montane forest ecoregions, and if so, which ones. Another point of view recognizes cloud forest as a distinct and separate ecoregion, merely adjacent to montane ecoregions in a majority of situations and somewhat similar in characteristics. Beard (1949) and Stadtmuller (1987) both cite four ecoregions, in ascending order, which they include in the cloud forest designation: lower montane rain forest, upper montane rain forest, montane thicket, and elfin woodland. Following their lead, many researchers consider "montane rain forest" to be synonymous with cloud forest (Bruijnzeel et al. 1993; Kitayama 1995). However, Cavelier and Goldstein (1989) and Kitayama (1995), among others, have argued that only upper montane rain forest can contain cloud forest, citing floristic differences and a constant cloud cover versus intermittent cloud cover in the lower ecoregion. In this more restricted definition, cloud forest is synonymous with the "mossy forest" associated with upper montane rain forest (Kitayama 1995). Several papers at the 1993 symposium described montane rain forest as grading into cloud forest, taking the stance that cloud forest is unique and separate from montane rain forest (Werner 1995; Young and Leon 1995).

It may be that a separate designation is proper for another reason as well. Labeling cloud forest with the descriptive words "rain" and "montane" may lead to perceptions that are not always accurate. At the 1993 symposium, researchers reported on cloud forest existing adjacent to dry forest or woodland, not rain forest, a situation previously noted by Vogelmann (1973) and Zadroga (1981) (Juvik and Nullet 1995; Gioda et al. 1995; Smith 1995; Sarmiento 1995). Stadtmuller (1987) proposed two general distinctions in categorizing cloud forest: areas where cloud forest occurs in combination with heavy persistent rainfall, and drier areas with seasonal rainfall. A term currently in vogue with scholars, "tropical montane cloud forest," seems to be an all-encompassing solution to the dilemma of acknowledging that cloud forest is not always associated with montane rain forest, climatically or floristically (Hamilton et al. 1995b).

One more variable to consider is elevation above sea level. At the 1993 symposium, Watling and Gillison (1995) described a cloud forest on Gau Island, Fiji, that is just 300 m (985 ft) above sea level. There may be many more cloud forests located at comparable elevations, such as on the eastern side of the island of Hawaii (Watling and Gillison 1995; Lydia Pulsipher, personal communication, April 1999). In this case, and others like it, cloud forest is clearly not located in a montane environment. It may be wind patterns that facilitate its presence at such a low elevation.

While scholars vary in their delineation of cloud forest on the basis of elevation, rainfall, and floristic patterns, all scholars do agree that all cloud forest captures water from clouds, and adds water to the hydrological system through a trickledown effect (Figures 2-1 and 2-2) (Hamilton et al. 1995b). In summary, the term cloud forest refers to any forest that is frequently covered in clouds or mist, thereby receiving additional water other than rainfall by the coalescence of water droplets on vegetation. The cloud cover, the vegetative system it fosters, and the associated moisture capture effect influence the hydrological regime, and the climatic, edaphic and ecological properties of the underlying terrain (Zadroga 1981; Hamilton

Figure 2-1. Cloud forest at 914 m on Chances Peak, Montserrat, 1994.

Source: Newton, E.C. 1994.

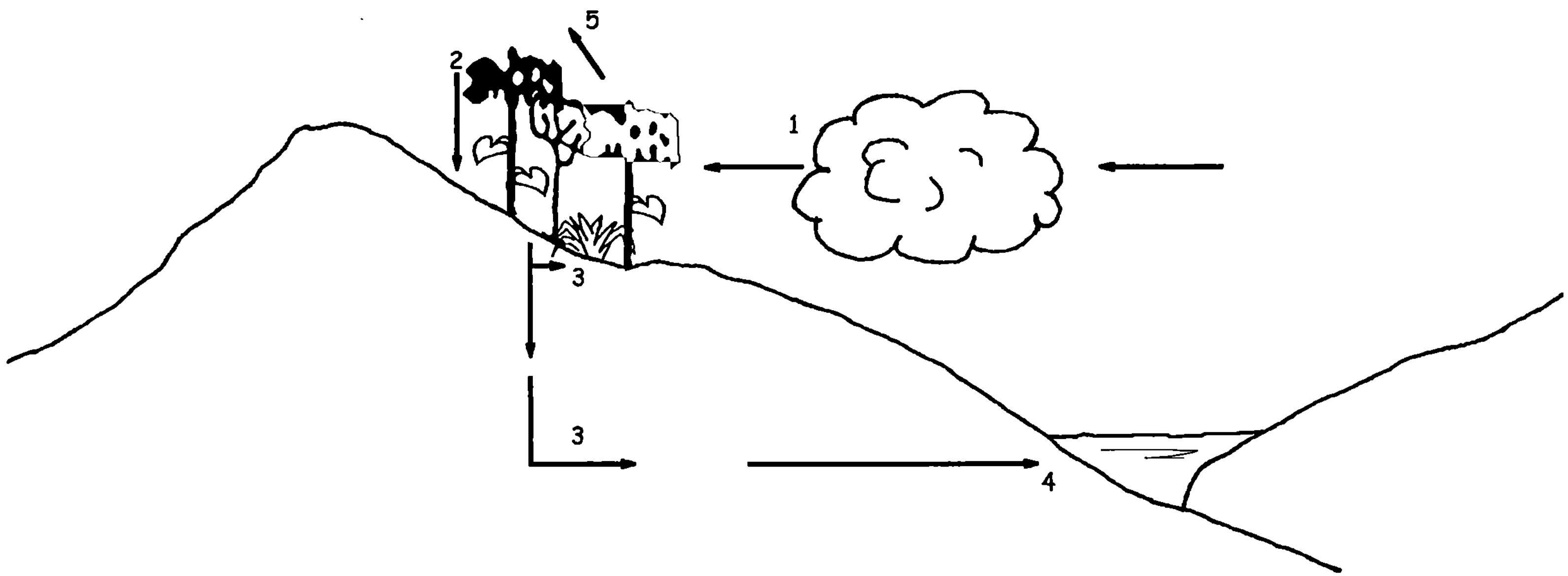

Figure 2-2. Simplified diagram of cloud forest hydrology. 1. Passing clouds collide with vegetation, forcing cloud droplets to coalesce into water drops. 2. Water drops trickle down trunks and stems or fall off branches and leaves to the forest floor. 3. Water enters the soil. Some water remains in soil; some recharges groundwater. 4. Groundwater travels to streams and/or springs. 5. Some water is lost back into the atmosphere through evapotranspiration.

et al. 1995b).

Biological Features of Cloud Forest

Several distinct biological factors characterize cloud forest and stimulate interest not only for hydrologists, but botanists, zoologists, ecologists, and even ecotourists, who are often seeking the opportunity to see an unusual and rare landscape in their travels. Compared to lower altitude tropical moist forest, cloud forest tree stature is lower, with a canopy of often less than 8 m (26 ft), a phenomenon I will address later in this chapter (Beard 1949; Stadtmuller 1987; Hamilton 1995). On small islands in the Caribbean, this stunted growth is particularly noticeable as an overall forest form takes shape that is recognizable from island to island, with cloud forest as a distinctive crown (Figure 2-3). Canopy trees are usually gnarled and twisted by the wind, with densely compacted crowns (Beard 1949; Stadtmuller 1987; Hamilton 1995). Trees and shrubs often have buttress roots, with greater stem density than lower altitude species, and they exhibit thick, leathery xeromorphic leaves (Stadtmuller 1987; Hamilton 1995). Soils are wet, sometimes waterlogged, and rich in organic material such as humus and peat (Stadtmuller 1987; Hamilton 1995). An abundant load of epiphytes, including mosses, lichen, orchids, and bromeliads, as well as filmy ferns, and bryophytes, provide a large portion of the biomass (Beard 1949; Stadtmuller 1987; Hamilton 1995). Epiphytes, taking advantage

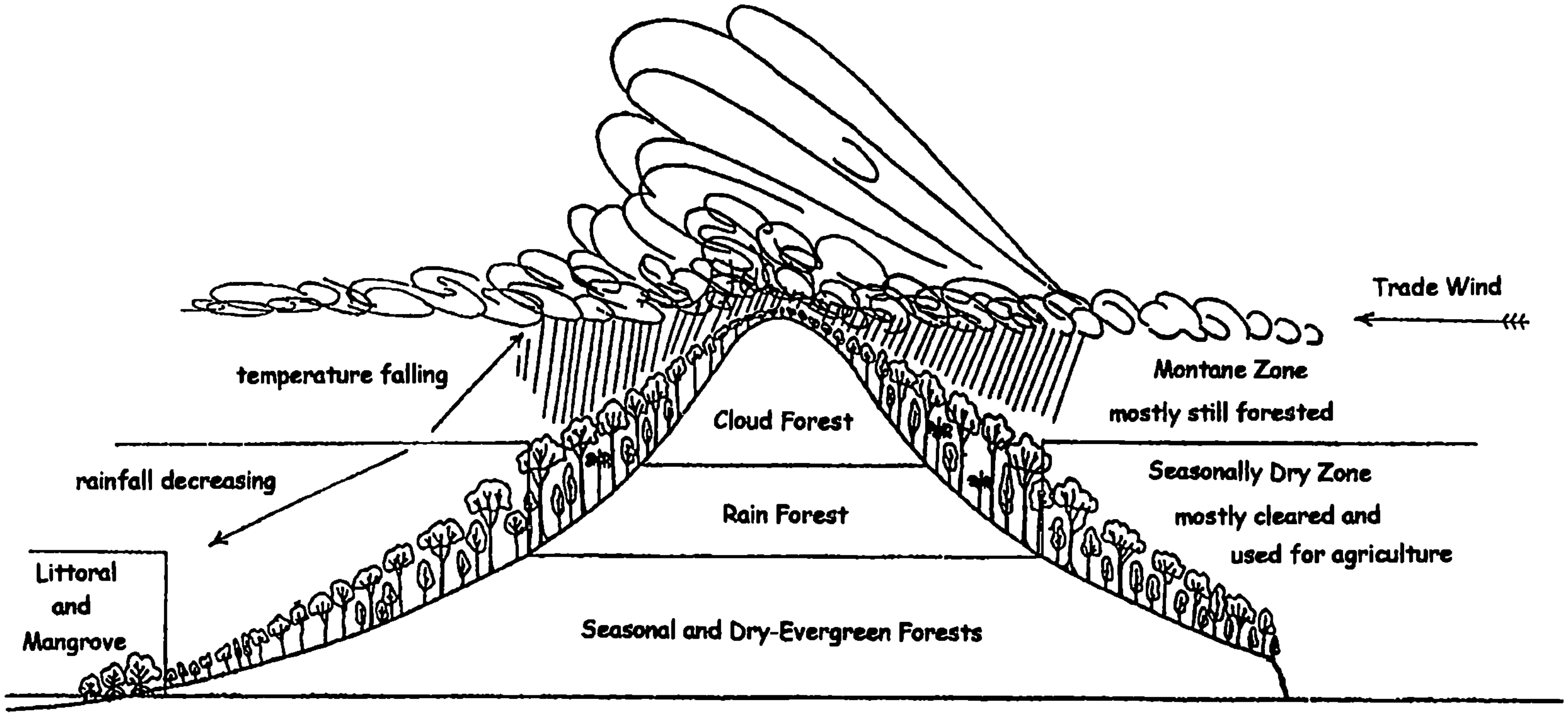

Figure 2-3. Idealized cross-section of a high oceanic island in the Caribbean showing typical arrangement of vegetation zones and reduced tree stature.

Adapted from: Beard, J.S. 1949. *The Natural Vegetation of the Windward and Leeward Islands* (p. 55). Oxford: Oxford University Press.

of moisture from the clouds, are often found in the upper levels of tree canopies, but they can also be seen covering the forest floor (Beard 1949; Stadtmuller 1987). The multi-level forest complex truly evokes a sense of lushness and thriving life.

Biodiversity, presumed to decrease with an increase in altitude in the humid tropics, is actually quite high in cloud forest, for several possible reasons. First, many species found in cloud forest are the same as those found at lower elevations, but they appear different, primarily because of the effects of wind and water (Beard 1949; Stadtmuller 1987). Therefore, what appears to be a loss in species diversity is actually only a matter of several species adapting in usually similar ways to the elements. One wonders if the adaptions truly are environmentally induced morphologic differences or incipient speciation, a question yet to be addressed in depth by researchers. Second, although more tree species are found in tropical lowland rainforest than in the mountains, there is evidence in Latin America that the diversity of herbs, shrubs, ferns, and epiphytes, all prevalent in cloud forest, increases with altitude (Wuethrich 1993). The increase in diversity in Latin America may be a result of glaciation, when floristic zones moved down, and deglaciation, when floristic zones moved back up, giving species of different vertical zones the opportunity to overlap in time and space (Hastenrath 1981). When cloud forest is situated between lowland rainforest and alpine grassland, the richer genetic resources available from the two bordering ecosystems create new species in the cloud forest habitat[1] (Weuthrich 1993).

Floral and faunal endemism in cloud forest is quite high, according to Long (1995) who claims that 260 of the world's endemic species have cloud forest habitats. Several cloud forests are home to magnificent animals documented only at those locales, including the mountain gorilla of Central East Africa, and the spectacled bear of the Andes (Hamilton 1995). On Chances Peak, Montserrat, the endemic Montserrat Oriole can often be seen venturing upwards to the cloud forest from its home in the rainforest below, perhaps to find respite from the heat. Two factors most likely influence the high occurrence of endemic species in cloud forest. In areas where surrounding habitats have been encroached upon by humans, cloud forest may act as a refuge for plants and animals, especially mammals. In the Andes, cloud forest is known by the name "ceja de la montana" (eyebrow of the mountain), used to describe the thick, bushy remnant of native vegetation on denuded mountains taken over by mining, cattle ranching, and agriculture (Price 1981; Wuethrich 1993; Hamilton 1995). In El Salvador, the cloud forest of Montecristo is the only remaining habitat for various mammals that have been exterminated in the rest of the region (Stadtmuller 1987). Endemism may also be attributed to the biogeographical effect of isolation on

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[1]In the Caribbean, this last scenario rarely occurs, as most islands do not presently reach elevations which support alpine or high elevation grassland. The Dominican Republic is a noted exception.

cloud forest when the forest occurs either as an oasis in dry areas, or as a last stand surrounded by harvested forest sites (Stadtmuller 1987). There is a greater incidence of endemism in cloud forest bordering on relatively dry zones, a situation many scientists have likened to Darwin's island study of evolution (Stadtmuller 1987). On Caribbean islands, the situation of both isolation and refuge is apparent. Island biogeography theory[2] suggests endemism would be high in any Caribbean forest, and cloud forest had been virtually the only area on many islands uninfluenced by human activity, until the introduction of telecommunications facilities and media transmitting stations into the forest (Ed Towle, personal communication, Spring 1994) and ecotourism. Some suggest that in Caribbean cloud forest, the degree of endemism may reach as high as 52 percent, with both the level of endemism and actual number of species expected to increase as the islands mature[3] (Watts 1987). Cloud forest's role as a unique landscape, strange and beautiful in terms of flora and fauna, should not go unnoticed. The cloud forest's role of harboring species needs to be recognized and protected if it is to continue, because this is a situation that human activity might endanger. Yet, paradoxically, the endangered features are precisely what make cloud

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[2]The theory of island biogeography is well documented, one facet being that islands are relatively isolated, species face distinct ecological pressures, and the population pool is usually small, therefore evolution is accelerated, producing a high percentage of endemic species. For a more thorough definition and suggested reading, see: Goudie, A. (ed.). (1994.) *An Encyclopedic Dictionary of Physical Geography* (pp. 285-287) (2nd ed.). Cambridge: Blackwell.

[3]Obviously, a catastrophic event, such as a volcanic eruption, would interrupt the evolutionary process.

forest so attractive to humans, especially ecotourists.

Location of Cloud Forest

The location and identification of cloud forest on a global scale is an ongoing process. Stadtmuller (1987) was the first to attempt a world map showing distribution within the tropics, but his endeavor was simply a generalized idea of where cloud forest might occur, not a detailed indication of actual cloud forest locations. To alleviate this lack of concrete data, scholars at the 1993 symposium set a goal to produce a global Geographic Information Systems (GIS) data bank to record confirmed cloud forest locations around the world (Hamilton et al. 1995b). The resources of the World Conservation Monitoring Centre (WCMC) were enlisted, and today, this organization continues to compile information on known cloud forests[4] (Hamilton et al. 1995b). Figure 2-4 presents a world map showing generalized concentrations of confirmed cloud forests. The first detailed map of cloud forest locations in the Caribbean and Middle America was done by LaBastille and Pool (1978), later added to by Vazquez-Garcia (1995), although his work concentrated only on parks and reserves containing cloud forest. Montserrat's cloud forest on Chances Peak is not included on either map, nor is it recognized in the current WCMC GIS data bank

[4]It is encouraged that information on known cloud forests (coordinates, elevational limits, area) be sent to: Habitat/GIS Unit, World Conservation Monitoring Centre, 219 Huntingdon Road, Cambridge CB3 0DL, United Kingdom.

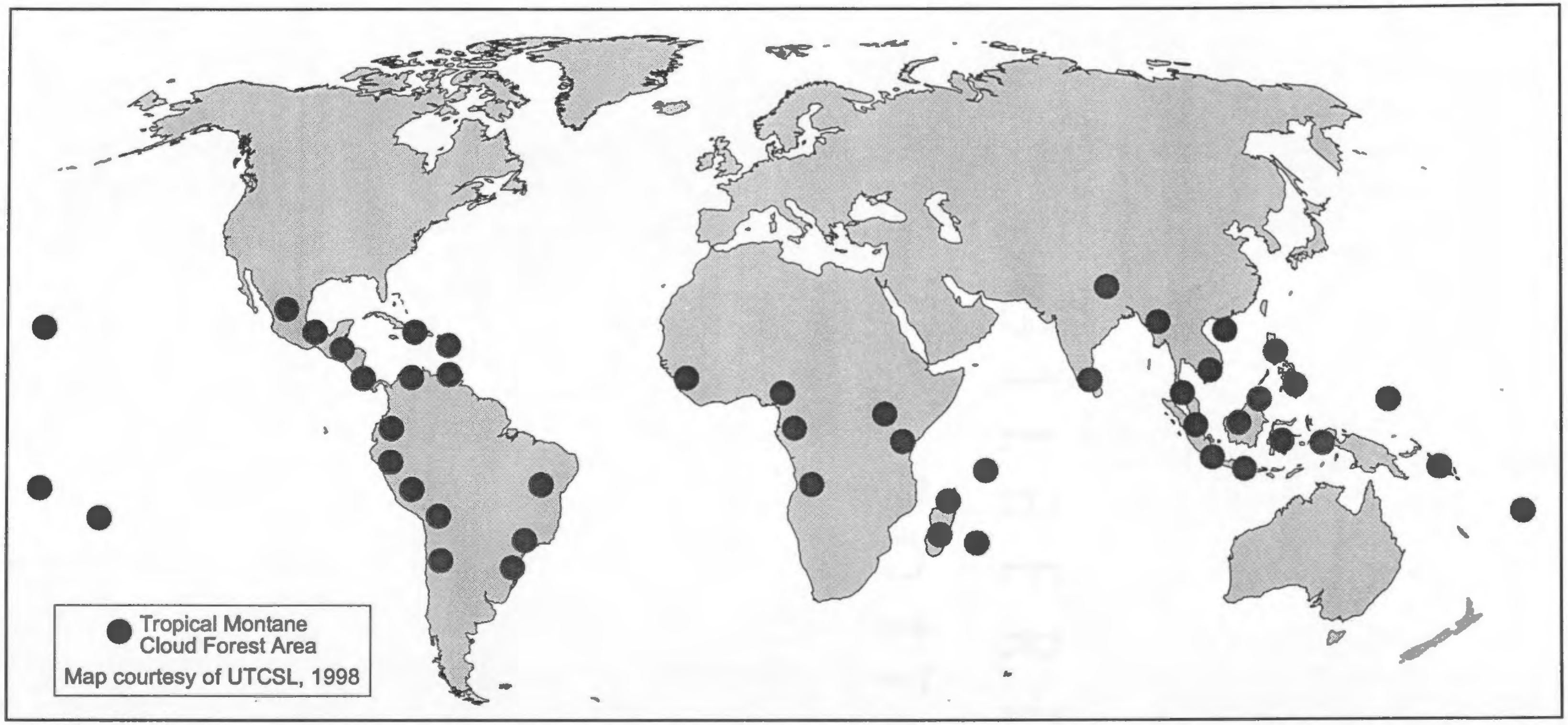

Figure 2-4. General concentrations of tropical cloud forest throughout the world.

Sources: Stadmuller, T. 1987. *Cloud Forests in the Humid Tropics* (National Resources Technical Series no. 33). Tokyo: The United Nations University. AND Hamilton, L.S., Juvik, J.O., and F.N. Scatena. 1995. The Puerto Rico tropical cloud forest symposium: Introduction and workshop synthesis. In L.S. Hamilton, J.O. Juvik, and F.N. Scatena (eds.), *Tropical Montane Cloud Forest* (pp. 1-23). New York: Springer-Verlag.

(LaBastille and Pool 1978; Vazquez-Garcia 1995; World Conservation Monitoring Centre 1998). It was my objective in 1994 to enter Chances Peak, Montserrat, into the WCMC GIS data bank, but since volcanic activity has rendered a charred landscape that may or may not return as cloud forest, its inclusion in the near future is in doubt. Figure 2-5 is a map of known cloud forests within the Caribbean, to which I have added Chances Peak.

As cloud forest is increasingly identified on a global scale, a general pattern begins to emerge, mainly related to oceanic weather influences. Cloud forest occurs around the world in the latitudinal belt of the tropics. Sites are situated on the peaks of islands in the Pacific, Indian, and Atlantic Oceans, and along coastal boundaries of continents with favorable wind conditions that bring moisture inland (Stadtmuller 1987). The cloud forests of Uganda, the Democratic Republic of Congo, and Sudan, occurring in the interior of the continent of Africa, are the exception[5] (Doumenge et al. 1995; Lush 1995). In the Caribbean, it is the Trade winds that bring moisture across island peaks (see Figure 2-3 and Chapter 1). There are more cloud forest sites in tropical America and Southeast Asia than in tropical Africa because in America and Asia there is a wider distribution of mountain ranges subjected to moisture-producing oceanic influences (Doumenge et al. 1995). Most often, cloud forest occurs in montane

[5]It is the presence of converging weather systems and high elevations that create these environments, not oceanic influences (Lush 1995). These African cloud forests exhibit characteristics unlike those of any other cloud forest in the world, thus this region is seen as unique, yet is still regarded as cloud forest (Lush 1995).

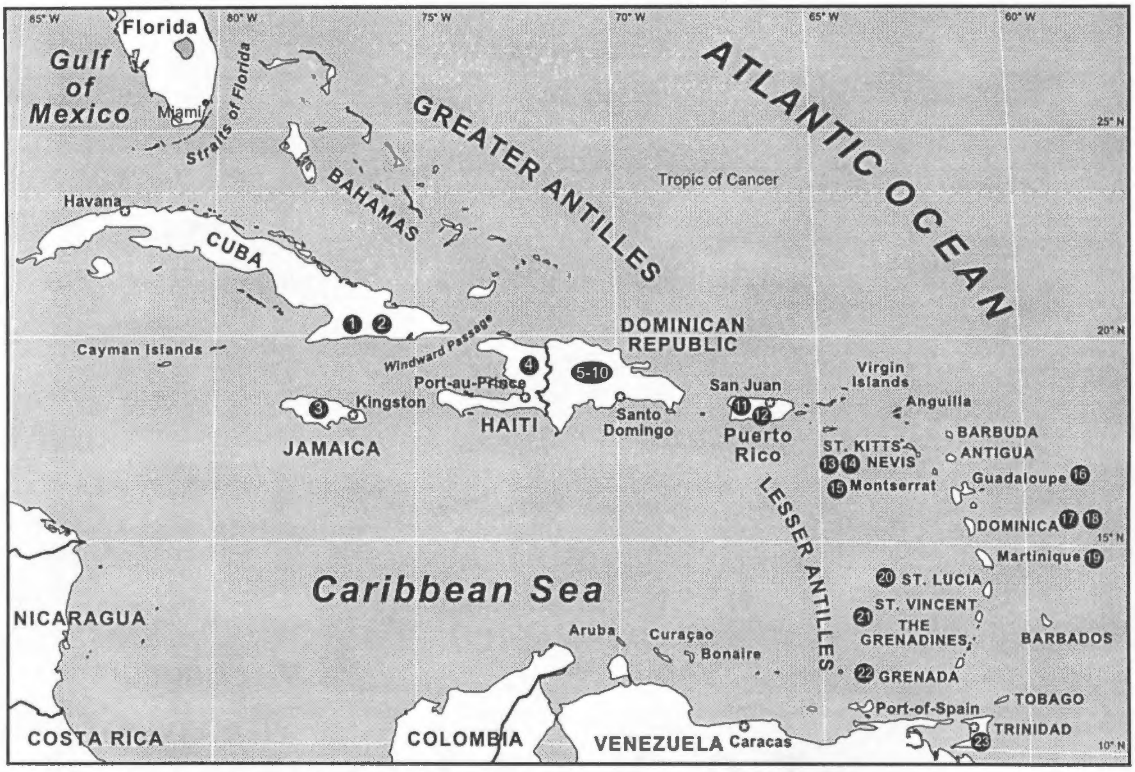

Figure 2-5. Location of cloud forests in the Eastern Caribbean.

Greater Antilles
1. Pico Turquino, Cuba
2. Sierra Maestra, Cuba
3. Blue Mountain Ridges and Peaks, Jamaica
4. unnamed cloud forest, Haiti
5. A.J. Bermudez National Park, Dominican Republic
6. Jose del Carmen Ramirez National Park, Dominican Republic
7. Sierra de Baoruco National Park, Dominican Republic
8. Ebano Verde National Reserve, Dominican Republic
9. Isabel de Torres National Reserve, Dominican Republic
10. Valle Nuevo National Reserve, Dominican Republic
11. Caribbean National Forest, Puerto Rico
12. Toro Negro Commonwealth State Forest, Puerto Rico

Lesser Antilles
13. Mt. Misery, St. Kitts
14. Nevis Peak, Nevis
15. Chances Peak, Montserrat
16. Soufriere, Guadeloupe
17. Morne Trois Pitons National Park, Dominica
18. Morne Diablotin National Park, Dominica
19. Mt. Pelee, Martinique
20. Mt. Gimie, St. Lucia
21. Soufriere, St. Vincent
22. Mt. St. Catherine, Grenada
23. El Aripo, Trinidad

Sources: Vazquez-Garcia, J.A. 1995. Preservation of fragmented montane ecosystems in tropical America. In L.S. Hamilton, J.O. Juvik, and F.N. Scatena (eds.), *Tropical Montane Cloud Forests* (pp. 315-332). New York: Springer-Verlag. AND Personal observation by the author.

and submontane forest, forest types that comprise more than 11 percent of all tropical forests (Doumenge et al. 1995). It is estimated that cloud forest occurs in one-fourth of these broader forest categories, making the worldwide total at about 50 million ha (Doumenge et al. 1995). A lack of precise data on the extent and distribution of cloud forest within montane and submontane forest, coupled with new information that suggests cloud forest may occur as low as 300 m (985 ft), make this a minimal calculation at best.

On a local level, several factors determine elevational limits of cloud forest. These include: cloud formation by convection, the effect of the trade wind inversion on cloud formation, the direction and velocity of the prevailing winds, the macro-relief of a mountain range (orientation and size), distance to the nearest sea and thus prevailing winds, and the surface temperature of the nearest sea (Stadtmuller 1987). Cloud forest on continents is typically found between 500 m and 3500 m (1650 ft and 11,500 ft), concentrated in a belt of 1200 m to 2500 m (3900 ft to 8200 ft) (LaBastille and Pool 1978; UNESCO 1981; Stadtmuller 1987; Doumenge et al. 1995; Hamilton et al. 1995b). These are, however, only general guidelines developed from cloud forests on continental margins.

It is enlightening to compare the altitudinal ranges of cloud forest on islands with those on coastal boundaries of continents. Substantial cloud forest formations are typically found on tropical islands at an average elevation of 800 m to 1000 m

(2600 ft to 3300 ft), a much lower and narrower range than the one for continental locations (Beard 1949; Stadtmuller 1987; Price 1981). In fact, on most isolated peaks, e.g., those on islands, all of the vegetational zones are contracted or compressed, showing defined boundaries but in much smaller bands and at much lower altitudes than on large mountain masses (Figure 2-6 and see Figure 2-3) (Bruijnzeel et al. 1993; Flenley 1995). One explanation for this may be the so-called "Massenerhebung" effect, or mass mountain effect. Originally, this effect was used to describe the appearance of higher timberlines and vegetational zones in the central European Alps than in the outlying margins (Schroeter 1908). The explanation holds that large mountain masses, by virtue of their huge mass and warming from exposure to intense radiation during cloudless periods, modify the temperature above them to the extent that a plant community can extend beyond its typical altitudinal range (Price 1981; Bruijnzeel et al. 1993). If this is true, then it follows that on isolated peaks, vegetational zones would be lower than on expansive mountain ranges. This is certainly the case in the Caribbean, where the above range is accurate.

There are those who dispute the Massenerhebung explanation for lower vegetational zones on island peaks. Many scientists contend that very few mountains are able to show a substantial Massenerhebung effect and that the effect does not adequately explain the contraction of vegetational zones on tropical islands, as it assumes that altitudinal limits of vegetation are governed by temperature, which is

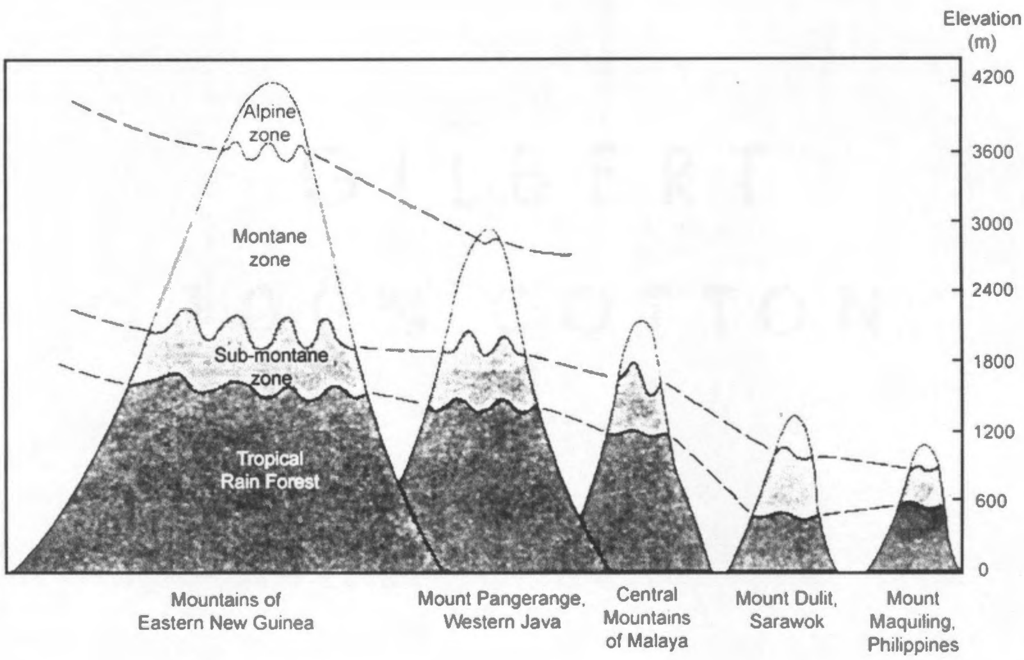

Figure 2-6. The phenomenon of concentrated vegetation zones on smaller and more isolated mountain peaks in the tropics of Indo-Malaysia.

Source: Price, L.W. 1981. *Mountains and Man* (p. 266). Berkely: University of California Press, Ltd.

fairly uniform in the tropics (Grubb 1971; Bruijnzeel et al. 1993). Newer theories about contracted vegetational zones are all directly related to the presence of clouds, and cloud forest patterns. Recently, researchers have begun investigating the idea that on tropical islands, increased atmospheric humidity levels produce a "cloud cap" that results in zonal contraction and in the stunted stature of upper-level forest (cloud forest) (Bruijnzeel et al. 1993; Flenley 1995). The effect of this cloud cap, and what it does to contract vegetational zones is not clear, especially since stunted growth is also found in continental cloud forest, (but there contracted zones are not found). Wind may play an important role in stunting growth, making the two characteristics of stature and zonation independent of each other. Grubb (1971) interprets the situation in terms of the availability of certain nutrients, suggesting that fog cover raises the soil water content, slows down the mineralization of organic matter, and decreases the degree of soil aeration, resulting in reduced availability of plant nutrients, particularly nitrogen and phosphorus, and possibly copper and zinc. Cloud forest, which cycles less nitrogen than most lowland forest, may be winning in competition with lowland rain forest in the cloud-covered zone (Grubb 1971). Perhaps the limited space on islands more readily reveals this competition, while it remains more hidden on continents. Odum (1970) and Weaver et al. (1973) agree that limited nutrient intake is a factor in contracted zonation. However, unlike Grubb (1971), they believe plant nutrients are available and low transipiration rates, caused by high humidity, depress the uptake of minerals (Odum 1970; Weaver et al. 1973).

Bruijnzeel et al. (1993), also concentrate on relating soil attributes to the stunted growth found in cloud forest and possibly to the contracted zones found on islands. They discovered a correlation between increased phenolic compounds in leaf litter and stunted growth under a cloud cap on Gunung Silam, Sabah, Malaysia. They think the stunted growth is caused by harmful effects on plant physiology due to the phenolic compounds (Bruijnzeel et al. 1993). They also measured insolation levels on Gunung Silam, and discovered 30 percent less insolation annually under the cloud cap than at unclouded sites in the same region (Bruijnzeel et al. 1993). Usually, a lack of sunshine results in elongated, spindly growth of plants. Flenley (1995) noted high doses of early morning UV-B light on tropical island peaks, as a result of reflection from clouds or the sea. Flenely (1995) suggests that UV-B light stimulates the production of UV-B absorbing compounds that are also phenolic, reinforcing the findings of Bruijnzeel et al. (1993).

Much more research in this area remains to be done, but all current theories revolve around the notion that cloud cover is in some way responsible for the contracted zonation found in the tropics, and also for the reduced stature of cloud forest trees. It may be that Whitmore (1989) is correct. He states that there is no single uniform set of causes for forest zonation and its compression on tropical island mountains. While the exact reason is unclear, the result remains that the altitudinal range of cloud forest on tropical islands, 800 m to 1000 m (2600 ft to 3300 ft), is much lower than the range of cloud forest on continents, 1200 m to 2500 m (3900 ft to 8200 ft).

Cloud Forest Hydrology

Evidence is mounting that cloud forest may be an exceptionally valuable resource from a hydrological standpoint for the simple reason that the mere presence of cloud forest may increase the groundwater supply beyond that which is accumulated through ordinary rainfall (OR). There are three possible components to this phenomenon that bear examination in cloud forest: apparent higher rates of net precipitation, low evapotranspiration rates, and contributions to groundwater and streamflow (including runoff and springs), especially in areas that experience a dry season (Zadroga 1981; Stadtmuller 1987; Bruijnzeel and Proctor 1995). The first two components explain how the climatic conditions of cloud forest affect the hydrologic regime, while the third is an expression of the effect of those conditions on the hydrologic regime.

The most dramatic of these components is the increase in net precipitation due to the movement of water onto vegetation surfaces via vapor condensation or by direct contact of cloud droplets. Clouds sweeping across forested peaks are literally blown against the leaves and branches of trees, forcing tens of millions of fog droplets to coalesce into larger water droplets, which eventually make their way down to the forest floor via throughfall and stemflow (see Figure 2-2) (Vogelmann 1973). A variety of terms to describe this input of water have been coined, the most common being horizontal precipitation (HP), and that term will be used here (Zadroga 1981; Stadtmuller 1987; Bruijnzeel and Proctor 1995; Hamilton 1995). Both vegetational factors and climate factors affect the quantity of HP, and variations between locations can be large. Vegetational factors include height of the flora, canopy size and structure, biomass, and the arrangement and physical properties of leaves and epiphytes (Bruijnzeel and Proctor 1995). Climatic factors include moisture content, cloud drop sizes, velocity and direction of prevailing winds with respect to the orientation of the forested slope or ridge, and duration of cloud cover (Zadroga 1981; Bruijnzeel and Proctor 1995). Temperature is rarely mentioned in literature on HP and it is assumed that HP is considered to be a product of that which is already a liquid in air that is saturated (Ken Orvis, personal communication, April 1999). Quantifying HP is a difficult task. Two approaches have commonly been used, measuring mist by forcing condensation with fog catcher devices or measuring canopy drip (throughfall) inside a stand of cloud forest vegetation (Bruijnzeel and Proctor 1995). The results of either method are compared to ordinary rainfall (OR) measurements, which are taken in a contiguous site for fog catchers and in an adjoining clearing for throughfall

(Vogelmann 1973; Cavelier and Goldstein 1989; Bruijnzeel and Proctor 1995). Both methods present problems of interpretation. Fog catchers, usually some type of mesh or screening, cannot adequately recreate each unique forest characteristic, such as canopy height, but can relay the relative importance of moisture contributions by low clouds (Cavelier and Goldstein 1989; Bruijnzeel and Proctor 1995). Throughfall, collected in a system of troughs, has the benefit of monitoring water captured by the actual vegetative canopy, except that which is intercepted and evaporated from the wet canopy, and that which is stemflow (Bruijnzeel and Proctor 1995). For my research on Montserrat's Chances Peak, I used a fog catcher, explained in specific detail in Chapter 3.

When using the fog catcher method, measurements taken from gauges collecting OR are subtracted from measurements taken from gauges fitted with a screen or mesh to collect both OR and HP , [(OR+HP)-OR=HP] (Vogelmann 1973; Cavelier and Goldstein 1989). Dividing these volume differences by the original OR measurements allows HP to be expressed as a percent of OR, (HP÷OR=percent of OR). For example, if a gauge fitted with mesh collected 100 mm of water, while a plain gauge collected 40 mm of water, then HP would measure 60 mm (100 mm minus 40 mm equals 60 mm), and would be expressed as 150 percent of OR (60 mm divided by 40 mm equals 150 percent). Percent of OR is termed "percent of rain" in cloud forest literature (Vogelmann 1973; Cavelier and Goldstein 1989; Bruijnzeel and Proctor 1995).

Since the fog catcher method only approximates the ability of cloud forest to capture water, most researchers seem reluctant to express HP in the context of percent of total precipitation (HP+OR), preferring to only compare the amounts recorded in gauges. One problem that arises with this method of analysis is that it is impossible to determine HP as a percent of OR if gauged OR is zero, a special problem for studies done in short periods of time in which no measurable OR was recorded. No method has been accepted to alleviate this situation.

Vogelmann (1973) used a fog catcher in the Sierra Madre Oriental of eastern Mexico, and found that HP measured 85 percent of OR during the local dry season and 15 percent during the local wet season. Using a device similar to Vogelmann's, Cavelier and Goldstein (1989) conducted studies in two South American cloud forests. In Serrania de Maguria, Columbia, they calculated that during the driest month, HP measured 63 percent of OR (Cavelier and Goldstein 1989). In Cerro Santa Ana, Venezuela, HP measured 66 percent of OR, also during the driest month (Cavelier and Goldstein 1989). During the wettest months HP measured only 33 percent of OR in Serrania de Maguria, Columbia, and 12 percent in Cerro Santa Ana, Venezuela (Cavelier and Goldstein 1989). These data suggest the possibility that groundwater is supplied predominantly by OR during wet seasons and by HP during dry seasons (Cavelier and Goldstein 1989). This scenario relates to all locales that have such a seasonal distinction, for example the Caribbean. Table 2-1 shows measurements of HP taken

Table 2-1. Measurements of horizontal precipitation (HP) in cloud forest using fog catchers. HP-horizontal precipitation, OR-ordinary rain, w-wet season, d-dry season

location	altitude m	HP mm/d	HP as % of OR
Colombia, Serrania de Maguira[1]	865	2.2	33w/63d
Costa Rica, Cerro Buenavista[2]	3500	2.1	18
Costa Rica, Balalaica[2]	1300	4.0	33
		1.6w	15w
Hawaii, Mauna Loa[2]	1580	2.1	30
	2530	1.9	68
Malaysia, Gunung Silam[2]	884	0.4	9
Mexico, Sierra Madre[2]	1330	1.6w/0.6d	15w/ 85d
	1360	0.8w/0.4d	17w/ 60d
	1900	0.6w/0.4d	14w/103d
Puerto Rico, Pico del Oeste[2]	1050	0.9	7
Venezuela, Cerro Sa Ana[1]	815	1.4	12w/66d
Cerro Copey[1]	987	1.3	6w/ 9d
El Zumbador[1]	3100	0.2	3w/19d

Sources: [1]Cavelier, J. and Goldstein, G. 1989. Mist and fog interception in elfin cloud forests in Colombia and Venezuela. *Journal of Tropical Ecology* 5:309-322. [2]CITED IN: Bruijnzeel, L.A., and J. Proctor. 1995. Hydrology and biogeochemistry of TMCF: What do we really know? In L.S. Hamilton, J.O. Juvik, and F.N. Scatena (eds.), *Tropical Montane Cloud Forests* (pp. 38-78). New York: Springer-Verlag.

in various cloud forests using the fog catching method.

The other method of measuring HP, using throughfall measurements, gives similar results to those of Vogelmann (1973) and Cavelier and Goldstien (1989), indicative of the role HP plays in the local hydrological cycle, but does not attempt to measure HP directly. Throughfall measurements, collected in troughs located within the cloud forest cover, are considered to be net precipitation, both OR and HP that does not evaporate before reaching the ground (Stadtmuller and Agudelo 1990). In this case, the throughfall measurements are expressed as a percent of OR, once more termed "percent of rain" in cloud forest literature, and are calculated by dividing throughfall measurements by OR measurements (Stadtmuller and Agudelo 1990; Bruijnzeel and Proctor 1995). OR is determined by placing a gauge or trough in the closest clearing or by using a known mean average precipitation for the area (Stadtmuller and Agudelo 1990; Bruijnzeel and Proctor 1995). The throughfall percentages of OR determined by this method are higher than the HP percentages of OR determined by the fog catcher method, because they include both OR and HP, or net precipitation.

In cloud forest, throughfall often exceeds 100 percent of measured OR (Stadtmuller and Agudelo 1990; Bruijnzeel and Proctor 1995). It is assumed the excess water is due to HP. Table 2-2 shows measurements of throughfall taken in various cloud forests. Throughfall varies, from 70 to 80 percent of OR in Tanzania,

Table 2-2. Measurements of throughfall (TF) in cloud forest. Ordinary rainfall (OR) based on mean annual precipitation. OR-ordinary rainfall, TF-throughfall

location	altitude m	OR mm	TF as % of OR
Columbia	1000	1600	78
	1700	3150	76
	1950	2200	85
	3000	1700	89
Columbia	2550	2115	87.5
	3370	1455	81
Costa Rica	1300	2510	101
Honduras	1795	1500	94
			129
			179
Indonesia	1750	3300	80
Jamaica	1020	3000	81
Jamaica	1550	2600+	92+
Mauritus	550	3175	70/76
New Guinea	2500	3800	67
Philippines	2200	3900	86
Puerto Rico, El Verde	450	2540	72
Puerto Rico, Pico del Este	1000	5400	115
	1015	4800	125
	930	6000	96
Tanzania	1500	1230	78
Venezuela	2300	1575	79.5

Source: CITED IN: Bruijnzeel, L.A., and J. Proctor. 1995. Hydrology and biochemistry of TMCF: What do we really know? In L.S. Hamilton, J.O. Juvik, and F.N Scatena (eds.), *Tropical Montane Cloud Forests* (pp. 38-78). New York: Springer-Verlag.

Papua New Guinea, and Venezuela, each a cloud forest with relatively light cloud cover, to 130 to 180 percent of OR in Honduras and Puerto Rico, where both cloud forests are located near a coast and on exposed ridges (Bruijnzeel and Proctor 1995). Cavelier and Goldstein (1989) noted that coastal cloud forest shows higher percentages of HP than inland cloud forest. Island cloud forest is considered coastal.

No correlation has been found between annual totals of HP and OR, and HP is considered to constitute an independent regime climatically distinct from other precipitation (Cavelier et al. 1996). However, relative values of HP appear to be higher at sites with low OR and during dry seasons (see Tables 2-1 and 2-2) (Bruijnzeel and Proctor 1995). This pattern exposes the importance of HP during dry seasons or in areas with relatively low OR, where HP may be the only source of water. Cavelier and Goldstein (1989) observed that in areas with a dry season, water supplied by HP is more constant on a year-round basis than water supplied by OR, a point to be considered in water management practices. Since elevations surrounding cloud forest often consist of dry to arid vegetation zones, downslope areas may actually be depending upon cloud forest to recharge groundwater (Vogelmann 1973; Hartshorn 1988; Cavelier and Goldstein 1989).

Low evapotranspiration rates are the second component of cloud forest that affects the hydrological regime and also reveals information about overall climatic conditions. The addition of HP would mean little in terms of groundwater increase if thirsty plants transpired great amounts of water back into the atmosphere or climatic conditions evaporated pools of water before it could seep downward into the soil. Evaporation rates of open water are expected to decrease with increasing elevation, as radiation, temperature, and vapor pressure deficits, are all reduced, though high wind velocities on exposed ridges would push evaporation rates higher (Oliver and Hidore 1984). Frequent moisture deposition, low insolation due to frequent fog, and a closed canopy certainly seem to support the claim of low evaporation rates within cloud forest (Weaver et al. 1973) Average values for evaporation of open water in cloud forest range from 2.0 mm to 3.75 mm/day (0.0787 in to 0.1476 in/day), whereas values recorded for tropical lowlands average 5 mm/day (0.1969 in/day) (Bruijnzeel and Proctor 1995). It has been argued that the values for cloud forest need to be adjusted to compensate for the fact that most evaporation occurs during fog-free periods, usually in the mornings (Bruijnzeel and Proctor 1995). When values for these periods are computed, rates more closely resemble those found on lower slopes (Bruijnzeel and Proctor 1995). Although cloud forest is foggy most of the time, some researchers suggest that these adjusted values imply that high humidity levels and a lack of radiant energy do not provide the complete answer as to why cloud forest often seems saturated with water (Bruijnzeel and Proctor 1995).

Evapotranspiration rates are uncommonly low in cloud forest when compared to rates found in almost any other habitat (Weaver et al. 1973; Zadroga 1981; Bruijnzeel and Proctor 1995). Total evapotranspiration from a vegetated surface consists of three elements: evaporation of precipitation intercepted by the vegetation (E_i), transpiration (E_t), and evaporation from the ground layer (E_s) (Bruijnzeel and Proctor 1995). E_s has been shown to be very small in lowland rain forest (Bruijnzeel and Proctor 1995). Most studies acknowledge its presence, but do not delve into great detail on the subject, concentrating instead on E_i and E_t. Evaporation from vegetation (E_i) is controlled by climatic and passive vegetational factors, while transpiration (E_t) is controlled by plant stomatal regulation in response to changing climatic conditions (Bruijnzeel and Proctor 1995). These factors and conditions include wind speed, available energy, vapor pressure deficit, vegetation height, roughness and size of leaves, and arrangement and total biomass of the canopy (Bruijnzeel and Proctor 1995). Evaporation is additionally affected by the duration and intensity of precipitation (Bruijnzeel and Proctor 1995). Assuming E_s to be negligible, Table 2-3 shows rates of evaporation (E_i), transpiration (E_t), and evapotranspiration (ET) for various cloud forest sites, all lower montane forest, except for the site in Puerto Rico, a paradigmatic cloud forest with dramatically low E_t rates. These results suggest that 35 percent to almost 90 percent of rain that falls within cloud forest is available to work its way into the soil as groundwater. Also, the transpiration rates (E_t), are clearly below the average transpiration rate of 1225 mm/year (48.29 in/year) derived for tropical forest not affected by low cloud cover (Bruijnzeel and Proctor 1995).

Table 2-3. Annual evaporation (E_i), transpiration (E_t), and evapotranspiration (ET) vs. rainfall in cloud forest. Values for ET not corrected for contributions by horizontal precipitation. E_t derived as net ET - E_i, except as noted. OR-ordinary rainfall

location	altitude m	OR mm/yr	E_i mm	+	E_t mm	=	ET mm	ET as % of OR
Columbia[1]	1150	1985	435		830		1265	64
	2100	2315	25		285		310	13
Costa Rica[1]	2400	2695	95		270		365	14
Indonesia[1]	1750	3305	660		510		1170	35
Malaysia[1]	870	2500	385		310		695	28
Philippines[1]	2350	3380	140		250		390	12
Venezuela[1]	2300	1575	305		675		980	62
Puerto Rico[2]	1000	4700			75*			

*E_t via cut shoot method.

Source: [1]CITED IN: Bruijnzeel, L.A., and J. Proctor. 1995. Hydrology and biochemistry of TMCF: What do we really know? In L.S. Hamilton, J.O. Juvik, and F.N. Scatena (eds.), *Tropical Montane Cloud Forests* (pp. 38-78). New York: Springer-Verlag. [2]Weaver, P.L., Byer, M.D., and D.L. Bruck. 1973. Transpiration rates in the Luquillo Mountains of Puerto Rico. *Biotropica* 5(2):123-133.

There are some unique situations associated with cloud forest that make such measurements difficult and open to interpretation. Estimates of E_i are usually made by subtracting throughfall and stemflow from OR (Bruijnzeel and Proctor 1995). The addition of HP, represented in throughfall and stemflow measurements instead of precipitation measurements, makes this technique difficult to apply in the case of cloud forest, as both total precipitation and evapotransipiration will be under reported. The presence of epiphytes also hampers measurements of E_i, as epiphytes are capable of absorbing large volumes of water with rather slow evaporation and drainage losses (Bruijnzeel and Proctor 1995). No measurement technique for evapotranspiration that considers occurrence and intensity of OR and fog, and epiphytic cover, has ever been employed. To date, there are few data available from which to firmly conclude that E_i rates are indeed lower in cloud forest.

Quantitative data on E_t in cloud forest are also lacking. However, Weaver et al. (1973) have presented some compelling and comprehensive data concerning the subject from studies in the Luquillo Mountains of Puerto Rico, mentioned above and included in Table 2-3. Their measurements, based on rates of water absorption by cut shoots and leaf energy budget calculations, showed an annual transpiration rate of 75 mm (2.95 in) compared to annual OR of 4700 mm (184.71 in) (Weaver et al. 1973). Their method of calculating a leaf energy budget differed from other studies and did depend upon many assumptions, so all numbers must be considered with caution. Data on E_t are scarce, but the evidence suggests that transpiration rates are low, and all calculated rates tend to be conservative (Bruijnzeel and Proctor 1995). Why these rates are low is a matter of considerable debate. Most suggested explanations involve the roles of soil mineral content, xeromorphic leaf structure, stunted tree growth, prevailing high wind speeds, fog cover and closed canopy, and relate to the ideas on zonal contraction and stunted growth discussed earlier (Weaver et al. 1973; Grubb 1977; Bruijnzeel et al. 1993; Bruijnzeel and Proctor 1995). Nonetheless, it appears water introduced into cloud forest by any source, OR or HP, is more likely to reach groundwater storage than in other forest.

The third component of hydrology within cloud forest is the regulation of groundwater and surface flow, a result of the first two elements discussed: increased net precipitation and low evapotranspiration rates. The direct effects of HP and low evapotranspiration rates on the local hydrological cycle are the base by which to claim cloud forest a water resource (see Figure 2-2). Examination of groundwater and surface flow helps determine the extent of cloud forest influence on local water budgets.

Cloud forest soil is typically described as wet, muddy, soggy, even slippery. Observations of soil water dynamics suggest that cloud forest would never experience severe soil water deficits, though most studies have only lasted about a year, and so the effects of rare tropical drought have not been assessed (Bruijnzeel and Proctor

1995). Vogelmann (1973) noted in his study in the Sierra Madre Oriental, Mexico, that the soil under cloud forest canopy was saturated to a depth of 8 to 10 cm (3.15 to 3.93 in), while outside the canopy, the soil was "powder dry". In a more detailed two-year study on Gunung Silam, Sabah, Malaysia, Bruijnzeel et al. (1993) compared soil moisture levels in cloud forest with lowland forest. Soil moisture levels in cloud forest were nearly always close to saturation, even during periods of little or no rainfall, while the soil moisture of lowland forest fluctuated wildly (Bruijnzeel et al. 1993). Soil water tension studies compiled by Bruijnzeel and Proctor (1995) show that in lowland forest, tension increases and decreases in accordance with wet and dry seasons, while in cloud forest, soil water tension remains at low levels indicative of persistent wetness[6]. Morphological data, also compiled by Bruijnzeel and Proctor (1995), confirm the presence of wet soil. Transect studies all note soil changes when passing into a zone of frequent cloud cover, most notably increased organic matter, darker colors, increased hydromorphic qualities, and the presence of aerial roots, all of which have long been associated with waterlogged conditions (Bruijnzeel and Proctor 1995).

Groundwater, except that which is held in capillary tension, eventually works

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[6]Soil water is stored in soil pores (open spaces between the particles that compose a soil.) In the most narrow pores, water is held by capillary forces, a condition in which adhesive forces overcome gravitational forces and hold liquids, even causing them to rise at times, such as water in a glass tube or straw. These forces bind soil moisture to soil particles, pulling water into pores. Therefore, water in an unsaturated soil can be thought of as being held under "tension." As moisture content decreases and adhesive forces increase, the remaining soil water is held yet more tightly in narrower pores. Thus, high soil tension rates indicate unsaturated soils with slow drainage, while low soil tension rates indicate soils that are nearly saturated and in which water flows freely. A completely saturated soil has a tension rate of zero (Dunne and Leopold 1978; Goudie 1994).

its way into streams and springs. Very few studies exist tying streamflow amounts directly to cloud forest, but when annual streamflow totals are expressed as a ratio of rainfall, values for cloud forest are among the highest reported for any tropical forest (Bruijnzeel and Proctor 1995). Zadroga (1981) analyzed data on rainfall and runoff in watersheds on the slopes of the Cordillera de Tilaran, Costa Rica. The Atlantic slopes contain cloud forest, and the Pacific slopes do not contain cloud forest (Zadroga 1981). The hydrology of the two sites differed considerably, with a runoff/rainfall ratio for the Atlantic slopes being 102 percent and the ratio for the Pacific slopes being 34 percent (Zadroga 1981). On the Atlantic side, runoff amounts in every watershed exceeded rainfall amounts over a seven month period, during which the moisture laden Trade Winds dominated the area (Zadroga 1981). Rainfall measurements did not take into account HP, the only possible source for the excess water. Horizontal precipitation, captured by the cloud forest, added water to the hydrological regime. Penafiel (1995) investigated watershed issues in the Central Cordillera Mountains, Philippines, where cloud forest is the headwater area for three river basins that supply water for hydroelectric power and irrigation. He found that cloud forest acts as a reservoir, slowly releasing stored water during dry seasons and renewing groundwater through HP. For this reason, the HP-cloud forest relationship is especially important in headwater regions (Penafiel 1995). Another example of the importance of cloud forest as a fresh water reservoir is in La Tigra National Park in

Honduras. This park of 7500 ha, primarily covered in cloud forest, provides 30 to 50 percent of drinking water for Tegucigalpa, the capital of Honduras.(Stadtmuller 1987). During the dry season, March, April, and May, the percentage of drinking water supplied by the La Tigra area increases dramatically, while other water sources drop in their availability (Stadtmuller 1987). The same scenario conceivably holds true for any region adjacent to cloud forest; namely that such regions are dependent upon cloud forest for groundwater, especially during dry seasons. The role of cloud forest in headwater areas in supplying water to populations and forests in downstream valleys is now undisputed by scientists and constitutes one of the main reasons for cloud forest conservation (LaBastille and Pool 1978; Zadroga 1981; Stadtmuller 1987; Hamilton et al. 1995b; Bruijnzeel and Proctor 1995; Doumenge et al. 1995; Penafiel 1995). It is as Stadtmuller (1987) states of cloud forest, "Water becomes the most important crop."

Conflict Over Cloud Forest

The attributes of cloud forest make it attractive for a variety of uses, some of which mandate its protection as a watershed or as a preserve for flora and fauna. Each use influences the ecosystem's ability to perform another use, and policy makers must consider which uses shall get priority or how the other uses could be made compatible. Worldwide, there are many activities deemed important to local communities that impede the natural functioning of cloud forest. These include: the extension of cattle or sheep grazing and of subsistence and commercial agriculture into higher elevations; commercial logging[7] and wood harvesting in higher elevations; exploitation of nonwood forest products (such as orchid collecting); hunting for sport, subsistence, or commercial trade; clearing for legal or illegal drug plant production; anthropogenic fire (in regions with a dry season); introduced (alien) plants and animals; mining and geothermal development; telecommunication facilities and media transmitting stations; and tourism and recreation (Hamilton et al. 1995b). In the Caribbean, the human activities threatening the ecological functions of cloud forest are telecommunication facilities and ecotourism, and to a much less and now declining extent, shifting cultivation. Media transmitting stations are usually located on hills and summits, areas that coincide with cloud forest on mountainous Caribbean islands. Even though these sites might be relatively small in actual space occupied, the intensive construction required and the frequent access needed for maintenance create impacts beyond their actual location (Hamilton et al. 1995b). Oil seepage has been a reported problem at many telecommunication sites (Hamilton et al. 1995b). Ecotourism brings problems of trails and tracks, litter, taking of plant and animal souvenirs, introduction of alien species, demand for firewood, and general

[7]Commercial logging is not a threat in most cloud forest, as the trees are too crooked and small to be of much commercial value and accessibility is difficult (Hamilton et al. 1995). However, in boundary areas with montane rain forest, some timber extraction is occurring, and roads associated with logging have permitted other interventions (Hamilton et al. 1995b).

deterioration of a delicate environment[8] (Hamilton et al. 1995b). In areas of high population pressure (like Haiti), the fallow periods allowed by shifting cultivation mau be far too short to allow for forest regeneration.

While all of the activities listed above may be considered crucial to a community's way of life or mere existence, fresh water is undeniably an essential resource as well. These necessary, yet consumptive, uses can have also detrimental effects on cloud forest. Water management tactics, most notably clear-cutting in an effort to increase runoff, have often resulted in the elimination of all or portions of a catchment's vegetative cover. Clear-cutting is practiced, in some places, based upon data that show clearing of cover results in an increase in streamflow (Zadroga 1981). The largest increases in streamflow usually occur in the dry season just after felling; thus the increase in water yield is presumably due to the availability of water that would normally be involved in the evapotranspiration process (Zadroga 1981). But in the tropics, if the forest in question is a cloud forest, deforestation may result in a substantial decrease in overall water yield, because vegetative cover in cloud forest increases water input by capturing cloud droplets. Meanwhile, very little water is lost through evapotranspiration, as explained earlier. Water management practices, or policies concerning the use of cloud forest for other activities, need to be based on

[8]As will be discussed in Chapter 4, telecommunication sites and ecotourism are also in direct conflict with each other. High voltage areas can be dangerous to tourists. Both telecommunications facilities and media transmitting stations create what some consider a visual blight on the landscape.

what is now known about cloud forest's hydrological role.

Changes in water yields will differ before and after clearing according to the relative magnitude of HP and evapotranspiration associated with the original cover. Total water yields may not decrease very much, depending in large part on the new cover, but the seasonal water yield may be dramatically altered. Erosion during the first years following clearing also constitutes a major concern, as topsoil is washed away and the infiltration and water-holding capacities of soil possibly degraded (Bruijnzeel and Proctor 1995). Understanding the questions surrounding the hydrological consequences of cloud forest loss is one of the most important challenges facing hydrologists working in cloud forest. Communities faced with making policies regarding cloud forest use will certainly be interested in these hydrologic consequences.

Harr's (1982) study in the frequently cloud covered coast of Oregon specifically addresses the question of cloud forest clearing and its hydrologic consequences. Although the study site is not a tropical cloud forest, it is pertinent to cloud forest hydrology and has been cited in cloud forest literature (Bruijnzeel and Proctor 1995). Harr (1982) investigated the results of logging in several watersheds where the predominant cover is redwood forest. Measurements of throughfall resulted in percentages of groundwater addition similar to those found in tropical cloud forest and attributed to HP (Harr 1982). Harr's (1982) analysis of summer stream flow data indicated a 20 mm (0.79 in) decrease in annual water yield in two Oregon watersheds that had experienced a 25 percent decrease in forest cover from patchwork-style logging. A streamflow increase of 100 mm to 150 mm (3.93 in to 5.90 in) had been expected due to reduced evapotranspiration when the vegetation was lost (Harr 1982). Harr's (1982) throughfall measurements beneath the forest canopy suggested that lost fog capture in the logged areas could have added up to 882 mm (34.72 in) of water yield annually to the watersheds via groundwater and stream flow. A follow up study by Harr (1985) suggested that after a five to six year period of regrowth, there was a recovery in water yield, possibly from renewed fog capture provided by the regrown vegetation. After five to six years, the taller redwoods had been succeeded by smaller trees, shrubs, and herbaceous cover with a high proportion of foliar surfaces, and these plants probably intercepted significant amounts of water (Harr 1985). Despite the location of this study in a temperate zone, the plausibility for cloud forest rejuvenation is unknown. Few experimental studies in tropical zones have been undertaken and observations have been limited because of the novelty of the subject.

Vogelmann (1973) reflected on the question of potential regrowth of cloud forest. Forests adjacent to his cloud forest study site in Sierra Madre Oriental, Mexico, were cleared for cultivation long ago, perhaps hundreds or thousands of years prior to his study (Vogelmann 1973). Vogelmann (1973) hypothesized that this clearing may have contributed to the semiarid conditions of the adjoining forests which prevail today. Elimination of fog-intercepting trees may have deprived the region of a substantial amount of water and, coupled with dry seasons, prevented the regrowth of cloud forest vegetation (Vogelmann 1973). Vogelmann (1973) recounts coming across places where a single tree stood, water dripping off the leaves, creating a circle of dampness at the tree's base, dampness that did not extend into the surrounding soil. Vogelmann's (1973) observations suggest that regrowth may be extremely difficult after vegetation loss, not only from cloud forest, but from other forests as well. One can hypothesis that this is a result of lack of water, low insolation, increased exposure to winds, and little material for re-seeding because all sources are downslope. Regardless, lack of timely regrowth in cloud forest is yet another consideration in any management decision concerning cloud forest use.

A review of the scientific knowledge surrounding cloud forest is the first step in forming a holistic management plan for a specific cloud forest. That review has been covered in this chapter. Next, a physical investigation into the local cloud forest is needed. That investigation is followed ideally by an assessment and prioritizing of the community's needs. Then, a rational and beneficial policy regarding cloud forest use can begin to take shape from these multiple sources of information. In this thesis, that local cloud forest is on Chances Peak, Montserrat, and the people who will formulate the strategy for its holistic management are the inhabitants of Montserrat.

CHAPTER 3

CHANCES PEAK, MONTSERRAT

Ideally, ecosystem management integrates scientific knowledge of ecological relationships within a social and political framework. The aim is to provide for the general good of that ecosystem and the society related to it. Such an ideal management system entails the gathering of scientific data pertaining to the physical aspects of a space to support or refute policy ideas, and facilitate informed decisions. My first task in Montserrat, in the summer of 1994, was to observe the physical workings of the cloud forest on Chances Peak and to gain insight on what the physical repercussions of disturbance might or might not be. This initial research is then placed in the social context of Montserrat. My research emphasis was hydrological. To fully inform the management process, other studies on Chances Peak could be helpful, such as a flora and fauna species inventory. Such studies were not within the scope of my research.

The Power Of a Mountain

I arrived in Montserrat on May 17, 1994, eager and excited about many things, one of which was the opportunity to explore a mountain. After searching for Chances Peak from my plane window to no avail (we had not crossed over the island), I climbed into a taxi driven by one "Mr. Nice," as he insisted on being called. As he drove along a winding road from Bramble's Airport, on the northeast side of the island, to my lodging, Marie's Guest House, on the west side, he delighted in pointing out local landmarks and informing me about the island's activities, offering to be my guide and driver on any excursion I might undertake. He seemingly knew everything about the island. At the first opportunity, I asked him about Chances Peak. He pointed up. Peering out the window, I saw the tallest peak on the island stretching upwards. Immediately, I noticed two structures, giant antennas, bright red, at the crest of the highest ridge. "Where are the clouds?" I pondered aloud. "Oh, it's unusually clear up there today," Mr. Nice answered, "but it gets cloudy. Then you can't see the top. If you want a view of the whole island, you can climb up there. But only if it's not cloudy. I can take you up there, maybe." (personal communication, May 1994).

As we drove on, I realized that from almost any spot on the south end of the island, Chances Peak dominates the landscape (Figure 3-1). Montserratians associate with the mountain at different levels, some simply aware of it as the backdrop against which their lives are played out. Others are tied to it more personally, perhaps having a garden on its gentle lower slopes. A few have actually hiked its upper slopes. I woke up almost every morning for the next three months consciously aware of whether there were clouds covering the top of the mountain or if the sun was shining brightly on it. I also learned that often reverence and pride are stirred when the mountain is

Figure 3-1. Chances Peak, rising 914 m, is the highest point on Montserrat and dominates the landscape in the southern third of the island. On most days, the peak is covered with a cloud cap.

Source: Newton, E.C. 1994.

mentioned.

As in any society, special places are often represented by a story or legend. Chances Peak is no different. Its legend involves a mermaid that lives in Chances Pond on top of the mountain. As told to me, she spends her days sunning and combing her hair with beautiful combs; meanwhile her person is protected by a snake. If someone takes her combs, runs down the mountain and then dips them into the sea, without being caught by the snake, that person will receive her treasure. I wondered what might constitute her treasure for someone with my set of interests and sensitivities.

My first trip up the mountain was an organized hike led by Drs. Lydia Pulsipher and Carol Harden of the University of Tennessee. The hike included classmates from Tennessee, members of the local Osborne family, and Gerard Gray, Chief Forestry Officer of the Montserrat Ministry of Agriculture, Trade, and the Environment. It was useful to me that my first outing on the mountain occurred in this setting, as the varied curiosities of the group helped me sense why tourists might want to climb Chances Peak.

The group set out from Marie's Guest House, just north of the capital, Plymouth, and drove through the city to the south side of the island. We passed through several villages south of Plymouth, which hugged the coast, turned inland at Kinsale, and slowly began to climb upwards from the sea (see Figure 1-2). The landscape changed from bustling centers of human activity to clusters of cows and goats grazing on low shrubs, with a few houses scattered about. It felt hot and dry and the countryside was brown with specks of green cactus and scrubby bushes. The dusty surroundings were at odds with the Caribbean Sea, which was still in view. The road became narrower and much steeper, straining our van, as we scraped overhanging tree branches now lining our path. Soon, there were no houses or animals, save one small place of corrugated metal with a garden out front that rivaled the most productive greenhouse I've ever seen. Then the road ended near a grove of tall trees. We pulled onto a small patch of pavement, not a parking lot, but enough space to place several vehicles. Where the air had just been sweltering, now it was much cooler, evidence we had entered the fringes of moist forest. I estimated we were about halfway up the mountain (450 m/1500 ft), on the west-south-west side, and I noticed for the first time since arriving at the southern end of the island, that I could not see the top of Chances Peak.

A large sign placed at a trail head welcomed us to Chances Mountain. This sign, emblazoned with the logos of Cable and Wireless and Montserrat National Trust, as well as drawings of the Montserrat oriole and heliconia, explained the code of conduct for visitors, and can be seen on the following page.

We all took a deep breath and began our march up the mountain. The trail consisted of steps, cut into the mountain and shaped by various sized boards pounded vertically into the dirt. Some of the boards were thick, like railroad ties, and some

WELCOME TO CHANCES MOUNTAIN

THIS TRAIL, RISING 3002 FEET IS SURROUNDED BY TROPICAL WILDLIFE SUCH AS OUR NATIONAL FLOWER, THE HELICONIA AND NATIONAL BIRD, THE ORIOLE WHICH CAN BE SEEN IN ITS NATURAL HABITAT.

ACCORDING TO THE LEGEND, A MERMAID LIVES IN A POND AT THE SUMMIT AND ANYONE WHO GETS POSSESSION OF HER COMBS, WILL BECOME RICH.

CODE OF CONDUCT

ENJOY AND RESPECT THE ENVIRONMENT
TAKE YOUR LITTER HOME
MAKE NO UNNECESSARY NOISE
EXERCISE EXTREME CAUTION

PROTECT WILDLIFE, PLANTS AND TREES
NO HUNTING
AVOID LIGHTING FIRES
NO LIVESTOCK PERMITTED

THE 2000 STEPS AND VIEWING PLATFORMS LEADING TO CHANCES PEAK WERE INSTALLED AND COMPLETED 13TH APRIL, 1992 BY CABLE AND WIRELESS TO PROVIDE BETTER ACCESS TO THE MICROWAVE STATION. HIKERS ARE WARNED THAT THEY CLIMB THIS TRAIL AT THEIR OWN RISK. PROCEED WITH CAUTION.

were as thin as plywood. The trail was wide, with a gentle incline at first, but at times it would narrow and become so steep that our movements were literally the same as climbing a ladder (Figure 3-2). It was a vigorous climb. At three intervals along the trail were platforms, for viewing wildlife, foliage, and to simply rest. Carol Osborne told me that some residents reportedly use the climb as exercise, although Gerard Gray doubted the practice was widespread [1] (personal communication, May 1994). Based upon the experience of our group, and other hikes I took, the average ecotourist would want to set aside at least three hours for a hike up and down the mountain. Many tourists would want to take the hike twice, once on a cloudy day, and again on a clear day, to experience both the mist and the view.

Hiking the upper 450m (1500 ft) of Chances Mountain, we traveled through three vegetation types, Lower Montane Rain Forest, Rain Forest, and Cloud Forest. These lush, dense forests came to us in a vertical line, giving the idea that if one were to draw concentric rings around the mountain, three stacked sections of vegetation would appear, much like Beard's idealized transect of Caribbean islands (see Figure 2-3). In truth, this general pattern does occur on the mountain, but the zones undulate in and out of steep ghauts (ravines) that flank the sides, and the pattern depends upon angle and orientation of slope, wind patterns, and variable rainfall.

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[1] I met one woman who used the trail for exercise. She hiked a portion of it each Sunday morning. An athletic friend, Henderson "Quincy" Davis, scurried up the trail in eighteen minutes, and pondered using it as a training regimen.

Figure 3-2. The author on her first climb to Chances Peak in 1994, seen here in secondary rain forest. The trail was constructed and is maintained by Cable and Wireless. Employees of the company use the trail, as well as tourists and some locals.

Source: Manos, L. 1994.

Typical of mountainous island profiles, as we hiked higher in elevation, trees became smaller in stature and girth, leaves were thicker and xeromorphic, stem density increased, and the appearance of trees with buttressed roots was more common. Even the animals shrank in size. "Mountain chickens," very large frogs found in the rain forest, were replaced by tiny frogs the size of a thumb. The air grew damper, cooler. The cloud forest must be close, I thought, as the path flattened a bit and curved. Suddenly, we gaped at our view, or lack of view. I knew I was in the cloud forest. We stood on a small peak, surrounded by mist sweeping across the top of the mountain, causing the trees to lean to one side and the air to feel wet against our skin (Figure 3-3). It was quite unlike anything I had ever seen. In the middle of this vista, fenced off, stood a "tower", a telecommunications structure belonging to the utilities company Cable and Wireless. On this first visit, I did not notice the other structure I knew to be on the mountain, an antenna owned by Antilles Television. The Cable and Wireless tower did seem out of place, but it could not detract from my awe and curiosity and so I ventured forth into the heart of the forest. The following account is a composite of notes taken on my first two visits to Chances Peak.

Vegetation Notes from Chances Peak

The canopy stretched upwards 3.5 m (12 ft) to 4 m (16ft) above the ground, primarily composed of two tree types, palms and hardwoods with jagged leaves, both

Figure 3-3. Entering the cloud forest on Chances Peak, Montserrat, visitors find themselves in an ethereal world of mist and wind-swept trees.

Source: Newton, E.C. 1994.

having slender trunks and many having buttress roots. Large ferns and philodendrons, 1 m (4 ft) to 2 m (6 ft) in height, filled the mid-section of the forest. Undergrowth consisted of seedlings, mats of moss, and filmy ferns. I was struck by the amount of moss in the forest - it covered the trunks and leaves of every tree and much of the forest floor. I estimated coverage to be 80 to 100 percent of the entire forest surface, ground and foliage, with 95 percent of the tree trunks having some moss on them. Forty to 60 percent of the leaves had some moss, with those leaves having about 40 percent of their leaf surface covered. These leaves were not as thick as leaves I had seen at lower elevations, or in other Caribbean cloud forest. This may indicate relatively new growth as a result of vegetation loss due to Hurricane Hugo in 1989. Dead branches and sheared trunks, probably a result of Hurricane Hugo, were also covered with moss. It seemed as if the only things holding them up were moss and other epiphytes, as they toppled easily when leaned against. Epiphytes other than moss were abundant, including impressive large vines, orchids, and lichens[2]. Approximately 40 percent of suitable host surfaces had some coverage. Up to 20 percent of a tree trunk carried epiphytes, usually at the base, while sheared trunks were almost completely covered. The variety of flora gave the forest an impressive array of colors: shiny greens, and bursts of purples, blues, whites, yellows, oranges, and reds emanated from various flowers and berries, including the heliconia. Bats and

[2]Epiphytes grow on other plants, but are not parasitic.

birds feed on such plants. On my visits to the cloud forest, I encountered birds, including the Montserrat oriole, one bat, small gray snakes, tiny frogs, and spiders whose intricate webs were bejeweled by the mist. A list of known plant species found in the cloud forest on Chances Peak is located in Appendix 1. It is clear, from my observations, that the floristic properties found on Chances Peak qualify the area as cloud forest, based on floristic properties of cloud forest reported in literature.

The cloud forest is an experience anyone's senses would appreciate. A colleague, Leah Manos, in Montserrat to do research on waste management, actually thanked me for choosing to investigate the cloud forest, because it gave her the opportunity to see such a unique environment (personal communication, May 1994). The title of this thesis came from a native Montserratian friend's reaction when he climbed the mountain for the first time (Ederson "Tyre" Daly, personal communication, May 1994). I know what my treasure from the mermaid was. And as much as one may want to protect the cloud forest's fragile and delicate treasures and therefore limit human visits, it is an experience worth sharing.

Edge Vegetation

As a researcher, one particular type of vegetation caught my eye. In my notes, I call it "fern fringe", because it consists solely of the waist-high fern, *Blechnum occidentale L.*, growing on the margin of the forest (Figure 3-4) (Howard 1999). This

Figure 3-4. Edge vegetation located between a cleared patch and cloud forest on Chances Peak, Montserrat. Although ferns are found under the forest canopy, the waist-high fern shown above, *Blechnum occidentale L.*, grows only in this zone.

Source: Newton, E.C. 1994.

variety of fern is not found in the heart of the forest. The most extensive area of "fern fringe" occurs on the east side of the cleared area that houses the Cable and Wireless tower. From the outside of the fence that encloses the area to the edge of the forest, 5.5 m (18 ft), nothing grows but *Blechnum occidentale L.* Sunlight, wind, and direct rain are more prevalent here, compared to areas protected by the canopy. Richard Howard (1999), a botanist who has done extensive research on Montserrat, has found that *Blechnum occidentale L.* not only fills edges, but all bare surfaces on Chances Peak, leading him to believe that bare soil surfaces, not an opening of the canopy, are responsible for the fern's dominance in cleared areas. This observation by Howard strongly suggests the fern has filled in the bare ground created in the Cable and Wireless tower construction phase. Whether the fern takes hold in forest where the canopy is disturbed, and hence open, or only where the soil is laid bare, *Blechnum occidentale L.* is definitely an invasive pioneer.

The alteration of vegetation at sharp transitions between natural and anthropogenic habitats, such as the growth of ferns between the Cable and Wireless fence and the cloud forest, is known as "edge effect" (Murcia 1993). Edge effect is a concern because forest-interior species may be unable to effectively overcome competition from edge species (Yahner 1988). Modification of the distribution and dispersal of forest plants affects the habitats of forest fauna (Yahner 1988, Hickman 1990). Nature trails, a part of most ecotourist development plans, including those on

Montserrat, have been shown to create corridors of edge habitat (Hickman 1990). Murcia (1993) specifically studied edge effects on the pollination of tropical cloud forest plants, but with no conclusive results. In the cloud forest on Chances Peak, however, flora has definitely changed where an edge has been created.

Another floristic anomaly appeared only on steel surfaces. A brown felt-like growth, which I assume was moss or mold, covered part of the fence that encloses the Cable and Wireless tower and the base of the Antilles Television antenna. I looked for this growth on trees and plants, but did not see it anywhere except on these structures. This growth does not qualify as edge vegetation per se, but is of concern because it may be an unnatural addition to the forest.

Area of the Cloud Forest and Clearings

One goal I had in researching the cloud forest on Montserrat was to estimate the extent of its area on the island, and how much of it had been cleared for telecommunication facilities and media transmitting stations. It is impossible to traverse the entire peak of Chances Mountain because of its steepness and density of plant stems, therefore, the best method for calculating area is to ascertain the elevation at which relatively continual mist and cloud forest vegetation begin, and then use topographic maps to compute area. However, a vegetational zone does not begin at a given point or line, rather a transitional zone exists. On Montserrat, the deep ghauts into which fingers of a vegetative type may protrude downward must also be considered. Generalized maps from past studies on Montserrat show cloud forest on Chances Peak and in the Centre Hills, putting its lower elevation at 610 m (2000 ft) to 700 m (2300 ft) (Butler 1991; Island Resources Foundation 1993). It is not clear if these often cited authors actually measured the beginnings of the cloud forest or what criteria they used. In St. Lucia, Michael Bobb, a forester, asserts that cloud forest on Mt. Gimie begins at these same elevations, confirming my observation of cloud forest on St. Lucia's Piton Flore (personal communication, June 1994). Though I saw signs of cloud forest vegetation at these elevations on Montserrat, I did not observe forest that was completely cloud forest below 791 m (2600 ft). Gerard Gray (1994), Chief Forestry Officer in Montserrat, agreed with this elevation. Different observations concerning elevation may indicate shrinkage of the cloud forest over time. I am conservative in my calculations for Montserrat, choosing to only include areas that definitely contain cloud forest vegetation and that are frequently covered in mist, and I readily admit the area could be larger.

I have only included the area above 791 m (2600 ft) on Chances Peak in my area calculations. I have not included any area in the Centre Hills because Gerard Gray (1994) and Lydia Pulsipher both stated they had not seen cloud forest in the Centre Hills in recent years (Lydia Pulsipher, personal communication, May 1994). Roches Mountain, a neighboring peak in the Soufriere Hills, rises to an elevation of 824 m

(2700 ft), and thus has the potential for cloud forest. I never went to the top of Roches Mountain, though from a distance I did see tell-tale wind swept trees. In the absence of confirmed evidence of the development of cloud forest, Roches Mountain is not included in my calculation for cloud forest area.

Using a starting elevation of 791 m (2600 ft), and an average slope of 22 percent, taken from measurements on the peak and topograpic maps, cloud forest area is calculated to cover 100.8 ha (248.90 acres), approximately one percent of the island. Again, this is a conservative estimate. One must consider map scale and errors in the maps used, treatment of the surface as planar, and treatment of the area as a singular peak[3] (a cone). All of these factors contribute to the possibility that there is actually more surface area than the stated total on which vegetation may grow, vegetation that traps fog[4].

There are six areas on Chances Peak that have been cleared for telecommunication facilities and media transmitting stations. These include: a fenced area containing the Cable and Wireless tower, the trail surrounding the Cable and Wireless fenced area, a cable car landing used in the construction of the Cable and Wireless tower, the trail to the Antilles Television antenna, a building adjacent to the

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[3]Chances Peak actually consists of two peaks, a large central peak and a smaller peak, causing the top of the mountain to be shaped like a saddle. There is also a sheer cliff on the east side of the mountain.

[4]Chances Pond, within the cloud forest, is an area where vegetation does not grow. I was not able to quantify its area, as estimates of its size varied greatly. It is less than 0.1 ha (0.25 acres).

Antilles Televison antenna, and the main trail leading to the peak, which was cut by Cable and Wireless and is used by their maintenance workers and tourists. Figure 3-5 provides a overview of the relationship of these areas to one another in terms of size and spatial location on the peak. Characteristics of these areas will be discussed in detail later. Linear measurements of the borders of each area were taken by hand using a tape measure. Total area cleared is 0.578 ha (1.43 acres). This totals two percent of the cloud forest area. Although these structures and trails have opened up prime cloud forest zones, this total is a small percentage. The existence of these clearings provided an opportunity to study the benefits and environmental consequences of small cloud forest patterns. The results of such studies could have been used by Montserrat to decide on regulations concerning future clearing had not subsequent volcanic activity occurred.

Structures on Chances Peak

There are two main structures on Chances Peak, each with supporting structures. The Cable and Wireless tower is a telecommunications facility. The other structure is a media transmitting station owned by Antilles Television.

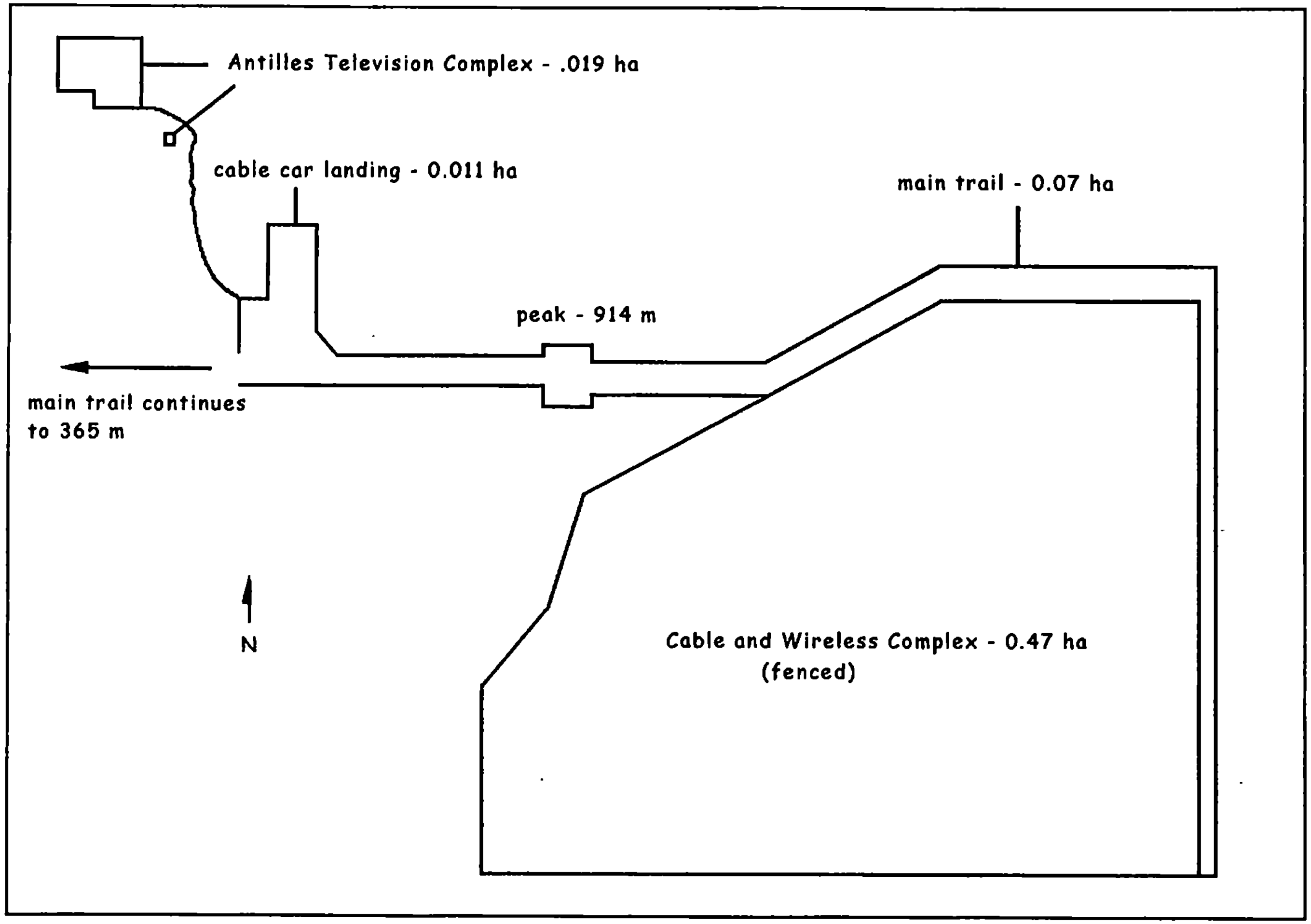

Figure 3-5. Layout of areas cleared for telecommunication facilities and media transmitting stations on Chances Peak, Montserrat. Total area cleared is 0.57 ha or almost two percent of the cloud forest. The average slope is 22 percent. Measurements taken by the author.

The Cable and Wireless Tower

The Cable and Wireless tower stands 65 m (213.2 ft), and carries seven satellite dishes (Figure 3-6) (Riley 1994). The tower's official name is "Digital East Caribbean Microwave Station" and it links telecommunications throughout the eastern Caribbean (White 1994). Surveying on the project began in 1987, and actual clearing for construction began in November 1988 (Riley 1994). Construction was difficult because of the steep terrain and inclement weather, and days had to be "chosen" because, as Clifton Riley (1994), Manager of Engineering for Cable and Wireless stated, "...sometimes up there it is so foggy." The work was contracted out to a local company of 20 men, who, in order to travel up the mountain, widened an existing footpath and built 2000 steps, creating what is now the main trail on Chances Peak (Riley 1994). Materials were transported up the mountain on this trail and in a pre-existing cable car (Riley 1994; White 1994). The cable car was later used for carrying diesel fuel to run the generators, until electrical cables were installed in 1992, taking advantage of a new domestic power plant to make the system electrical (Riley 1994; White 1994; Garcia 1994). Occasionally, a helicopter was flown up to the peak, hovering to take photographs (Thomas 1994). At one point, Cable and Wireless considered laying a road to the top of the peak, but that idea met with opposition (White 1994). Lights, similar to those one might see lining a driveway in the United States, were installed along the length of the trail, but are only turned on in

Figure 3-6. The Cable and Wireless tower sits enveloped in clouds on Chances Peak, Montserrat. Rising 65 m above cloud forest, the tower supports seven satellite dishes and provides telecommunication services to the island.

Source: Newton, E.C. 1994.

emergencies because of resistance to their possible interference with visibility of the night sky by island residents and tourists (Riley 1994). Excavated dirt from the construction site was temporarily placed in Chances Pond and then returned to the site for leveling (Riley 1994; Skeet 1994). The tower became operational in 1989[5] (Riley 1994; White 1994).

Support structures associated with the Cable and Wireless tower include a building, which houses a generator and a toilet, a septic tank buried under a concrete slab, and a stand-by oil drum to run the generator in emergencies (Riley 1994). Oil is stored in the building as well, and has spilled on the ground[6]. There is a chain-link fence surrounding the structures to keep unauthorized people out. The entire complex occupies an area of 0.475 ha (1.17 acres). Maintenance of the facility is carried out by four men, Bernard French and Adolfus Morgan, workers who hike to the peak at least three times a week, and Williams Weekes and Cecil Tuitt, supervisors who check the generator once a week (Riley 1994). French and Morgan's primary responsibilities are to maintain the main trail by cutting back vegetation to one foot on each side (using a string trimmer, which leaves fragments of plastic scattered on the trail), keeping the area inside the fence manicured, and making sure the entire area is clean and free from

[5]Amazingly, the tower only lost two dishes during Hurricane Hugo in 1989, when winds on the peak were estimated at 200 mph. It was discovered that the two dishes were of faulty design, thus testifying to the strength of the tower's design (Riley 1994).

[6]Oil seepage from support structures related to telecommunication facilities and media transmitting stations is a noted problem in many cloud forest sites (Hamilton et al. 1995).

debris (Riley 1994; Bernard French and Adolphus Morgan, personal communication, June 1994). The area inside the fence is quite large and French and Morgan have been granted permission to grow provisions there (Riley 1994). They have planted a small garden with dasheen and banana trees. It is doubtful that these plants pose a danger as invasive species, as the garden is kept neat and tidy, and any wayward flora are immediately destroyed. There are also wild strawberries growing inside the fence, but the men do not partake of these (Bernard French and Adolphus Morgan, personal communication, June 1994). Palms are left growing for aesthetic reasons (Bernard French and Adolphus Morgan, personal communication, June 1994). Most of the area is covered with short grass that is mowed bi-weekly (Bernard French and Adolphus Morgan, personal communication, June 1994).

The Antilles Televison Antenna

The other main structure on Chances Peak, the Antilles Television antenna, was installed in 1985 (Osborne 1994). It was used to pick up broadcasts from the Leeward Islands and the Windward Islands as far south as Dominica, until it was damaged during Hurricane Hugo (Osborne 1994). Following the hurricane, the company offered the antenna and the station equipment to the Montserrat government, but plans fell through, and today the antenna transmits FM radio[7] (Osborne 1994). The antenna is a diamond shaped structure, measuring one square meter at its base, and is adjacent to a small building housing a generator (Figure 3-7). The building occupies a space of 0.007 ha (0.02 acres). There is no fence surrounding the property. I thought the structures had been abandoned because the area is overgrown with vegetation and the trail leading to the site is barely one meter (3.3 ft) wide. This limited impact is deliberate, at the insistence of Mr. Comminges, the Swiss owner of Antilles Television, and a self-proclaimed conservationist (Osborne 1994). Workers involved in construction of the antenna and building arrived at the site by forging a footpath up the mountain, the predecessor to the main trail, but did not carry materials up the path (Osborne 1994). Instead, Antilles Television built the aforementioned cable car to transport materials to the site (Osborne 1994).

Hydrologic Research on Chances Peak

One objective of my research was to examine the hydrological properties of Chances Peak as it relates to groundwater supply. The cleared areas, in particular the mowed area immediately surrounding the Cable and Wireless tower, provided the opportunity to compare a formerly forested area to the forest complex. Specifically,

[7] Antilles TV had planned to begin re-broadcasting in 1994 or 1995, but volcanic activity prevented this.

Figure 3-7. The base of the Antilles Television antenna on Chances Peak, Montserrat, measures one square meter. The massive antenna was originally used for intercepting television signals emanating from other islands in the Lesser Antilles. Today it is used for transmitting FM radio.

Source: Davis, H.Q. 1994.

I studied the ramifications of cutting down vegetation in terms of lost horizontal precipitation (HP), soil density and penetrability, and the ability of the soil to hold water. I also determined the actual water content of the soil on Chances Peak.

Horizontal Precipitation (HP)

HP, as discussed in Chapter Two, occurs when fog or mist is forced to form drops when it collides with vegetation. My pretense for examining this aspect of the cloud forest is twofold; I want to establish that HP occurs on Chances Peak and I want to deduce what the consequences are when vegetation is removed in terms of lost groundwater supply. To gain insight into the quantity of HP affecting Chances Peak, I assembled a fog catcher out of a rain gauge and installed it next to a plain rain gauge for comparison. For the fog catcher, galvanized wire mesh was rolled up three times and tucked into the gauge, rising 60 mm above the gauge. The wire mesh simulates vegetation by providing finely divided surfaces on which fog or mist forms drops. The condensation then trickles down the mesh into the gauge, much as water droplets would trickle down a tree trunk or plant stem. The fog catcher catches both HP and ordinary rainfall (OR). The other gauge, without wire mesh, catches only OR. Each gauge measures collected water to 130 mm. This simple design is meant only to expose basic hydrological activities. A more accurate design would take into account type of vegetation, amount of cover, height of canopy and variables such as temperature, wind speed, dew point, etc. Unfortunately, such a fog-catching device has yet to be invented.

Data were collected at two sites. Figure 3-8 shows the relationship of these sites to each other and the forest. At the fence site, a pair of gauges was placed on the north side of the fence surrounding the Cable and Wireless tower at a height of 1.5 m (5 ft). The site was located approximately 60 m (200 ft) downslope from the peak of the mountain, where it was protected from the strongest winds. At the peak site, a pair of gauges was nailed into the ground at the edge of the main trail as it crests the peak. Table 3-1 shows the amount of HP measured over various lengths of time (0.5 days to 21 days), and HP expressed as percent of OR. Expressing HP in this manner is standard in cloud forest literature (see Chapter 2). On two occasions, expressing HP as percent of OR was not possible because OR was zero.

The measurements taken from each gauge at each site were drastically different. At the fence site during time period B (4 days), 2 mm of rain were measured in the OR gauge. In contrast, the adjacent fog catcher contained 104 mm. The excess water could only have come from HP. When one considers the amount of HP an entire forest could produce, especially with a deep vegetative canopy, values are staggering. Over long periods of time, as more rain falls, the relative contribution of HP as percent of OR decreases. However, a total increase in available water of 382 percent over 51 days, at the fence site, is still remarkable.

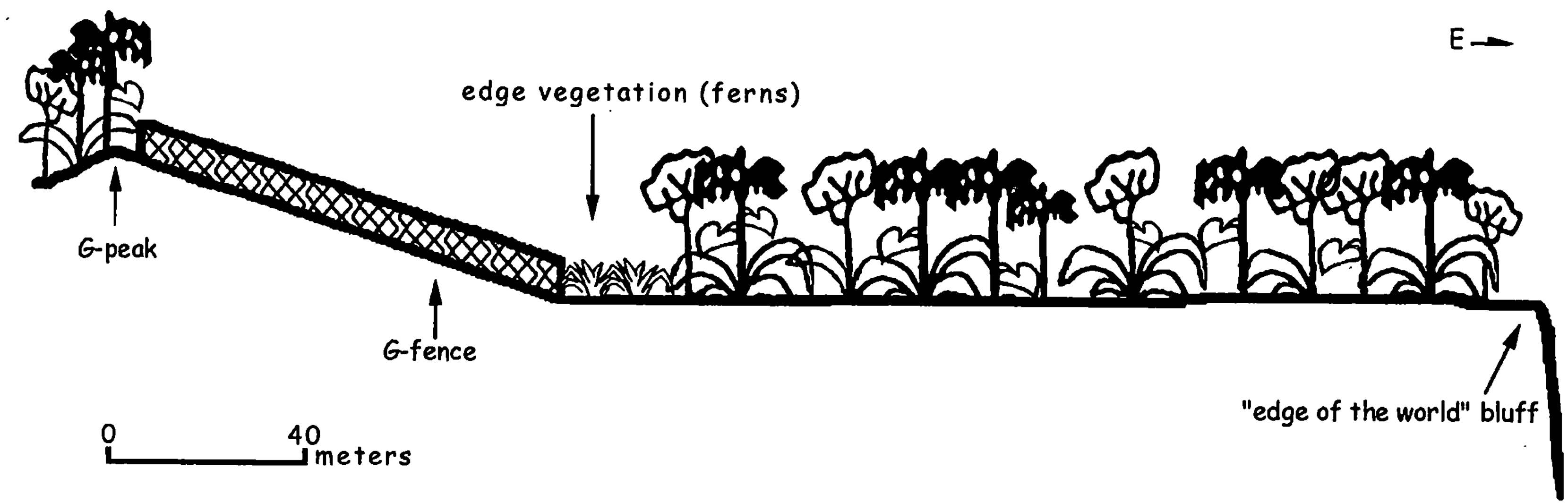

Figure 3-8. Profile view of Chances Peak, Montserrat, indicating slope and location of rain gauges used to determine horizontal precipitation. Two gauges were placed at each location, on the fence surrounding the Cable and Wireless property and on the peak. One gauge collected horizontal precipitation and rain. The other gauge collected only rain. G=gauges.

Table 3-1. Measurements of horizontal precipitation (HP) in cloud forest on Chances Peak using fog catchers. Measurements taken during the dry season. OR-ordinary rain

site	days elapsed	OR mm/day	HP mm/d	HP % of OR
Fence[1]:				
5/21 - 5/27	6	5.8	100.2	1728
5/27 - 5/31	4	2	102	5100
5/31 - 6/4	4	2	128[3]	6400
6/4 - 6/11	7	20	110[3]	550
6/11 - 6/11	.5 (9 hrs)	0.5	1.95	390
6/11 - 6/26	15	88	42[3]	48
6/26 - 7/7	11	58	72[3]	124
7/7 - 7/10	3	5	125[3]	2500
7/10 - 7/10	.5 (3 hrs)	0.0	11	n/a[4]
total for site	51	181.3	692.15	382% (mean)
Peak[2]:				
5/27 - 5/31	4	1	20	2000
5/31 - 6/4	4	0.5	12	2400
6/4 - 6/11	7	19	22	116
6/11 - 6/11	.5 (9 hrs)	0.0	2	n/a[4]
6/11 - 6/24	13	22	53	241
6/24 - 6/26	2	20	30	150
6/26 - 7/7	11	60	70[3]	117
7/7 - 7/10	3	4	29	725
total for site	45	126.5	238	188% (mean)

[1] The fenced site represents measurements taken at a height of 1.5 m.
[2] The peak site represents measurements taken at ground level but exposed to high winds.
[3] The fog-catching gauge was overflowing, so HP may be greater.
[4] Calculations were not available for percent of OR as OR for this period was zero.

Three observations and several deductions can be made from these results. First, HP does occur on Chances Peak and does provide water that can potentially become part of the soil and groundwater. Because HP requires certain types of leaf surfaces (or surrogates) to be caught, removing forest vegetation would greatly decrease the potential for this source of moisture for the island. Since the captured water can infiltrate the soil and contribute to soil moisture and groundwater supplies, removing this moisture source would make less water available on island.

Second, my measurements were taken during the dry season on Montserrat (June), when rainfall is lower than at other times of the year. Hence, we now know that HP on Chances Peak occurs in measurable quantities during the dry season. HP captured during the dry season is especially significant because it can recharge soil and groundwater reservoirs when they are at their driest.

Third, as seen in Table 3-1, the fence site gauges captured more water than the peak site gauges. The gauges at the peak were exposed to stronger winds, even though they were at ground level. The wind on the peak may have prevented OR from falling vertically into the gauges. The lower values for HP may suggest that some certain circumstances of height and wind are needed to effectively capture fog or HP.

Soil Penetrability

The amount of HP produced is not beneficial as groundwater supply unless it is able to penetrate the surface of the ground and infiltrate downward. One method of examining soil penetrability involves using a cone penetrometer, a waist-high device that is pushed into the ground to a standard depth, in this case, 22 cm (10 in). Readings, representing resistance, are expressed as kg/cm^2 and converted to a strength value using a standard formula (Terzaghi and Peck 1948; Brainard-Kilman 1994). Strength values for the type of soil on Chances Peak, a clayey silt[8], are expressed as ranges, noting the variables of the soil. Strength values, known as unconfined compression, hve been categorized as very soft, soft, medium, stiff, very stiff, and extremely stiff (Terzaghi and Peck 1948). Softer soils are more apt to allow the infiltration of water (Terzaghi and Peck 1948).

I examined soil penetrability at three locations, one in the forest complex, one in edge vegetation, and one on short mowed grass. Site one, the forest zone, was located approximately 65.1 m (214 ft) into the forest and 1.7 m (5.6 ft) from a little used footpath. Site two, the transitional zone, was located 5 m (16.5 ft) from the east side of the Cable and Wireless fence in edge vegetation bordering the forest. Site three, the cleared zone, was located inside the Cable and Wireless fence. Figure 3-9

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[8]Lang classifies (1967) the soil on Chances Peak as English's humic silt, although there is some confusion in his report as he refers to the same soil as a "loose, freely drained sand" (Lang 1967). My field tests confirm that soils sampled were clayey silt.

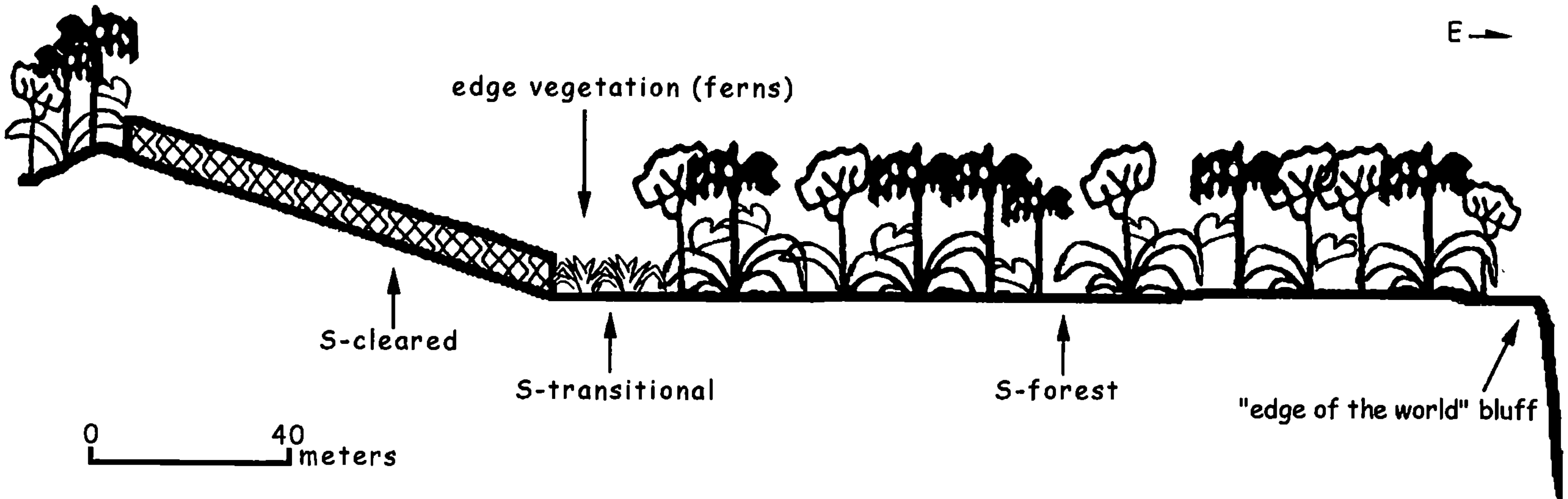
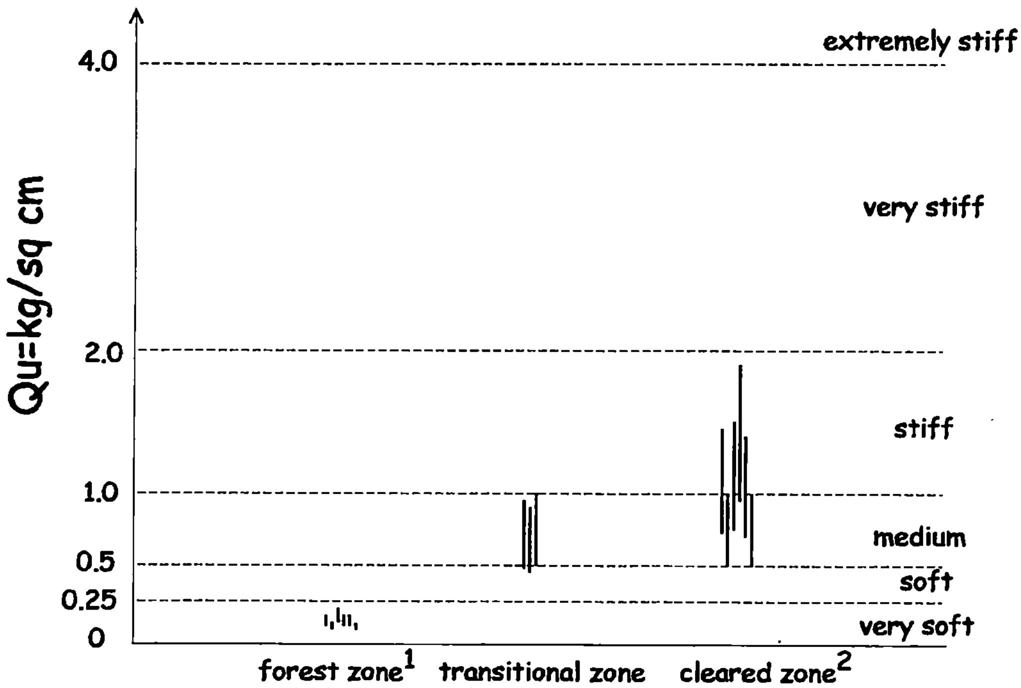


Figure 3-9. Profile view of Chances Peak, Montserrat, indicating slope and location of soil samples used to determine soil penetrability, soil compaction, and soil water content. Samples were taken at three locations: the forest zone, the transitional zone, and the cleared zone. S=soil sample.

shows the relative locations of the sites. Nine readings were taken in the forest zone and the cleared zone. Three readings were taken in the transitional zone. In each case, points were chosen by a colleague using a random selection technique. In the forest zone and the cleared zone, the penetrometer tip was placed directly on exposed soil and pushed in. In the cleared zone, clumps of grass were pushed apart to allow the penetrometer tip to directly enter the soil. Figure 3-10 shows the unconfined compression, or strength values, for each reading.

Although penetrability varied more in the cleared zone than the forest zone, there is no overlap between those ranges; they occupy distinct domains. All of the readings in the forest zone were categorized as "very soft." At three points in the forest zone, the soil was so soft that a reading could not be made. All of the readings in the transitional zone were categorized as "medium." The readings in the cleared zone ranged from "medium" to "stiff." At three points in the cleared zone, the soil was so hard, I could not push the penetrometer deeply enough into the ground deep to obtain an accurate reading. The difference in penetrability between the forest zone and the cleared zone indicate that forest cover kept the soil looser and softer than grass cover in the cleared zone, facilitating penetration and infiltration of water. This may be a result of more varied and deeper root structures, more hospitable environments for soil fauna, and/or greater supply of organic material. Also, the cleared zone has undoubtedly been more trampled by humans and had heavy equipment



1 On three attempts, the soil was too soft to obtain a reading.
2 On three attempts, the penetrometer could not be pushed to a depth at which a reading could be taken.

Figure 3-10. Unconfined compression (Qu) of soil measured in the forest zone, the transitional zone, and the cleared zone on Chances Peak, Montserrat. Measurements were taken using a static cone penetrometer. Softer soils are more apt to allow infiltration of water into the ground.

Sources: Brainard-Kilman. 1994. *Portable Static Cone Penetrometer.* Stone Mountain, GA: Brainard-Kilman. AND Terzaghi, K., and R.B. Peck. 1948. *Soil Mechanics in Engineering Practice.* New York: John Wiley and Sons, Inc.

piled on it, increasing its compaction and lessening its penetrability.

Soil Compaction

Once water is able to penetrate the ground surface, there must be space available in the soil to hold water. I compared the degree of soil compaction in the forested zone to that of the cleared zone, by determining bulk density of samples taken from the sites of penetrability experiments (see Figure 3-9). Six samples of eaual volume (93.3 cm^3) were taken at each site using a soil auger. Each soil sample had a cylindrical shape, 5.05 cm (2 in) tall, with a diameter of 4.85 cm (1.9 in). No sod or peat was removed from the soil surface before taking samples, as there was not a significant amount of either present. The undisturbed samples were dried and weighed; then bulk density, the weight of the dry soil divided by the known volume, was calculated. Table 3-2 shows the bulk density for these samples. The bulk density of soil in the forest zone ranged from 0.33 g/cm^3 to 0.5 g/cm^3. The bulk density of soil in the cleared zone ranged from 0.7 g/cm^3 to 1.4 g/cm^3. This indicates that soil in the forest zone is less compacted. Thus, it has more room for holding water and allowing water to percolate through the soil in the forest zone than in the cleared zone.

Table 3-2. Bulk density of soil taken in cloud forest zone and cleared zone on Chances Peak. Volume of all samples was 93.3 cm^3

site	dry weight g	bulk density g/cm^3
forest zone		
a	43.9	0.471
b	31.3	0.335
c	47.8	0.512
d	32.4	0.347
e	42.9	0.460
f	37.6	0.403
cleared zone		
a	102.5	1.099
b	103.1	1.105
c	90.2	0.967
d	121.4	1.301
e	134.0	1.436
f	70.1	0.751

Water Content of the Soil

Two soil factors[9] that influence the uptake and transmission of water by soil in the cloud forest (or in any area) are penetrability of the ground surface and available space within the soil to hold and transport water. If HP is lacking in the cleared zone and the soil is less penetrable and more compacted, then the water content of soil in that area should be less than the water content of soil in the forest zone. I took six soil samples in the forest zone and six samples in the cleared zone, using the same soil auger at the same sites for which soil compaction samples were collected (see Figure 3-9). Soil samples were taken from the surface to a depth of 5.05 cm (2 in), the length of the soil auger. According to data from my gauges, 60 mm of OR fell in the 11 days preceding my collection of the soil samples. Undisturbed samples were weighed wet, oven-dried, and then re-weighed. Water content was calculated gravimetrically as percent by weight [(wet weight-dry weight)/dry weight]. The water content of soil in the forest zone ranged from 69 percent to 70 percent. The water content of soil in the cleared zone ranged from 27.6 percent to 40 percent, with one anomaly at 53 percent. Table 3-3 provides the soil water content for each sample. My comparison of soil water content, then, establishes that soil in the forest zone has a higher

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[9]Low evapotranspiration rates are another factor that influences the hydrology of cloud forest and are discussed in Chapter 2. Evapotranspiration on Chances Peak has been estimated at 1400 mm (55 in) per year with an annual rainfall of 2550+ (100+ in), but should not be compared to other cloud forests cited in Chapter 2 because the data for Chances Peak include rain forest and cloud forest (Pekurel and Hadwen 1983).

Table 3-3. Measurements of soil water content taken in forest zone and cleared zone on Chances Peak.

site	wet weight g	dry weight g	water content g	% water
forest zone				
a	132.4	43.9	88.5	66.8%
b	100.3	31.3	69.0	68.8%
c	140.6	47.8	92.8	66.0%
d	109.09	32.4	76.6	70.2%
e	131.1	42.9	88.2	67.3%
f	122.5	37.6	84.9	69.3%
cleared zone				
a	166.6	102.5	64.1	38.5%
b	165.7	103.1	62.6	37.8%
c	149.9	90.2	59.7	39.8%
d	180.6	121.4	59.2	32.8%
e	185.2	134.0	51.2	27.6%
f	150.7	70.1	80.6	53.3%

moisture content than in the cleared zone. Thus, my data from Chances Peak on HP, soil penetrability, soil compaction, and soil moisture indicate that the cloud forest offers a set of characteristics that favor water capture and retention, increasing the potential for water to reach groundwater.

By simply comparing soil in the cloud forest to that in other areas, one comes to the conclusion that the cloud forest soil is wetter. The soil in the cloud forest was dark brown, moist to the touch, pliable, and so slippery it was hard to walk at times without grabbing a friend or tree for support. The soil in the cleared area was hard and crumbly when rubbed between the palms. There was a spot on the far edge of the peak where the cloud forest ended and the mountain dropped off into a sheer cliff. My friends and I call this spot "the edge of the world." Here, in a natural setting where trees did not grow, the topsoil of the cliff was bone dry. Yet, if you stood there you would be drenched by a "wet wind". And only a meter away in the cloud forest, the soil was saturated. Figure 3-11 shows a tree, only 5 steps from the "edge of the world." Water droplets cover its mossy trunk, trickling downward towards the forest floor. It is a testament to the role vegetation plays in the hydrological properties of the cloud forest.

Figure 3-11. Water drops form on a mossy tree trunk as clouds pass over Chances Peak, Montserrat. Most of this water will trickle down to the forest floor, making its way into the soil.

Source: Newton, E.C. 1994.

Hydrogeology of Chances Peak

Hydrological studies on Montserrat are lacking in both scope and number. However, a general overview and some insight as to the role of the cloud forest in Montserrat's overall water cycle and supply can be obtained from planning documents obtained from Montserrat Water Authority (MWA).

Montserrat is a recent volcanic island, with coarse pyroclastics, agglomerates, lavas, and lava flows, ranging in age from 4.3 million to less than 400 years old, composing its land formations (MWA 1992). The center of Chances Mountain is an impervious lava dome resulting from lava flows. The outer layer consists of a young volcanic pile (Chances Peak), superimposed on an older formation, an impervious pyroclastic bed (MWA 1992). The older pyroclastic bed has been weathered to clays of very low permeability with a cemented surface, but the younger lavas and pyroclastics of the volcanic pile are well jointed and faulted (MWA 1992). Thus, this younger layer not only has a topsoil that allows rapid infiltration, but also has considerable secondary permeability and forms an important aquifer supporting major springs found at lower elevations (MWA 1992). Most springs are located near the contact between the volcanic core rocks (the dome and younger pyroclastics), and the agglomerates and pyroclastic deposits of the mountain flanks, ranging from 180 m (600 ft) to 425 m (1400 ft) (MWA 1992). These springs are the main source of the island's fresh water supply (Pekurel and Hadwen 983; MWA 1992). Some water does infiltrate below the upper-level springs, through fractures in the lava, and emerges as valley springs from deep alluvial gravels and pyroclastic deposits (MWA 1992). However, as shown in Figure 3-12, the higher elevations of Chances Peak are far more important to groundwater recharge than the lower flanks.

Surface runoff occurs in a radial pattern from the top of the mountain down ghauts, which act as stream channels (MWA 1983; MWA 1992). Surface runoff is ephemeral, restricted to times of intensely heavy rainfall (MWA 1992). Surface runoff has been calculated to account for 20 to 25 percent of annual OR, based on records of springflow and evapotranspiration (MWA 1992). Baseflow, in alluvial deposits in the stream channels, barely exists, because upper-level springs are tapped for water supply (MWA 1992). Potential sources for water supply could lie in alluvial deposits in the valleys, recharged by streamflow, but limited investigations into this possibility are inconclusive and the threat of salt water intrusion may restrict any pumping (MWA 1992). Therefore, the main water supply on Montserrat is, and will probably remain, upper-level springs[10].

The importance of forest vegetation in maintaining upper-level springs is revealed by examining groundwater catchment areas. The springs rely on groundwater from the catchment area immediately above them, that is the cloud forest, not

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[10]Wells and rainwater harvesting are other sources of potable water, but are not covered here. Quantitative data are lacking, but estimates indicate up to ten percent of Montserrat's total water supply is supplied by private wells (MWA 1992). My focus is on public water supply practices.

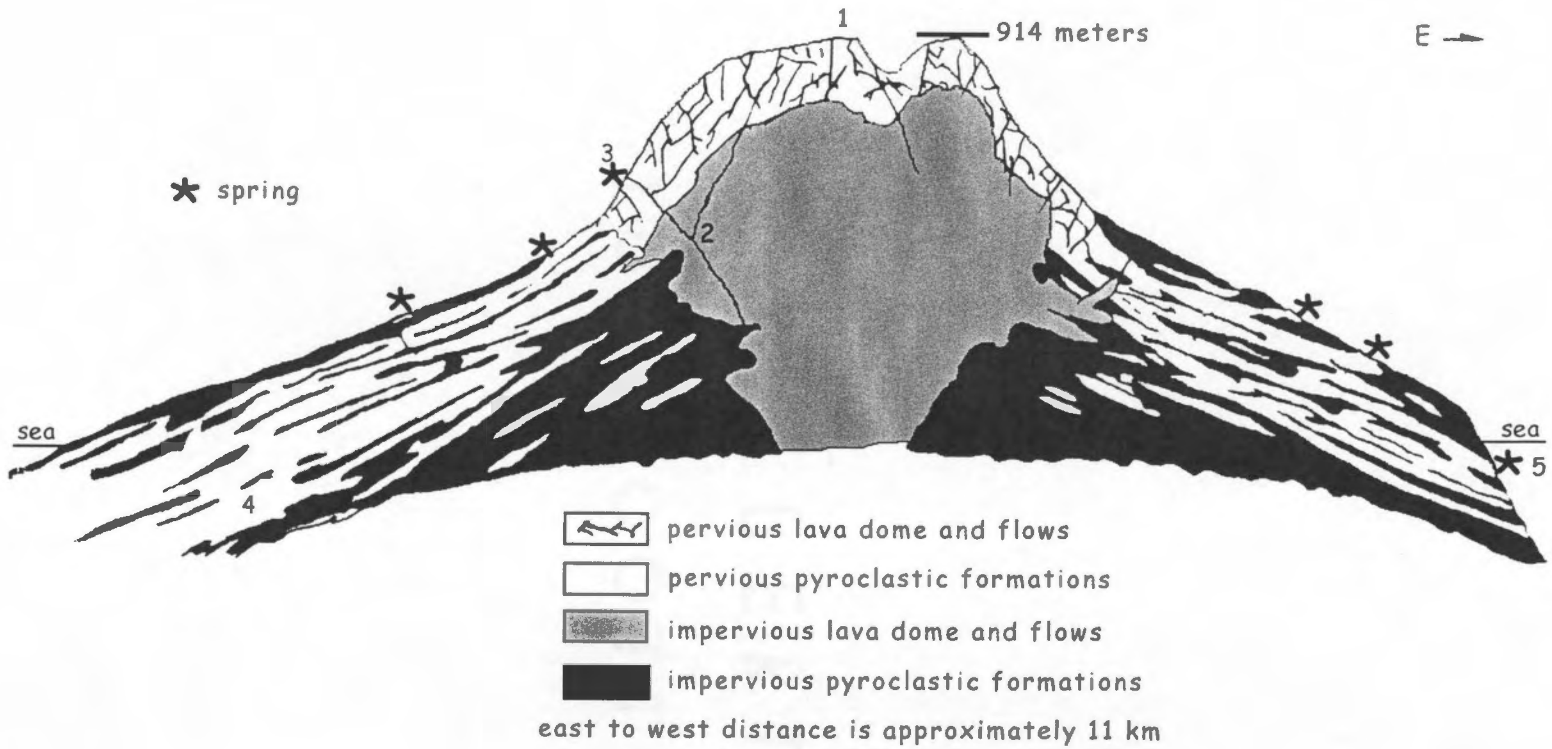

Figure 3-12. Hydrogeological model of Chances Peak, Montserrat. 1. Water enters the youngest layer of material at the top of the mountain, the recharge area, and travels downward along joints and faults. 2. Only a small amount of deep infiltration occurs in the center of the mountain. 3. Water that intersect the surface appears as springs in higher elevations (and streams in lower elevations.) 4. Water that does not intersect the surface settles in open spaces in older pyroclastic formations creating reservoirs. 5. On the eastern side of the mountain, submarine springs occur.

Adapted from: Montserrat Water Authority. 1994. Soufriere Hills Hydrogeological Model: Tentative cross-section (sketch).

surface runoff for their water supply (MWA 1992). An individual spring acquires its groundwater from a three-dimensional area larger than the visible surface catchment area immediately upstream of the spring. Therefore, the whole area which contributes to upper-level springs should be considered as one catchment (MWA 1992). That catchment is the cloud forest. Cloud forest vegetation is paramount as a water procurer because of the addition of HP, more permeable soils, and higher infiltration rates than non-forested surfaces.

When I began this phase of my research on Chances Peak, there were four questions I wanted to answer. First, is the area atop Chances Peak comparable to other tropical ecosystems known as cloud forest? Through examination of the vegetative characteristics of Chances Peak and determination of the presence of HP on Chances Peak, I determined that it was a cloud forest. Second, I wanted to determine how large the cloud forest area was and how much of it had been cleared for telecommunication facilities and media transmitting stations. I estimate that cloud forest occupied an area of approximately 100.8 ha (248.90 acres), 0.578 ha (1.43 acres) having been cleared for structures related to telecommunication facilities and media transmitting stations. I also wanted to determine if the cloud forest was a potential water source for the island of Montserrat. By establishing the presence of HP, and examining the properties of soil penetrability, soil compaction, and soil water content, I found that the presence of cloud forest provided an opportunity for the capture of HP and enhanced the uptake and transmission of water in the soil, thus providing the potential for water to reach groundwater. Lastly, I wanted to examine how clearing forest vegetation might affect the physical properties of the cloud forest. In comparing the areas cleared for telecommunication facilities and media transmitting stations to a forested zone, I found that vegetation had been altered, soil penetrability was lower, soil compaction was greater, and soil water content was less. These observations indicate that the clearing of cloud forest vegetation may compromise the established hydrological benefits of the cloud forest.

Water is an important resource and commodity. Montserrat, unlike many other Caribbean islands, is fortunate to have an abundant water supply. MWA is aggressively monitoring the island's fresh water resources and communicating with other departments in the government to ensure water does not run out. They recognize the importance of the cloud forest in the island's hydrological cycle. The next step for MWA, and for all the agencies in Montserrat involved in land use decision making, is to examine the physical data and enact measures that satisfy as many other uses of the cloud forest as possible, without compromising the community's basic water supply. It is a complicated task. Chapter 4 examines how Montserrat is tackling this issue.

CHAPTER 4

THE HUMAN USES OF CHANCES PEAK

(This chapter is written in the ethnographic present, which was 1994.)

In Montserrat, most people realize that protecting the natural assets of a space usually protects the very resources the space provides to them. The difficult task for Montserratians is meshing the goal of landscape protection with the goal of using a space for the betterment of their society. As Reuben Meade (1997), past Chief Minister of Montserrat, told me, "We need to mix environmental protection with basic requirements for living." Montserratians must decide what their basic requirements for living are. Their perceptions about such needs, and the issues that surround them, will forge the future for the cloud forest on Chances Peak.

Chances Peak has value to Montserratians in three distinct roles: as an integral component in the local hydrological system, especially in the southern part of the island, as a site for telecommunication facilities and media transmitting stations, and as an attraction to entice visitors to Montserrat, specifically ecotourists. All three of these uses have direct and potential benefits to the inhabitants of Montserrat. In the following sections, I will examine the community's perceived need for each of these uses, current activities geared towards promoting each specific use, as well as the potential detriments of each use.

The Cloud Forest as a Hydrological Component

As has been discussed in Chapter 3, the cloud forest on Chances Peak is an important water resource for Montserrat. It adds groundwater to the hydrological system through horizontal precipitation and enhances the uptake and transmission of water by the soil, water which eventually emerges as springs in the Soufriere Hills. There are five major springs used by Montserrat Water Authority (MWA) for water supply that are fed by the Chances Peak catchment area: Amersham A, Amersham, B, Amersham C1, Amersham C2 and Brodericks (MWA 1983; MWA 1992). These springs produce an average of 140,000 gallons of water per day, 51.1 million gallons per year (MWA 1992). The springs are tapped and water is stored in three reservoirs, Amersham, Trials, and O'Garros. The latter supplies water to the villages of Kinsale and St. Patricks and adjacent outlying areas (Pekurel and Hadwen 1983; MWA 1992). Consumption for the O'Garros district is 16 million gallons per year. Kinsale and St. Patricks are two of the smaller villages in Montserrat and not developed for tourism at this time. The area accounts for only nine percent of total water consumption on the island. However, trends indicate that more water may be demanded in the future all over the island, and in that case, the untapped water supply in the Soufriere Hills could supply that need, both at the south end of the island and by pumping water to the north.

There are three trends that suggest water demand will rise in Montserrat.

First, consumption remained steady or rose each year in the late 1980's and early 1990's, even though population decreased over the same period. The following table shows consumption figures for the period 1987 to 1991, the most recent data available.

Table 4-1. Water consumption from 1987 to 1991 on Montserrat. Million gallons/year.

1987	1988	1989	1990	1991
180.9	175.7	175.0	180.9	191.3

Source: Montserrat Water Authority. 1992. Report on Water Authority Planning Study. Overseas Development Administration: Montserrat.

This trend may be a result of the increase in the number of consumers with water piped directly into their home. In 1970, only 27 percent of households had individual connections, whereas in 1991 this had risen to 73 percent (MWA 1992). In the same time period, those relying on standpipes in their yard fell from 43 percent to six percent (MWA 1992). As people have more convenient access to water, use increases. For instance, people do not buy washing machines when relying on a standpipe for water. They do their laundry by hand. But with a piped water connection, the option of making such a purchase becomes viable. The type of household with a connection to piped water directly affects consumption as well. In areas of high-cost housing, household water use was about 134 gallons a day in 1991, while the island average was

98 gallons per day, and households using a standpipe averaged only 29 gallons per day (MWA 1992). If Montserrat develops a tourist base, consisting of either hotel occupants or retirees, water consumption is likely to increase because these types of visitors generally stay or reside in high cost housing and have higher per capita use habits. MWA predicts that an aggressive tourism development scheme on just one part of the island would raise consumption rates from 0.77 million gallons per day in 1992 to 1.11 million gallons per day in 2002, or 144 percent (MWA 1992). This extra water must come from somewhere. The Centre Hills reservoirs are already bearing the brunt of demand, providing 80 percent of the island's water supply, and often "borrowing" water from the Amersham and Broderick reservoirs. In the future, water may not be borrowed from these sites, but pumped directly to the north or Plymouth for use. There are nine major springs that remain untapped in the Soufriere Hills that could also supply water, notably Mefraimie and Lola springs (MWA 1992).

Currently, the MWA is able to provide service to almost everyone on the island, with relatively few worries about shortages. However, they also know that development plans for the future of Montserrat may create demands that would strain the system in place today. I asked several people if they ever thought of the cloud forest as purely as a water resource. Most people did not know of its hydrological function specifically, but rather mentioned that forest in general is important within watersheds for control of erosion and certainly the clouds would aid in the lushness of a forest (Darby 1997; Meade 1997). Conversations would inevitably turn to the need for protection of the forest complex for conservation purposes, in particular providing a habitat for the Montserrat Oriole (Francis 1994).

Although protecting the cloud forest for hydrological reasons is not precisely the same as protecting it for conservation purposes, I believe the motivation for both is similar. Montserrat embraces conservation in many ways. Environmental awareness reached a height on the island in the one to two years following Hurricane Hugo (1989) and some of that enthusiasm endures (Francis 1994). There are celebrations for Earth Day, park clean-ups, and summer recycling programs (Garcia 1994). I participated in both a television show and a radio panel discussion on environmental concerns. It was well received, as after my appearance on each program, I was stopped on the street and asked about my projects. I also attended a meeting of the National Trust where community concerns about erosion from mountain bike trails were expressed.

I asked Reuben Meade (1997), now a citizen rather than Chief Minister, how he felt about Chances Peak, since he had been to the top several times, and he commented, "The trail to the peak...is challenging for those who wish to go [there]. This...reduce[s] numbers and casual visitor[s]. [Being] a challenge to get to...reduce[s] the baggage taken on the hike, thus reducing the pollutants - plastic bags, wrappers, bottles and the like." Comments like his are commonplace. People want to keep their island green and, in their eyes, beautiful. The phrase on a poster given out by the tourist board expresses this as "Montserrat: the way the Caribbean used to be," with a picture of waterfall above the slogan. Another phrase used to describe Montserrat is "the emerald isle," a throwback to the island's Irish heritage, but also a reflection of the pride its inhabitants have for its lush green landscape. One curious thing I noticed in speaking with Montserratians about conservation arose during discussions on a national park. A plan is in the works for all land above 460 m (1500 ft) to be designated as a national park, but it has not yet been passed in legislation (Gray 1994). However, people mentioned the national park as though it already existed, satisfied that it was a good thing. Environmental protection of the island is increasingly important to the people, and this value would coincide with the preservation of the cloud forest as a hydrological component, were its function as such widely understood.

The hydrologic role of the cloud forest is passive in a physical sense for two reasons. First, fulfilling this purpose means the cloud forest continues as is, requiring that people limit their actions in the space, treating it as a natural resource with limited access. Second, the cloud forest in this capacity has no negative physical effect on the of other uses, only positive ones. It could be argued that construction of further structures may be hampered by the presence of vegetation and "bad" weather, but this situation could be accommodated as it was in the past. The presence of the cloud forest certainly does not hamper that quality (height) that makes it an ideal site for telecommunications facilities and media transmitting stations. Tourism, especially ecotourism, is actually enhanced by the cloud forest's unique landscape and challenging hike, daring a relative few to discover its wonders. When weighing the ramifications of each use, considering the hydrologic function of the cloud forest is peculiar. By requiring conservation of the space, this function controls and mediates the possible extent of the other uses. How much clearing and building can be done without destroying the ecosystem's integrity? How many visitors can the cloud forest sustain until it shows signs of duress from trampling, litter, noise, etc.? Clearly, this use limits the extent of the other two uses.

The Cloud Forest as a Site for Telecommunications Facilities and Media Transmitting Stations

Modern telecommunications services are necessary if Montserrat is to participate in the global community. Thanks to Cable and Wireless, a global telecommunications company headquartered in England, local and international phone service is excellent on the island. Although Montserrat is often considered to be a developing nation, one can easily enjoy and readily use modern technology there, such as fax machines, e-mail, conference calling, and many other information gathering and processing facilities. In a survey done for Cable and Wireless in 1992, customer satisfaction was measured in a number of areas relating to telecommunication services

(Garcia 1992). This survey provides a glimpse into the attitudes of the community towards the use of such conveniences directly related to the placement of the Cable and Wireless tower on Chances Peak. Over 70 percent of those surveyed were very satisfied (the highest category) with the quality of local calls and overseas calls, and more than 72 percent felt Cable and Wireless provided up-to-date technology to the island (Barbados External Telecommunications LTD 1992). The only complaint within the survey dealt with high costs to consumers, a result of expensive underground wiring used on the island to protect against hurricane damage (Garcia 1992).

Antilles Television did not broadcast long enough to survey customer satisfaction, but the replacement company, Cable TV, which uses less powerful satellite facilities on St. George's Hill, is quite successful (Emmanuel 1994). Two-thirds to three-fourths of all Montserratians with televisions have cable, as there is little reception without it (Emmanuel 1994). The programming, consisting of locally produced news and special interest shows and cable from abroad, is very loosely adhered to and any Montserratian can request a specific program to be aired (Emmanuel 1994). At 5:30 pm two and one-half hours of local programming are run; topics usually concern political news or environmental and cultural education[1]. The most popular shows on Montserrat, however, are US soaps, US basketball games, and

[1]In 1994, during my stay on Montserrat, two colleagues and I were featured on local programming discussing our research projects. It was after this exposure that information gathering became much easier, as people would often stop me in the streets to ask about my work.

cricket matches (Emmanuel 1992).

Radio is heard everywhere on Montserrat. It is a form of community dialogue as well as a cultural window into the rest of the region. Politicians and social commentators use the radio to broadcast their messages. I was introduced to several musical groups and styles I had not heard before, blasting from radios playing in the town square on Friday nights. In all, both telecommunication services and the ability to hear the cultural activities of the island and the region are now part of the amenities expected in Montserrat. My own view is that although parts of life on Montserrat are less complex because of its situation as an island and small population, communication is one necessity islanders are not willing to do without. Two residents expressed their feelings to me about the structures on Chances Peak. Ex-patriate Douglas Darby (1997) stated the structures were "necessary communications apparatus." Former Chief Minister Reuben Meade (1997) felt "Chances Peak should not be used for construction of large facilities, (but) the Cable and Wireless tower...should not be seen as being environmentally unfriendly...(it is a) basic requirement for living." Cable and Wireless states its mission as "emphasizing a way of life" and "pushing quality" (Garcia 1994). Communication is a need and is recognized as such on the island.

Telecommunications facilities and media transmitting stations within the cloud forest have had detrimental effects on the space in terms of its hydrological role, as shown in Chapter 3. Loss of vegetation precedes a loss of valuable horizontal precipitation. Soils in cleared areas show decreased penetrability and increased soil compaction, and most importantly, show less water content. However, as the total area occupied by these structures represents only one percent of the total cloud forest, it is unfair to say at this point there has been a great degradation of the cloud forest's ability to function in its hydrological role because of the clearings. Rather, the findings of Chapter 3 should serve as a red flag, a warning against too much clearing and as a recognition of the delicate nature of the ecosystem. It is doubtful that other telecommunications facilities will be installed on Chances Peak (White 1994).

As proposals might arise to install other media transmitting stations on Chances Peak, it is valuable to examine the installation of the Antilles Television antenna. This antenna is relatively low-impact, requiring little maintenance and taking up a small space (one meter at its base). When the antenna was installed, Montserrat National Trust[2] (MNT) and Antilles Television entered an agreement stipulating certain requirements for the care of the cloud forest (Osborne 1994). These stipulations, adhered to by Antilles Televison, include: staying at least 100 ft from the summit,

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[2]MNT's mission involves historic preservation and environmental awareness (Francis 1994). Although the group doesn't have legislative powers, it is generally considered the custodian of public lands, or at least what is treated as public lands, such as Chances Peak. The areas which house the Cable and Wireless tower and the Antilles Television antenna are "leased" (involving no payment) by MNT to the respective companies.

causing as little damage to the environment as possible, removing rubble and debris from the site, and restoring disturbed areas to former conditions (MNT 1983). The base of the antenna is not live, and therefore no fence or warning signs for the public's safety were necessary (Osborne 1983). The antenna is a relatively hidden structure on the mountain, with minimal environmental impact, both in terms of damage to the space and visual blight, a concern in developing a tourism strategy.

There is one scenario that must be mentioned in regard to such a massive structure standing in the cloud forest. On June 8, 1994, I visited the site of a collapsed media transmitting station on the Piton Flore in St. Lucia. The entire antenna had fallen, apparently because of high winds. The huge metal structure had been bent at its mid-section as it crashed into the peak of the mountain. A testament to the powerful force with which the structure hit the ground was the considerable damage to the vegetation on the mountain. This accident presents a real concern in managing cloud forest, especially in areas of high winds such as island mountain peaks. A stronger structure anchored more firmly to the ground may have prevented the damage I witnessed. The Cable and Wireless telecommunications structure on Montserrat is much more resilient to high winds than any media transmitting antennas I saw in the Caribbean, as it was built using thicker beams and is anchored by deeply buried concrete blocks. Yet, for this very reason, the Cable and Wireless structure takes up more space and required more invasive construction tactics. It is a debatable choice, minimizing the space occupied by a structure or protecting against possible damage in the future by building a larger structure.

Although neither the Cable and Wireless structure nor the Antilles Televison antenna poses an immediate threat to the cloud forest, current maintenance practices by Cable and Wireless could be improved in terms of environmental degradation. Maintenance of the main trail, which shows signs of soil erosion, has especially been a source of confrontation between Cable and Wireless and MNT. Although MNT was consulted prior to planning permission being granted for a footpath to Chances Peak, MNT was not notified by the Land Development Authority or Cable and Wireless of planning permission being granted, nor did any consultation take place once work on the footpath began (MNT 1992). In 1992, the MNT investigated the footpath and composed an agreement to be presented to Cable and Wireless concerning repair of the environmental damage caused by installing the steps of the trail. Cable and Wireless signed an amended agreement with the MNT in 1992, which included a promise to "...correct erosion of topsoil and restore all vegetation which has been destroyed by construction works so as to eliminate soil erosion" under the leadership of the Ministry of Agriculture (MNT 1992). Strict guidelines concerning the cutting of trees and pesticide and herbicide use were cut from the original document (MNT 1992). It is not clear what effect such chemicals would have on the cloud forest. I never witnessed the use of pesticides or herbicides on the mountain, and the topic never was brought up in interviews. Erosion of the trail, however, is of great concern. Workers for Cable and Wireless are instructed to maintain a buffer zone of approximately one meter on either side of the trail by cutting down all of the vegetation in the zone (Bernard French and Adolphus Morgan, personal communication, June 1994). Clearing this area hastens soil drying, rapid runoff, and the loss of valuable topsoil around the trail. Also, the creation of such a large open swath through the forest could feasibly cause persistent edge vegetation, as discussed in Chapter 3.

The trail leading up to Chances Peak was installed originally for the sole purpose of providing access to the Cable and Wireless tower by maintenance workers (Riley 1994; White 1994). It has acquired a seemed purpose by tourists and islanders as a trail for hiking. This is a benefit in terms of ecotourism development, although not all people are happy with the trail's composition. Mr. Keith Thomas (1994), of MWA, states that "access was sufficient when needed" with the original footpath, and "the steps do not provide an easy hike, but regulates one to a repetitive motion and provides no real hiking." He also thinks that travel up the slope by maintenance workers occurs too often, causing too much erosion (Thomas 1994). However, in light of the fact the trail is there, MNT has decided to use it and the accompanying viewing platforms as a method of sparking interest in Chances Peak (Francis 1994). Cable and Wireless added a section to the above mentioned agreement between themselves and the MNT, stating that Cable and Wireless would "...not accept any liability whatsoever for injury, damage or consequential loss incurred by any person using the path who is not an employee of the Company" (MNT 1992). This point is very important to Cable and Wireless. No matter whom I spoke with in the company, this topic came up. It was repeatedly stressed to me that although Cable and Wireless maintains the trail, it is not accountable for the use or misuse of the trail by anyone except its employees (Riley 1994; White 1994; Garcia 1994).

While debate about the trail continues, whether it was good for ecotourism or allowed too many people access to the mountain, another question must be raised about the structures on the peak as they relate to ecotourism. Advertising about the hike to Chances Peak always mentions the view from the top (Serverson 1993; Cable and Wireless 1994). The view as advertised does not include two structures of red steel so large one can see them from any point on the southern end of the island; and they are even more imposing once in the cloud forest. To those seeking a wilderness experience, the structures are a visual blight. Fortunately, there are only two structures at this point. Land use decision makers should consider, however, that a field of metal spires might be intolerable to ecotourists.

Nonetheless, the impact of the structures on the hydrologic and tourism uses of the cloud forest seems to be minimal at this point. Perhaps the best plan for land use in the forest related to telecommunication facilities and media transmitting stations is to cease or restrict any further development of this type. Moderation in this realm suggests that this use can coexist with other uses.

The Cloud Forest as a Destination for Ecotourists

The history of tourism on Montserrat was mentioned in Chapter 1. It is already a chief component of the economy, although its full potential is yet to be realized (Garroway 1995). Government strategists who hope to further emphasize the potential of the industry and its capacity to contribute to the economy formed the Tourist Board in the Spring of 1994 ("Tourism Rep." 1994). Government has targeted a ten percent increase in tourist arrivals by the year 2000, a five-fold increase (Garroway 1995). The product they wish to market to lull visitors to Montserrat is "ecotourism," a concept that calls for both exploitation and protection of the island's natural resources (Garroway 1995). In 1995, the Tourist Board began advertising "Adventure Tourism Packets" on the internet (Montserrat Tourist Board 1995). This drive for an alternative to "3S tourism" (sand, sun, and surf), stems from circumstances unfavorable to mass tourism, such as a lack of beachfront suitable for resort development, and the small size of the island (Weaver 1995). Instead Montserrat can rely on its distinctive natural assets, such as vistas of mountain, cliffs, and sea, and its considerable biodiversity (Weaver 1995). And of course, Chances Peak, with its hike and cloud forest and view, fits into this development scheme perfectly. Douglas Darby (1997), a ex-patriate American retiree on Montserrat, commented to me that his natural intuition regarding any resource the cloud forest provided was its "potential to attract people." The mountain is already mentioned in brochures given out at the airport, in the glowing words "exciting climb made easier with 2,000 steps installed by Cable and Wireless" (Cable and Wireless 1994). In the *Philadelphia Inquirer*, a Philadelphia newspaper, the following was written in a 1993 article touting Montserrat as a spring travel destination: "For the truly hardy, there is the climb to the top of the island's highest point, Chance's (sic) Peak, at about 3000 feet. Despite the recent installation of steps on the trail, the climb is arduous. But those who get to the top are rewarded with panoramic views of Montserrat, the sea and the islands of Antigua to the northwest and Guadeloupe to the southwest." (The article should have made clear that often these views are obscured by cloud cover.)

Tourism dollars can help enhance the economy of Montserrat. In such a small population, secure jobs can be hard to come by. Tourism would provide jobs, especially in the service and construction sector (see Chapter 1). Another facet of tourism is the informal economy. My taxi driver[3] on Montserrat, James "Mr. Nice" Bradshaw, told me on our first ride together from the airport to Marie's Guest House, that he would show me anything on the island I wanted, even Chances Peak (personal

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[3]Taxi drivers on Montserrat are quick to establish a relationship with their customers. Most will drop by your place of lodging to ensure that any plans for travel you might have includes using them as your driver. The exchange never seems pushy or invading, but rather establishes the driver as a caretaker. Within a week or two of my stay on the island, "Mr. Nice" became the only taxi driver I would use.

communication, May 1994). This is a typical way for taxi drivers to garner extra money. On a hike to the cloud forest just before I departed Montserrat, several taxi drivers accompanied me to the peak. Their goal was to educate themselves about the cloud forest, so they would be more able to give their customers reliable information about the space. Rose Willock, a local radio personality who went on the hike as well, postulated that taxi drivers could educate the public and visitors about the environmental aspects of the forest, an idea readily embraced by the taxi drivers (personal communication, July 1994). I was impressed by the ingenuity of the group, trying to exploit a space for monetary gain while at the same time educate people on how to protect it.

Ecotourism is the most contradictory and complex use in terms of its impact on other uses in the cloud forest. The destructive effects of ecotourists increases with their enthusiasm for a place. Just how much ecotourism intrusion into the cloud forest can be tolerated is unknown (Weaver 1995). The cloud forest was relatively untouched by humans until the late 1980's, when the Cable and Wireless and Antilles Television structures were built on Chances Peak. At present, few people hike to the top. These numbers will certainly increase if the forest is advertised as a must-see destination for visitors. One can only speculate about the damage that might occur with heavy volumes of traffic, and certainly the Cable and Wireless steps will need replacing.

Much of the flora of the cloud forest occurs on the forest floor, where hiking boots could cause irrecoverable damage to mosses and lichens. The soil is slippery and hikers tend to grab nearby trees and stumps that are covered with flora as well. I twice saw sheared tree trunks topple because of the weight of a person leaning on them for support. A rarely used secondary trail in the forest complex was only walked on a total of approximately ten times by myself and friends, and yet it was becoming obviously worn and cut by the time I left Montserrat. Unfortunately, if irreversible environmental damage occurs to the cloud forest as a result of too many visitors, ecotourism will fail. Ironically, ecotourism could have a detrimental effect not only on the cloud forest hydrological system, but also on itself. Economic concerns for Montserrat are often foremost in the minds of land use decision makers, but if ecological insights are ignored in planning for nature tourism, the development strategy for Montserrat's future will fail. The roles of the cloud forest as a hydrological function and as a site for ecotourists are intertwined, as they both require environmental protection on some level to further their use.

The negative effects of ecotourism on the use of the peak as site for telecommunication facilities and media transmitting stations are minimal and manageable. One consequence could be vandalism of the structures. This problem is solved by fencing and locking the area containing the structures, a method already employed by Cable and Wireless (Riley 1994). The main concern at this time appears to be the liability status of Cable and Wireless in cases of injury (Riley 1994; White 1994; Garcia 1994).

THE VALUE OF A "PHANTOM" NATIONAL PARK

Much mention has been made of land use decision makers. These are the people and agencies that will choose what management policies apply to Chances Peak and the cloud forest. There are many agencies on Montserrat that are involved either directly or indirectly with the policies formulated for Chances Peak. Basically they can be divided into three groups, government, non-governmental organizations (NGOs), and the business sector. Table 4-2 lists the principal agencies involved in land use decision making in Montserrat, limited to Chances Peak.

Each group differs in its character and responsibilities. The government agencies are primarily responsible for legislation and thus it would seem the survival of the cloud forest as an ecosystem depends most directly upon them. But the environment is the shared responsibility of 18 agencies distributed among four ministries and the Office of the Chief Minister (Weaver 1995). Such overlap hinders the legislative process. Projects and decisions could fall under several jurisdictions and this often promotes feelings of being left out, or conversely, of the need to monopolize projects once they are assigned (Francis 1994).

In light of the cloud forest's hydrological properties, it would seem the most

Table 4-2. Principal agencies involved in land use decision making on Montserrat.

Government	
	Overseas Development Administration (ODA)
	Organization of Eastern Caribbean States (OECS)
	Chief Minister
	Executive Council
	Legislative Council
	Ministry of Agriculture, Trade, and the Environment
	Department of Forestry
	Montserrat Water Authority (MWA)
	Montserrat Tourist Board (formerly the Department of Tourism)
Non-Governmental Organizations	
	Montserrat National Trust (MNT)
	United Nations Development Program (UNDP)
	World Wildlife Fund
	RARE Center for Tropical Conservation
Business	
	Cable and Wireless
	Antilles Television
	Tourism Services - e.g., taxi drivers, hotels, mountain bike concession

obvious opportunities for enacting protection status for Chances Peak would fall to the MWA. Water ordinances do exist, with enforcement power given to MWA. But these ordinances are either inadequate or not enforced (MWA 1992). Currently, watershed protection is limited to water intake areas around springs, but does not include entire catchment areas (MWA 1992; Government of Montserrat 1993). Many ordinances are 30 to 40 years old and not appropriate any longer, and funds are lacking for educating the public about water laws that are applicable (MWA 1992). In 1992, a study done by the MWA put its support behind the formation of a national park system, which would include Chances Peak, and advised more suitable water ordinances be tied in to any park legislation (MWA 1992). It was noted that Chances Peak should receive watershed protection of the highest level (MWA 1992).

The main project affecting land use control on Chances Peak centers on the planned creation of a national park system in Montserrat. Around 1989, the Renewable Resources Department of the Organization of Eastern Caribbean States (OECS) presented Montserrat with a National Forestry Action Plan, based on work done by several NGOs and updated in 1993 (Gray 1994). This plan called for an ordinance that all lands over 460 m (1500 ft) be established as a national park (Tropical Forests Action Programme 1993). The plan also called for the entire Soufriere Hills region to be a top priority for long term watershed protection (Tropical Forests Action Programme 1993). The document was given to the Ministry of Agriculture, Trade, and the Environment and it was hoped that the Forestry Department, a division of the Ministry, would control management of the park (Garroway 1994). However, since the Ministry of Agriculture, Trade, and the Environment has not only a Forestry Department, but also a Wildlife Department and a Parks Management Department, the question of selecting who should enforce the ordinance became a matter of debate and slowed the process down (Gray 1994). The debate has yet to be settled. Once an ordinance is proposed by a Ministry or department, it goes to the legislative council, which must meet on it three times before voting it into law (Gray 1994). Management decisions, however, must go to the executive council (Gray 1994). The intentions of all the agencies involved are well-meaning, but the process is very slow. It is perhaps a realization of the bureaucratic contentions that makes Montserratian citizens convey the notion that they already have a national park system, when indeed there is no legislation on the books.

The MNT, a local NGO, supports the idea of a national park, as well as ecotourism to some extent. Its president, Sarita Francis (1994), stated, "We would like to see a development that leaves the island as green as possible. Tourists appreciate this approach over skyscrapers on the beaches. But at the same time, the Trust is aware of the economic pitfalls." The MNT does exert influence on legislative decisions, while attempting to educate the public about environmental concerns, but it has no legislative power.

Funding for a national park is also a concern. The National Forestry Action Plan suggested additional staff and office space were needed to appropriately manage the forests (Tropical Forests Action Programme 1993). This may be another reason legislation has been slow to come about. Often, funding for projects comes from outside sources, mainly NGOs, such as the World Wildlife Fund and RARE Tropical Center for Conservation, a regional group. Funding from NGOs is usually designated to the MNT, because the NGOs feel in the hands of the ministries "the money would be lost" (Francis 1994). Ecotourism is being studied by external NGOs, namely United Nations Development Program (UNDP) (Richard Polloway, personal communication, July 1994). The UNDP has promised to provide funds for environmental projects and trail development related to ecotourism (Garroway 1994). It would like to see the national park initiative in the hands of the MNT (Garroway 1994). The MNT would like to see fees charged for entrance into national parks (Francis 1994). They believe the revenue is needed to keep and protect the sites and provide educational materials, such as site markers and guide pamphlets (Francis 1994). But again, even in the realm of funding, the issue seems to be one of territoritalism, as the government wants control of the park system (Garroway 1994; Gray 1994).

In 1993, the government was set to receive funding from the Overseas Development Administration (ODA) to last until 1998, for "assistance in the forestry sector within the National Forestry Action Plan, comprising institutional strengthening and field actions, principally management of watersheds" (Government of Montserrat 1993). Assistance included everything from renovating office buildings to fencing in the immediate vicinity of spring water intake and relocating local farmers (Government of Montserrat 1993). Over 1300 ha (3200 acres) in the Soufriere Hills were categorized as needing protection (Government of Montserrat 1993). The receipt of these funds from the ODA was contingent upon the acceptance of the National Forestry Action Plan, and changes in several pieces of legislation in Montserrat, including the Water Authority Ordinance, all to occur within six months (Government of Montserrat/BDDC 1993). The government of Montserrat, ever changing under the parliamentary system, wasn't ready to accept the conditions that quickly (Gray 1994). And again, there was recognition of dual projects competing for the same power and control. Project documents from the ODA explicitly note the work of the UNDP in Montserrat in the process of creating a national park system, yet the ODA documents never discuss a coming together of the groups, but merely point out if Montserrat chooses to accept funding from ODA, NGOs will be less involved in the process and management of creating a national park (Government of Montserrat 1993).

There is one further impediment to the formation of a national park, besides the slow process of legislation and funding shortages. The land in question, particularly on Chances Peak, is not legally assigned to either the government or the MNT (Tropical Forests Action Programme 1993). The land on the southwest side of

Chances Peak is handled by MNT, and encompasses the majority of the mountain (Land and Survey 1994). Abutting this area are four parcels controlled by seven different land owners. Although MNT holds a large portion of land that would be designated as a national park, the remaining land currently does not fall under the legislation and management of the government because it is privately owned (Government of Montserrat 1993). Businesses on the island command attention because of their monetary clout, the fact that they provide employment to the population, and their function of fulfilling consumer demand. Businesses involved in the tourism sector also support the idea of a national park system. The Montserrat Tourist Board, a government agency, is very involved in furthering the economic development of the island by representing businesses involved in tourism. My observations lend me to consider the board part of the business sector, because its purpose is that of a lobbying group. The Tourist Board wrote a campaign in 1994 pushing legislation for a national park (Garroway 1994). The rationale is that a national park would give the business sector something to advertise, and would bring visitors to the island, thus injecting money into the economy. Businesses in Montserrat, for the most part, would not be affected by the location of a national park and can only benefit from its formation. They do request whatever agency holds charge over the plan to instigate a tour guide service, possibly using taxi drivers, to provide more job opportunities (Garroway 1994; Rose Willock, personal communication, July 1994). The one drawback the tourism sector has with a national park initiative deals exclusively with setting precedents that may harm the environment. As Jasmin Garroway (1994), a tourism consultant to the Montserrat Tourist Board, warned, "one trail can easily become five." Nonetheless, the concern of tourism businesses is to not spoil the very image they are pushing, and so they would like to see some environmental controls initiated to protect their product.

Other businesses involved in the future of Chances Peak are Cable and Wireless and Antilles Television. Cable and Wireless is an enormous global telecommunications company with offices in over 50 countries on five continents, mainly in developing countries in the Caribbean, the Middle East, the Far East, Europe and the Americas (Cable and Wireless 1994). It is a top-100 company in the London Stock Exchange (Cable and Wireless 1994). On Montserrat, Cable and Wireless employs 95 workers, including 93 native Montserratians (Garcia 1994). The company likes the idea of manageable, not massive, tourism (Garcia 1994). Increased tourism provides a market for Cable and Wireless, and the company has considerable clout on Montserrat. It is involved in many aspects of Montserratian society, funding sporting events, youth development programs, cultural festivals, health improvement programs (such as Meals on Wheels), and making donations regularly to the Red Cross, the MNT, the YWCA, and several churches (Garcia 1994). It is also a member of the Tourist Board (Garcia 1994). And although it is doubtful that it will install any more telecommunication facilities on Chances Peak, the company does count into the decision making process through its involvement in the community and its seats on the boards of several community organizations, such as the Rotary Club and the MNT.

The immense size and foreign nature of Cable and Wireless makes many on the island distrust its motives. Ederson "Tyre" Daly stated that the environmental slogan "the way the Caribbean used to be," could easily refer to the neo-colonialist tactics by Cable and Wireless (personal communication, July 1994). The strongest words come from a communications manager who feels his company was slighted by the disregard of Cable and Wireless to environmental guidelines set up by the MNT. This person states: "Cable and Wireless does not respect anybody in the region. They're an English company, they think that this is their colony and they have a God-given right to do whatever they want to do. It offends me greatly. I get along very well [with their employees], but then [they are] a cog in the wheel and [they have] to do [as bidden]. But we didn't like it at all. The size of the [Chances Peak] complex [is] totally unnecessary." (Anonymous, personal communication, July 1994). This opinion is reflected by many on the island. The inhabitants like the services of Cable and Wireless, but are not sure of the company's ambitions, even when the support of the company lies with the majority of the islanders, as it does in the case of a national park.

Every sector on Montserrat, governmental, non-governmental, and business, seem to be in agreement on the basic assumption that eventually Chances Peak will become a national park. It is predicted that the park will be used by ecotourists and will be protected under the authority of the Forestry Division (Gray 1994). What is missing on Montserrat is serious collaboration between each sector. Communication is happening on one level, as all of the agencies and boards involved rely on the same documents and research to support their positions, and so each are familiar with the same reports and suggestions for land use on Montserrat. Each sector has basically the same position; Montserrat needs a national park system. Yet, questions surrounding management, funding, and legal authority hinder the process of making the idea of a park a reality. This slow and cautious method of planning, involving many voices, is to be commended. It is certainly more reasonable than quick, uninformed, oligarchic policy making. But without any clear, forward progress on the implementation process, it becomes doubtful that Montserrat will ever actually have a formal national park system. At least, Montserrat will not have a formal national park system that is grounded in government legislation and managed in cooperation with NGOs.

On the other hand, as stated throughout this chapter, Montserratian citizens already speak as if a national park exists. Whether or not legislation is ever enacted creating a national park, one is already in place in the minds of Montserratians. Every citizen I spoke with about conservation or the environment in general, related to me that the area above 460 m (1500 ft) was "the national park." Their descriptions were never vague, but rather specific in their delineations of the area, most often citing Chances Peak as the showpiece. There are no actual laws outlining acceptable behavior in this park. However, I was told that no grazing was allowed, and if I was going to Chances Peak, I should be respectful by not littering, taking plants, or disturbing the wildlife present. When I asked who was in charge of the park, answers usually incorporated both the Forestry Department and the MNT. It seemed every person on Montserrat I spoke with had read the related documents concerning a national park system, decided they liked the idea, and accepted the recommendations of the document's authors. In this sense, Montserrat's society has created a "phantom" national park. It is a method of working around the law, taking the next step in land use policy without regard to the formalities of legislation. In Montserrat, a place with a small population, this seems to work. Word spreads easily from neighbor to neighbor. Once an idea is accepted by a majority of the people, going against the will of the community may bring chastisement. In this sense, I think the people have become the default managers of the national park.

The only drawback to this paradigm is monies. Funding for infrastructure, additional forestry staff, education, enforcement of regulations, and so forth, is still lacking. However, maybe these needs will be met by the community. Perhaps infrastructure is not an immediate need, as ecotourists looking for a wilderness experience might appreciate a landscape that is unspoiled, even by a trail marker. I was able to get around the cloud forest quite well, relying completely on the directions of local citizens. If the community acts as its own watchdog, additional forestry staff may not be a priority. And certainly, if the community has educated itself to the degree of teaching its members the actual dimensions of proposed park lands, surely they can continue to educate each other about the environmental aspects of the area. The taxi drivers have already taken that initiative, quizzing me about my research. In a society that doesn't always trust authority, as seen in comments about Cable and Wireless and the British government, maybe the phantom park actually functions whereas a legislated system would not.

A national park that includes Chances Peak is certainly the most appropriate land use decision in regards to preserving each use of Chances Peak I have discussed. Each use, a hydrological component, a site for telecommunication facilities and media transmitting stations, and a must-see destination for ecotourists, has inherent consequences with its application, as discussed earlier. A national park, even a phantom national park, provides the best solution for exploiting each use without damaging the aspects of the cloud forest that provide other uses. Environmental education stemming from curiosity about the park can lead to environmental respect. This respect facilitates the protection of cloud forest vegetation, thus protecting the forest's hydrological function. The Cable and Wireless tower and the Antilles

Television antenna represent minimal damage to the forest, and, most likely, there will be no future installations. The guidance of ecotourists by educated locals, such as taxi drivers, as to appropriate actions within the forest should help ensure that intrusions by visitors are not so destructive as to compromise the integrity of the forest. The number of visitors to the forest should remain manageable, especially as long as the national park does not have an official designation and cannot advertise as such. Rather, it seems the hike to Chances Peak will remain a destination that is discovered by word of mouth, most likely at the suggestion of your taxi driver.

CHAPTER 5

NEW CHALLENGES FOR CHANCES PEAK

In the summer of 1995, volcanic activities began to reshape the physical landscape of Montserrat. Parts of this thesis were purposely written as though these events never occurred, primarily so that the reader could focus on cloud forest hydrology and more typical issues surrounding cloud forest management options that may be applicable to situations beyond Montserrat. However, I would like to address the reality of Montserrat's situation in 1999 at this point.

Ecological Impacts of the Volcano

In 1996, I received a message from Peter Black of Montserrat. He was the first to inform me the cloud forest was gone, "nothing but a charred landscape." (see Figure A, Foreword) (personal communication, April 1996). Dr. Deborah Brosnan, of Sustainable Ecosystems Institute, wrote this description in 1996:

> ...our helicopter and hiking surveys of the volcano...indicated that vegetation loss...on the top of Chances Peak and surrounding area was severe. The cloud forest had disappeared. Tree ferns were dead, and the *Heliconius* butterflies had all but disappeared from the crater area. In contrast to our first hikes up Chances Peak, by early 1996 we recorded almost no animal life close to the summit of the volcano. We cannot imagine what food resources are left to defend, because most of the plant life is dead. (Brosnan, 1997).

Pictures available on the internet confirm her report, and indicate the situation has only worsened in the last two years (Innanen 1998). In August of 1997, the last standing object on Chances Peak, the Cable and Wireless tower, succumbed to a violent volcanic explosion[1]. The cloud forest is gone and so are the structures and the potential for ecotourism that caused the contentions of 1994.

As of mid-1999, new concerns are arising out of the total loss in vegetation on Chances Peak; they include erosion and increased runoff in water catchment areas. Sediment loads in Montserrat's major rivers, the Belham River and the White River, have increased dramatically (Brosnan 1997). However, there is not much that can be done by humans on Chances Peak at the present time to alleviate these conditions, even if the volcanic activity stops all together. The soil is still extremely hot and the landscape is unstable, making it dangerous to travel there (Innanen 1998). Chances Peak is currently off-limits to anyone.

Perhaps cloud forest vegetation may return to the mountain one day. For this to happen volcanic activity must cease, simply to end the production of acid rain from crater sulfur emissions (Brosnan 1997). Next, seeds must be available to germinate and grow. These seeds could be blown over from the Centre Hills, which contain similar species as Chances Peak once did; or animals, especially bats and birds, could transport seeds to the mountain (Brosnan 1997). Pioneer species on Chances Peak,

[1]A new Cable and Wireless tower was erected in St. Johns on the northern tip of the island in 1997 (Richard Aspin, personal communication, 1997).

those that first inhabit an area, would need to be tolerant to high amounts of light, temperature, and wind. Interestingly, the name *Heliconia*, borne by many (former) cloud forest species, means "sun-loving," although the presence of clouds would most likely still be a factor in rejuvenation (Brosnan 1997). Once these pioneer species were established, more shade tolerant species could move in, creating more diversity. Tropical forest tends to recover faster than temperate forest, with one study in Puerto Rico showing recovery after a hurricane in about 40 years (Brosnan 1997). However, because of the complete destruction of vegetation, rejuvenation will probably take much longer.

Recreating the Peak's Hydrological Function

In a situation where the deforestation of cloud forest is imminent for whatever reason: logging, cultivation, heavy traffic, or a catastrophic event, it may be possible to supplement the water supply through fog harvesting. In fog harvesting systems, fog droplets are caught on polypropylene mesh fog collectors that have been erected on mountain ridges or hillsides. Wind speeds of three to ten meters per second are required to carry the fog through the collectors. These speeds are easily attained in most cloud forest zones (Schemenauer and Cereceda 1993). One benefit of fog harvesting is that gravity can be used for transport, since cloud forest occurs on high ridges and island peaks and population centers tend to occur at lower elevations. This enables the water delivery system to be a passive one. Another benefit is that with the fog coming in straight off the ocean, the water collected is usually not polluted, so only minor treatment systems, such as a chlorination plant to remove accumulated residues in the piping system, are required. A potential problem on Montserrat is that sulfur emissions from the volcano may produce "acid fog," which would weaken the nets and possibly the produce water that would not be potable (Brosnan 1997).

The potential of fog harvesting was demonstrated in a seven-year project in the Atacama desert of northern Chile. On the unforested El Tofo ridge, seventy-five 12 m (39 ft) by 14 m (46 ft) mesh nets hang on concrete and wooden posts 2 m (6.5 ft) above the ground (Pearce 1993). These nets capture moisture that rolls in off the Pacific Ocean as fog, providing 11,000 liters of drinking water a day to 350 residents in the village of Cgungungo. The nets collect between 20 and 65 percent of the moisture in the fog, producing about three to four liters of water per square meter of mesh (Pearce 1993). In 1992, the project became a permanent source of drinking water for Cgungungo (Pearce 1993).

One of the main considerations in implementing any municipal water system has to be the cost, especially how the cost compares to other methods of water reclamation. The countries of the world that contain cloud forest are typically "growing" economies. This status includes Montserrat in its post-volcanic reliance on aid from outside sources. In Cgungungo, the cost of fog water is about $2 US per cubic meter of water, much lower than the previous cost of $8 US per cubic meter of water when it was trucked into the village (Schemenauer and Cereceda 1993). The capital required to start a fog water project is approximately $100,000 US, and maintenance and repair costs are virtually null (Pearce 1993).

While fog water harvesting could be a practical solution for replacing or complementing natural fog water inputs into catchment zones in areas of deforestation or burgeoning population, it may also benefit the natural environment. In Peru, harvested moisture is used to water tree seedlings, which, when they grow, will capture their own fog water (Pearce 1993). This scheme could be used to replace destroyed vegetation in other cloud forest zones, too. One day, perhaps the practice could be used on Montserrat.

CHAPTER 6

CONCLUSIONS

Cloud Forest Management

Each cloud forest and each society that makes decisions about cloud forest is unique. Such is the case in Montserrat. Most cloud forest managers usually face the dilemmas with which Montserrat previously found itself concerned. Since many cloud forests, especially those in the Caribbean, play relatively similar societal roles, general comments concerning management of cloud forest can be made. Cloud forest on islands that promote themselves as a tourism product and cloud forest in relatively accessible areas, such as Luquillo National Forest in Puerto Rico, are becoming more susceptible to the problems that arise with high volume traffic, including litter, trail degradation (erosion), introduction of alien species, and demand for firewood. In larger cloud forests, development schemes may become an issue. In the Pacific, in Sabah's Mount Kinabalu ,and in Malaysia's Cameron and Genting Highlands, golf courses have been built in cloud forest (Hamilton et al. 1995b). In most instances, however, tourism in cloud forest is almost entirely non-consumptive, consisting of bird-watching, mountain hiking, photography, and visitation to experience the cool, misty climate (Hamilton et al. 1995b). Management dilemmas mainly center around being unprepared for large numbers of people (Hamilton et al. 1995b). Managers need to anticipate possible side effects associated with high volume traffic, develop restrictions on damaging activities in advance, and plan for public education. Training and using local guides and managers can also provides employment opportunities.

The installation of telecommunication facilities and media transmitting stations, another activity found primarily in cloud forest on islands, is relatively unintrusive at the actual site, except to those who argue their presence is a visual blight (Hamilton et al. 1995b). The ecological impact comes from the construction of the equipment and the frequent access needed for maintenance (Hamilton et al. 1995b). In Pico del Este, Puerto Rico, a landslide associated with the road to a telecommunications site has been reported (Hamilton et al. 1995b). The most promising future involves new technologies, such as fiber optics and satellites, that require smaller facilities with less intrusive construction demands, or eliminate the need for such sites altogether.

In general, information sharing between scientists, researchers, local government agencies, and grassroots organizations is the key to successful cloud forest management anywhere. Educating the decision makers about the ecological workings of cloud forest and educating the researchers about societal needs, enables management plans to be preventive in an ecological sense, and more sustainable in an economic sense. Ironically, an "environment-versus-economics" mentality seems to have developed in many societies, when often, the two sides have the same fundamental needs. But it is only through communication that this is understood.

Holistic Environmental Management

In the holistic approach to environmental management, managers recognize that societal issues will influence decisions about a space, and ultimately influence its physical properties. By exploring such societal issues, some insight can be gained as to what policies are most realistic within a community. At the same time, managers must not lose sight of environmental knowledge they have acquired about a space. Planning in such a holistic manner is admittedly a difficult task, but it is the only method that acknowledges all of the components that affect a space.

To tackle the issue of what uses are appropriate for a space, potential uses must be identified. Then decision makers must consider how critical each use is in the community, as well as what environmental effects each use has on other benefits of the space. Also, the organizations and individuals involved in land use decision making must discern if knowledge about the space is being shared. Only then can these groups and persons determine whether their goals are congruent or in conflict with each other. This exercise exposes certain values of a culture, not necessarily its needs per se, but what needs the community wishes to address. Finally, by developing a complete understanding of the needs of the community and the needs of the environment that supports it, reasonable policies can be enacted to satisfy both. This holistic environmental management practice often requires using multiple forms of methodology and data acquisition.

As a geographer, I am personally fascinated by the hydrological and ecological dynamics of cloud forest, and would encourage protection of those assets. However, I can only relay my research findings to the proper agencies, and hope they become a part of the total process that governs land use decisions. Space, and the resources it contains, is often limited, and communities have the prerogative to use the space available to help them survive and thrive. Careful planning can help not only ensure that designed goals are attained, but that they are sustainable. As Reuben Meade (1997) of Montserrat, stated so clearly, "We need to mix environmental protection with basic requirements for living."

Having the courage to approach management in a holistic manner requires rethinking the research methods that inform decision-making. Such research can, and should, when appropriate, mix quantitative methods, such as counting and surveying, with qualitative methods, such as participant observation and interviewing. In my case study, it was logical to mix quantitative data (such as measurements of horizontal precipitation and soil water content, and a telecommunications customer satisfaction survey) with qualitative data (such as vegetation observations and interviews with employees of Cable and Wireless) to determine the physical aspects of the cloud forest and predict what particular human activities might affect those aspects.

Holistic, multi-method research enabled me to understand that the socioeconomic issues surrounding ecosystems such as the cloud forest on Chances Peak eventually determine the uses of these spaces.

The paradigm of multi-methodology challenges geographers to not only search for explanations, but also to interpret those explanations in an integrated fashion. Analysis of quantitative data (horizontal precipitation measurements), complemented by qualitative data (vegetation observations), led to my inference of the important hydrological role of the cloud forest in Montserrat. Analysis of qualitative data led to my theory that a "phantom" national park exists in the social consciousness of the people of Montserrat. Multi-methodology allowed me to investigate and write holistically about the cloud forest on Montserrat and the people who are affected by the forest's challenges and opportunities.

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APPENDIX

APPENDIX

Flora found in cloud forest on Chances Peak, Montserrat, circa 1994. This record is based on examination of Montserrat specimens and living plants growing in their natural habitat. Field notes for most of the following specimens are filed at the Arnold Arboreum of Harvard University, 22 Divinity Avenue, Cambridge, Massachusetts, and at the Institute of Jamaica, Kingston, Jamaica. This list is not exhaustive, but does includes species confirmed to have grown or strongly believed to have grown on Chances Peak in 1994. syn=synonym

ORCHIDACEAE
Malaxis spicata
Ornithidium coccineum

PTERIDOPHYTA
Dicranopteris linearis
Dicranopteris pectinata
Polypodium loriceum L.
Polypodium pectinatum L.
Trichomanes angustifrons

MONOCOTYLEDONEAE
Euterpe dominicana
Isachne disperma
Paspalum conjugatum
Paspalum notatum
Paspalum nutans Lam. (possible)
Scleria secans (L.)
Scleria pterota
Scleria latifolia
Trichomanes angustifrons

DICOTYLEDONEAE
Charianthus spp. (genus presents problems as speciation may be active)
Cinnamomum elongatum *syn* Phoebe elongata
Columnea scandens L. (may be mistaken for Columnea hirsuta)
Desmodium adscendens (Sw.) *syn* Hedyosmum aborescens Sw.

Freziera undulata Sw.
Ilex dioica (possible)
Ilex nitida
Ilex sideroxyloides (Sw.)
Lobelia cirslifolia *syn* Tupa cirsiifolia (poss)
Myrsine coriacea Sw. *syn* Caballeria ferruginea
Psychotria guadalupensis *syn* Psychotria parasitica
Relbunium guadalupense *syn* Galium hypocarpium (poss)
Richeria grandis
Sauvagesia erecta
Sloanea dentata
Ternstroemia elliptica
Utricularia alpina *syn* Utricularia montana
Viola stipularis Sw. (possible)
Weinmannia pinnata L.
Wercklea tulipiflora *syn* Hibiscus tulipiflerus

Source: Howard, Richard A. (ed.). 1974-1989. Flora of the Lesser Antilles: Leeward and Windward Islands (Vols. 1-6). Cambridge, MA: Harvard University.

VITA

Ella Christina Newton was born in Winston-Salem, North Carolina on August 22, 1966. She attended public schools in California and North Carolina, and graduated from Whiteville High School, North Carolina, in 1984. That fall she received a full scholarship to Wake Forest University, attending until 1986. In 1988, she enrolled at the University of North Carolina at Greensboro, graduating magna cum laude in 1992, earning the Bachelor of Arts degree in Geography. She was inducted into Phi Beta Kappa in the spring of 1992. After working in the catering business, she enrolled at the University of Tennessee, receiving the Master of Science degree in Geography in 1999. While at the University of Tennessee, Ms. Newton taught an introductory course in World Geography for three semesters. She received an award for Outstanding Teaching Associate from the Department of Geography in the spring of 1996. She plans to continue her career in the field of resource management, with special emphasis on environmental education.