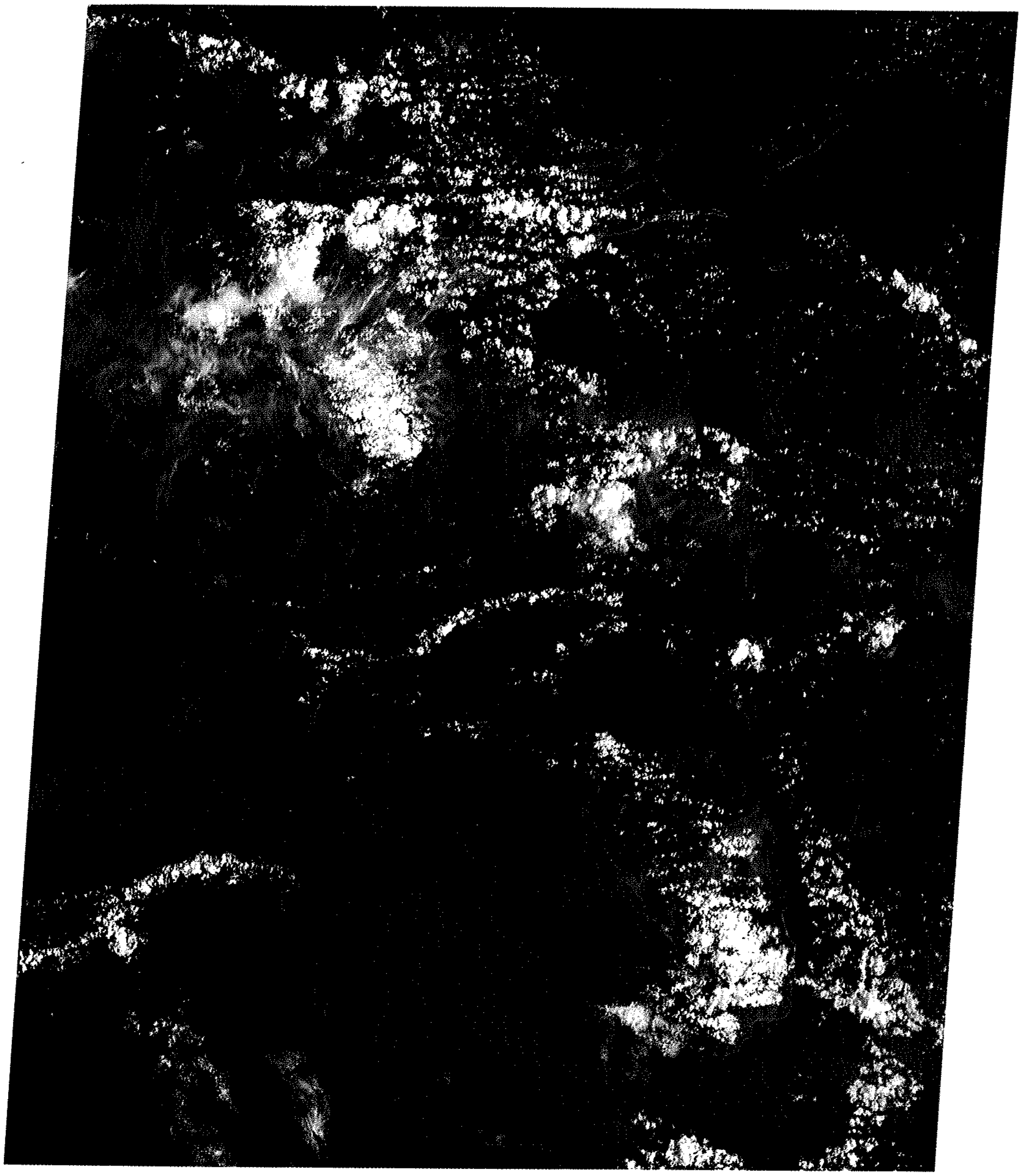
WATERSHED MANAGEMENT IN THE CARIBBEAN



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Cover: Landsat infrared image of a sector of the Caribbean. The two large islands are Dominica (lower right side) and Guadeloupe. Also visible are the islands of Marie Galante and Iles des Saintes (between Dominica and Guadeloupe), and La Desirade and Ile de la Petite Terre (east of Guadeloupe). The photo was a courtesy of the NASA, Houston Space Center.

WATERSHED MANAGEMENT IN THE CARIBBEAN

Proceedings of the Second Workshop of Caribbean Foresters held in
Kingstown, Saint Vincent and the Grenadines
March 19-23, 1984

Edited by Ariel E. Lugo and Sandra Brown

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PREFACE

It all started in a hotel room in Saint Lucia when Gabriel Charles suggested the idea of regular meetings of Caribbean Foresters. Only once before, in 1946, had Caribbean Foresters met before Gabriel's suggestion.

This workshop is already the second meeting of Caribbean Foresters. It was held in Kingstown, Saint Vincent and the Grenadines during 19-23 March, 1984. The workshop was sponsored and supported by the following organizations:

Funding: US Man and the Biosphere Program through its Tropical Forests and Caribbean Islands Directorates

Administration: University of Puerto Rico's Center for Energy and Environmental Research

Organization: Saint Vincent Ministry of Trade's Forestry Division (local arrangements led by Mr. Calvin Nicholls) and USDA Forest Service's Institute of Tropical Forestry (Southern Forest Experiment Station).

Attendance to the meeting was 57 people representing nine islands (Puerto Rico, Dominica, Saint Vincent and the Grenadines, Saint Lucia, Montserrat, Guadeloupe, Martinique, Jamaica, and Grenada), three additional countries (Canada, Haiti, and U.S.A.), and six other institutions (Canadian International Development Agency, US Agency for International Development, Organization for American States, US Forest Service, University of Illinois, and the US Geological Survey).

The proceedings for the Saint Lucia meeting were published (Lugo and Brown 1982). Copies are still available through the Institute of Tropical Forestry, P.O. Box AQ, Rio Piedras, P.R. 00928. In that meeting we made the commitment of putting forestry in its rightful place among the other sectors of each islands economies and agreed on where our priorities stood.

Training and watershed management were high on the list of our priorities from the first meeting. Perhaps coincidentally, UNESCO was organizing a new program in the Caribbean: The Caribbean Environmental Action Plan and through the generosity of the US Agency for International Development we secured a grant to put into practice many of the recommendations of the workshop. This grant was part of the U.S. Government's contribution to the UNESCO program. Examples of the programs that were implemented are:

-two 3-month-long training courses were held in Puerto Rico and 27 young Caribbean foresters were trained in all aspects of tropical forestry;

-a Saint Vincent forest inventory was conducted;

-a wildlife inventory was conducted in 9 Caribbean islands;

-a follow-up assessment study on the hurricane effects on forests was conducted in St. Lucia and Dominica;

-three automatic stream gauging stations with recording rainfall collectors and with provisions for sediment and water quality collections were installed in Dominica, St. Lucia, and St. Vincent and the Grenadines.

The second meeting of Caribbean foresters was dedicated to watershed management. Each island presented a paper summarizing the state of watershed programs and problems and these were followed by technical presentations of the subject by invited specialists. The papers that follow summarize these formal exchanges.

Among the primary objectives of the meeting were the fostering of communication among islands foresters, reviewing forestry activities taking place in the Caribbean, discussion of problems of common interest, and the development of an agenda for coordinated future action in the area of watershed management. Meeting participants developed a series of recommendations aimed at all institutions concerned with watersheds in the Caribbean. The recommendations took the form of a proposal for integrated action on island watersheds. This proposal or set of recommendations is included in these proceedings.

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FINDINGS AND RECOMMENDATIONS FOR DEVELOPING WATERSHED MANAGEMENT PROGRAMS IN THE FORESTRY SECTOR OF ISLANDS OF THE EASTERN CARIBBEAN

The Caribbean foresters workshop on watershed management held in St. Vincent and the Grenadines recognized and concluded the following:

- Watershed management is critical for the maintenance of resources such as land, forest, soil, water, wildlife, and coastal ecosystems.

- Furthermore, without the proper natural resource base, economic development in Caribbean islands cannot be sustained without massive aid from outside the region.

- In short, natural resources are a cornerstone of island development; the forestry sector, through watershed management, can make significant contributions towards the goal of optimizing the contribution of natural resources to island economies.

- Because the forestry sector of Caribbean islands has been neglected for many years, it is necessary that this sector be upgraded to the point where it can perform its role in the economy optimally.

- Watershed problems are critical, hence the need for immediate action in order to conserve options that may be lost if inaction continues to rule.

- The financial resources to address these concerns is frequently beyond the means of these small island states. Therefore, we look to the international development community to assist us in carrying out this much needed effort.

The workshop recommended a multiple approach to the development of watershed management programs in the forestry sector. Some recommendations are designed to contribute to institution building, others to improving land management, to develop monitoring systems that can gauge progress, and still others to develop regional approaches to problems that cannot be addressed by islands individually. It was also recommended that state-of-the-art developed technology be applied to island problems, hoping that these technologies may mitigate the decades of neglect in this sector and provide powerful problem solving tools that have proven useful in other regions of the world.

These recommendations are not meant to be an all or none proposition. Parts of the total package may be implemented as resources permit. However, a full package is presented as a descriptive contribution of what is needed to elevate forestry and watershed management in its rightful place within island economies.

I. ORGANIZATIONAL OR INSTITUTION BUILDING RECOMMENDATIONS

- The need for training in all aspects of forestry continues to be the top priority of island forestry departments'.

- Public education is also critically needed.

- High level policy makers must be involved in and informed of the watershed problems and solutions. Their participation in regional, local, and international forums where these issues are discussed is encouraged.

- Mechanisms for facilitating intra-government coordination of watershed management actions are urgently needed.

- Comparative analyses of the laws under which forestry programs operate and of the organizations of forestry program are needed.

- A computer linkage between islands using inexpensive personal computers (about $5,000/island) is needed to facilitate communications and rapid exchange of information.

- Communication among all islands and regional research institutions should be encouraged.

- Giving legal status to critical watersheds should be considered as an option designed to facilitate their management.

II. LAND MANAGEMENT

- It is critical to learn, as soon as possible, current land uses, land capabilities, and potential for use. Satellite technology now available could help significantly in the deliniation of land uses.

- Because tropical watersheds are little known and are subject to different conditions than the familiar temperate zones ones, it is imperative to begin land-use-erosion studies designed to provide baseline information on normal and human-induced rates of erosion.

III. WATER RESOURCES

- Rivers on the islands have not been gauged adequately. River gauging programs provide information on water quantity, quality, seasonality in availability, and serve as a monitor of the success or failure of management actions.

- We strongly recommend that the gauging program started by the U.S. Geological Survey and U.S. Forest Service under funding by USAID be continued and expanded to other islands.

IV. DISTURBANCES

-There should be a continuous alertness and interest in identifying catastrophic events (hurricanes, landslides, volcanoes, earthquakes, human interventions) to understand their periodicity, intensity, effects, and rate of recovery.

V. INTEGRATION AND SYNTHESIS OF THE ABOVE

-We recognize that the value of information is best measured by its use and impact on action programs. We thus recommend that what is learned from the proposed activities be integrated into maps, models of watershed dynamics (including energy and economic models), management recommendations, and watershed management and use plans.

We recommend that action and study plans be implemented in selected watersheds of participating islands. The three watersheds already under study in Dominica, Saint Lucia, and Saint Vincent and the Grenadines could be the core of such a program. All activities, training, experiments, management, etc. could be conducted in the selected watersheds where monitoring could be done by gauging stations and satellite imagery. Selected watersheds become centerpieces of development and for demonstration. Local expertise should be in charge of programs and provide training. Outside assistance would be available as needed. International reseach would be encouraged.

ADDRESS BY THE HONOURABLE V.I. BEACHE, MINISTER OF TRADE AND AGRICULTURE, ST. VINCENT AND THE GRENADINES

I am glad that this meeting is taking place in St. Vincent and the Grenadines at this point in time. There is no doubt that we have undergone two recent disasters that have reaped havoc to a certain extent on our environment and to a greater extent to our economy.

Now we are slowly recovering and this is in no small means due to the forestry department in the Ministry of Agriculture which is really doing a lot of hard work in this respect. I was going through some papers the other day and I was reading that forests cover about 1/3 of the non-polar regions of the land surface, and that economically and financially contribute to certain countries substantial amounts to their Gross Domestic Product.

From the earliest days before civilization developed, our ancestors lived in forests. Before technology developed to what it is today they survived and got all their sustenance, clothing, food, and water from the forests. This in itself is telling us that the forest must be very important. In the tropical region, forests become even more important since we have no snow lines, and whatever water we get must be from rain. Hence, we take forests for granted and sometimes we see wanton destruction because of financial reasons and ignorance.

There is quite a lot of cost-benefits in having forests and some of us only look at the quantifiable benefits; we can sell lumber, we can use it for pulp, we can exploit the wildlife, etc. But, the non-quantifiable benefits are even more important. In St. Vincent and the Grenadines, for instance, without the forest we would have no water supply and it will mean massive amount of funds to be expended to provide water either by desalinazition or other sources; we have to do this now in the Grenadine islands. We are very well aware of what is happening and to this extent have taken the initiative to further extend and amend our legislation to ensure that we can have better protection for our forests and other areas.

At present, in St. Vincent and the Grenadines 45% or so of our electricity is generated hydrologically (through C.I.D.A., World Bank and E.I.B.). We have now put into place and will soon start constructing another hydroelectric station on the leeward end of the island which, I think, will augment our supply by possibly another 25% to 35%. Without the forests this could not be possible because there would be no running water to do this.

As a boy I remember that when the first hydroelectric station was built we had so many problems in containing the flow of water that we had to pay substantial amounts of compensation to people whose lands were washed away by overflow from what is known as the balancing tank. In those days we had three generators running fully and the dams had to be opened up so that the water could run out. Unfortunately the decision was taken soon after to allow logging and charcoal-burning operations to be carried out. Now we do not have enough water to run two generators in this same power station. Because of these operations large gommier trees that may have been well over 100 years-old which nested one of our most beautiful birds, the Amazona guildingii parrot were also destroyed. This also resulted in the destruction of the natural habitat of these birds, and we started gradually losing the population of the St. Vincent parrots, so much so that at one time they nearly became extinct. We had to take some very harsh measures to correct this (in so much that I think the Ministry is not now looked on very kindly). We had to collect birds that were in captivity, the younger ones that is, so as to prevent the destruction of these very beautiful species which you may see in their natural environment or some of them that are still in cages in captivity.

The Forester is a very 'hardy' and hard-working person who has to be dedicated to be able to tramp in the forest day after day in lonely isolation. This should not only be done because of dedication; the benefits should be commensurate with the responsibilities.

We know that without aid and without dedication, the destruction of our forests would have been more rampant and to this, I feel that we have to thank those persons, not only in St. Vincent and the Grenadines but within the Caribbean for the assistance received. I firmly believe that because our close proximity and as it is established that forests play an important role in weather moderation, what affects one country, it is bound to have some kind of reaction on one or more of the other countries.

It is not only as I said before the quantifiable benefits that are important. The non-quantifiable benefits are even more so, if we take a case in point, Switzerland. This country obtains more out of the scenic beauty from the forests as tourist attractions rather than would be obtained in benefits such as timber.

It is said that the latent energy that comes into the atmosphere because of transpiration cannot be counted but yet scientists feel that it plays a very important part in this respect. One thing I know it doesn't take a scientist to see is that in any desert there is no forest cover. We must ask ourselves the question, why this is so.

We know that as time goes on, science becomes more involved and I think that more emphasis should be placed on training and education. To this end we have been trying to arrange courses and seminars. But one of the ironies of this whole situation is that the aid donors have their own guidelines in this respect. Education, for one thing, is not counted as a productive sector. Most donors are prepared to give assistance only in what they term the productive sector, e.g., agriculture (yes, grow more food). They are not prepared to give aid to education, they are not prepared to give aid to re-afforestation because as far as they are concerned these are non-productive sectors; but without the forests, we would have no agriculture. This is well defined, this is well accepted, and this is well known.

We have all seen what has happened with the forests in Haiti and we have also seen the massive amounts of funds that are needed now to try to get these lands back into some kind of forest cover. I hope that the message will be clear and for those of you from the Universities, etc., I hope you will bring a little bit of pressure or influence to bear on those aid donors, maybe, to alter their concept of what productive sectors are from what non-productive sectors are.

I was looking through our digest of statistics just the other day and noticed that in 1981, which is the latest report we have, we spent over EC $6 million for the importation of lumber into St. Vincent and the Grenadines. This was about 50% of what we spend for food. It was more than we spent for almost any other single commodity that was being imported. If we were able to generate hardwood, for instance, we could save 50% of this; it would have been a substantial saving towards the economy of St. Vincent and the Grenadines.

Again let me reiterate that I welcome you, I am glad that this meeting is taking place here. We are very conscious and concerned about what is happening in our forestry regions, and as such have given Dr. Lugo sometime ago, the assurance that we would amend our legislation. Unfortunately I am not in a position to tell him that this has been done. This is not because of laxity but because of pressure of work on our legal department. However, I can assure you that at the next meeting, if it is held next year or the year after we would be in a position to give to you copies of our amended legislation so that you can have the satisfaction in knowing that something is being done. Thank you.

PRINCIPLES OF SOUND WATERSHED MANAGEMENT

Ariel E. Lugo
Project Leader
Institute of Tropical Forestry

The watersheds of Caribbean islands deserve special attention from all sectors of society because of their importance to the economies of the islands (Beller 1979), the extreme human and environmental stress under which they function, and the little information that is available about their response to manipulation. Comparisons with continental lands in the Caribbean establish that Caribbean islands have a higher population density, higher intensity of land use, and lower forest cover (Lugo et al. 1981). Thus, it is not surprising that island watersheds yield sediments at high rates (Table 1) and with significant year to year variations (Table 2). The intensity of rainfall, combined with land use (Table 3) appear to be the most important variables regulating sediment yield (Fig. 1).

A watershed is a hydrologic unit defined by the catchment area and drained by a river. Watersheds include land, water, and biotic resources and behave as ecological units. A watershed can easily be demarcated and all its components are linked, just like islands. Water is the factor that integrates the function of a watershed. However, its quality and quantity are themselves regulated by other components of the watershed. A watershed has many subsystems that function within the context of a larger system. All subsystems are connected to each other some how. When one subsystem changes, all others are affected. In some instances changes are insignificant, but on occasions they can be radical.

Management of watersheds must be well integrated. Normally, each subsystem has a different manager. Wildlife, trees, agricultural crops, water, and urban subsystems within a watershed are all managed by different professionals working in isolation from one another but significantly affecting each other's job. Society, which owns all the subsystems of a watershed, benefits or suffers from the consequences of watershed management.

The total value of a watershed is the sum of all the values of its parts. However, not all values can be maximized at once because by maximizing a value in one, the value of another could be reduced. Thus, a particularly strong manager who is able to maximize yield from one sector at the expense of others, could in fact reduce the total value of the region by affecting in a negative sense all other watershed values.

Foresters, through the management of forest lands can usually affect the value of a large number of watershed subsystems e.g., water, wildlife, soil, agriculture, economic, social, etc. Managing lands with a watershed perspective uses different criteria than managing the same lands for a wood yield only. It does not follow, for example, that maximum wood yield will also produce maximum water quality and quantity, or maximum abundance of wildlife. In fact, maximizing wood yield may reduce water quantity, could deteriorate water quality, or reduce the diversity of wildlife. Obviously, forest managers must understand the complexities of watershed function if they are to play their role as watershed managers properly.

Unfortunately there is incomplete understanding of tropical watershed function. It is critical that forestry programs maintain as strong a commitment to watershed research as they do to management. Only through research and a willingness to change management prescriptions when necessary, will we be able to live up to the responsibility bestowed upon us by society.

Williams and Hamilton (1982) reviewed the literature on the behavior of tropical watersheds and Hamilton (1984) used this review to identify myths that confuse watershed management. Among the myths suggested by Hamilton are the following:

-deforestation causes floods,

-logging of forests lowers the water table, springs, and wells,

-reforestation reverses the trends just listed,

-grass is better cover than trees, and

-forests increase local rainfall.

Based on what is known about watersheds, the statements could be rephrased as follows:

-floods are not caused by deforestation but by poor zoning of land (which exposes people to floods) and by climatic events,

-logging increases water yields because there is less water evaporation by trees,

-reforestation has many benefits but it does not increase water yield or decrease floods significantly,

-which cover type is best depends on the management objective, and

-forests have little effect on local rainfall particularly in islands under the influence of trade winds.

Many of these statements are debatable and the reader is referred to Hamilton (1984) for a complete discussion. The point is that what appears to be common sense, is not necessarily correct. This by itself justifies research. On the other hand, there is a wide gap between available knowledge and practiçe of watershed management. The following recommendations of Hamilton (1984) make sense:

-protect at least 50 m on each side of stream banks because these buffer zones are critical areas in the control of water quality;

-identify and protect areas susceptible to massive erosion, e.g., steep slopes of a watershed;

-protect cloud forests because they provide a major water input to the watershed;

-focus attention on roads, ditches, and logging tracts; these are the uses that promote the most erosion in watersheds;

-minimize non-absorbing surfaces;

-revegetate critical areas first;

-build management and maintenance into changes of land use; and

-always do research to learn what you are really doing and its consequences.

Hopefully this workshop will address these issues and provide recommendations that can help Caribbean islands manage their watersheds sustainably and for maximum benefit to humans.

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Table 1. Representative sediment yields from watersheds*.

Type of watershed	Sediment yield (t/ha.yr)	Source
Temperate		
Eastern U.S.	0.31 (4) †	Patric *et al*. 1984
Western U.S.	0.37 (13)	Patric *et al*. 1984
Pacific Coast U.S.	8.93 (112)	Patric *et al*. 1984
Tropical Islands		
Santo Domingo	95 - 346	Tirado and Lugo-Lopez 1983
Puerto Rico	0.2 - 48	Lugo *et al*. 1980

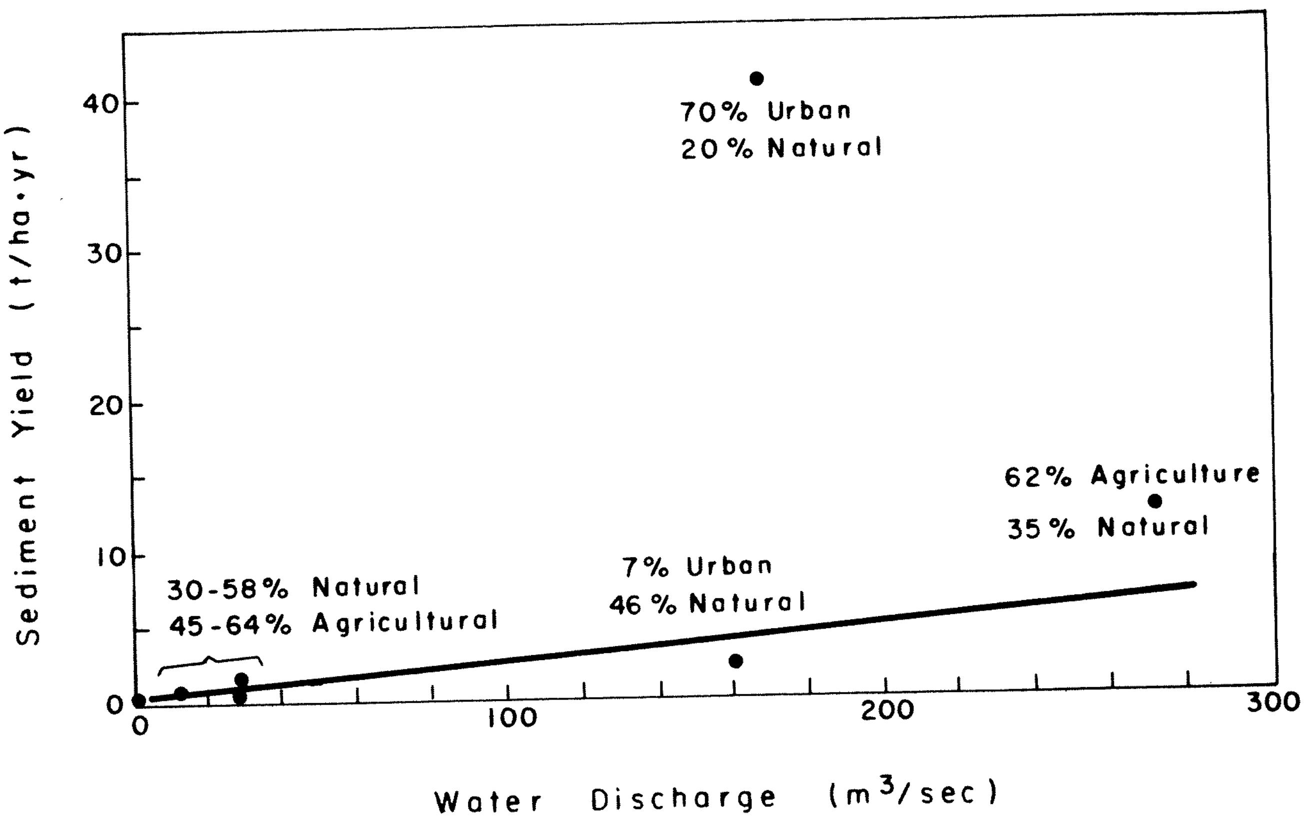
* Recommended maximum for temperate region: 0.56 t/ha.yr (Patric *et al*. 1984).
† Maximum recorded.

Table 2. Annual variation in sediment yield of watersheds in Puerto Rico (Lugo *et al*. 1980).

Watershed	Annual yields				
	1968	1969	1970	1971	1972
	(t/ha.yr)				
Tanama river	32.8	18.7	1	13.7	9.0
Pellejas river		48.6	40.7	1.8	29.7
Vivi river		19.6	32.3	3.8	1.9

Table 3. Erosion from different land uses in Puerto Rico (Smith and Abruña (1955).

Land use	Soil loss (t/ha) per inch rainfall and % slope
Exposed soil	0.30
Annual crops except sugar cane	0.20
Coffee without litter of understory	0.11
Coffee, well managed	0.012
Pastures	0.009
Sugar cane with straw left in place	0.006



Sediment Yield (t/ha·yr)
40
30
20
10
0
0
100
200
300
Water Discharge (m3/sec)
70% Urban
20% Natural
62% Agriculture
35% Natural
7% Urban
46% Natural
30-58% Natural
45-64% Agricultural

WATERSHED MANAGEMENT IN DOMINICA

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INTRODUCTION

The Forestry Division of the Ministry of Agriculture Lands and Fisheries is mainly responsible for watershed management on the island. Other agencies involved in watershed management are the Agriculture Division, which is responsible for soil conservation as it relates to agriculture, the Central Water Authority which is responsible for legally declared water catchments and the Physical Planning Section of the Economic Development Unit.

The Forestry Division which is responsible for all government forested and protected lands, has the greatest responsibility for watershed management on the island. The status of forestry in Dominica including a description of the resource, forestry activities and the responsibilities of the Forestry Division are given in Gregoire (1982).

LEGISLATION

There exists a number of laws which provide for watershed management activities on the island. Chapter 80 of the Laws of Dominica entitled 'Forests', makes provision for the control of felling of trees and the extraction of forest products in the state. It also empowers the forestry and conservation officers to carry out their duties.

The Stewart Hall Catchment Rules (S.R.O. No. 11 of 1975) establishes the only legal catchment in Dominica. This law which is administered by the Forestry Division affords the Stewart Hall Water Catchment protection from felling of free and agricultural practices. The Stewart Hall Catchment provides the southwestern section of the island, including Roseau, with water.

The National Park and Protected Areas Act of 1975, seeks to protect land in the state for scientific, educational and recreational purposes. The law stipulates that there should be absolutely no cutting of trees within a National Park.

The Forestry and Wildlife Act of 1976 also provides for the protection of forests as well as wildlife in Dominica.

POLICY

Embodied in the overall forest policy of Dominica are provisions for the Forestry Division to manage forest reserves:

-to prevent floods;

-to prevent soil loss;

-to preserve adequate water supply;

-to preserve scenic beauty and ultimately encourage tourism;

-to ameliorate climate; and

-to preserve flora and fauna to retain the balance of nature.

These management objectives are in addition to those providing for timber and other forest products, employment, foreign exchange, and revenue.

WATER RESOURCES

Dominica is said to have 365 rivers. Annual rainfall ranges from about 7500 mm (300 inches) in the wet interior to 1000 mm (40 inches) on the drier west coast. It is obvious then, that there is an abundance of water on the island, as a result of the rugged terrain and mountainous nature of the island.

The main watersheds are the Picard River watershed in the north, the Layou River watershed in the centre, the Roseau River watershed in the south and the Maclauchlin River and White River watersheds on the east coast. The Roseau River watershed is being tapped for hydroelectricity while other areas are being investigated for that purpose.

Shanks and Putney (1979) estimated that there are 35 water catchments on the island, providing water for domestic purposes to the populated areas. In 1964, a World Health Organization team proposed a consolidation of those 35 water catchments. Under such consolidation, 19 water catchments would be phased out, and the island's water supply would be met by 21. Some of the systems proposed and those to be retained would have their sources within National Park and Forest Reserve areas.

Although there is a certain level of contamination of water, caused mainly by agricultural practices and human settlement, the quality of water in Dominica is rated among the purest in the world. Earlier this year, a plant to bottle spring water for export was opened, and a contract to supply water to Aruba was signed and is being implemented.

LAND USE

Shanks and Putney (1979) observed that all types of natural vegetation on the island (Table 1) provide watershed protection and soil stabilization benefits, and there is no evidence that one type is better than another in this regard. Each vegetation type is suited to survival in a particular climate and soil zone, and as such, provides the most reliable watershed protection for that zone. Agricultural crops may or may not provide equivalent watershed protection, and usually they do not.

The ownership of the lands of Dominica is shown in Table 2.

WATERSHED MANAGEMENT PROJECTS

After the devastation of hurricane David in 1979, and the initial concern demonstrated by the government and the general public, a watershed study financed by the U.N.D.P. - F.A.O. was completed in July 1980. The study recommended that while the critically deforested areas should be reforested, the other areas should be left untouched. It was felt that natural regeneration would repair the damage caused to the watersheds by the hurricane.

Although natural regeneration to an extent helps to control land slides, soil erosion, and flash flooding, there was still need to implement some form of reforestation programme to improve the quality (merchantable value) of the forest.

A reforestation and soil conservation programme financed by the International Labour Organization, (ILO) was put into effect in 1981. At the completion of the first phase in 1983, a total of 506 ha (1250 acres) of land was reforested in the three major watersheds of the Roseau River, Layou River and White River. ILO also provided finance for the maintenance of these areas for three years.

Quite recently there has been a great need to gather information on the rivers of Dominica. Such information is required to assess the potential of rivers for hydro-power and to gather information on factors such as water-quality, sedimentation, and water-levels.

At the moment, stream gauging activities are being carried out on eight rivers and streams scattered around the island. The information gathered will help watershed managers in assessing the nature of the watersheds and assist them in making decisions.

WATERSHED MANAGEMENT PROBLEMS

The clearing of forest land and the use of this land for other purposes have created most of the problems on the island. The introduction of the chain-saw in Dominica has accelerated land clearing operations. Most significant are clearing along steep slopes, rivers, and streams. The cultivation of steeply sloping land also creates problems associated with landslides, soil erosion and landslips.

The absence of adequate and reliable information on the watersheds also creates problems for the manager, and watershed management is hampered by the unavailability of adequate manpower and equipment.

RECOMMENDATIONS

The proposals made in this section are by no means exhaustive. They are the minimum required to strengthen the position of the Forestry Division with regards to watershed management activities on the islands.

-The training of local staff in watershed management is a vital aspect of any watershed management programme. There are many young officers who have been exposed to the principles of watershed management who are eager to further their education in this field.

-Only one water catchment is defined and protected by law. The difficulties associated with not providing legal status for water catchments are very evident. The use of pesticides, the cutting of vegetation and other such malpractices are carried out in catchments not legally protected. All important water catchments should be given legal status to safe-guard their water resources.

-Stream gauging activities should be carried out in more rivers. With only eight rivers being monitored, there is need for many more to be studied.

-An assessment of all major watersheds should be done. Such an assessment must include factors such as rainfall, vegetation, wildlife, land-ownership, drainage pattern, soils, land use, and potential for development to cater for the needs of the country.

CONCLUSION

The Forestry Division is very impressed with what has been achieved in the islands since the holding of the First Caribbean Foresters Meeting in St. Lucia in 1982. Every effort should be made to ensure that Caribbean Foresters meet on a regular basis.

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Shanks and Putney. 1979. Dominica Forest and Park Systems Plan. Eastern Caribbean Natural Area Management Program and Dominica Forestry Division.

Table 1. Land area of major vegetation type (from Shanks and Putney 1979).

Vegetation type	Land area (ha)	% of total
Agricultural, urban, village	23,133	29
Scrub forest and savanna	7,507	9
Littoral woodlands	666	1
Freshwater swamp	126	-
Landslide zone	237	-
Montane swamp forest	1,754	2
Elfin woodland	2,332	3
Montane thicket	3,758	5
Fumerole vegetation	31	-
Riparian rain forest	1,101	1
Secondary rain forest	20,133	25
Mature rain forest	18,222	23

Table 2. Land ownership (from Shanks and Putney 1979).

Land use	Area (ha)	% of total
Reserved:	15,573	20
Morne Trois Pitons National Park	6,349	8
Central Forest Reserve	410	1
Northern Forest Reserve	8,814	11
Unallocated state land	10,526	13
Privately owned or claimed lands	52,901	67

WATERSHED MANAGEMENT IN GRENADA

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Over the past decades the country's natural vegetation has been subjected to the destructive activities of man. Indiscriminate felling of trees on steep slopes, both on private and government lands, have left the soil unprotected against the destructive forces of nature. The Government of Grenada is fully aware of the erosion problems which exists in the country but there is still a great need for coordination and funds to effect conservation programmes.

Watershed management is no longer used as a legalistic term but refers to an entire concept. Base on the regulation and the utilization of water in the watershed, the central aim of watershed management is to improve the economy or at least the value of the watershed to the public in terms of water production, prevention of soil erosion and regulation of rivers and flooding. Moreover, attention is being paid to improve the private sector of the economy by promoting growth in production and income of the landowners within watershed areas. The present demand for water in Grenada is 8 million gallons per day. This is expected to increase significantly in the next few years to cater for industrial development, growth in population, etc.

LAND EVALUATION SURVEY

During the early part of 1983, aerial photographs of the entire country were taken by the government for use in the preparation of development plans. A land evaluation survey on crop suitability for rained agriculture is now in progress. The country is divided into three zones in regards to land use: agriculture areas, industrial areas, and residential areas.

Agricultural areas have been further divided into watersheds, 72 of which have been identified. A detailed study of soil properties, climate, crop suitability, etc. is being conducted in each watershed separately.

The necessity for soil and water conservation measures has intensified now that the thrust of the administration is towards crop diversification, concentrating on the production of non-traditional crops for the expanding agro-industry and export market.

CONSERVATION INSTITUTIONS

Sectors of the government concerned with the conservation of natural resources are the Lands Use Division in the Ministry of Agriculture, the Forest Development Corporation (FDC), Central Water Commission (CWC), and the National Science and Technology Council (NSTC).

CWC and NSTC have not played an active role in water and soil conservation and the Land Use Division mainly disseminates information to farmers on hillside farming. The general response of farmers to such methods, however, is only fair.

The Forestry Development Corporation is the sole body responsible for upper watershed management. It was established in 1982 and charged with the responsibility of promoting forestry in the interest of the public and the economy. It controls all government forest reserves which total about 4,050 ha (10,000 acres) plus a 203 ha (500 acres) estate in the Annadale watershed area.

The activities of the FDC for the past two years have been limited to exploition. Due to lack of working capital and qualified technical staff no afforestation program has been effected. A 10-year afforestation plan, however, has been formulated for the Grand Etang Forest Reserve and is now under consideration by the government.

A three year afforestation plan for the Annadale estate watershed has also been drawn up. This is a pilot project which needs considerable financial assistance to be effected.

The Annadale estate forms the major part of the Annadale watershed which supplies drinking water to the Town of St. George's. The area had water pollution problems resulting from heavy use of herbicides and fertilizers. In 1964, the government took over the area and declared it to be a protective watershed area. However, the area has served as a center for illegal regular charcoal burning and other forms of larceny. There are virtually no trees left in some sectors. There is much evidence of soil and gully erosion, frequent siltering of the two dams in the area, and significant drop of water volume during dry periods.

The Les Avocates watershed is a complete contrast to the Annadale watershed. This area once suffered similar problems to that of Annadale but such problems no longer exist because the area is now completely forested with <u>Hibiscus elatus</u>. This reforestation programme not only helped in preventing floods, siltation, erosion, etc., but also helped in maintaining a continued supply of good-quality water throughout the year.

CONSERVATION PROGRAMMES

The Agricultural Development Project (Government of Grenada U.N.D.P./F.A.O.)

This project which was formulated in January 1976, became operational March 1977 with three components: soil and water conservation, production - including the accelerated propogation of the non-traditional trees crops, and marketing.

Project Activities

The project was designed to cover the Chemin Valley (watershed No. 9) but such an undertaking was found to be too ambitious after an evaluation of the project. All activities, therefore, were concentrated in Madigras (site No. 1) which occupies an area of 30 ha (75 acres). Two dams with an estimated capacity of 3.5 and 0.2 million gallons have been constructed to cater for irrigation and domestic uses.

Modern soil conservation methods, e.g., terracing are used in the production of both annual and perennial crops. Conservation forests are also being established on the steep upper slopes and blocks are divided by wind breaks.

Production is being sold to the Grenada Marketing and National Importing Board or to Agro-Industries Plant. The possibility of integrating livestock into the project to provide the exhausted soil with organic nutrients is under consideration. Fingerlings of Tillapia milotica from Kenya are also been raised in the large dam.

Teaching and Training

-The project has four new diploma graduates on its staff who have been trained in all project activities.

-Teaching and training in all aspects of the project work is also provided at the Mirabeau Farm School.

-Inservice training, as required for extension service personnel, is also carried out.

-Farmers, 4 H people and other interested individuals are trained upon request.

Research

Observation trials from time to time are established to evaluate planting material, fertilizer response, soil pH, herbicides, and pesticides.

Achievements

-the project opened avenues for research and training;

-valuable statistical data on planting material, fertilizer, soil pH, herbicides and pesticide etc. have been accumulated;

-experiments are also being conducted on agroforestry techniques and gully control measures;

-farmers have begun to adopt the methods and practices utilized on the project, and

-erosion of top soil has been greatly reduced as demonstrated by the non-appearance of "red sea water" around the coast after heavy showers.

Other Programmes

Other conservation programmes which are still in the planning stage are: Levara National Park, U.N.D.P./F.A.O. Upper watershed management project, and soil and water conservation with complete gully control.

PROBLEMS OF WATERSHED MANAGEMENT

-Finance - lack of funds is the main problem in watershed management for without money, conservation programmes cannot be effected.

-Training - our knowledge of watershed management is very limited; training at professional and sub-professional levels is urgently needed.

-Coordination among the various bodies involve in conservation is lacking.

-Protection of watersheds - the old forest act needs revision and laws prohibiting illegal activities in protective forest areas need implementation.

-Equipment - machinery and equipment conducive for conservation works are needed.

-Inappropriate agricultural practices - farming methods on steep slopes is a problem because not all farmers adopt the use of conservation method in farming.

-The general topography and climatic conditions of the country also create many problems in watershed management.

CONCLUSION

Forestry is a long term enterprise which does not yield immediate monetary benefits. This fact is causing many governments in the Caribbean and elsewhere to give little or no priority to forestry. It must be realized, however, that the intangible benifits of the forests in preventing soil erosion, water conservation, and providing aesthetic values cannot be measured in monetary terms.

Technical matters in which the country needs cooperation are associated with: comprehensive watershed planning, vegetative cover management, operational issues, forest hydrology research, erosion and sediment studies, and environmental impact assessment.

We see research and technical training, particularly at the very basic levels, as the most critical aspects at this stage of the country's watershed development programme.

WATERSHED MANAGEMENT IN GUADELOUPE

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The Forest Service action for protecting the forests of Guadeloupe combined with a decreasing pressure of agriculture on the lands since World War II have made erosion problems of lesser importance in Guadeloupe. Therefore, and because of rather independent activities of both the Agriculture and Forest Service in the island, the watershed management problems have not been considered as immediately urgent.

In this paper we present some past actions that have been undertaken concerning agricultural management, at different altitude conditions, and a recent study that has been carried out by the Agriculture Service because of the need for watershed management for the security of Guadeloupe's main city which faces floods.

PAST WATERSHED MANAGEMENT PRACTICES

Matouba

The management area is located on the fringe of the lower part of the state-owned forest, along the southern side of the Basse-Terre mountain range, on the leeward side of Soufriere. Located at 750 m elevation on steep slopes (25% average), this management area occupies rich and thick volcanic soils. Annual rainfall is 5000 mm.

The area of concern is state-owned land under long-term lease to small farmers, on the edge of the forest. Farmers grow vegetables and flowers and raise a few head of cattle. Their techniques of traditional cultivation are characterized by intensive use of the soil; tilling and rafting always effected along the steepest slope. This causes erosion and accumulation of the fertile soil at the bottom of the slope. The farmer is thus compelled to collect this soil and spread it again over his field.

In order to cope with the consequences of such techniques so disastrous to the ground and soil, the "Service Forestier" effected a series of works for protecting the soil over a dozen hectares in 1961 and 1962. The purpose of this project was to develop a demonstration project to be used as an example of sound soil conservation practices. This demonstration project used a network of bench terraces laid out in a "fishbone" design every 4 m downward with a slope of 1%. This caused rainwater to flow very slowly from the top to the bottom of the slope. The cost of these experiments, all done by hand, proved to be quite high; it took one whole day to build a 1 m terrace.

In a few years, project design proved efficient in reducing erosion and, above all, because farmers were obliged to reduce the length of cultivation in their fields. Unfortunately, they never took to using other new techiques of cultivation.

The growing dependence of Guadeloupe on food importation and the eruption of Soufriere in 1976, have brought about an important decrease in agricultural activities in this region. The management was given up by farmers due to an increase in cattle breeding and forest activities.

Bouillante

This is an example of another past management practice operated by the "Service Forestier". It is situated near the coast, at an elevation of about 50 m, on the dry slopes of the leeward coast at a few kilometers north of Bouillante. The Soils belong to the group of volcanic vertisols and slopes are steep (30% average). Annual rainfall is 1250 mm.

This example of a watershed management project was performed on private land. The "Service Forestier" rented this land to demonstrate how to farm the impoverished land that was then being used for cattle grazing and over -explotated by charcoal producers.

In 1964, the Service Forestier constructed a system of terraces similar in design to that of Matouba. The costs were cheaper than at Matouba because the terraces were built with machinery which took less time. Fruit trees (Anacardium and mango trees) were planted every 2.5 m along the edge of the benches. For financial reasons, the Service Forestier abandoned the project and it was not maintained by the landowner. Fifteen years later the terraces are still in good condition but the planted trees have disappeared.

Basse-Terre

Various torrents flow across the town of Basse-Terre situated at the foot of Soufriere (1467 m) because the catchment basins periodically receive heavy rainfall bringing about dangerous overflowing to heavy populated areas.

Some sudden and significant flows (10 $m^3 s^{-1} km^{-2}$) transport soil, rocks, and broken trees that are potentially, extremely disasterous, thus it is necessary to prevent or control such a danger. The local assembly financed an inquiry that was carried out by the Agriculture Service to define the means by which to cope with this worrying situation.

The main results were:

-An "active" fight seems to be inefficient because of:

--the abundance of vegetation in the catchment basins no special action is necessary for producing a continuous cover.

--access difficulties, modification of the river bed and slope would involve considerable effort and money.

-A "passive" defense can only be considered which includes:

--construction of small scale works for diverting into neighboring valleys the more violent flows which may reduce their intensity in the sensitive zones;

--creation of a series of dams and settling ponds for removing sediments from the floodwaters ensuring that the dams are regularly cleaned;

--a network of paths provides an efficient means by which a constant watch can ensure prevention of natural dams from being erected from entangled pieces of rocks and wood. These represent the most dangerous risk whenever they yield under the rush of waters;

--the use of proper agricultural techniques to reverse the consequences of clearing for irrigated vegetable growing.

This recent study has led to a series of observations and measurements on torrent flows to prepare the above mentioned map. The Agriculture Service has also set up a series of recommendations:

-no clearing on the steep slopes

-wind rowing the extracted stones along the contour lines

-building terraces spaced every 2 to 3 m

-controlling water-spray.

WATERSHED MANAGEMENT IN THE CARIBBEAN WITH SPECIFIC REFERENCE TO ST. LUCIA

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INTRODUCTION

Catchment-area-forest, whether natural or created artificially, are to be seen in many parts of the West Indian islands and are recognized as an important adjunct of municipal or other water supply schemes. Their beneficial effects came into play in hilly and mountainous areas rather than level ground, where there is far less run off. Hence forest maintained for the preservation and regulation of water supply are situated in the catchment basins of the hills rather than on level ground in the valleys. It is sometimes customary to stop all activities in catchment-area-forests maintained in connection with town water supplies, the object being to prohibit entry and thus prevent pollution of the water supply. These areas, known as forest reservations, were set aside to be maintained permanently under forest.

HISTORY OF FOREST RESERVATION IN THE WEST INDIES

Jamaica: The island was originally thickly clothed with forest. Since 1655 when the British took it from the Spaniards, practically all the profitable land had been alienated and the great bulk of the forests destroyed. In 1886, E.D.M. Hooper produced a report recommending the reservation of forests for regulating the water supply and providing protection against north winds. This included the formation of certain forest reverves in the mountains and on all Crown Lands in limestone areas. In consequence, legislation was enacted in the form of the mountain and river reserves law of 1889 and was amended in 1893. Both laws were repeated by law No. 14 of 1893. The law to regulate afforestation, in 1927, gave power to declare and acquire forest reserves and prohibit cutting or damaging trees and shrubs or cultivating in forest reserves without permission. The laws were difficult to apply and were largely ineffective in protecting the forest. Up to 1937 only one forest reserve, the Blue Mountain Reserve of 30,760 acres (12449 ha) had been established. This reserve lies for the most part over 5,000 ft (1,520 m) elevation. The slopes on both sides of the main ridge are very steep and the soil is loose and shaly. The slopes particularly on the south side have been very denuded by cultivation of coffee and other crops, and large quantities of soil and debris have been washed down the valleys causing silting and flooding. A. Wimbush, reporting on the subject in 1935, recommended the constitution and demarcation of a reserved forest; protecting it against fire, cutting and other forms of damage; appointing a trained forest officer with the necessary subordinate staff; and revising legislation. A full-time forest officer was appointed in 1937. Since then forest reservation has made considerable progress and new legislation have been enacted in the shape of the Forest Law. Under the new law, private land required for protective purposes may be declared a protective area, on which clearing, gazing and burning are prohibited or regulated.

Antigua: With a comparatively dry climate (rainfall about 44 inches or 1,120 mm) fire is the chief source of danger and the Bush Fire Ordinance, No. 5 of 1901, provides the means of dealing with it, though forest destruction has been extensive. There is no Forest Ordinance.

Montserrat: A Forestry Board was established under Ordinance No. 10 of 1927. Under the Forest Reserve Resolution in 1932, five forest reserves have been declared on the upper slopes and tops of hills.

Nevis with St. Kitts had a Forestry Ordinance, No. 10 of 1903, which was amended by Ordinance No. 5 of 1928, giving the Governor power to form a separate Forestry Board for each island. The Forestry Board consisting chiefly of planters, appears to realize the importance of protecting the mountain forests. St. Kitts: Forestry Ordinance, No. 10 of 1903, established a Forestry Board and prohibits the clearing of forest land or felling of timber without a permit from the Board. Its provisions have been well carried out and the mountains of the interior have been strictly protected by estate owners.

Trinidad and Tobago: The Forest Ordinance of 1916 had no provisions applying specifically to protection forests, though it prohibits unauthorized cutting, grazing, burning and other acts in forest reserves and in Crown Lands not included in forest reserves. R.S. Troup wrote in 1940 that Trinidad with Tobago has a properly constituted Forestry Department. Most of the highland of the island has been reserved, primarily for protective reasons, and there are other areas set aside for windbelts. In Trinidad and Tobago, soil and water conservation began with forest conservation. The Forest Reserve on Main Ridge in Tobago is the oldest in the Western Hemisphere. In 1766, the Young Commission demarcated a narrow 2,430 ha band of virgin forest running along Main Ridge for the "Protection of the rains". In 1904, the original belt was increased to 3,958 ha and was proclaimed a Forest Reserve, which is mainly protective in function.

Grenada: The Forestry Ordinance No. 13 of 1906, an ordinance introduced to protect and conserve the forests and water sources of the island, gives power to constitute "rain reserves" and "forest reserves". The former term applies to a portion of an estate surrounding sources or feeders of any spring, river or other water supply. Forest Reserves include estates or portions of estates in hilly or mountainous country or on the wooded sides of ravines or on areas where reforestation is desirable. The owners of areas to which the law applies are compensated by the remission of land tax or otherwise. The Forestry Ordinance appoints a Forestry Board with wide powers but the Board is handicapped by the fact that, except for the Grand Etang Reserve of 2,727 acres (1,104 ha), almost all the land is privately owned. At present cocoa and nutmeg plantations afford good protective cover to the soil, but shifting cultivation is practiced too far up the mountain sides and further forest reservation is desirable.

Dominica: Prior to 1940, there were no Forestry Ordinances and the forest had suffered greatly form shifting cultivation and timber exploitation. An Ordinance was introduced in the 1950's and since then much progress has been made to protect the forest from further destruction.

Dominica is the largest of the Windward Islands. The highest peak reaches a height of 4,750 ft (1,448 m). The forests are estimated to cover 65% of the total land area and, for the most part, cultivation is confined to lands at lower elevations. The principal crops are citrus fruits, bananas, coconuts, and cocoa. These tree crops provide a permanent cover and afford protection to the soil in the same manner as natural forests. Shifting cultivation was formally practiced indiscriminately in the more accessible forests but measures are now being taken to settle these cultivators on suitable land and to exclude them from areas to be retained as Forest Reserves.

The rugged topography with high mountain peaks and ridges induces a heavy rainfall well distributed throughout the year. Consequently, the mountains are covered with a luxuriant type of tropical rainforest containing a variety of valuable and useful timbers. Dominica is usually described as the land of "rivers", there are 366 rivers. However, in 1979, Hurricane David visited Dominica and caused extensive damage to the forest and private property and loss of life. The primary function of the forest of Dominica will always be protective and it is essential that they be preserved to regulate stream flow and to prevent erosion and landslides.

St. Vincent: In common with the other islands of the Windward group, it is volcanic in origin. St. Vincent is a relatively young volcanic "pile" and the Soufriere mountain in the north of the island errupted in 1902 and as recently as 1978. The topography, is extremely broken with peaks and ridges rising to 3,500 feet (1,067 m). The mountain mass from the sea induces a heavy and well distributed rainfall. The undulating land at lower elevations is devoted to the cultivation of arrowroot and sugar cane, while coconuts and bananas are grown on the valley slopes and cocoa in the wetter areas up to the 1,200 ft (366 m) contour. The rugged mountainous interior is covered with tropical forest except for the upper slopes of Soufriere which are bare as a result of the eruptions of 1902 and 1978.

The primary function of the forests in St. Vincent is essentially protective. Owing to the excessively steep slopes and broken nature of the terrain, the land remaining under forest is unsuitable for agriculture. It is important that it should be preserved to regulate water supplies, prevent landslides and to maintain the moist conditions necessary for production of cocoa, bananas and other agricultural crops.

In St. Vincent, general protection to trees and forest on Crown lands is given by the Land Trespass Prevention and Crown Lands Protection Ordinance, No. 5 of 1888. By proclamation in 1912, the Administrator (comparable to Governor) reserved all Crown Lands, 1,000 ft (305 m) in elevation and over, but in the absence of any clear line of demarcation encroachment has taken place. The situation is very bad at this present time.

St. Lucia: The Crown Lands Ordinance, No. 45 of 1916, prohibits squatting, encroachment and injury to trees and forest on Crown Lands. Under No. 23 of the Regulation under the Ordinance an attempt had been made to safeguard the water supply by prohibiting timber cutting on Crown Lands above 1,500 ft (457 m) without a licence from Governor. As the 1,500 ft (457 m) line has not been marked the prohibition had only a paper value.

As a result, considerable areas of forest have been ruined by shifting cultivation. In 1885, the Castries Waterworks Reserve, Dennery Waterworks Reserve, and Warrick Forest Reserve were established and proclaimed and gazetted in 1916. In 1886, Mr. E.D.M. Hooper produced a report recommending that the central reserve should be in line with those already reserved. Mr. A. Wimbush reported on the subject in 1935. In 1944, Dr. J. S. Beard, then Assistant Conservator of Forests, Trinidad and Tobago, carried out a preliminary reconnaissance and report on forests in St. Lucia in conjuction with similar work in the other Windward and Leeward islands. It was largely as a result of his report that the Forest Division of the Department of Agriculture was established in 1946 and the introduction of the Forest, Soil and Water Conservation Ordinance.

The forests of St. Lucia have been steadly exploited from the time of the first settlement by the English in the year 1638. Gradually, the natural forest has disappeared from the coast inward where the cover was cleared for agriculture. Today the forest is largerly confined to the more inaccessible interior mountainous region. Even in this region shifting cultivation by the local population has had a marked effect on the forest cover and gardens of bananas, coconuts, citrus and dasheen are not uncommon throughout the forest at the present time.

The forests are primarily protective and those remaining owe their survival to their inaccessibility. They perform an essential function in regulating stream flow, conserving water supplies, preventing erosion, and landslides and in maintaining a well distributed rainfall for the production of the principal agricultural crops: bananas, coconuts, citrus, and cocoa. With an expanding population, an increasing demand for agricultural land and an extension of communications, the broken terrain may not afford adequate protection in future. The existing gazetted forest reserve is 6,220 acres (2,517 ha), a proposed forest reserve recommended in 1885 is 10,100 acres (4,087 ha) and presently CIDA is carrying out surveys with a view to further extend these areas. A Forest Management Plan was prepared by J. A. Goodlet in 1970, but was never presented to the Cabinet for acceptance due to the low priority forestry had at the time. In 1982-83, CIDA was in the process of preparing for the St. Lucia Government, a forest management plan for Forest Reserve, Crown Forested land and Private Forested lands.

ST LUCIA

Introduction

The motto adopted by St. Lucia (The Land, The Light, and the People), reflects national awareness of the island's critical resources - the foundation upon which to build a young nation.

The island is of volcanic origin and for the most part is very mountainous but there are low-lying hills in the north and a plain at Vieux Fort in the south. It is intersected by three wide flat valleys filled with allivium, two on the west and one on the east. The total area of these, however, is relatively small and the greater part of the country consists of an extremely disordered topography dissected by steep valleys with peaks and ridges rising to 3117 ft (950 m). The formation of St.

Lucia is identical with that of the adjoining islands in the long chain of the the Lesser Antilles. It was formed by volcanic eruption through the coral and other stratified rocks below the sea.

The island when clothed in its natural vegetation used to be well watered with streams running down in all direction from the hills. Those towards the north and windward side have the longest course while the rivers on the south run in a direct line from the central hills and have by their torrential flow, cut for themselves deep courses through the rich soils at the base of the hills.

Topography of Forest Reserve

The mountainous area comprises the island's main watershed. This is a south-southwest to north-northeast axial ridge with numerous disorded, off-set, steep-sided spurs and valleys extending from it. Slopes are mainly steep and very steep and elevations range from 300 ft to 3,117 ft (91-950 m) above sea level. The general elevation of ridges is 900 ft (274 m). The highest peaks are Mount Gimie (3,117 ft or 950 m), Mount Houelmon (2,100 ft or 640 m) in the geologically younger southwest area, and La Sorciere (2,200 ft or 670 m), Piton Flore (1,875 ft or 572 m), Mount La Combe (1,1442 ft or 439 m) and Piton St. Espirit (2,050 ft or 625 m) in the remaining older part.

Climate

The island's tropical climate is modified by oceanic influences. The main features are uniformly high temperatures the year round, mitigated by the northeast trade winds.

Reliable temperature statistics are few. Mean temperature (^{o}F) over 31 years at the Botanical Station, Castries, approximately at sea level, are as follows:

JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
74.2	74.0	74.2	76.2	78.4	78.0	77.0	77.7	77.8	77.3	75.6	74.0

The rainfall of St. Lucia is low and intermittant in the coastal areas and high and continuous in the mountain interior. Generally, the forest area lies within 60 to 150 in (1,524-3810 mm) zone. The dry season is normally distinct between January and May; November is the wettest month.

The prevailing winds are the northeast trades which freshen considerably during the dry season. In addition, hurricanes may occur, mainly in the period August to October with accompanying torrential rains. Hurricane damage has been frequent, the most recent ones during 1967, 1979 - 1981. Hurricane Beulah in 1967 and David in 1979 were associated with heavy rains, causing numerous landslides. In 1981, Hurricane Allen, which was associated with heavy winds, seriously affected 80% of the forest water catchment areas.

Geology and Soils

St. Lucia is of volanic origin of the Pleistocene age and the main rock types occuring are andesites, dacites and basalt in various forms. Most of the rocks occur as pyroclastics, varying from coarse agglomerates and breccias through agglomeratic ashes to fine ashes and tuffs, though coarse frangmental rocks predominate. Basalts occur as dykes or flows.

Soils have been derived from the underlying rocks and from more recent showers of fresh dacitic ash. The number of soils type is large and they vary widely in stability, intensity of weathering and degree of leaching. (The soils of St. Lucia are described and classified by Start, Lajoie and Green of the Regional Centre, ICTA University of the West Indies, in "Soil and Land Use Surveys", No. 20 of St. Lucia, July 1966). Generally, they can be described as freely drained acidic clays and clay loams which are red, yellow or brown in colour and of low fertility. Owing to their usual great depth and clay texture, landslips are inevitable on the typically steep slopes when the forest cover is removed.

Hydrology

The forest area is drained by numerous rivers on either side of the main watershed. Those flowing to the west coast include Cul de Sac, Roseau and Canaries and those reaching the east coast include Marquis, Louvet, Fond D'Or, Dennery, Praslin, Troumassee and Canelles. The Vieux Fort River flows southwest to Vieux Fort Bay.

Land Use

St. Lucia has always had a varied agriculture, with cocoa, coffee, nutmeg and a variety of other tree crops being much more important in the past. Coconuts were planted in most non-sugar areas, particularly in the west, central-west and southwest. Over 15% of arable area of the island now carries some coconuts, but often at low density and in association with other crops. Coconuts remain the second crop of St. Lucia, and production improved substantially after 1950, benefitting from fertilizer applied to under-planted bananas.

In the 1950's, bananas became important as an export crop while commercial sugar production was discontinued. The result of this was the virtual removal of cocoa and the conversion of sugar land to bananas. Bananas, with an assured market has become the dominant crop and is grown everywhere on all classes of land regardless of land capabilities. Wherever a cultivator can find land, bananas are cultivated.

Problems with Land Use

There have been many problems with banana cultivation, in particular, the indiscriminate use of this crop on land of very varied capability. Severe problems over quality have continued, leading to a high rejection rate of bananas from small farmers and consequently low returns. The steep increase in the cost of fertilizer and chemicals has, however, continued to limit their use by small farmers even though fertilizers are sold at a subsidized price. Much of the excellent work done by the Windward Island Banana Association (WINBAN) Research Centre at Roseau has benefited mainly the larger producers, despite strong efforts to reach the small farmers in recent years.

Beyond these problems, there have been environmental difficulties. The banana boom began in the 1950's and early 1960's during a period of relatively high rainfall. The subsequent decline in rainfall has created increasing difficulties because bananas are particularly vulnerable to soil drying. Bananas are also vulnerable to damage by strong winds, which can affect fruiting and bruise the fruit even while leaving the tree apparently in tact. Moreover, the high rainfall in 1981 together with the replanting by almost all growers after Hurricane Allen in 1980, created glut conditions by the middle months of the years. The wisdom of banana monoculture was questioned as far back as 1966 by Start, Lajoie and Green. They said "The trend towards a monoculture of bananas, a crop very susceptible to hurricane damage is alarming inspite of immediate benefits derived from this well organized industry.

Diversification of crops should be actively encouraged as soon as possible, as a safeguard against the chance of disease, hurricane or other calamity affecting the banana industry".

Soil Erosion

Soil erosion is widely regarded as a very major problem in St. Lucia and the clearance of steep slopes for bananas and other crops by small farmers is generally blamed for a great deal of damage. It is also maintained, however, that uncertainties over land tenure, by restricting the area that is cultivated and fragmenting that area into parcels, has the effect protecting the land from the sort of erosion that might follow a consolidation of cultivation due to land reform.

In the island and mountainous area of St. Lucia most damage is caused by mass movement of soil. This takes several forms. On very steep slopes where there is little soil and often only a light forest cover, rock and soil slides occur frequently during and after heavy rain but they do little damage to cultivated land. On the lower slopes the most common form of mass movement takes the form of numerous small landslips many of which generate mudflows. These latter may attain considerable size and flow for several meters. Exceptional flows, such as those of 1939 (Hardy and Rodriguez 1949, Box 1939) and more recently from heavy rains in 1981, may flow for more than a kilometre, blocking streams, disrupting domestic water supplies and causing floods, as well as overwhelming whatever lies in their path. There are also large rotational landslips which bring down a whole section of hillslope. Once triggered these are very difficult to control.

In the drier part of St. Lucia mass movement is not a problem of the same order, but there is abundant evidence both of gullying (locally) and sheet erosion. These remove topsoil from the surface of wide areas under only light vegetation during heavy rain. The most seriously denuded areas are probably in the drier tracts of the north, south, and east coast, where shallow soil and large areas of outcropping rock provide evidence of top soil removal.

The area of St. Lucia excluding water, is 238 mi^2 (609 km^2), with a population of approximately 120,000.

Land use on the island is given in Table 1.

Water Supply and Demand

Most water comes from surface sources and there are no significant impounding facilities for raw water prior to treatment. In most cases the effective capacity of the individual system is severely curtailed by the fluctuation of flow at the source, resulting in acute shortages during periods of drought.

Total effective system capacity for the island was 4.45 million gallons/day (MGD) in 1975. Treatment facilities are not standardized and vary widely. Some small rural systems receive little treatment if any. It is estimated that the total island wide domestic demand for water was 1.70 MGD in 1975. Demand for commerical/industrial and other uses was estimated at 1.70 MGD, giving a total demand for water of 3.4 MGD. Given the absence of significant raw water storage capacity, the sharp seasonal fluctuations of flow in sources of rivers and the total service storage capacity of only 3.3 MGD, the island, particularly the Castries/Gross Islet area, remains prone to water shortages during the dry season. Water demand in recent years has risen most significantly in areas of rapid population growth, especially the northwest coastal zone and Vieux Fort. These areas have witnessed not only a growth in per capita consumption, as an increasing proportion of the population become served by private connections, but also a matching growth in demand from non-domestic consumers, particularly, the tourist sector. Agricultural irrigation is carried out on a very limited basis only.

The Central Water Authority is a statutory board with authority given under the Central Water Authority Ordinance. They are responsible for supplying communities with water for domestic purposes and for industrial use. They have the power under the Ordinance to declare any water catchment area a Forest Reserve once it can define the area on a map and on the ground. The maintenance and protection of such an area then becomes the responsibility of the Forest Division. Health authorities in the island also look after some of the water systems.

Water Abuses

Deforestation or removal of the protective cover from steep hillsides invites erosion, leaving the soil so degraded that it is too poor to support either crops or new forest. Example of the latter can be seen at Delcer, Choiseul and Dennery.

Other abuses include:

-contamination of rivers with inorganic materials, i.e., rubbish (trash);

-contamination of rivers with organic material, i.e., human faeces and timber waste;

-contamination of rivers with harmful chemical agents, i.e., detergents, pesticides, etc.

One of the biggest problems faced in the management of our water supplies is wastage. These wastages are often due to the following: dripping tap, faulty tap, running tap while brushing teeth and showering, car washing, and running hose during car wash, etc.

A Comparison of Water Problems With Other Islands

A comparison of four Caribbean islands relative to water supplies and water management problems is shown in Table 2.

A comparison between the water costs of two Caribbean islands, namely St. Lucia and Bonaire demonstrates the value of forest cover. The former depends on Forest Reserves for water management for the conservation of water. The latter is now a true desert island which once depended on management of forest water catchments for its supply; it now obtains its drinking water from a desalination plant installed in 1961. Water cost for St. Lucia in 1973 was EC$1.00 per 1,000 gallons and by 1979 it had risen to E.C.$2.25 per 1,000 gallons. Water cost for Bonaire in 1979 was approximately E.C.$13.50. This high cost is due to the use of the desalination plant.

Forestry Division of St. Lucia

The Forestry Division is a branch of the Department of Agriculture and is managed by a Forest Supervisor and his staff. The Division is charged with the responsibility of managing and protecting all forest reserves and assisting with the protection of forested Crown Islands.

A working plan was prepared in 1970-1980 to manage Forest Reserve Lands, the objectives of which are to:

-maintain the protective function of the forest;

-provide the maximum production of timber from exploitable areas on the basis of sustained yield;

-effect improvements in the growing stock in order to increase its productivity;

-preserve the island's natural flora and fauna in selected sites; and

-provide amenity, recretion and access for the public.

Field work is divided into five forest ranges, each with a staff of 3 officers and 12 labourers. The officers must patrol all known forest boundaries, check on forest squatters, manage plantation, etc.

Timber exploitation has been controlled by a schedule of minimum girth limits and the appointment system of sales.

The Forestry Division is guided by the Forest, Soil and Water Conservation Ordinance of 1946, revised in 1957 and 1983. Forest officers have the power to arrest and charge forest offenders, conduct its own court cases, and have the power of search and seizure.

Forest fines were ridiculously low despite efforts by the Forest Division to increase it so as to be effective. Presently, forest fines have increased from $240 to $2,000 for the first offense, $3,000 for the second offense, and a jail sentence of one year for the third offense. In addition, there is an amendent which makes it mandatory that all existing chainsaws be licensed and that a permit must be issued before an order is made to purchase new chainsaws.

The biggest problem in managing the resource stems from uncontrolled deforestation due to shifting cultivation by squatters and landless farmers. With the 1983 amendment, the increased fines should have the desired effect.

A "Forest Charge" levy has been recommended by the Forestry Division for consideration by the Cabinet. This levy would appear on the waterbills and funds raised would be paid into a sundry account. Such a procedure will have the following advantages: educate the public as to the importance of forestry and its inter-relationship with water, raise revenue to purchase private lands in critical watersheds; provide funds for the maintenance and improvement of existing watershed areas.

By charging a meagre 10c EC per 1,000 gallons we would raise a total of $300,000 EC per year without adding a large financial burder on the individual consumer.

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Table 1. Land use on the island.

Land use	Area acres	Area ha	% of total land	Ownership
Urban	15,000	6,070	10	Crown e Private
Banana cultivation	13,500	5,463	9	Private
Crops and pasture	23,000	9,308	15	Government and Private
Mixed agriculture	53,000	21,440	35	MDC and Private
Forest	48,000	19,426	31	Crown lands/Forest Reserve/Private
Forest reserve	16,385	6,631	10.8	Forest Reserve

Table 2. Rainfall and water use and management problems in several Caribbean islands.

Island	Rainfall (mm/yr)	Water production (gal/capita)	Water management problems
St. Lucia	medium, 2108	40	High pumping costs, severe restrictions in dry period, high rate of deforestation, difficult terrain to service.
Dominica	high, 4445	48	Difficult terrain to service.
Antigua	low, 1219	29	High evaporation rate, little forest cover.
Barbados	low, 1626	95	Protection of groundwater due to population pressure on limited land.

A REVIEW OF WATERSHED PROBLEMS AND PROGRAMMES IN JAMAICA

Barrington Cameron
Acting Chief Soil Conservation Officer

and

Lennox Taylor
Soil Conservation Officer

INTRODUCTION

Jamaica became aware of the need to protect its watersheds in the 1930's as demonstrated by an article written by Groucher and Swaby in the Department of Science and Agriculture Bulletin No. 19 entitled "Soil Erosion and Soil Conservation in Jamaica 1937". They listed the chief causes of erosion as: unsuitable agricultural practices, unwise selection of land for agriculture; and lack of appreciation for the seriousness of the problem. Today, five decades later, the problem of lack of appreciation is removed, but there still remains the other two factors although to a lesser extent.

LEGISLATION

Having accepted soil erosion and watershed degradation as serious problems, legislation for the effective utilization of our natural resources were enacted to support the actual field operations. Four are worthy of note:

- Forestry Act 1939: This act provides for Forest Reserves, Prohibited Areas, Protective Areas and Monitoring of all forest activities.

- Land Authorities Act 1951: This act empowers Land Authorities to encourage proper land use, participate in improving operations of private land users, implement compulsory improvement schemes, implement afforestation, rehabilitation, and develop of improvement areas.

- Watershed Protection Act 1963: Under this act the Watershed Protection Commission was established which had the power to declare watersheds with an aim of increasing water yield and/or quality and prohibit, regulate or restrict planting of particular crops and/or cultivation practices. In addition, it allows for assistance in watershed improvement work, compulsory improvement schemes, acquisition and granting compensation.

- Land Development and Utilization Act 1966: This seeks to see that all agricultural lands are utilized.

THE PROBLEM

Jamaica's watershed problems are many. The following is a brief listing of some of them:

-Unsuitable agricultural practices and unwise selection of land for agriculture.

Following the abolition of slavery in 1838 many freed slaves took to the steep but productive hillsides instead of continuing to work on the plantations. In these hillsides shifting agriculture was practiced. Vegetation was cut and burned, trenches made down the hillsides, and clean cultivated food crops produced. All these practices led to severe soil erosion, loss of fertility, and, eventually, a reduction in yields. All types of land were used intensively, irrespective of capability. As such, today many slopes are denuded and severely eroded. In most countries with a history of agriculture, land capability classification scheme is in place. In Jamaica, a very practical scheme exists based primarily on two physical factors, soil depth and slope. Under this capability systems all lands over 25^{o} (irrespective of soil type, depth and fertility status) should be planted in commercial or protective tree crops. However, due to the intense pressure on the land, these lands are constantly being cleared for root crops and vegetables, while many thousands of acres of fertile flat lands lay idle or underutilized.

-Improper logging and pasturing.

In many instances the practice of skidding logs out of the steeply forested lands leads to serious disturbance of the soil surface. Channels often develop into deep gullies and contribute much silt to reservoirs, beaches, harbours, and other low lying areas.

In many of the islands pastures (improved and unimproved) overgrazing is common, leading to little or no vegetation on some areas at certain times of the year. Intense rainfall at such times results in loss of a significant amount of soil.

-Roads, Gullys and Homesteads Inadequate of Maintenance.

Jamaica has the greater percentage of its roadways in the steep watershed areas. These roads are necessary to serve the often high population in some rural townships. However, the combination of poor road maintenance and poor homestead water disposal result in large gullies and loss of many tons of productive soil, and a number of fruit trees annually.

-Lack of Coordination among Watershed Organizations.

There is adequate legislation and enough trained persons to deal effectively with watershed problems. However, these agencies operate independently of each other, thus the desired effects are rarely achieved as programmes of a complementary nature are done at different periods.

-Land Tenure.

Much of the land is owned by absentee owners who rent to farmers without long-term legally binding contracts, or the land is jointly owned and operated by families. With this situation farmers are reluctant to grow permanent crops on such lands. In many instances such crops are the most appropriate use for these lands if soil erosion is to be minimized.

-Treatment Maintenance.

Thirty years ago, Jamaica started an ambitious programme of healing wounded slopes through its soil conservation programmes. These programmes were implemented with much vigor, but at the point where it counts most, all these programmes have failed. The Government, to encourage protection of watershed areas, subsidized farmers to do the work, but the non-appearance of a subsidy for maintenance of these treatments resulted in neglect of most treatments in over 70% of all cases.

-Deforestation and Fire Protection.

The denudation of slopes under natural forest for cash crops, charcoal burning, firewood, etc., is increasingly becoming a major problem. The effects are obviously short term satisfaction and long term grief in the form of soil loss, habitat destruction and turbid domestic water supply among other problems. A sister problem to this is that of fire protection. Although Jamaica has never suffered from thousands of acres being destroyed by fie in a single block, nevertheless, fire, frequently occurs in some of our watersheds, destroying vegetation and leaving the area bare for severe erosion in the succeeding rainy season.

-Destruction of Wildlife Habitat.

Any of the aforementioned problems or combination thereof seriously contribute to the destruction of natural breeding or spawning areas for birds and fish through pollution and/or over exposure to the natural forces.

THE PROGRAMMES

Once the Government became convinced of Jamaica's watershed problem erosion control prorammes were developed to reduce the danger to the country.

Some of the programmes were: Farm Improvement Scheme, Farm Recovery Scheme, Farm Development Scheme, Land Authorities, Agricultural Development

Programme, and Farmers Production Programme.

Farm Improvement Scheme

Was set up in 1945 and offered a subsidy to the farmer for the establisment of soil conservation treatments. The treatments practiced then included grass barriers, rock barriers and contour drains.

Farm Recovery Scheme

Started in 1952 after the 1951 hurricane and it offered a 75% subsidy for apropriately established conservation practices on farms. This scheme ran concurrently with the Farm Improvement Scheme.

Farm Development Scheme

Under this scheme 26,000 acres (10,522 ha) of farm lands were treated with appropriate soil conserving techniques. The treatments included, grass barriers, contour trenches, runoff drains, strip cropping, bench terraces, stone barriers, etc.

Land Authorities

The enactment of the Land Authorities Law in 1951 paved the way for the establishment of the Yallahs Valley Land Authority and the Christiana Land Authority in 1954. They were given the responsibility of restoring eroded areas. Today there still remains much of their work.

Agricultural Development Programme

This programme ran for two of its planned five years, 1960-1962, and it offered incentives for proper land use practices and soil conservation in watershed areas.

Farmers Production Programme

Started in 1963, it offered incentives for conservation works and tree crop development.

The Transition Period

An important feature of the soil conservation programmes which spanned the period 1944 to the early 1970's was their temporary nature in most cases, resulting in their gradual disappearance. This project successfully carried out the following activities: watershed surveys and planning, establisment of demonstration centres, assisted with extension activities, training of national staff, experiments and instrumentation in soil loss studies, agro-meterology, and proposed a national soil conservation programme. The project designed, developed and tested six major soil conservation treatments and seven different kinds of waterways suitable for conserving Jamaica's hilly lands at the Smithfield Demonstration Centre.

These investigations have formed the basis for all the soil conservation activities carried out since 1973 by the Soil Conservation Division of the Ministry of Agriculture.

Projects and Programmes since 1973

Soil Conservation Works Programme

Under this programme soil conservation demonstration centres were developed and maintained, and assistance given to farmers for soil conservation works in all parishes.

Soil Conservation Works in the Parishes

The major objective of this is to assist private farmers to conserve their land to increase and sustain farm production.

There are two types of projects under this programme namely; as follows:

- Farmers Assisted Project where a farmer can benefit up to 75% of the cost of undertaking soil conservation works on his holding.

- Authorized Projects which are funded 100% by the Ministry and involve works which benefit a group of persons or a community.

Allsides Pilot Development Project

The main objectives are to:

- develop a new system of production based on multiple cropping on a group of small hill farms which have been previously treated with soil conservation measures;

- increase the productivity and production of certain food crops;

- increase food production, income, nutrition and improve the standard of living of approximately 300 farm families occupying 622 acres (252 ha) of hilly lands in the project area;

- develop an institutional framework capable of implementing similar changes in other areas of Jamaica;

- gather accurate production figures for crops grown by the small hill farmer; and

-provide training for local professionals and technicians.

First Rural Development Project

The objective of this project is to complement government rural development policies by increasing agricultural production and income. The project is located in the County of Cornwall and has three main components: agricultural settlement, regional settlement, and regional infrastructure.

Soil conservation and forestation works were carried out under the agricultural settlement component.

Second Rural Development Project

As part of its current integrated rural development strategy to revitalize the agricultural sector and reduce unemployment, the Ministry of Agriculture had identified watershed areas deserving priority treatment with respect to soil conservation. One such area is the Pindars River/Two Meetings project area. Specific objectives of this project are to:

-increase agricultural production on small hillside farms;

-control soil erosion in the watershed, thereby protecting the agricultural base (soil); and

-strengthen the capability of human resources in the Ministry of Agriculture.

GOJ/FAO/UNDP/NORWAY - National Soil Conservation Programme

The two main components of the project are:

-Institutional Strengthening: This was done through concentrated inservice training locally and supplemented by overseas training to increase the operational capacity of the Soil Conservation Division of the Ministry of Agriculture. Training was provided in seven key areas considered necessary for any integrated watershed development. These were: appropriate soil conservation measures; watershed forest management; agronomy including non-forest tree crops; extension methods, including the involvement of the rural farmers in the development process, utilizing the bottom-up approach; applied watershed economics; and planning and managing integrated watershed development projects.

-Preparation of detailed costed work plan. These plans were prepared for nine watersheds, and will be submitted to the government for decision regarding implementation.

Projects to be Implemented

Jamaica Small Farmers Hillside Farmers Project

This project will be located in five watersheds. The project seeks to increase agricultural production in 7,000 to 10,000 ac (2,833 - 4,047 ha) of small farmers land through improved management and low cost soil conservation measures.

Small Farmers Credit Project

This small farmer credit project will provide funds for the agricultural development of 4,000 ac (1,619 ha) of land. The primary goals of the project are to increase farm family income and the development of a small farmer credit programme.

WATERSHED PROBLEMS AND PROGRAMMES OF MONTSERRAT

William Johnson
Peace Corps Forestry Technician

INTRODUCTION

Montserrat is a volcanic island 39 mi^2 (100 km^2) in size. It is 11 mi (17.6 km) long and 7 mi (11.2 km) wide, with a discontinuous ridge of mountains running north and south. They are, from north to south, Silver Hill, Centre Hills, Soufriere Hills, and South Soufriere Hill. Chances Peak in the Soufriere Hills, at 3,002 ft (915 m), is the highest point on the island. Generally speaking, the mountain slopes are very steep above the 1,200 ft (366 m) contour, but generally gradually flatten to the sea below that elevation (Fig. 1).

Rainfall varies from about 40 in/yr (1010 mm/yr) in the lower, semi-arid areas, to 100 in/yr (2,500 mm/yr) at the tops of Soufriere and Centre Hills. There is a direct relation between the amount of rainfall and topography (Fig. 2).

THE WATERSHEDS

The main watershed areas of Montserrat are considered to be the Centre Hills and Soufriere Hills. The Centre Hills soils are predominantly of clay loam, and have moderately rapid infiltration. This rate of infiltration may be seen as an advantage when considering the topography and slope of the land, which is very broken and very steep (35% - 60%). However, with a view towards dam construction for water storage, this rate of infiltration is seen as a disadvantage. Even with a good vegetative cover of rain forest, elfin woodland, and somewhat erosion-resistant soil, there is an erosion hazard where vegetation is removed.

The Soufriere Hills soils are humic silt, of which about 50% is organic matter. Land in this area above the 2,500 ft (762 m) level, is one of the few parts of the island that has not been under cultivation at one time or another. Rate of infiltration is rapid to very rapid, which is beneficial when given the broken topography and 35% to 200% slope. As in the Centre Hills, the vegetative cover of the Soufriere Hills is rain forest and elfin woodland (Lang 1967).

SOCIO-ECONOMIC

The largest threat to Montserrat's watersheds is tradition. For many generations people have practiced slash and burn techniques to clear land for food production. From the farmers point of view, this is very logical because the climate is moist and the soil is well suited for agriculture. Another problem caused by tradition is indiscriminate cutting of trees for poles and fuelwood. Although clearing and cutting has not caused major damage throughout the watersheds as yet, there do exist severe localized erosion problems.

Lack of understanding by people of what a watershed is and how it works helps to perpetuate the bad practices. These practices are not seen as bad by the perpetrators, but simply as the way things have always been done.

WATERSHED WORK PLAN

A watershed work plan has not been set forth. Part of the reason is because accurate information on rainfall, runoff, vegetation, spring flow, etc., is not available. Time and money are needed to produce this information, and the latter is not available locally. Also not available locally is a trained watershed manager. Nor is there any one authority specifially responsible for managing the watersheds. Since there is no one body to regulate or monitor the use of the watersheds, a sort of apathy towards them has developed. This apathy extends to enforcement of laws concerning watersheds areas.

There does exist in the laws of Montserrat, under Chapter 171 entitled Watercourses and Waterworks, laws which generally could be applied to watersheds. However, in properly managing a legally established watershed, these laws would be insufficient.

While watersheds exist on Montserrat simply by their natural, physical characteristics, there are no legally designated watersheds. The proper legal extablishment of these watersheds is complicated by the number of private individuals who own land in the watershed areas: eight in the Centre Hills and seven in the Soufriere Hills.

WATER SUPPLY AND DEMAND

Montserrat is fortunate to have a water system which is able to supply water to most of the islands approximate 11,733 people (1983 mid-year population estimate), with very few interruptions. The population of the island has remained very static since 1976 (1976 mid-year population estimate of 11,647), yet there has been a 2.5% yr increase in water consumption (151,154,000 gal metered consumption in 1983). This is due in part to the comparatively high consumption of the approximately 250 high cost homes recently constructed on the northwest coast. Most of the owners of these homes are from North America and their consumption tends to be three to four times that of the local population. It is likely that this pattern of increasing consumption will continue if the remaining 80% of these lots are developed and the standard of living and industrial use continue to rise.

In 1983, about 35 gal/day was consumed. It is projected that consumption will reach 45 gal/day by 1993. With only 17 of the islands 28 springs being utilized, and 2 of the islands 28 wells tapped (Pekurel and Hadwen 1983), the Montserrat Water Authority believes it will be able to meet the increase in demand.

CONSERVATION PROGRAMMES

Montserrat has a National Soil Conservation Programme that was established in 1982. It was primarily organized by the island's Agricultural Engineer, and has included a public awareness campaign consisting of field days with school children, lectures, and film shows. As part of this programme there is a demonstration project now beginning, funded under a regional programme, by CARDI, EDF, and Montserrat's Ministry of Agriculture. The work is being done in the Upper Lees, Molyneaux and St. George's Hill sub-watershed areas, where erosion problems or potential problems exist due to farming practices. This project include contour banks, contoured vegetative barriers, terracing, field drainage systems, road improvement, and reafforestation. Meetings will be held with farmers from these ares at later dates to determine their acceptance of the soil conservation measures.

There is a Soil and Water Conservation committee which meets quarterly to review programmes on soil and water consevation and to advise the Government of Montserrat on related matters. The committee is made up of: Director of Agriculture, Manager of Montserrat Water Authority, an Agricultural Engineer, the Forestry Officer, an Agricultural Extension Officer, and two farmers.

CONCLUSION

While the programmes now underway are a step towards watershed improvement, there is still a lot to do for proper watershed management and protection. Education needs to continue, basic watershed data need to be gathered, a watershed work plan needs to be developed, an authority with personnel trained for management of watersheds needs to be established, legally defined watershed areas need to be established, and laws need to be written to deal specifically with watersheds.

Montserrat has no water problem right now, but if good alternative agricultural practices are not implemented and traditional farming and cutting practices are allowed to continue, the island will be faced with increasing watershed damage, that when combined with future water demands, could lead to water shortage.

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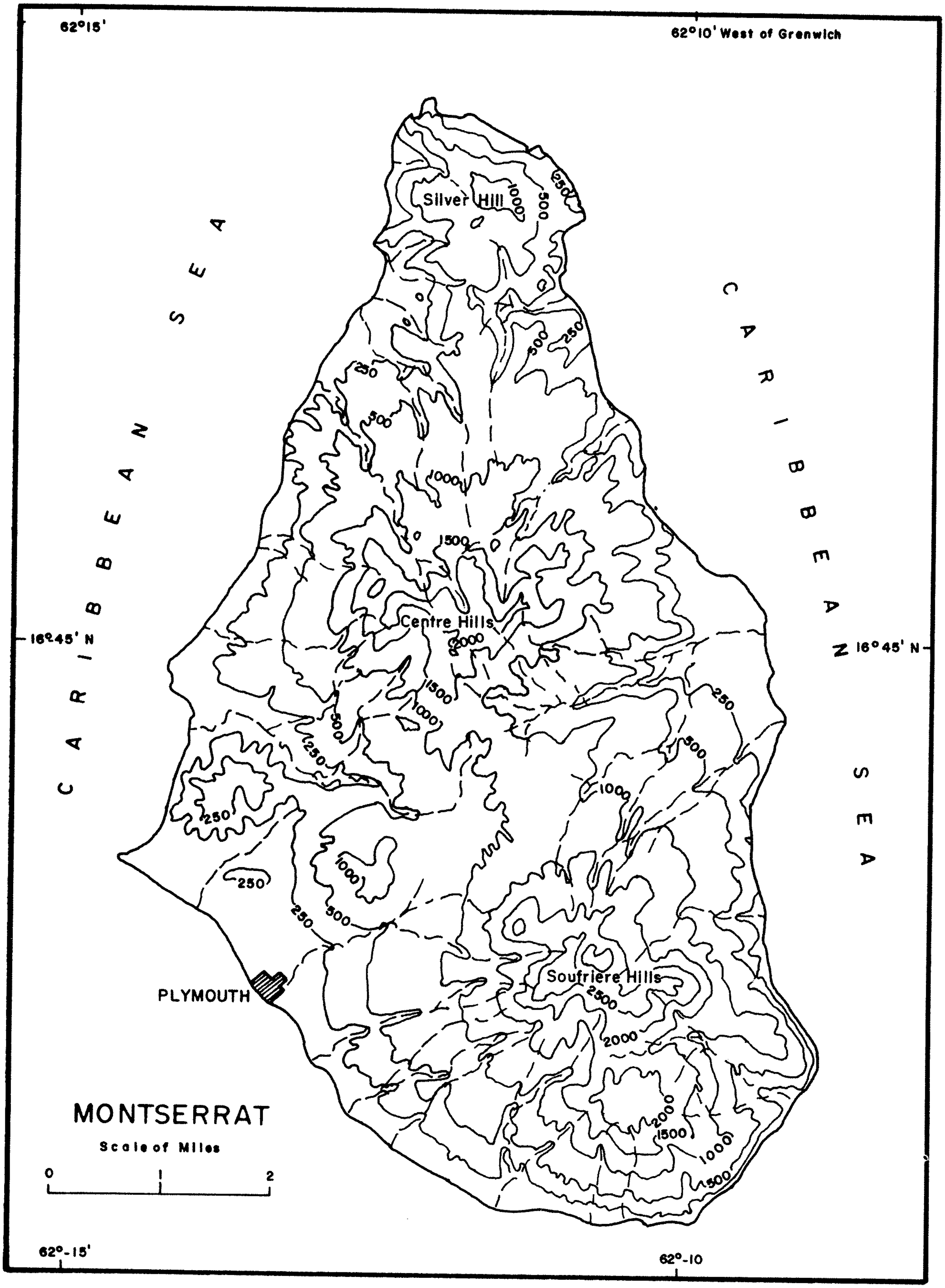


Figure 1. Topographic map of Montserrat.

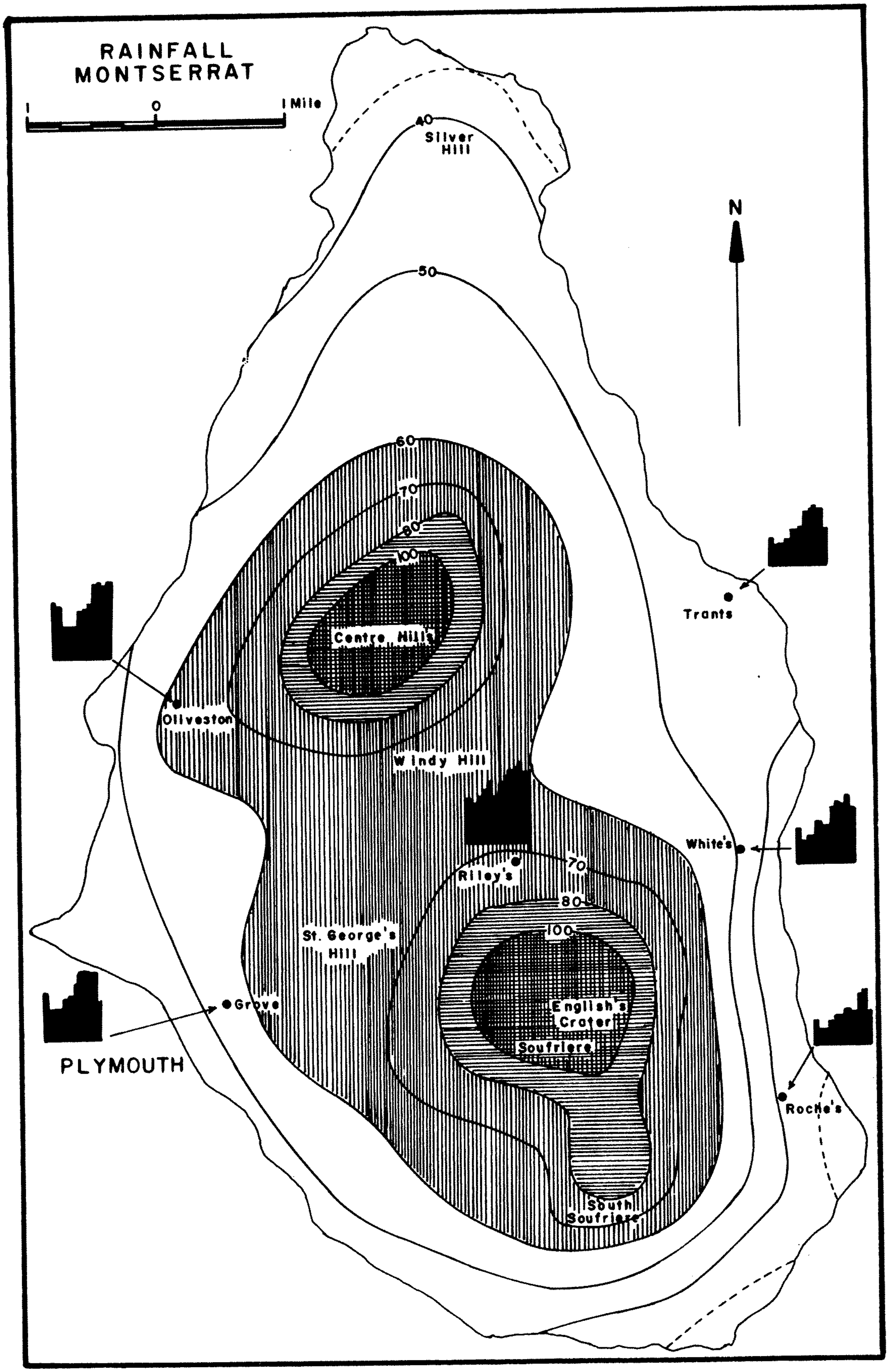


Figure 2. Distribution of rainfall in Montserrat.

FORESTRY IN ST. VINCENT AND THE GRENADINES

Calvin F. Nicholls
Agricultural Officer, Forestry

INTRODUCTION

In recent years the Forestry Division of Saint Vincent and the Grenadines has become an integral part of the Ministry of Trade and Agriculture. The process of total integration within the Ministry continues. The acceptance has been somewhat slow, but has come about mainly from the efforts of the Division itself through hard and persistent struggles to change its own image; and to impress on the Ministry and the Administration that Forestry is as much a scientific discipline as any other area of study. The Forestry Division is not merely the semi-police organization for which it was previously known.

To bring about this change the Forestry Division also had to sensitize a community, hither to almost totally unaware of the benefits of forestry and environment quality. Like many educational programmes the process has been slow. There has been some positive signs, however, that the programme has been filtering through to the community. Forestry and environmental matters are now more readily understood and appreciated.

ORGANIZATION

The Forestry Division is headed by an Agricultural Officer (Forestry) who is assisted by two Forest Rangers, one of whom is currently on a study leave, pursuing forestry studies at North Carolina University. Twenty junior forestry officers (Forest Guards) complete the staff. The Chief Agricultural Officer by virtue of his office (technical head of the Department of Agriculture) continues to carry the title of Chief Forest Officer.

In 1982, for the first time, the Division received a Peace Corps volunteer who has been assisting mainly in the area of surveying and to a lesser extent with on-the-job-training of junior staff.

FOREST RESOURCES

There has been no recent survey to ascertain accurately the area of the forest estate. Beard (1945) estimated that mainland Saint Vincent had some 41,500 acres (16,795 ha) of state lands, of which 95% were under forests. Figures for the Grenadines are not available. It is estimated, however, that there are approximately 300 acres (121.5 ha) of state lands on Union Island, approximately 250 acres (101 ha) in Bequia, and approximately 70 acres (28 ha) on Cannouan. State lands in all the Grenadines once had fairly rich stands of white cedar (*Tabebuia pallida*). Similarly good stands of mangrove forests once existed there. Unfortunately, owing to mismanagement and indiscriminate felling in the past, few of these stands remain.

FOREST TYPES

In his book "Forestry in the Windward Islands", Beard mentioned that there were 254 species of trees and shrubs of which seven were endemic to Saint Vincent and the Grenadines. The rain forest of mainland Saint Vincent belong to the Dacryodes sloanea association of the Lesser Antilles. Trees in this association reach heights of 100 ft (30 m) with a two, sometimes three strata, close and crowded. The Gommier (Dacryodes excelsa), Jumbie bead (Omsonia monosperma), and Laurier (Lauraceae sp.) are good examples.

Of the five forest types identified by Beard, two have been seriously affected, one through human intervention and indiscriminate fellings and the other by natural disasters. The mangrove forests and coastal littoral woodlands have almost disappeared. The primary elfin woodlands have been seriously affected by the eruption of La Soufriere in 1979. Some recolonization of the latter type has begun.

FOREST LEGISLATION

Technical assistance has been requested to update the forest ordinance, and to prepare a new wildlife act. The present forest legislation is grossly inadequate to cope with the type of offenses currently encountered in the forest.

The present bird and fish ordinance is also outmoded and does not meet the type of prerequisite legislation necessary to qualify for project funding proposed by World Wildlife Funds (WWF) for the preservation on the Saint Vincent parrot (Amazona guildingii).

MANAGEMENT

To date, the Forestry Division is without a working plan. There is need for a documented plan, rather than the haphazard approach currently adopted. The need has been recognized, and to this effect a strong recommendation has been made to seek technical assistance to address that need.

Within the limits of its constraints, the Division continues to carry out both watershed management and soil conservation work in areas threatened by erosion. Since the Saint Lucia Workshop the Forestry Division has stopped up its vigilance in the watersheds and catchment areas. There are some twenty water supply sources supplying water for domestic purposes and for agriculture. Two of the sources supply water for hydro-electricity; a third is to be harnessed in 1984 for commissioning in 1986/87.

All the water used on mainland Saint Vincent is produced from above-ground streams and springs. It is imperative, therefore, that a proper management regimen be carried out in all the watersheds. In the Grenadines water is collected in private tanks and in public concrete catchments and ponds. The islands depend heavily on rainfall (approximately 40 in/yr or 1000 mm/yr) for their water supply.

Wildlife management is now receiving much greater attention. The parrot (Amazona guildingii) being the national bird and currently on the endangered species list, is being given top priority.

Reafforestation to extend existing plantations and to establish new areas continues. Some 60 acre (24.5 ha) mainly of Blue mahoe (Hibiscus elatus) and Gliricidia sepium have been established during 1983. Tending operations have kept apace. Unfortunately, thinning operations have been somewhat neglected due mainly to lack of funds to carry out the operations and lack of proper utilization of thinnings.

Some limited management prescriptions continue in natural stands, specifically at "Kings Hill" Reserve 1791, a 55 acre 22.3 ha) parcel of dry woodland mixed species located in the southeast of mainland Saint Vincent; at Fair Hall, approximately 25 acre (10 ha) of white cedar (Tabebuia pallida); at Walibou, another mixed species composition of white cedar, angelin (Andira inermis) and Greenheart (Lonchocarpus spp.); and at Camden Park where a 16 acre (6.5 ha) stand of West Indian mahogany (Swietenia mahagoni) and white cedar predominate.

In the area of Soil Conservation, the establishment of screw pine (Pandanua utilis), bamboo (Bambusa spp.), roseau (Bractrix major) and sisal (Agave spp.) continued in areas threatened by land slips and soil erosion. All three plant species used to control erosion are useful for and are in great demand in the local handicraft industry.

AGRO-FORESTRY

In addition to natural stands of guava (Psidium grajava) and tamarind (Tamarindus indica) currently under management, the Division, in collaboration with the Extension Division of the Ministry of Trade and Agriculture, established three 0.5 ha plots of mixed fruit tree species in 1983. Included in these plots were West Indian cherry, sour-sop (Annona muricata), tamarind, red and yello plum, sapodilla (Manilkara zapota), sugar apple (Annona squamosa), citrus species, mango (Mangifera spp), coconut (Cocos nucifera), mauby, cinnamon (Cinnamomum zeylanicum) and cashew (Anacardium occidental).

PRIVATE FORESTRY

Private forestry activities are very limited in Saint Vincent and the Grenadines. The Division continues to give technical assistance and to offer encouragement to land owners to improve any potentially good woodlots or where necessary to plant new areas. Forestry seedlings are made available at nominal cost, (sometimes free) to persons who wish to establish windbreaks, boundary lines, livestock shade or ornamentals.

FIRE PROTECTION

Until very recently fire protection was practically unnecessary. In the last 5 yr, however, the incidence of bush and forest fires has increased considerably and is now a major concern of the Forestry Division and the State. Four of our prized natural stands including the Camden Park Swietenia mahogani/Tabebuia pallida dry forest and the Kings Hill Reserve are annually threatened by fires. Some of our hillsides have now developed fire climax vegetation. These areas now present a somewhat depressing sight to conservationists and to visitors to our State. Training in fire protection and fire fighting equipment are now essential.

RESEARCH

This is probably the most neglected area due to lack of trained personnel to plan research programmes and lack of funds for implementation. With technical assistance from our Peace Corps volunteer a limited amount of work has begun in the following areas:

- Surveying, compartmenting and plotting of plantations.
- Establishing and measuring sample plots.
- Inventoring.
- Seed-tree identification and selection.
- A small arboretum approximately 0.75 ha was established in 1983. Plans are under way to extend this plot and also to expand our nursery facilities.

In 1979, La Soufriere erupted violently, destroying the vegetation for approximately one mile around the crater (except in the Windsor Forest area). Recolonization has begun in some areas and very soon normal plant succession will start. It is unfortunate that the Forestry Division does not have the skilled manpower to study and document this. The result of this constraint is that a unique opportunity to do research is this area is likely to be lost.

TRAINING

To date the Forest Division has not been able to attract junior forestry staff with the necessary academic background to undergo formal training, the reason being the very low salaries offered. The opportunity is taken here to record my personal appreciation and that of the Government of Saint Vincent and the Grenadines to the Trinidad and Tobago Forestry Division for accomodating two members of our staff and to CIDA for funding their attachment. Also to the Luquillo Experimental Forest, Puerto Rico for similar accomodation for another two and to USAID for funding their attachment.

Of special mention is the US Forest Service in two 12-week courses held at the Institute of Tropical Forestry, Southern Forest Experiment Station in Puerto Rico under the Caribbean Environmental Action Plan, sponsored by USAID. Incidentally, the funding for the current first inventory study and the watershed and wildlife studies were also provided by USAID. Six members of our staff have benefited from training in Puerto Rico.

It may be useful to mention that all the above came as a result of the Saint Lucia Workshop in 1982. It may not be premature here to serve notice that the Saint Vincent and the Grenadines delegation to this workshop will again be making strong recommendation for further training; the need for which is probably greater now than it was two years ago.

FORESTRY EDUCATION/INFORMATION

There has been increased activities in this area since the Saint Lucia meeting. Lectures to groups, newspaper articles, radio releases to the general public, and film shows to schools are now done quite frequently.

Much greater efforts are necessary in this area, however, to continue the dissemination of forestry information in wildlife watershed, fire protection and environment quality. Technical assistance is welcomed.

PROGRESS REPORT FOR THE PUERTO RICO FOREST SERVICE

Ralph C. Schmidt
Chief Forester for the Commonwealth of Puerto Rico

INTRODUCTION

The past two and one half years have seen substantial growth in Puerto Rico's forest management programs in terms of financial, human, and organizational resources. Due to the efforts of the Secretary of Natural Resources of Puerto Rico, the Honorable Hilda Diaz-Soltero, and a very capable and dedicated staff of young professionals, I am pleased to report that many of the aspirations and projections related to the First Caribbean Foresters Workshop two years ago have today become realities.

ORGANIZATION

Programs require adequate financial suport to function properly, but just as important as money is proper organizational structure and institutionalized program planning. The Forest Service of Puerto Rico has been formally reorganized in the last year, an accomplishment which required extensive justification and approval at many bureaucratic levels.

The land management activities of the Department of Natural Resources have been unified under the Area of Forests, Sanctuaries, and Natural Reserves. Five different types of land management units are administered by two bureaus each having two divisions. Forests are extensive areas, often containing plantations and timber management programs, recreational activities and special land use permits of various kinds. These lands are managed under the Division of Forest Management and protected by the Forest Law of Puerto Rico of 1975. The Area also manages Natural Reserves, Wildlife Refuges, and Estuarine Sanctuaries (Fig. 1).

These different types of land management units require different kinds of expertise, and the organization allows managers to specialize in that which they know best. The land area managed by the Department has expanded by thousands of hectares in the past two years and much expansion is planned in the future. This structure provides the basis for smoothly incorporating new areas into management programs.

BUDGET

Due to careful justifications and ceaseless efforts on the part of the Secretary, the Forest Service budget has steadily expanded over the past three fiscal years. Essentially it has increased from $450,000 in September 1981 to $3,000,000 in 1984. About 10% of this is from revenues which have increased tenfold in the past three years and continue to show great potential for future expansion. Most of the rest of the budget finances permanent professional positions which have been created within the organization. Only the Assistant Secretary is appointed; the Chief of the Forest Service and the Chief of the Sanctuaries and Natural Reserves Bureau and all other employees are permanent civil servants.

TRAINING

As we have resolved issues of organization, budget and staffing, we have found that training and staff development was our major need. With few professional foresters or natural resource managers and no university-level forestry courses in Puerto Rico, our approach has utilized a variety of other techniques.

Experts in hydrology, logging, silviculture, forest inventory, nursery management and tree improvement and resource interpretation have come from the US Forest Service or universities and conducted group sessions as well as worked with our staff one on one. Also, we have sent managers on field training asssignments to participate in and observe management programs in the United States and other countries.

The Department has entered into a new program of tropical resources management with The School of Forestry and Environmental Studies of Yale University. Supported by a three-year program development grant from the Andrew Mellon foundation, students earn a Master's Degree completing course work in New Haven and special field projects and courses in Puerto Rico. Already we have hosted students from Asia, Africa and Latin America as well as the United States who are pursuing some interesting and useful study projects. Dean John Gordon of Yale is interested in encouraging international participation in the program, complete scholarships are available, and I hope all of you will consider sending promising young foresters and ecologists to obtain Masters Degrees in this innovative and much needed new program.

PROGRAMS

Timber management programs continue to progress and expand very rapidly and to give good results. All treated posts and lumber that can be produced are immediately sold. With advise from US Forest Service logging and sawmilling specialists, many knids of new equipment have been acquired such as post peelers, portable sawmills, farm tractor winches, tilt trailers, fork lifts and others. These operations are all designed to demonstrate methods to promote forestry activities in the private sector, and are especially adopted to fairly labor intensive operations in plantations and secondary forests of small area.

A forest cover and type inventory similar to that conducted in St. Vincent and in secondary forests of Puerto Rico has been completed in the Toro Negro Forest. We are starting a stand inventory hardwood plantation in the Rio Abajo Forest where 20 to 30 million board feet of teak, mahogany and mahoe stand on 1,000 to 2,000 acres of plantations. It would appear that the sustained yield of these plantations will have a value at least equal to the current annual budget of the Puerto Rico Forest Service.

Reforestation programs are proceeding well on private farms and public lands owned by agencies other than the Department. The demand for timber tree seedlings for plantings on private lands is greater than our current capacity to supply them. Several agencies have developed interest in reforesting their lands, and we are currently reforesting reservoir watersheds, retired agricultural lands including wetlands, and the surface area of an extensive limestone cave system. Furthermore, agreement has been reached between the Commonwealth of Puerto Rico and the US Navy to designate several natural reserves and to commence a reforestation project on the island of Vieques.

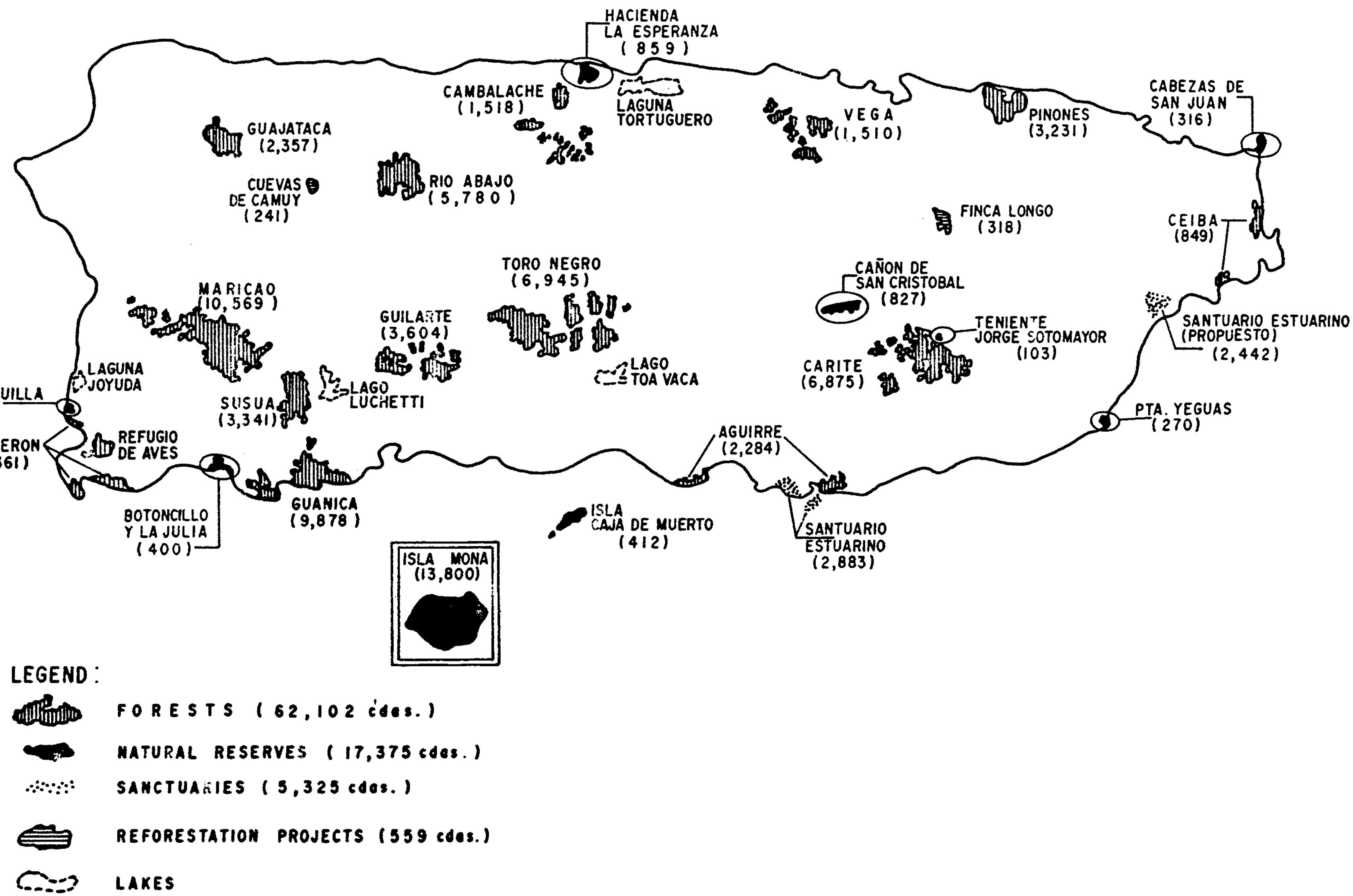
Several industries and municipal governments have formed a consortium to land treat secondary sewage sludge by applying it on areas to be planted to forest trees. By adding water and substantial nutrients and organic matter, productivity in this subtropical moist site may be substantially increased. Ground water and soil conditions will be carefully monitored by hydrologists. Sewage wastes are inevitably produced by human development on our islands. Once treated, alternatives to land treatment such as incineration, land filling or ocean dumping are expensive and environmentally harmful.

The natural reserve and forest system of Puerto Rico should continue expanding. The office of the Secretary has initiated the Propatrimonio Natural Program to identify key biotic elements for site selection of future reserves. This program is conducted in cooperation with the Conservation Trust of Puerto Rico and the Nature Conservancy. The latter maintains an international office with programs in the Caribbean and Latin America.

Land is obviously at a premium on our relatively small densely populated islands. We all need land for agriculture, roads and buildings as well as for forests to produce timber and conserve water, wildlife and genetic resources. However, as we focus on the scarity and value of land the prime importance of water may be overlooked. Recent recommendations for modern agricultural practices in Puerto Rico concluded that water and not land was the primary limiting factor for agriculture. Slightly less than 10% of the island's land was all that could be used for economically profitable agricultural enterprises. Pasture for all types of livestock programs would occupy no more than an additional 25%. Even allowing 15% for transportation and urban infrastructure, this leaves half of the island (400,000 ha) for forest conservation. Some of this would produce timber and some would not. Our estimates indicate that about 80,000 ha of well managed softwood and hardwood plantations would produce much if not all of the island's currently imported lumber consumption.

The lesson seems clear that for Caribbean islands careful selection of critical watersheds for appropriate land use and management programs is a top priority. Furthermore, with quality water for human use, agriculture, and industry becoming an ever critical factor, large proportions of our rugged islands must be slated for conservation in programs directed by forest land managers.

FORESTS , NATURAL RESERVES , AND SANCTUARIES OF THE COMMONWEALTH OF PUERTO RICO



HYDROLOGIC CHARACTERISTICS OF ISLAND WATERSHEDS AND SUGGESTIONS FOR THEIR MANAGEMENT

Russell E. Curtis, Jr.
Chief, Hydrologic Records Section, USGS

To illustrate the hydrologic characteristics of Caribbean islands, I am going to use data collected and analyzed for Puerto Rico (Fig. 1). Although Puerto Rico is larger than the Lesser Antilles islands, their climate and watershed response are very similar.

The hydrologic cycle shown in Fig. 1 is basically the same on all of the islands. The biggest difference between islands is the heights of the mountain peaks which in turn affect the average precipitation and slopes of the watersheds. These factors of course influence the vegetation and land use.

PRECIPITATION

The average annual precipitation for Puerto Rico is about 76 in (1930 mm) but it varies widely from one part of the island to the other. This type of pattern will occur on most of the islands. The almost constant northeast trade winds are lifted as they approach the mountains producing the heaviest rainfall near the north or east coasts. The air leaving the islands is much dryer, consequently the south or west coastal areas usually receive less rain.

May and October are usually the months of highest rainfall in Puerto Rico but the extreme events do not necessarily occur in these months. The rainfall pattern that occurred during a four-day period in December 1981 when a cold front stalled north of the island resulted in storm totals that ranged up to 25 in (635 mm) along the north coast but almost no rain fell on the south coast.

In September 1982, a tropical storm passed to the south of Puerto Rico and caused rains totaling up to almost 13 in (330 mm) on the normally dry southwest coast while the north coast received relatively light rain.

STREAMFLOW

As expected, average streamflow follows the general pattern of average rainfall (Fig. 2). These graphs show the comparison between normal and current streamflow at two of our "index" stations. One is on the north coast and the other on the south. Both streams are at their highest during the fall months and at their lowest during the winter. We compute these records each month so that we know the current status of the streamflow.

Most of the streams on the islands will be very "flashy". During a typical flood peak on one of the many small streams in Puerto Rico, a stream may rise from less than 2 ft stage to almost 8 ft and back down to 4 ft in 1 hour.

Flooding will occur mostly near the islands coastlines. This has occurred in Puerto Rico over about the last 25 years. Very few serious floods have affected the interior mountainous areas.

Low flows usually occur during late winter. The result of a low-flow survey we made in Puerto Rico during March 1983 (Fig. 3) shows the total volume of water flowing to the sea at that time. This is an indication of the minimum amount of surface water available during the year. Because of the high average rainfall in the islands, few streams go completely dry.

STREAM CHEMISTRY

Flowing water on the islands is quite pure except when polluted by man. Unfortunately, there are very few streams left that are not polluted. The chemical makeup of streamflow is very complex but there are some items which are practical to measure and give some indication of its purity.

One such element is phosphorus. Phosphorus occurs naturally in some areas but as a general rule in this part of the world, it is an indication of pollution by man. High phosphorus content of streamflow has been measured near the populated areas of Puerto Rico (particularly San Juan) as compared to the low concentrations in the interior mountain streams. Another common indicator of human sewage pollution is coliform bacteria. This is a definite indication of human pollution. Heaviest concentrations tend to be around the populated areas, the same as with phosphorus. Drinking untreated water from any polluted streams could cause severe illness and possibly death. Fortunately, coliform bacteria can be killed by clorination, otherwise there would be very little water left for us to drink.

STREAM SEDIMENT

The sediment carried by streams varies widely depending on the geology and land use of the watershed. A very rocky forested area will yield low sediment concentrations compared to an alluvial farming area. Because of the geology, topography and land use of Caribbean islands, sediment concentrations are relatively low. However, they do vary from one area to another.

There are several reservoirs in Puerto Rico. The loss of storage due to sedimentation varies from 0 to 2%/yr. After 50 yr, Guayo will be completely full of silt. This type of problem is becoming a serious problem all over the world.

GROUND WATER

The occurrence of ground water on the islands is not nearly as common as in many other parts of the world. The steep, rocky mountains cause most of the water to run off into the sea before it can be absorbed into the ground. The exception to this is Barbados which is relatively flat and mostly alluvial soil.

In Puerto Rico, ground water is used only for about 20% of the public water supply. Puerto Rico probably has a higher percentage of ground water available than most of the other Caribbean islands except Barbados.

From a hydrologic point of view, the actions required to properly manage a watershed are fairly simple to describe but may be difficult to achieve. The steps should include:

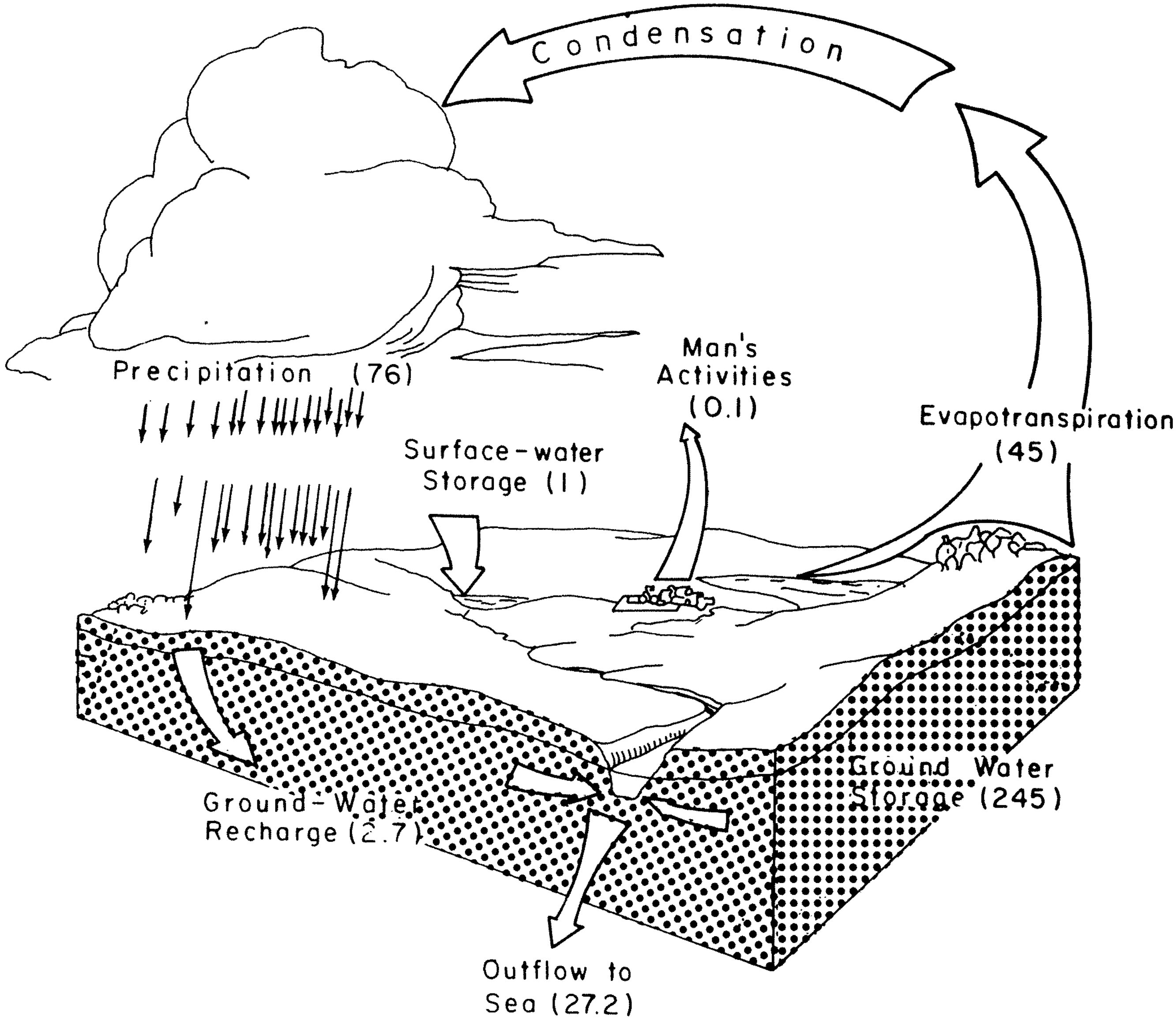
- Establish a network of streamflow-monitoring sites. The highest priority should be given to the largest watersheds.

- Continue to operate this network for at least 5 yr and expand it to the smaller basins.

- After 5 yr of data have been collected, analyze the changes that are taking place.

- Use these data as a basis for making management decisions for improvement of the watersheds.

Some progress in this direction has been made on St. Vincent, St. Lucia and Dominica by initiating step one.



WITHDRAWALS, IN INCHES
SURFACE WATER 3.0
GROUND WATER 2.0

CONVERSION UNITS
INCHES X 228 hm^3
INCHES X 165 MGD

Figure 1. The hydrologic cycle of Puerto Rico.

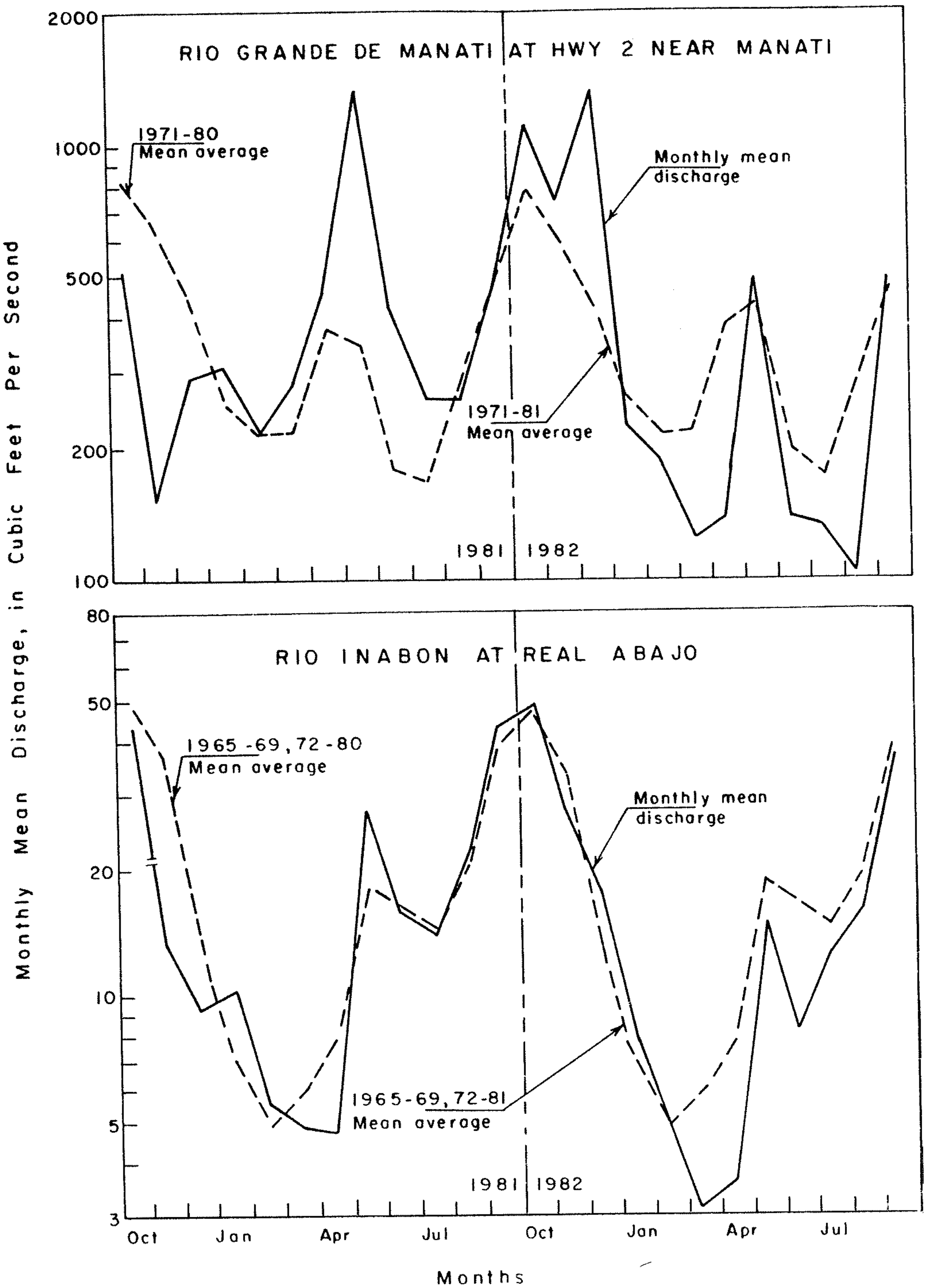


Figure 2. Discharge curves for two stations in Puerto Rico.

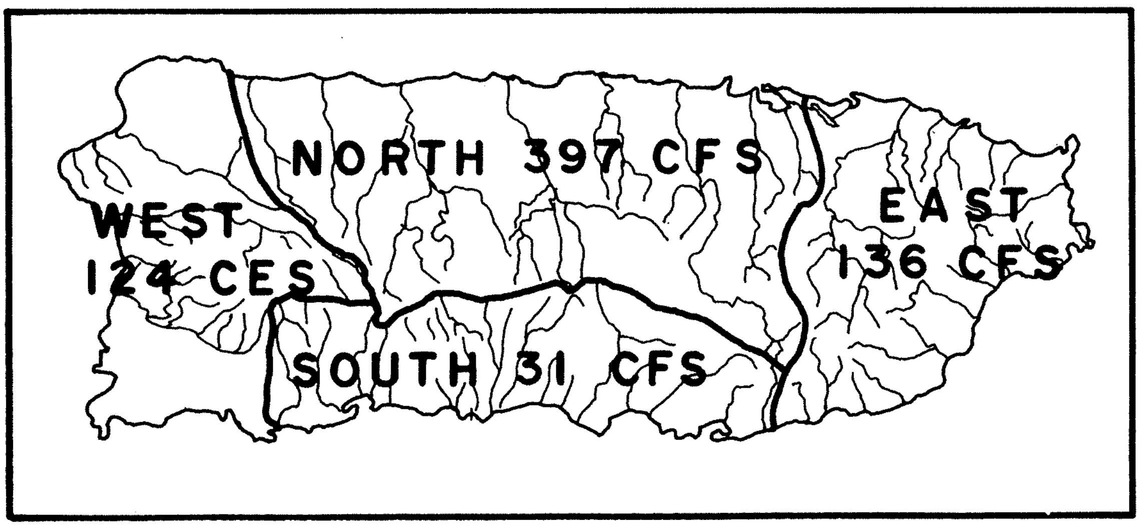


Figure 3. Total volume of water flowing to the sea during March, 1983.

FOREST WATERSHED MANAGEMENT IN THE CARIBBEAN

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Hydrologist
USDA Forest Service

The Proceedings of the First Workshop of Caribbean Foresters held in Castries, Saint Lucia, May 1982 revealed several forest watershed management opportunities and problems including:

-watershed protection and rehabilitation,

-watershed research needs,

-landslide prevention and rehabilitation,

-forest road construction and logging, procedures for preventing erosion and sedimentation,

-forest management for soil and water construction, and

-soil compaction and its mitigation.

These opportunities and problems were associated with major issues concerning damaged fisheries, failing water supplies and impaired soil productivity, all seriously affecting the wellbeing of the societies. The participants at the first workshop recognized the potential of forestry and the forest industry as a means to correct problems and create opportunities to benefit society. However, improper forest management can aggravate some problems. Several practical and basic principles can be employed by forest managers to prevent or mitigate problems.

Watershed protection management is the management of a drainage area for the production of timber, recreation, wildlife, fishery and agriculture products, while maintaining or improving water yield, water quality, timing of streamflow, and soil productivity. Watershed managers must solve landslide, soil erosion, sedimentation, flooding, soil compaction, road construction and logging problems, and implement soil and water rehabilitation projects.

PROBLEMS AND SOLUTIONS FOR WATERSHED MANAGERS

Landslides

Landslides are very difficult and expensive to rehabilitate. Therefore, the best approach is to try to prevent them from occurring. To prevent landslides requires the ability to recognize land subject to slippage if disturbed (Schuster and Krizek 1978). Good soil maps will identify slide prone soils, but such maps are not generally available.

Foresters need to look for landslide evidence in the field.

Landslides and unstable soil mantles can be recognized by slopes having protruding toes with scarps and tension cracks above (Fig. 1); leaning trees having the base of the stem leaning with the top portion of the trunk growing vertically (Fig. 2); sunken and patched road sections (Fig. 3); and center line markings of roads displaced down slope (Fig. 3).

Landslides should be left virtually undisturbed. Roads trigger landslides, thus roads should not be built across them if an alternate route can be located (Schuster and Krizek 1978). If a road must cross a landslide, only two locations are reasonably safe, if special construction practices are employed (Gedney and Weber 1978). The two locations are the very top and the toe of the landslide (Fig. 4).

When building across the top of a slide, the road is built by removing soil (thus weight) from the top (Gedney and Weber 1978). The weight in the toe balances the weight upslope. By removing weight from the top, stability is increased. The road is built on a full bench section, that is, the road is cut into the slope with all excavated soil transported off the slide to be deposited in a stable area. Runoff from the road must be carried by an inside ditch and discharged onto stable soil or preferably carried by pipe to a stream. Never discharge runoff onto a landslide, because gullies form and as gullies grow they trigger larger and larger landslides. Eventually, the whole slope and road will slide downhill.

When crossing the landslide toe, add as much weight as possible. The road is built on fill, adding weight and increasing stability to the slide (Fig. 4). Never cut a road through a toe of a slide, because this removes weight from the toe, reduces mechanical strength within the slide and creates an unstable condition.

If you plan to cross the center of a slide, you better have a lot of money and equipment to keep the road open. There are some things, however, that can be done to increase slide stability at such a location:

- The road should be built as narrowly as possible to minimize the depth of cut into the slide.

- Water concentrates in the soil at the base of a road cut and saturated soils led to slides. This water concentration can be reduced by inserting rows of pipe drains into the soil in the cut, with the pipe sloped uphill. Water is collected by the drains, and flows into a collection pipe or the inside ditch of the road, which carries and deposits the runoff on a stable site or into a stream (Gedney and Weber 1978). Removing soil moisture increased stability.

When crossing the top or center of the slide, never build a road by pushing soil over the side to create a fill. The slide is at the angle of repose, that is, the angle at which the soil is at rest or stable. Side casted material form sliver fills which exceed the angle of repose, are unstable and will slide downhill (Fig. 4). When a sliver fill slides, gullies can form leading to a major landslide.

Completely forested landslides are known to slide when saturated. However, forest cover help stabilize landslides by two means; trees remove soil moisture and discharge it into the atmosphere, and soil is physically bound together by extensive and strong tree roots. Retaining forests on landslides is a primary management strategy for minimizing their occurrence.

Forest on landslides should not be clearcut or converted to other land uses. Forest removal increase soil moisture and the roots will decay, creating an unstable landslide. Commercial forest can occur on landslides and their harvest must reflect landslide hazards. Selective harvest systems which remove a small percentage of the basal area are recommended. Narrow strip or very small patch harvests can work, too. Harvest systems should be designed to retain the water removing function of the forest, while adequate rooting strength is retained to bind the soil together.

Road Location

Roads are known to be major contributors to erosion and to sedimentation of streams. Proper location of roads can eliminate the majority of road related problems (Hartung and Kress 1977). Roads should be located so that they can drain properly, avoid springs and seeps, on grades less than 12%, and where they will not trigger landslides. A good location is often just one side of the ridge line, which facilitates road drainage. The road should cross streams at right angles.

Bridges or culverts should be used to cross streams (Hartung and Kress 1977). These structures should be large enough to pass flood flow through them, thus preventing the structure from washing out and closing the road. If the road is to be used only to harvest a stand, temporary log-bridges can be used and removed after logging is completed (Fig. 5). Shallow rock lined streams can be crossed with a ford with minimum impact to the stream. The number of stream crosses should be minimized.

Road drainage is accomplished by using outsloped roads, inside ditches and culverts, and the rolling dips (Hartung and Kress 1977). Outsloped roads can be used if the road surface is gravel and not slippery when wet. Outsloping allows surface runoff to flow uniformly off the side of the road. For safety reasons, inside ditch and culvert drainage is often used. Rolling dip roads have minor reverse grades spaced to discharge water onto stable ground (Fig. 6). Rolling dip roads are inexpensive to build and to maintain. The spacing of culvert drains, lead out drains, and dips can be computed by the following formula:

$$\text{Spacing} = \frac{400 \text{ ft}}{\% \text{ grade}}$$

Another method for spacing drainage is this rule of thumb: when the road has an elevation change of 4 feet above or below the last drain, install another drain.

To control erosion and sediment from roads under construction, build roads during dry periods. Wet weather construction is costly in time, money, and environmental damage. Sediment movement from road construction can be minimized by building brush piles just-below the road out of limbs and branches, brush, and non-commercial logs cut out of the right-of-way (Fig. 6).

Road surfacing reduces erosion and sediment over a dirt road. Surfacing with large 2 to 4 inch gravel to a depth of 3 inches or more will reduce erosion by approximately 75%. Paving with asphalt will eliminate surface erosion. The cut and fill slopes should be revegetated to prevent erosion.

Proper road maintenance reduces erosion and sedimentation. Culvert heads should be inspected for debris plugging entrances. Plugged culverts will cause runoff to over-top the culvert and run either across or down the road, carving gullies and possibly washing out the road.

Grader operators are bad about gouging material out from the base of the cut slope. The structural strength of the cut slope is weakened by this practice and often leads to small landslides (slumps) in the cutbank. Grader operators often rebuild the inside road ditch when it is not needed. Vegetation in the ditch is destroyed, accelerating ditch erosion.

Logging

Logging requires skidding logs to a deck where they are loaded onto trucks to be transported to the mill. The deck should be placed on ridges and not in stream bottoms. Ridge top decks requires skidding uphill, which means that surface runoff is being dispersed (Fig. 7). Stream bottom decks require skidding downhill, thus surface runoff from skid trails is concentrated at the deck, thus increasing erosion and sedimentation potential (Fig. 8).

Crossing streams with skid trails should be minimized (Hartung and Kress 1977). Skid trails should be located before logging begins. Stream crossings should be at stable sections of the stream, for example where rock is present. Skid tails should have structures to cross streams, for example, temporary log bridges, culverts and log bundles. The latter should be used in only very small streams that carry a little runoff during the shortly after heavy rains. All stream crossing structures should be removed after logging is completed.

Skid trails, decks and temporary roads compact soil, increase surface runoff and erosion, and decrease soil productivity in the compacted area. The area of compacted soil should be limited by careful location of skid trails, decks and roads. Generally, roads and decks should be less than 5% of harvest area. Skid trails should be limited to 15% of the area.

Rehabilitation of Logged Area

After logging is completed, temporary roads, skid trails and log decks need watershed rehabilitation treatments. Roads are closed by using chains between trees, locked gates, or ditches dug deep enough to prevent a vehicle from crossing (Hartung and Kress 1977). Roads, skid trails and decks are water barred (Fig. 9), diverting surface runoff onto vegetated and stable soil. Waterbars are spaced by using Table 1.

Waterbars can be constructed with hand tools or bulldozers (Fig. 9). It is best to start at the end of the skid trail or road and construct waterbars as the tractor backs out because waterbars are damage if crossed by equipment. Waterbars are angled across the trail or road at 30° down slope. The waterbar is created by digging 6 to 9 inches into the soil with the excavated soil piled adjacent to the downhill edge of the ditch forming a mound running the length of the ditch. The outflow end of the water must be open to permit proper drainage.

Compacted soils can be rehabilitated by plowing or ripping to a depth of 6 to 12 inches, respectively. Ripping is done by a bulldozer equipped with road rippers. Rip when the soil is dry enough to shatter as the implement is pulled through it. If the ripper slices through the soil, it is too wet. Animals or a tractor can be used to plow compacted soil. After plowing or ripping, the soil should be disked to create a seed bed, seeded and possibly mulched with straw or herbaceous vegetation depending on soil erosion hazard, amount of precipitation and other factors. Sometimes fertilization is needed because soil nutrients are low or have been removed during the construction of the trail, road or deck.

Filter Strips

A technique used to reduce the amount of eroded soil from roads and logged areas reaching a stream is to leave a filter strip, an essentially undisturbed strip of vegetation, and forest floor to intercept surface runoff and sediment (Fig. 10). Filter strips are not taken out of production. Timber can still be harvested and regenerated, but heavy equipment and major soil disturbing activities are excluded. For example roads and skid trails are excluded, except at stream crossings.

Filter strips should be left between any forest disturbance and intermittent or perennial stream. Table 2 has are recommended filter strip widths on various slopes in the temperate USA. These may need adjustment for tropical regions because of higher rainfall.

With proper road and skid trail location, construction, maintenance, and closures, these filter strip guidelines will keep the majority of the sediment out of the stream.

Site Preparation for Tree Planting

Some general watershed principles must be applied when preparing sites for tree planting. To prevent erosion and surface runoff, the soil surface must be protected by leaving litter and debris in place. How much litter and debris to leave increases as the slope increases. On 0 to 10% slope, 50 to 70% of the soil might be exposed without excessive erosion. However, on slopes >50%, 20% soil exposure might be unacceptable. Specific guidelines will vary by climatic and soil conditions.

Also, implementing practices that retain organic litter and topsoil on site will maintain soil productivity (Dissmeyer 1984). Organic materials contain a large quantity of nutrients. If these materials are removed to prepare a site for tree planting, valuable nutrients for tree growth are removed. In the United States, early tree growth is a function of the amount of nutrients on site at the time of planting. Therefore, those practices that retain organic material, thus nutrients, are those practices that reduce erosion and runoff, while best maintaining soil productivity.

EROSION EVALUATION AND RESEARCH

To formulate sound soil and water conservation policy and direction, agencies require data on the nature, extent and magnitude of the problem. For erosion and sedimentation, watershed analysis and planning can be done with tools presently available. Watersheds can be divided up into area of the same soil, slope class, timber type, and potential forest management, if source maps and information are available or they can be generated. An erosion rate for forest conditions can be developed from field observations and with the Universal Soil Loss Equation (USLE; Dissmeyer and Foster 1980). The condition class area times its erosion rate will yield an estimated erosion volume from that specific condition. Erosion volumes from all conditions are summed to produce a total for the watershed. Agriculture and other land uses can be evaluated by the USLE (Wischmeier and Smith 1978) too, and incorporated into the watershed analysis and erosion total. These data and analysis can be used to develop a soil and water plan and policy for addressing erosion problems on a priority basis.

The USLE has been adapted to forest conditions in the United States and validated (Dissmeyer and Foster 1980). The use of the USLE is expanding into many countries. Before adopting the USLE for use, it should be checked to see if any of the equation's factor relationships need modification (Dissmeyer and Foster 1983). Technical expertise in the USLE can be sought and the equation can be checked using an inexpensive technique - fabric dams.

Fabric Dams

Fabric dams are basically fences constructed on a slope, faced with an erosion control fabric (Fig. 11; Dissmeyer 1982). The fabric allows water to seep through while filtering out sediment. The dam has wing walls straight upslope at each end to prevent runoff from escaping around the ends. The volume of trapped soil can be measured (Fig. 12) and compared to the estimate made by the USLE.

Fabric dams have some advantages over other research techniques because they are cheap and can be used to demonstrate how much erosion is occurring in various landuses (Fig. 13). People not expert in erosion evaluations and terminology have a very difficult time relating to or visualizing what is meant by tons per acre, tonnes per hectare, milligrams per liter, and parts per million. However, soil trapped behind a fabric dam is visible.

Fabric dams have been installed in a thinned pine plantation, pasture, and a banana plantation in Puerto Rico. Last summer, no sediment was observed behind the dam in the pine plantation, a very small amount in the pasture dam, and a lot of soil behind the banana plantation dam. Such visual observations by laymen and policy-makers creates in their minds "hard" evidence as to which land uses yields the most erosion and where to concentrate efforts to minimize erosion and sediment problems.

CONCLUSIONS

This paper has tried to summarize many of the practical and common sense practices that can be used to minimize watershed impacts from forest management activities. Behind these practices are many fundamental principles of watershed management. When evaluating a proposed management or land use practice, careful evaluation and judgement must be employed to determine which practice to implement. The guidelines and tools suggested are starting points and with experience in using them, some modifications will become evident to improve watershed management in a particular country.

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Table 1. Waterbars spacing

Road and skid trail grade (%)	Approximate distance needed between waterbars (ft)
1	400
2	245
5	125
10	80
15	60
20	50
25	40
30	35
40	30
50	25

Table 2. Recommended filter strip widths.

Slope of land between road and stream (%)	Width of filter strip (ft)
0	25
10	45
20	65
30	85
40	105
50	125
60	145
70	165
80	185
90	205

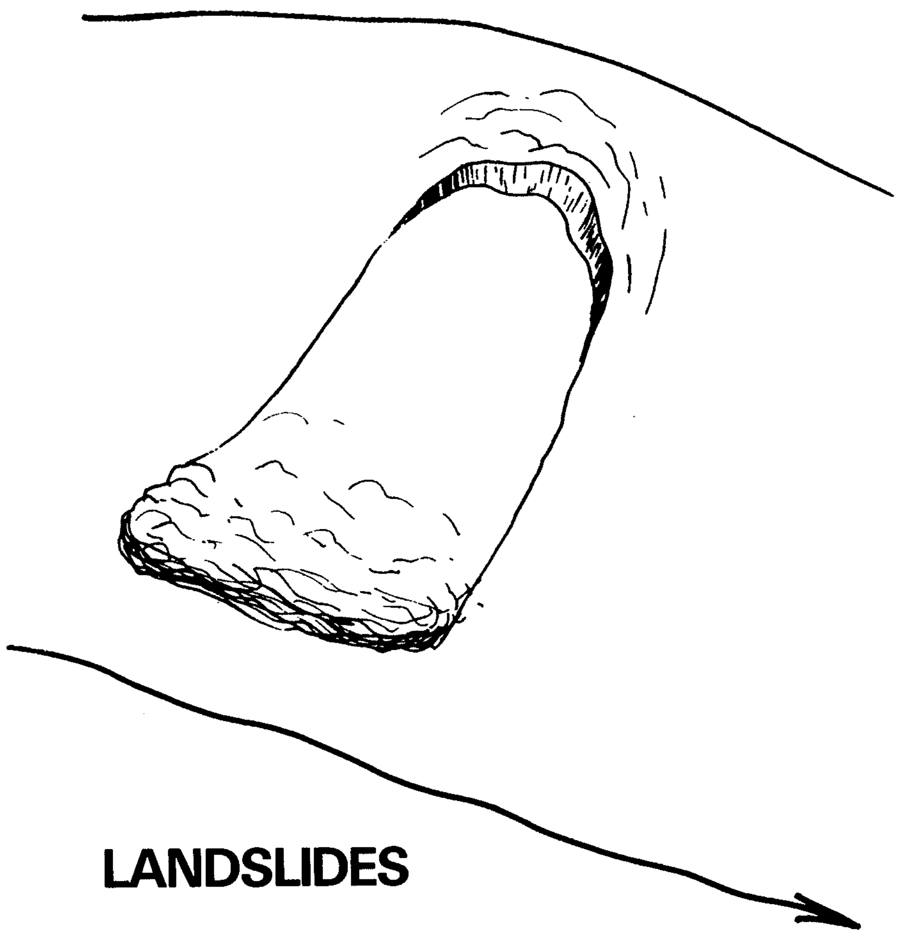


Figure 1. Landslides have hummicky and protruding toes, with scarps and tension crack commonly found at its head.

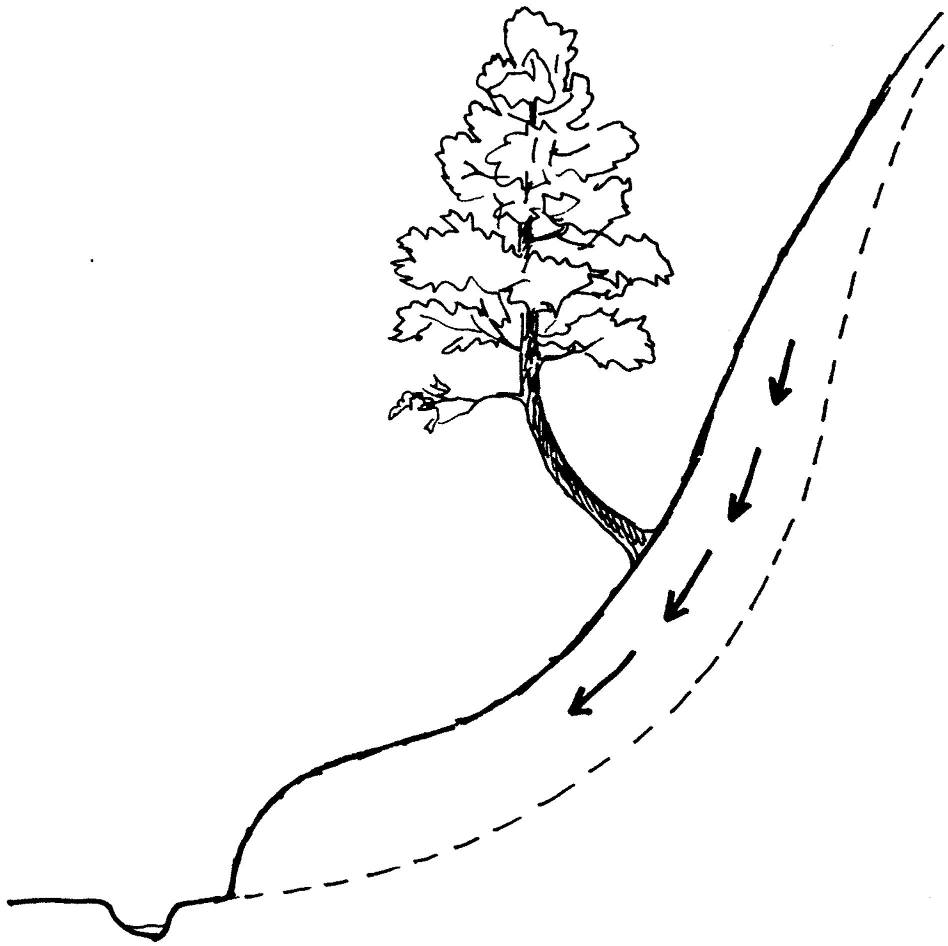


Figure 2. Unstable landslides often have deformed trees.

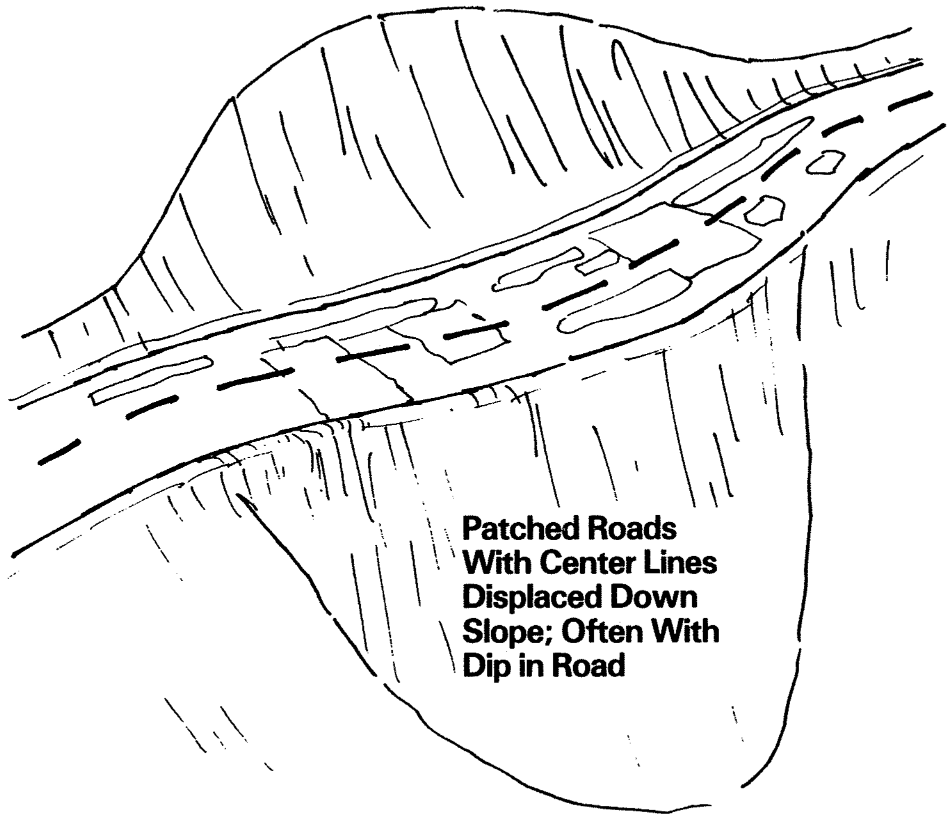


Figure 3. Unstable landslides can be detected by condition of roads crossing them.

CROSSING LANDSLIDES WITH A ROAD

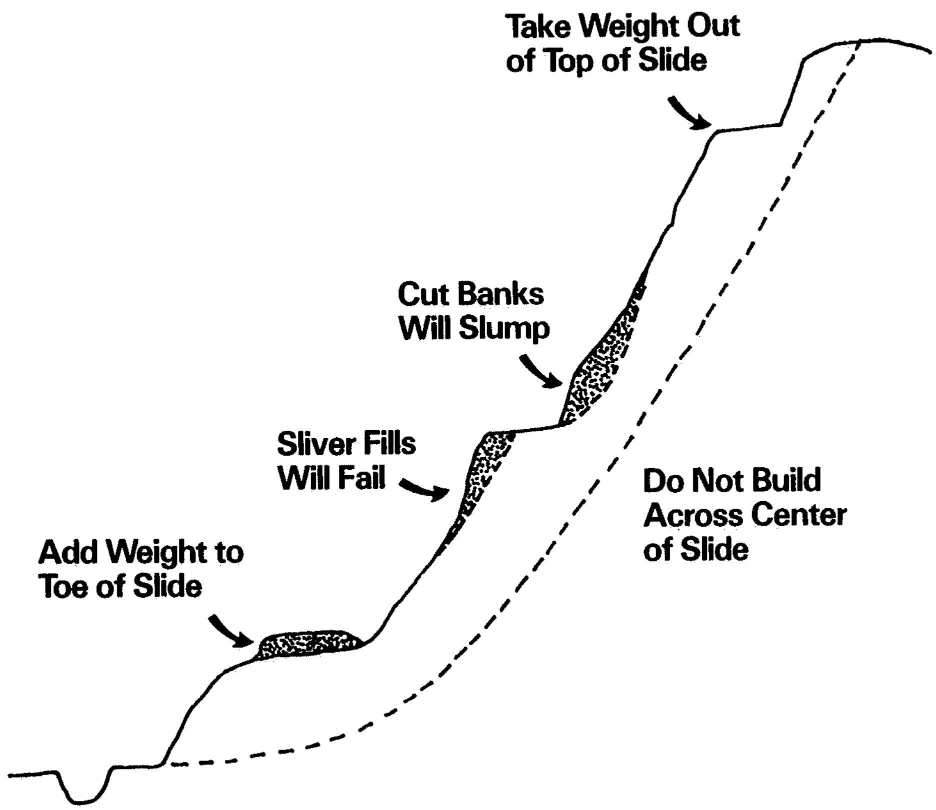
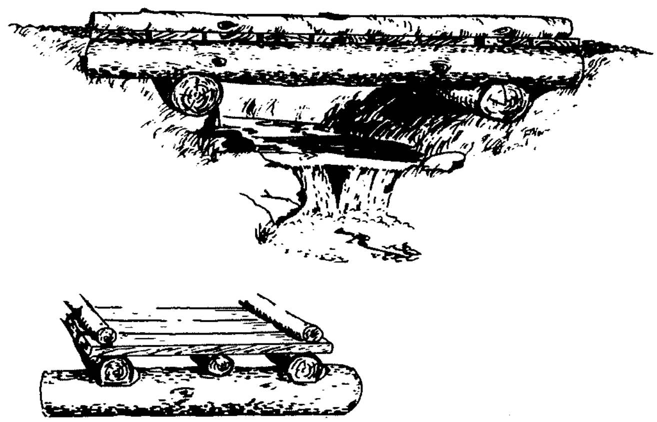


Figure 4. Basic principles for crossing landslides.

A SIMPLE LOGGING ROAD BRIDGE DESIGN



1. Bridge streams crossings if there is a potential sediment or polution source.
2. Use alternate road location to avoid the necessity of a bridge, if possible.
3. Bridge crossing should be located where the stream channel is straight with an unobstructed flow of water.

. Abutments should be in a direction parallel to the stream flow and imbedded in good foundation material.

Locate at right angles to stream flow where approaches are reasonably level for a minimum of 50 feet from both sides.

Figure 5. Temporary log bridges.

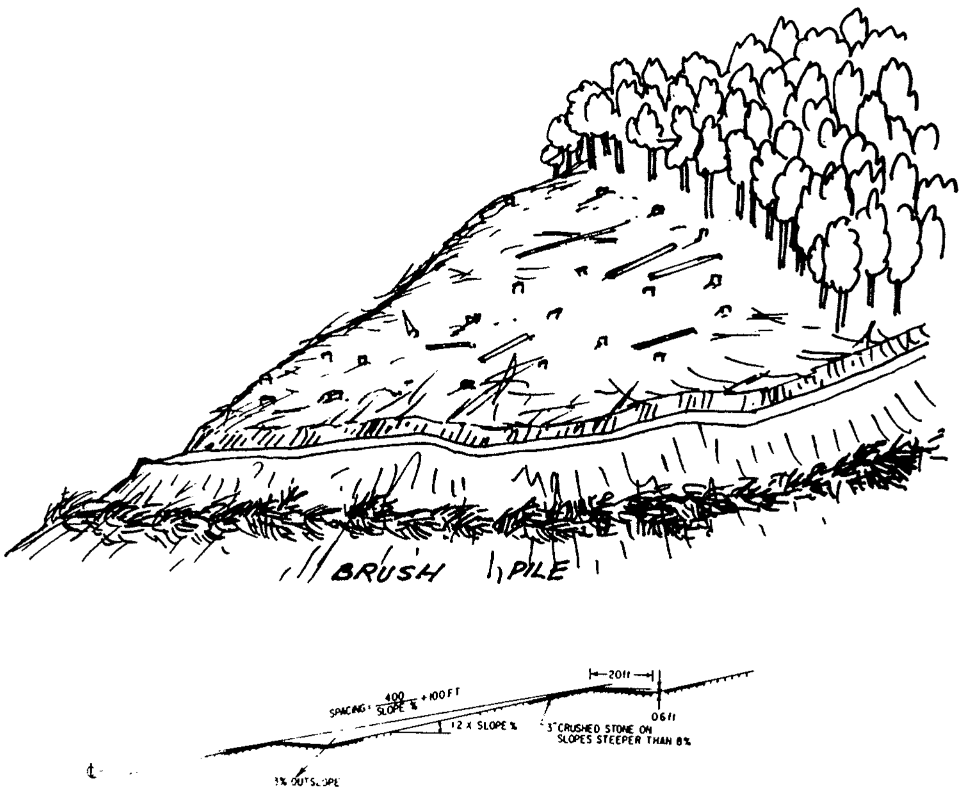
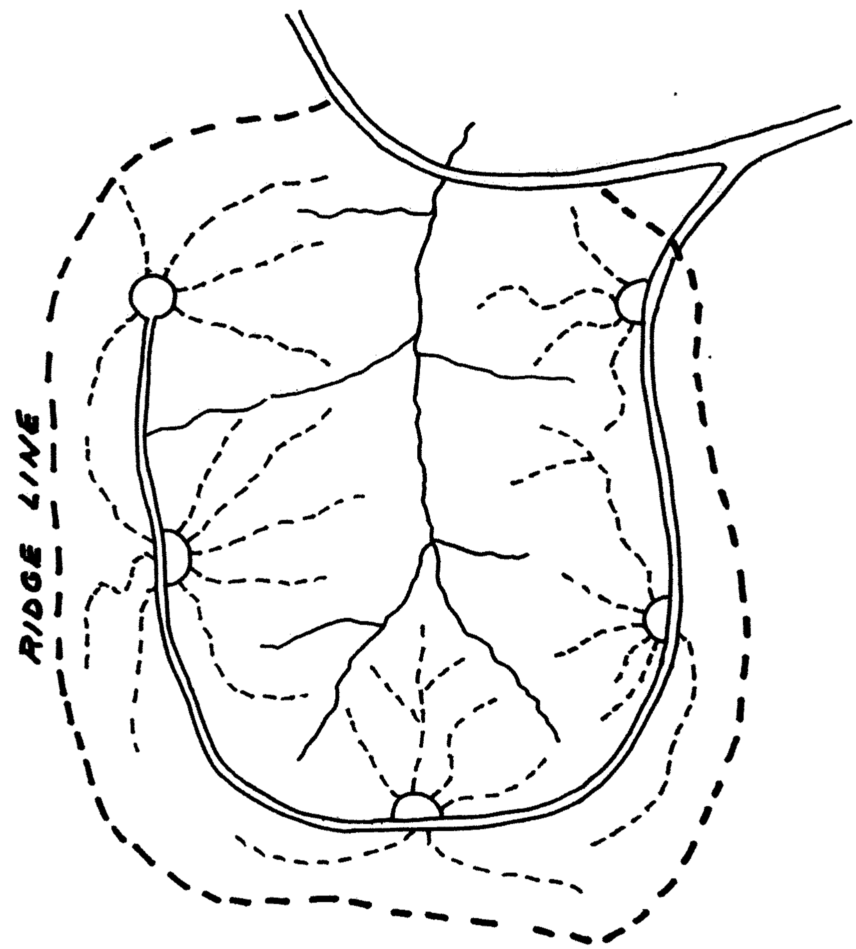


Figure 6. Rolling dip road.



Legend

Roads

Skid trails

Log decks

Stream

Figure 7. Road location governs the number of stream crossings, log deck location, and direction of skidding.

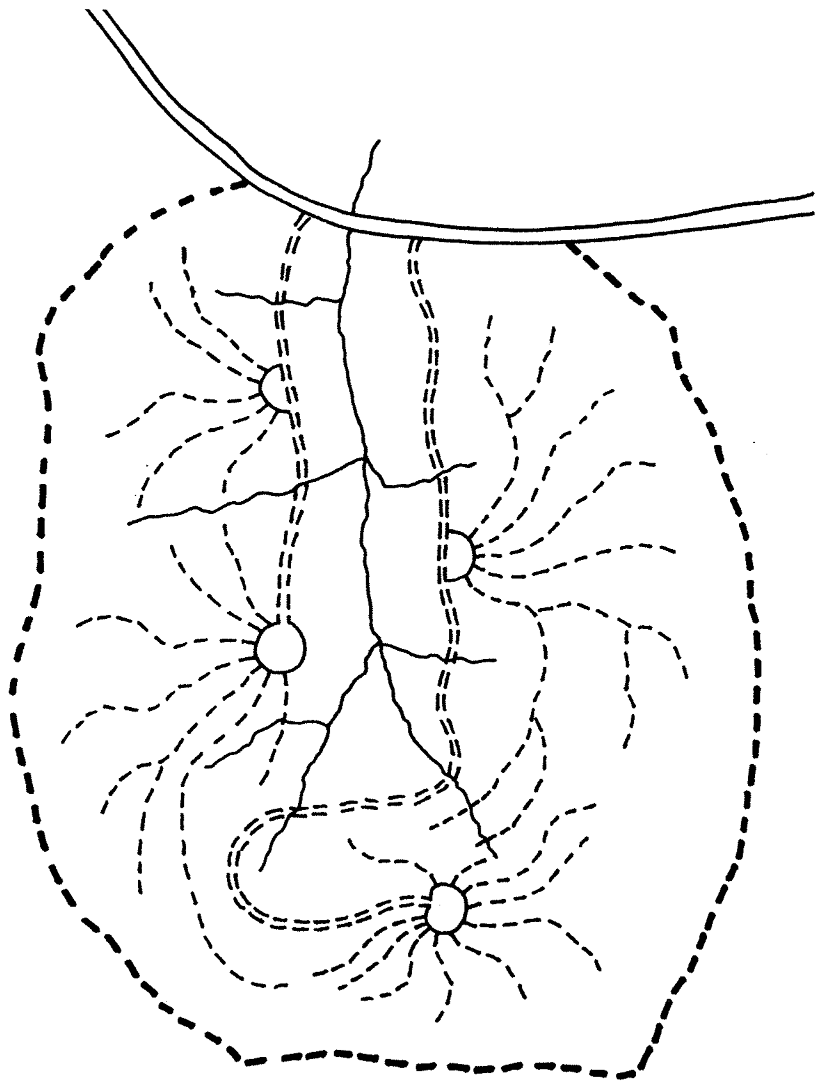
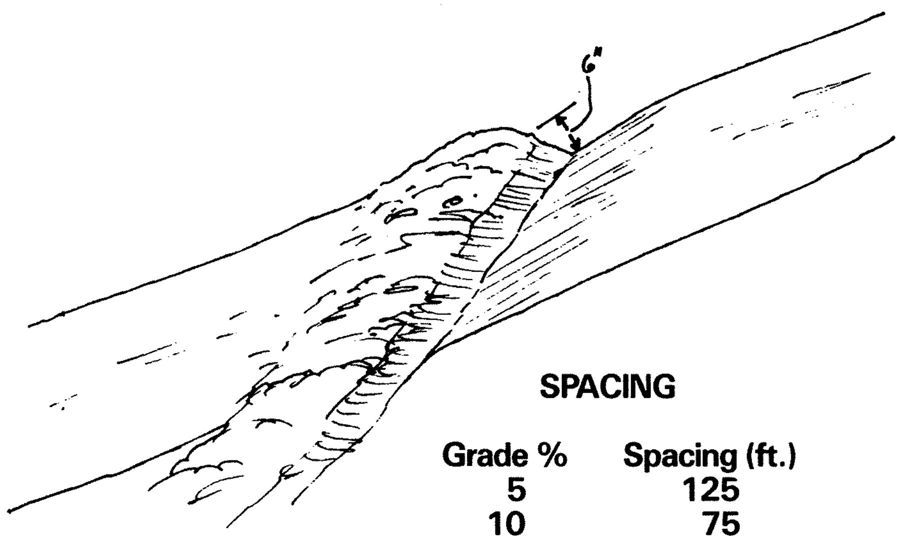


Figure 8. Valley bottom location of roads increases the number of stream crossings, fosters downhill skidding and increases the potential for erosion and sedimentation.

WATER BARS



SPACING

Grade %	Spacing (ft.)
5	125
10	75
20	50
30	35
40	30

Figure 9. Treating abandoned roads and skid trails with waterbars' controls surface runoff, reduces erosion and sedimentation.

Figure 10. Filter strips left between roads or other forest disturbances and streams will intercept eroded soil and reduce stream sedimentation.

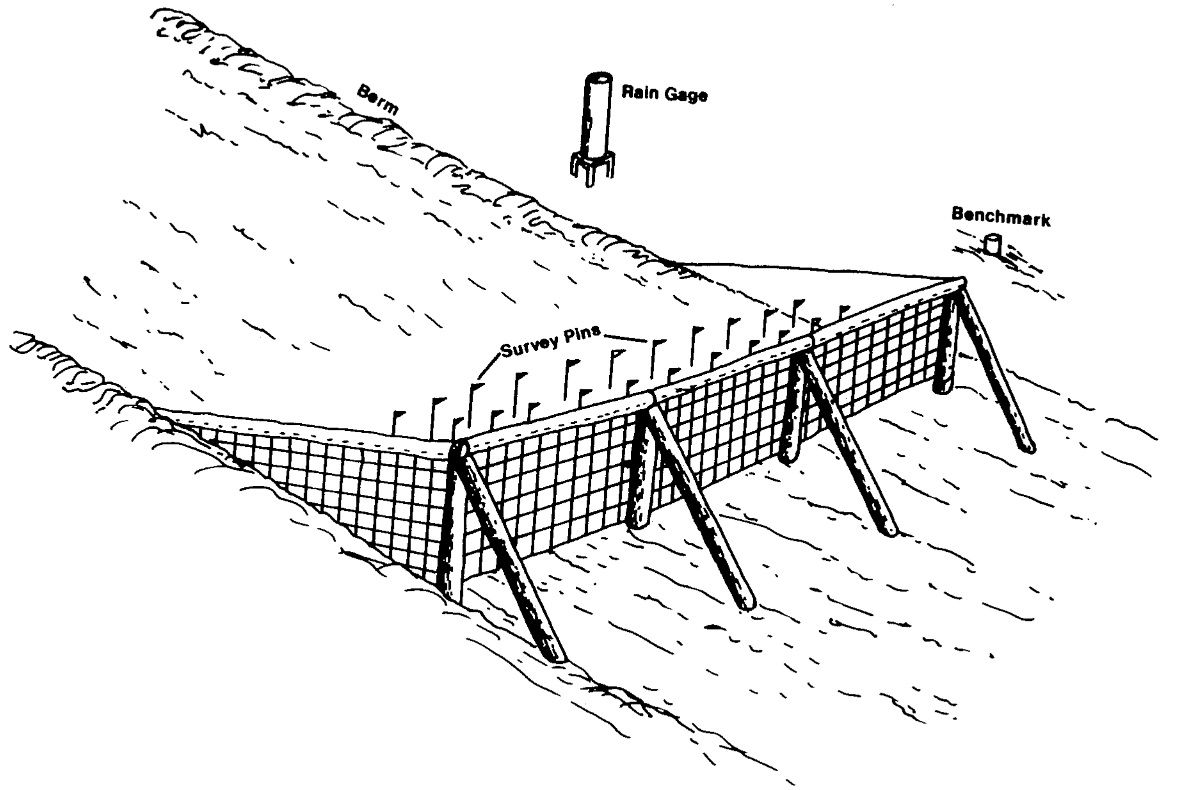


Figure 11. Fabric dams are a good technique to demonstrate erosion associated with various land uses and to validate erosion prediction equations.

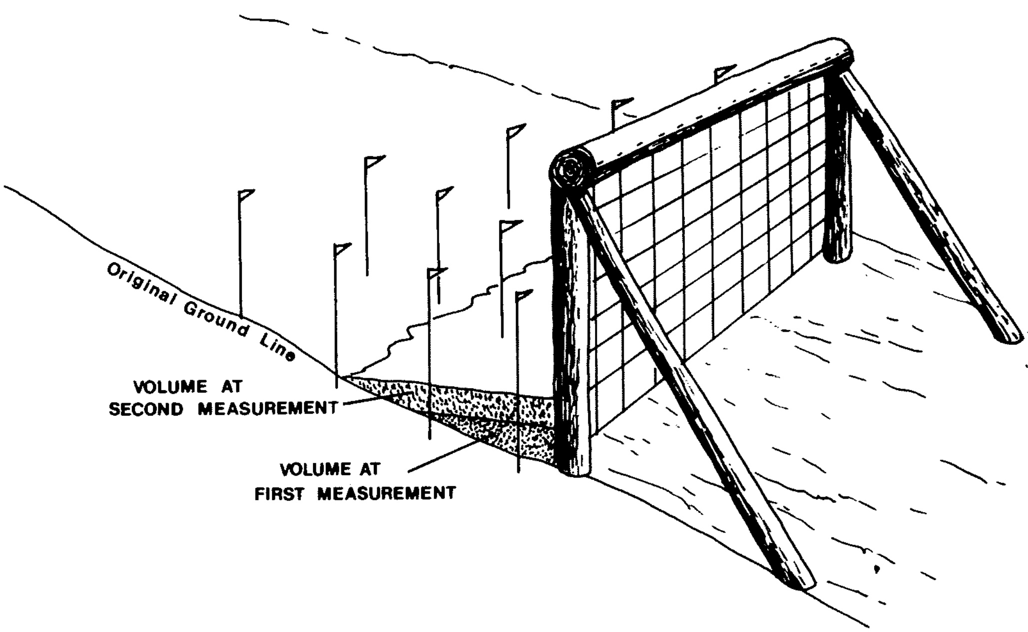


Figure 12. Eroded soil trapped behind fabric dams can be measured periodically to document erosion trends.

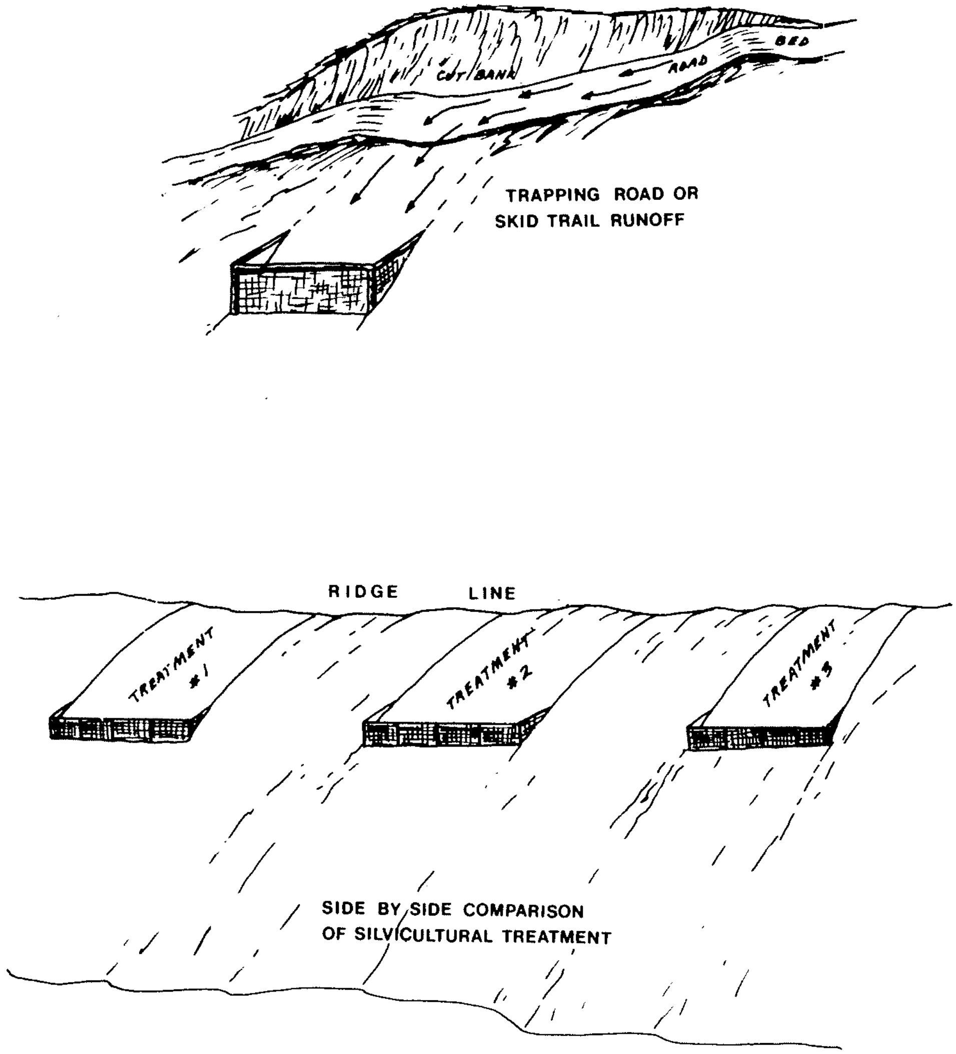


Figure 13. Fabric dams can be used in side by side comparisons of various landuses, including roads and skid trails.

DEVELOPING DATA BASES FOR SUCCESSFUL WATERSHED MANAGEMENT IN THE CARIBBEAN

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Chief, Hydrologic Records Section, USGS

To properly manage any watershed for any purpose it is necessary to collect background data and then continuously monitor changes. The most important items that foresters need to monitor include streamflow and dissolved or suspended material in the water. Once these parameters are documented under "normal" conditions, it should be relatively easy to monitor the changes taking place in the watershed.

Last year, Dr. Lugo asked us (US Geological Survey) to assist him in his watershed-management project by installing a streamflow-sediment gaging station on each island, and helping train local foresters in the methods of measuring and sampling streamflow. We agreed to do this and last November, Dr. Lugo and I came down to talk to the local foresters and decide on the best locations for gaging stations. We chose watersheds that drained from mostly natural, undisturbed forests, and yet were large enough to be representative of a large part of the island. We also required a bridge that was suitable for the installation of an inexpensive gaging station. We chose sites on St. Vincent, St. Lucia and Dominica.

We have (with the complete cooperation of the local foresters) established one continuously recording gaging station on each of the three islands. We also established a recording raingage in each watershed and made a channel survey at each streamflow gage site.

After gage construction was completed on each island, our hydrographers gave their local counterparts a short training session on streamgaging and sampling.

MEASUREMENT OF STAGE (OR GAGE HEIGHT)

Although river stage is not something we need to know, it is the most practical way to calculate streamflow. The continuous measurement of streamflow is possible but it is usually too expensive to be practical. The most common way of measuring river stage is by constructing a stilling well. The basic requirements are a "well" which remains in contact with the river at all times and an instrument shelter that is weather proof and not subject to flooding. The stilling well creates a water level the same as the river but without the velocity and surges. A float can then be put in the stilling well and attached to a stage recorder at the top. The river gages we installed for this project are of this type but of a much simpler design. The stilling wells are made of 6 inch (15.2 cm) PVC pipe and attached to bridge piers or abutments.

The next most common type of stage-measuring device is the mercury manometer or "bubble gage". This is the type of installation we use most of the time in Puerto Rico. The river stage is measured indirectly by bubbling nitrogen gas through a tube fixed permanently in the streambed and measuring the back pressure. The higher the river stage, the more pressure that's required to cause the gas to escape. The mercury manometer attached to the other end of the bubble tube measures the pressure in the bubble tube and converts it to feet of stage.

The instruments are somewhat complicated. The advantage of this type of installation is that the shelter can be easily located almost anywhere and a bridge is not required. The disadvantages are that the equipment is expensive and hydrographers must be highly trained to operate them properly. The recorders used in these river gages are the same regardless of whether it is a stilling well or bubble gage. The standard since 1935 has been the graphic recorder.

About 25 years ago the USGS developed the Automatic Digital Recorder (ADR). This recorder converts the river stage to numbers and punches these numbers on a paper tape. The paper tape can be translated directly into our computers which eliminates the need for the gage-height data to be computed manually. The only disadvantage of this recorder is that it is not easy to read in the field and gaging problems are sometimes overlooked. This is the type of recorder we are using here on this project.

MEASUREMENT OF DISCHARGE

The discharge of a stream is the volume of water passing the gage site at the time of the measurement. We measure it in cubic feet per second. The equipment required is a tagline (to measure width), a wading rod (to measure depth), and a current meter (to measure velocity). The meter is suspended on the wading rod. The width and depth are measured directly. The velocity is measured by counting "clicks" on the current meter.

The Price AA current meter has been the standard measuring device for the USGS for at least 50 years. Each time the bucket wheel makes one revolution, the hydrographer hears a "click" in his headphone. He counts clicks and after at least 40 seconds, he records the number of clicks and the number of seconds as shown on his stopwatch. He then looks at his conversion table. This converts the readings into feet per second. By multiplying the depth (in feet) by the width (in feet) by the velocity (in feet per second) he computes the volume of water flowing at that section.

Twenty-five to thirty sections are usually required to properly define a stream channel. The volumes of the subsections are then added up to give the total flow passing the gage site. The gage height of the stream is also noted before and after the measurement. If any change occurs, a mean-gage height is computed.

For the project gages in the three islands only wading-type measurements will be attempted. The equipment and training required to make high-stage current-meter measurements make it impractical.

STAGE-DISCHARGE RELATION

Now that we have a continuous record of gage height and discharge measurements at various stages, we can develop a relationship between the two to give us discharge continuously.

Figure 1 is a typical stage-discharge analysis. A curve is drawn between the measurements to give a discharge for every gage height. This project will have measurement data only for low flows (up to maximum wading stage). The channel analysis I mentioned earlier will provide a theoretical relationship for medium and high stages.

By selecting points along this curve and feeding the data into our computer, we can obtain a "rating table". This table can be used to convert any gage height at this station to discharge in cubic feet per second. These rating curve points can now be stored in the computer and along with the gage-height data from the digital tapes, be used to automatically compute discharge for every day of the year.

SEDIMENT SAMPLING

To define the sediment concentrations and compute the total sediment load of a stream, samples must be collected.

Figure 2 shows a diagram of a sediment sampler in a stream. The sampler must be moved up and down from the water surface to near the streambed to get an accurate sample. The water is collected in a glass milk bottle.

The sample must be capped securely and identified (Fig. 3). The information required is station name, date, time, gage height and initials of person taking sample. Since we will only take one sample at a time on this project, we don't need to show the section station or bottle number. The important thing is to take samples at different river stages.

The sediment concentrations change rapidly with stage and on a major rise, many samples may be required. On this project we are suggesting 3 or 4 samples at different stages during a major runoff event. During low-flow periods, 1 sample every 1-2 weeks is sufficient.

These sample results are used along with the gage-height record to draw continuous concentration curves (Fig. 4). This is an example of the ideal situation with many samples to define the curve. Unfortunately, we don't very often have this many samples to work with.

Now that we have continuous stream discharge and sediment concentrations, we can compute total-sediment load. Simple mathematics will give the total-sediment loads (in tons) for each day, month or year. Over 50,000 tons of sediment can pass a station during one year.

CHEMICAL SAMPLING

In addition to sediment samples, we will be taking chemical samples. These samples will be taken at the same time as those for sediment and will be mailed to the Center for Energy and Environment Research of the University of Puerto Rico for analysis.

These samples will be analyzed for nutrients including nitrate, ammonia, and phosphorus among others. Like sediment data, these analyses can be combined with stream-discharge data to calculate the total amounts of the various items leaving the watershed.

RECORDING RAINFALL

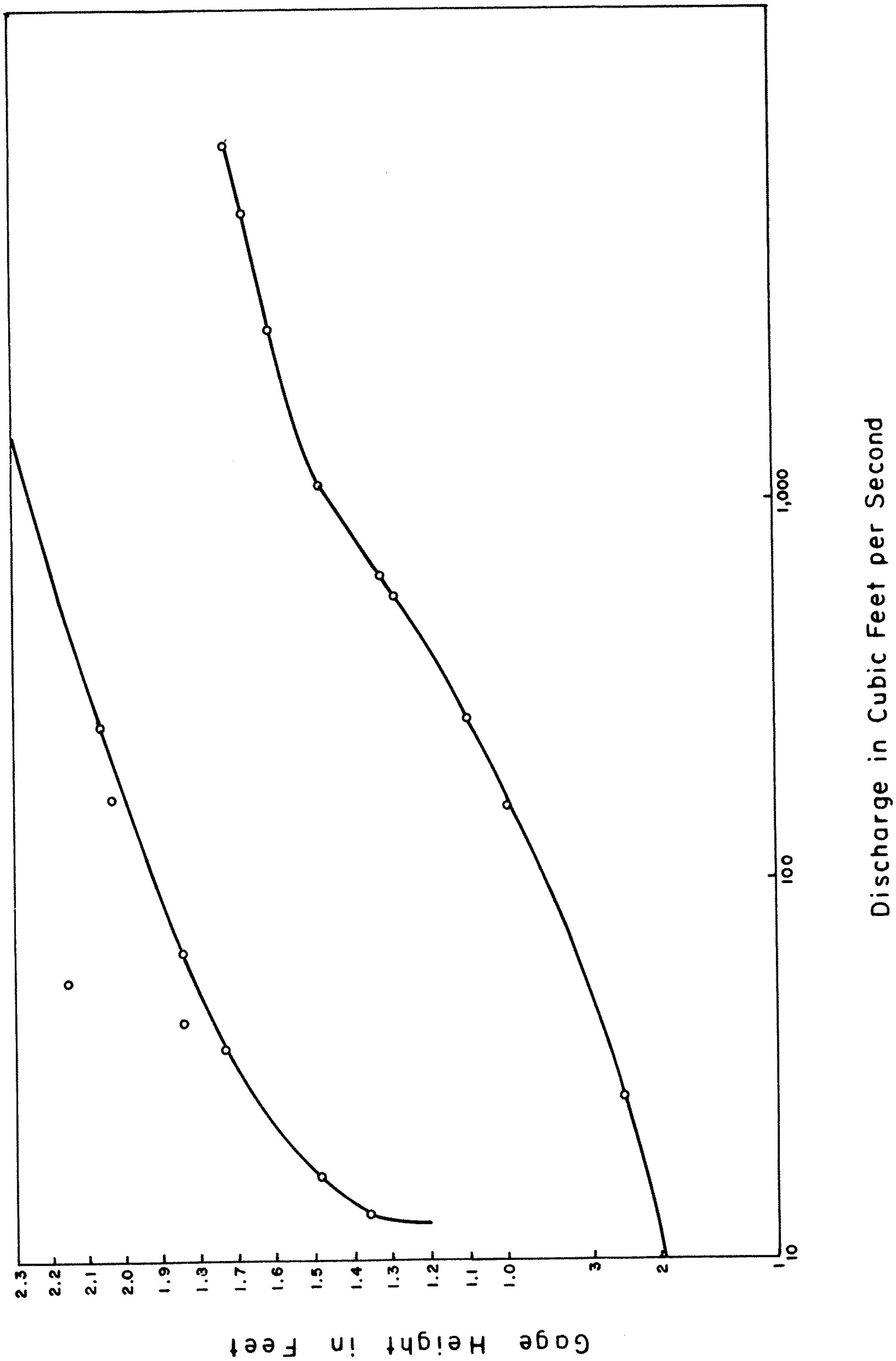
In each of the three watersheds in this project we installed a recording rain gage. The same type recorder (ADR) is used with a float and standpipe. The rain catchment on top of a shelter funnels the rain water into the plastic pipe and every 15 min the ADR punches the elevations on the paper tape. The gage is calibrated to record in hundredths of inches and will record up to about 5 inches before it must be drained manually. We have plans to add a siphon arrangement which will drain the gage automatically.

The paper tapes from the rain gages will be fed into our computer and it will calculate the rainfall for each 15 minutes, hour, day, month and year. These data can then be correlated with the streamflow, sediment, and chemical data. By monitoring the rainfall-runoff ratios over long periods, we could determine what changes are taking place in the watersheds.

USES OF THE DATA

All of the data collected and analyzed will be published in a report similar to our annual data report. It will be furnished to the local foresters as soon as it is considered final. It is also anticipated that the individual investigators will use these data for various interpretive reports of their own.

The results of this project should produce a data base that can be used to monitor the changes taking place on the various islands and provide some basis for suggestions for improvement in watershed management. In addition, these data can be used for decisions regarding water supply, dam and reservoir construction, flood control, bridge and road construction, and pollution control.


Gage Height in Feet
2.3
2.2
2.1
2.0
1.9
1.3
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1.0
3
2
10
100
1,000
Discharge in Cubic Feet per Second

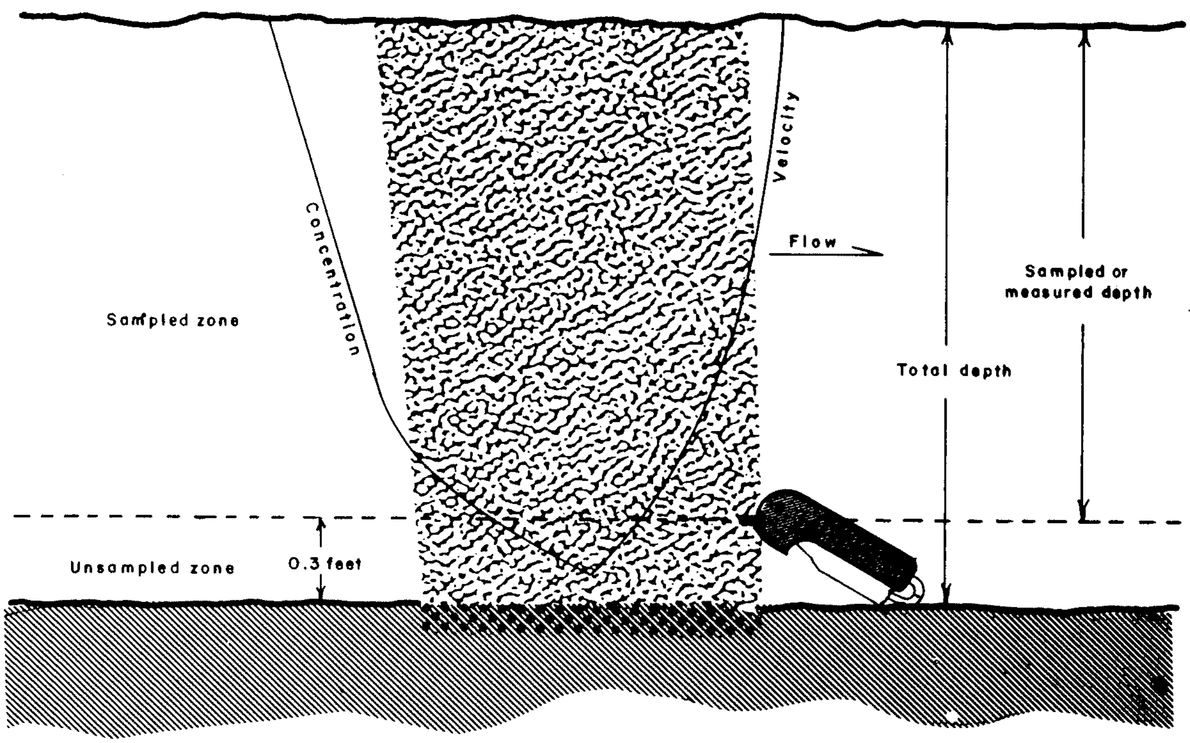


Figure 2. Measured and unmeasured sampling zones in a stream sampling vertical with respect to velocity of flow and sediment concentration (J.K. Culbertson; written communication, May, 1968).

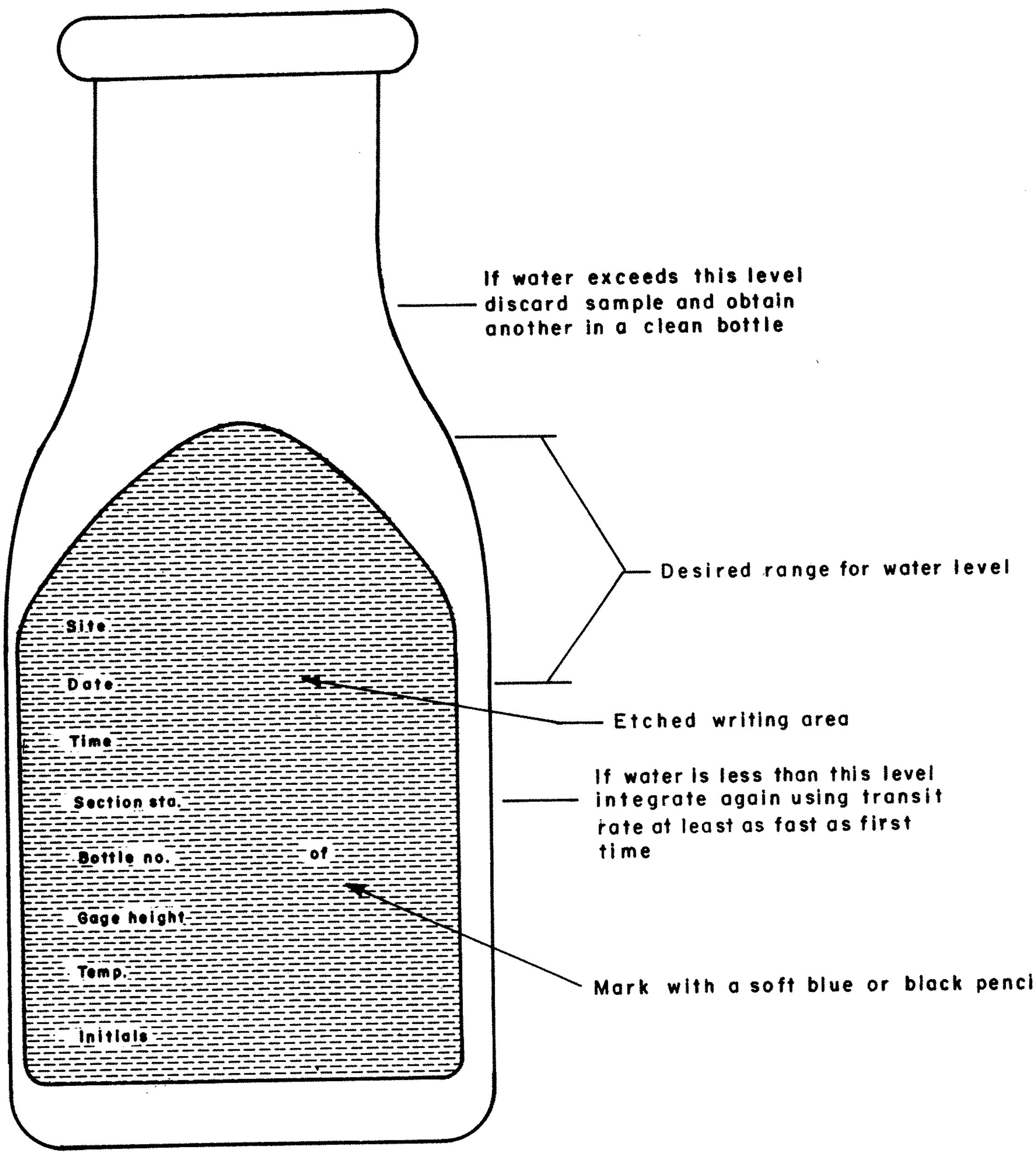


Figure 3. Diagram of sample bottle showing desired water levels and essential recorded information. Sometimes other information concerning type of sampler used, the section location, and stream conditions should also be noted.

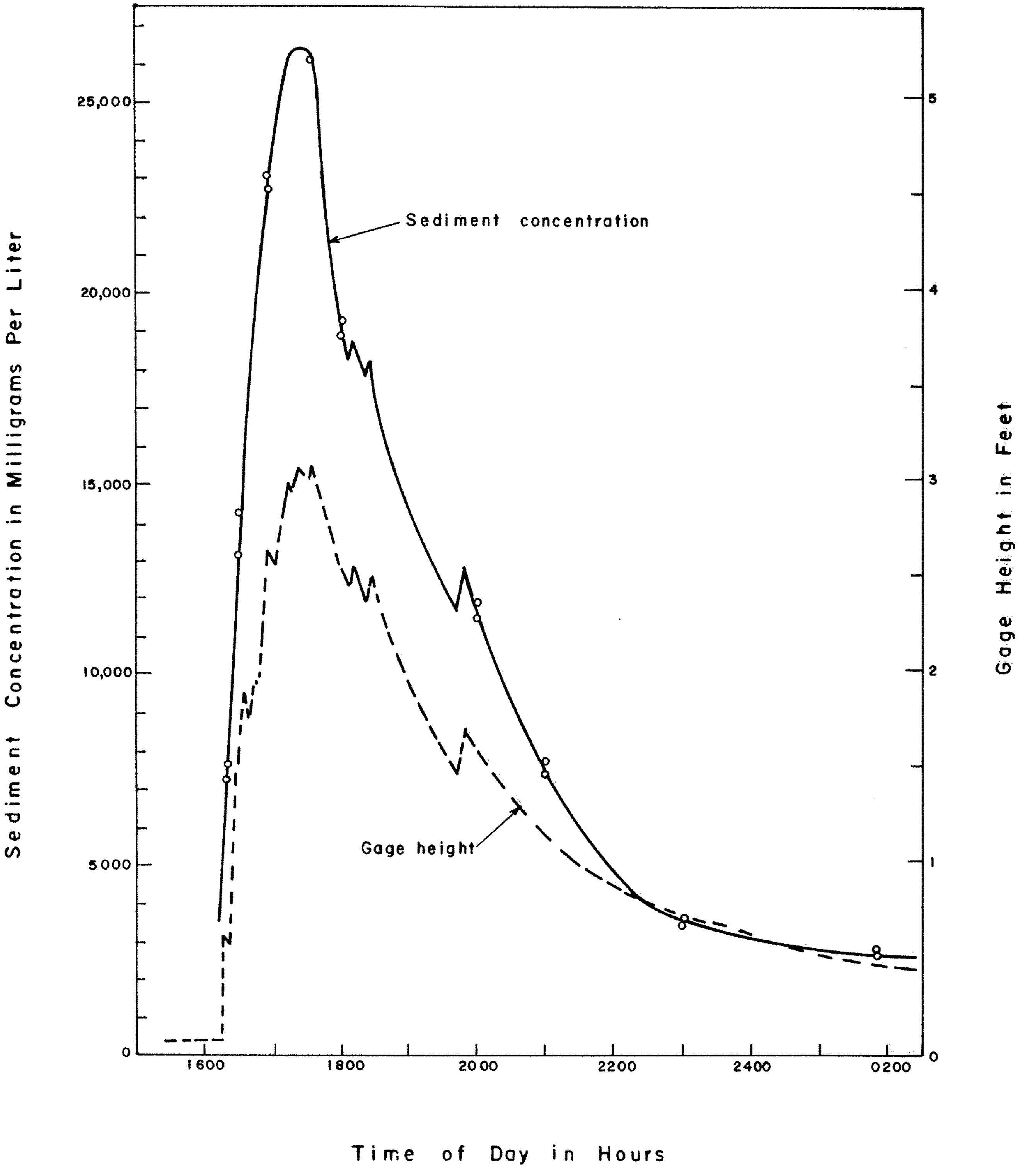


Figure 4. Gage height and sediment-concentration graph typical of many ephemeral streams showing desirable sample distribution.

TIMBER PLANTATIONS AND WATER RESOURCES ON ST. VINCENT, WEST INDIES

Peter L. Weaver
Institute of Tropical Forestry,
Research Forester

and

John Valenta
Peace Corps Officer

INTRODUCTION

St. Vincent (Fig. 1) is one of the windward islands of the Lesser Antilles. It is located at 61°10' W longitude and 13°15' N latitude and occupies 345 km^2 (133 mi^2). A north-south mountain range divides the island into two nearly equal parts. The high point is 1220 m (4000 ft) above sea level just north of the crater of Soufriere. This active volcano dominates the northern third of the island. The southern 2/3 of the island are highly dissected by deep, narrow valleys to the leeward and somewhat gentler sloping lands to the windward.

Rainfall gauging stations show that both the windward and leeward coastal areas receive over 2000 mm/yr (about 80 in/yr). Mean annual temperature for the same areas is about 26°C (about 80°F). The interior mountains are cooler and wetter, with rainfall estimates ranging from 3800 to over 6000 mm/yr (150-235 in/yr) at the highest elevations (Macpherson 1977; Caribbean Conservation Association et al. 1980).

The natural vegetation was described by Beard (1942, 1949) and consists of lowland rainforest between 300 to about 500 m (1000-1650 ft), palm brake above 500 to 600 m (about 1650 to 2000 ft), and dwarf forest on the summits of the highest mountains. Secondary vegetation surrounds the area dominated by Soufriere which was disturbed by volcanic activity in 1902-03, 1971, and 1979. Secondary vegetation is also found in areas worked for subsistence crops in the southern two-thirds of the island.

Population growth has placed increasing demands on the island's forest, water and soil resources. Expanding from 48,000 persons in 1930 and 80,000 in 1960 (Byrne 1969) to 111,000 in 1979 (Nicholls 1982), the current population density is 320/km^2 (about 835/mi^2). Although terrain above 300 m (1000 ft) is owned by the government, shifting cultivators are growing dasheen, tannia, and sweet potatoes in many areas. Below 300 m, permanent cultivation with bananas, coconuts, arrowroot and sugar cane is commonplace, along with scattered mango, breadfruit, cacao, and citrus trees. Future development of water supplies for domestic and commercial uses, and hydropower, will require the careful management of the government's forest resources (Weaver 1982).

The main objective in visiting the island was to initiate an inventory of the forest resources of St. Vincent similar to that conducted in Puerto Rico (Birdsey and Weaver 1982). Because information on structure and growth of plantations was not available, a quick survey of representative species was conducted in order to: characterize standing timber (height, diameter, basal area and volume), and growth rates, by species and site. In addition critical water supply sources were located and silvicultural practices were suggested to enhance stand growth.

METHODS

Hibiscus elatus, Pinus caribaea, and Swietenia macrophylla, the most commonly used plantation species (Nicholls 1982), were selected for study. In addition, Calophyllum antillanum and Cordia alliadora were examined on three sites.

Plantations of the above species were inspected visually and representative areas, usually midslopes, were selected for sampling. A stake was placed in the ground for the plot center and all trees intercepted by a basal area 10 prism (that is, 10 ft^2/acre or 2.3 m^2/ha) were tallied. Diameter was measured on all intercepted trees to the nearest 0.1 cm and height was determined to the nearest 0.1 m using an optical rangefinder. The dates of plantation establishment were obtained from the offices of the Ministry of Trade and Agriculture and confirmed with field personnel. Thinning dates were estimated from stump diameters and likewise confirmed (Table 1). All initial spacings were 1.8 x 1.8 m (6 x 6 ft).

A previously measured secondary stand dominated by Swietenia mahagoni and Tabebuia pallida at Camden Park was also included in the analysis. In this instance, three 0.10 ha (0.25 acre) plots were established and height was determined with a Clinometer.

Mean diameters, mean heights, total volumes, and growth rates were then derived. Volumes were estimated using the following equations:

-for Hibiscus elatus, Cordia alliadora, Calophyllum antillanum, Tabebuia pallida, Swietenia macrophylla, and Swietenia mahagoni

$$V = 0.0368 + 0.545\ GH \text{ where}$$

V is the volume in m^3, G is the basal area in m^2 at 1.3 m above the ground, and H is the total height in m. The equation ($r^2 = 0.98$) was derived from 30 trees of eight species, one of which was Swietenia macrophylla, in three different Caribbean countries (Dawkins 1961).

-for Pinus caribaea

$$V = 3.639 + 0.036972\ (D^2H) \text{ where}$$

V is the volume in dm^3, D is the diameter in cm at 1.3 m height, and H is the height in m. It was derived from 664 tree measurements in Surinam but no r^2 was given (Voorhouve and Bower, no date).

RESULTS AND DISCUSSION

Of the 50.6 ha (125 acres) of plantations for which we could find records, Hibiscus elatus accounted for a little over 70% of the total area (Fig. 2). Pinus caribaea and Swietenia macrophylla accounted for another 18% of the plantations. About a third of the plantations were established in 1968-69 and about 40% in 1982 with a steady rate of 2 to 4 ha (5 to 10 acres) planted in most intervening years (Fig. 2). The increase in activity starting in 1981 was possible due mainly to financial assistance from USAID under its basic Human Needs Programme, administered by the Caribbean Development Bank. At the First Workshop of Caribbean Foresters (Nicholls 1982), Hibiscus was reported to occupy 75 ha (185 acres) on St. Vincent, Pinus 30 ha (75 acres), and Swietenia 18 ha (45 acres). The dimensions and use of these and other species surveyed in this study are summarized in the Appendix.

Stand structure varied considerably by species, site, age, and previous silviculture, and ranged from 5.6 m^3/ha (about 80 ft^3/acre) for Cordia at Government House to 575 m^3/ha (about 8220 ft^3/acre) for Pinus at Hermitage (Table 2). In Young man's Valley, where all the species were planted in 1969 and thinned in 1976, Pinus attained the greatest mean diameters, mean heights and total volume. At Hermitage, where plantings were done in 1962-63 and thinnings in 1976, again Pinus showed the largest mean dimensions and volume. The latter plantation was located on a terrace and appeared to have been well tended. Both of these factors contributed to the fine growth. The thinned Swietenia plantations at Hermitage had higher mean diameters, mean heights and total volumes than the unthinned stand.

At Vermont, Calophyllum, Hibiscus, and Pinus were established between 1971 to 1973 and had never been thinned. Pinus again had the largest dimensions and volume. Hibiscus and Calophyllum had nearly equal diameters and volume while the height of Hibiscus averaged about 2 m taller.

At Montreal, the plantations of Hibiscus and Pinus were established in 1966 and 1967. The Hibiscus were thinned in 1974. One of the Pinus plantations was thinned in 1979 and another in 1982 while the last plantation remained unthinned. The Hibiscus growing on the slope had larger dimensions and volume than that on the bottomland. The Pinus thinned in 1979 had greater mean diameter and mean height but less volume than the unthinned stand, both of which were on gentle midslopes. The remaining Pinus stand, thinned in 1982, was situated in an area exposed to wind and had less height and volume than the other stands.

In the secondary forest at Camden Park, Swietenia mahogani composed 75% of the stems (Table 1). Its mean diameter and height was considerably less than that for Tabebuia pallida (Table 2). Basal area for both species combined was 17.8 m^2/ha (77.4 ft^2/acre) and the total volume 134.8 m^3/ha (1926.3 ft^3/acre).

Diameter growth rates ranged between 0.62 and 2.06 cm/yr (0.24 to 0.81 in/yr), height growth between 0.66 and 1.80 m/yr (2.15 to 5.91 ft/yr) and volume growth between 0.42 and 28.76 m^3/ha.yr (6.00 to 410.98 ft^3/acre.yr) for all species and sites combined (Table 3). In general, the best growth was attained by Pinus and the poorest by Cordia. Hibiscus showed the least variation in diameter, height and volume growth regardless of age, site or silvicultural treatment. On the other hand, Swietenia macrophylla appeared to have better diameter and volume growth when thinned.

The variety of conditions affecting growth and development of the different stands and the limited data herein make valid comparisons among species and sites impossible. Some premilinary observations, however, are possible even in a quick survey like this one. Among them are the following:

-Swietenia macrophylla showed poor form on most sites, with low branching and excessive crown development. Most of this poor form is probably attributable to shoot borer (Hypsipyla grandella) infestation. Lack of a 16 foot (5 m) clear stem will seriously reduce the stand value and utility at maturity.

-About 70% of the stands had high basal areas in excess of 25 m^2/ha (108 ft^2/acre). Although Pinus and Hibiscus are narrow-crowned species, and able to tolerate high stem densities for several years, continued development without thinning will result in slower growth on the rotation trees and high stand mortality. Without studies using different spacings and thinning regimes on several sites, it will be difficult to prescribe the best management practices. Unthinned Swietenia at Hermitage has already begun to slow in diameter growth because of stand density.

-Incomplete records make assessment of growth and development, and the extrapolation of volumes on an areal basis, extremely difficult. Accurate data on plantation establishment dates, original spacings, dates and types of thinnings, and recurrent measurement of select plots for growth analyses are needed.

MANAGEMENT RECOMMENDATIONS

-Except for Government House, the forest plantations are concentrated high in watersheds where clearing and cultivation of subsistence crops is underway. Most of the land is government property that has been "reclaimed" through the establishment of plantations. Efforts to increase plantations in these areas should continue both for the provision of lumber and to deter further advance of cultivation into the interior of the island.

-Twenty water supply sources and hydropower sites are located in several watersheds circumscribing the central mountains (Fig. 1 and Table 4). With population growth, domestic water demands will increase. Likewise, future expansion of tourism or the introduction of small industry on the island will create greater demands for water. The continuous supply of good quality water throughout the year is dependent on maintaining forest cover on government owned lands in the interior. These lands should be protected against further intrusion and plantations should be established on steep slopes to conserve water, and to reduce soil erosion and reservoir sedimentation.

-Many of the plantations are very dense. The close spacing that is traditionally used throughout the island offers a chance for selection of better stems after 4 or 5 years. Thinning at this time would enhance the development of better trees and maintain good growth over a longer period of time. Other spacings and thinning regimes should be studied. Perhaps the 1981-82 plantations established with USAID assistance could provide a starting point for silvicultural research in cooperation with outside institutions.

-An alternative method for the establishment of Swietenia macrophylla should be investigated. The tree's high value and utility assure a ready market. Shoot borer infestation may be diminished by line planting widely spaced Swietenia interspersed with other fast growing timber species. In subsequent thinnings, the better formed Swietenia should be favored.

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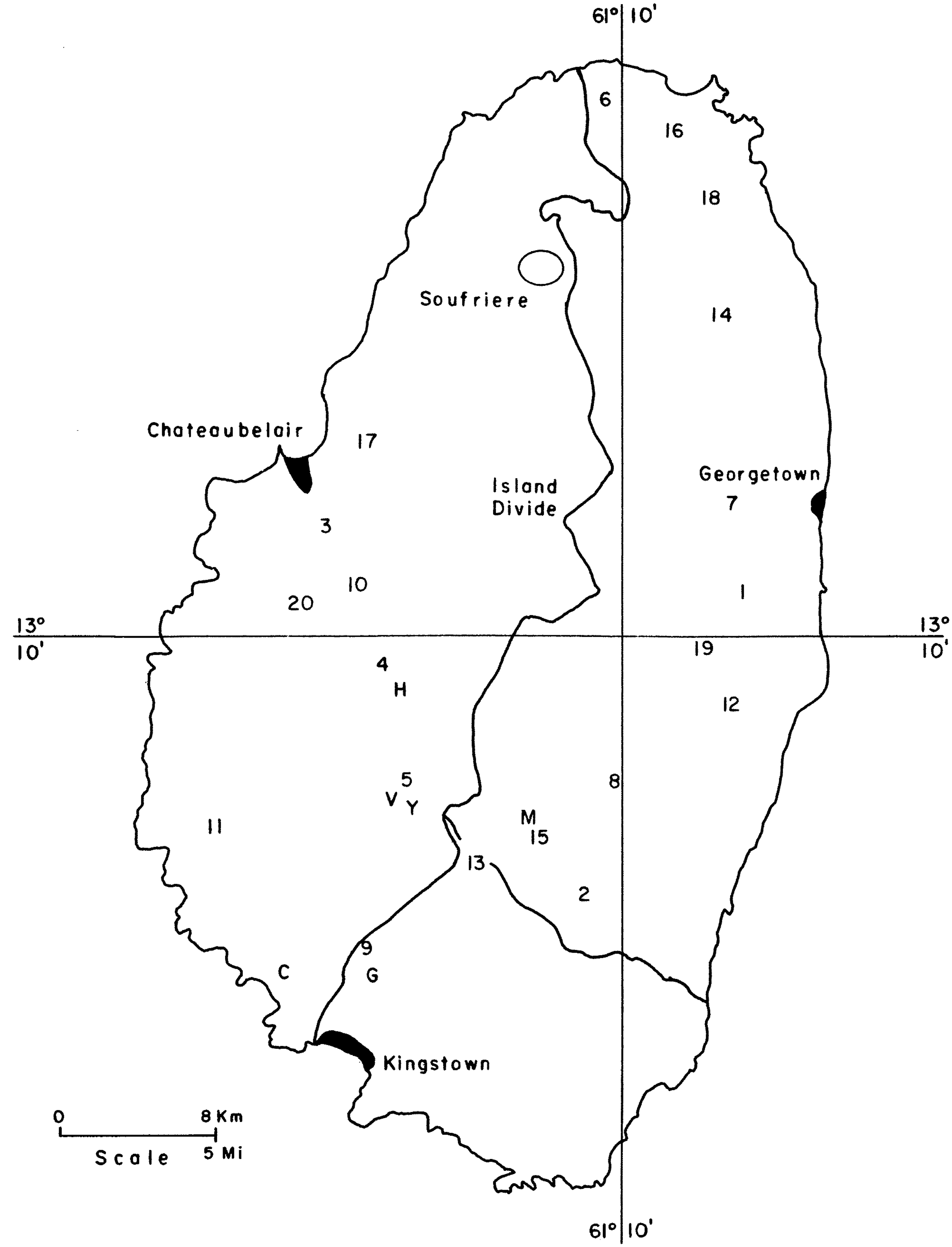

Figure 1. Location of existing water supply intakes and hydropower sites (numbered) and plantations sampled in this study (lettered). The letters are coded to takes 1, 2, and 3 and the numbers to table 4.

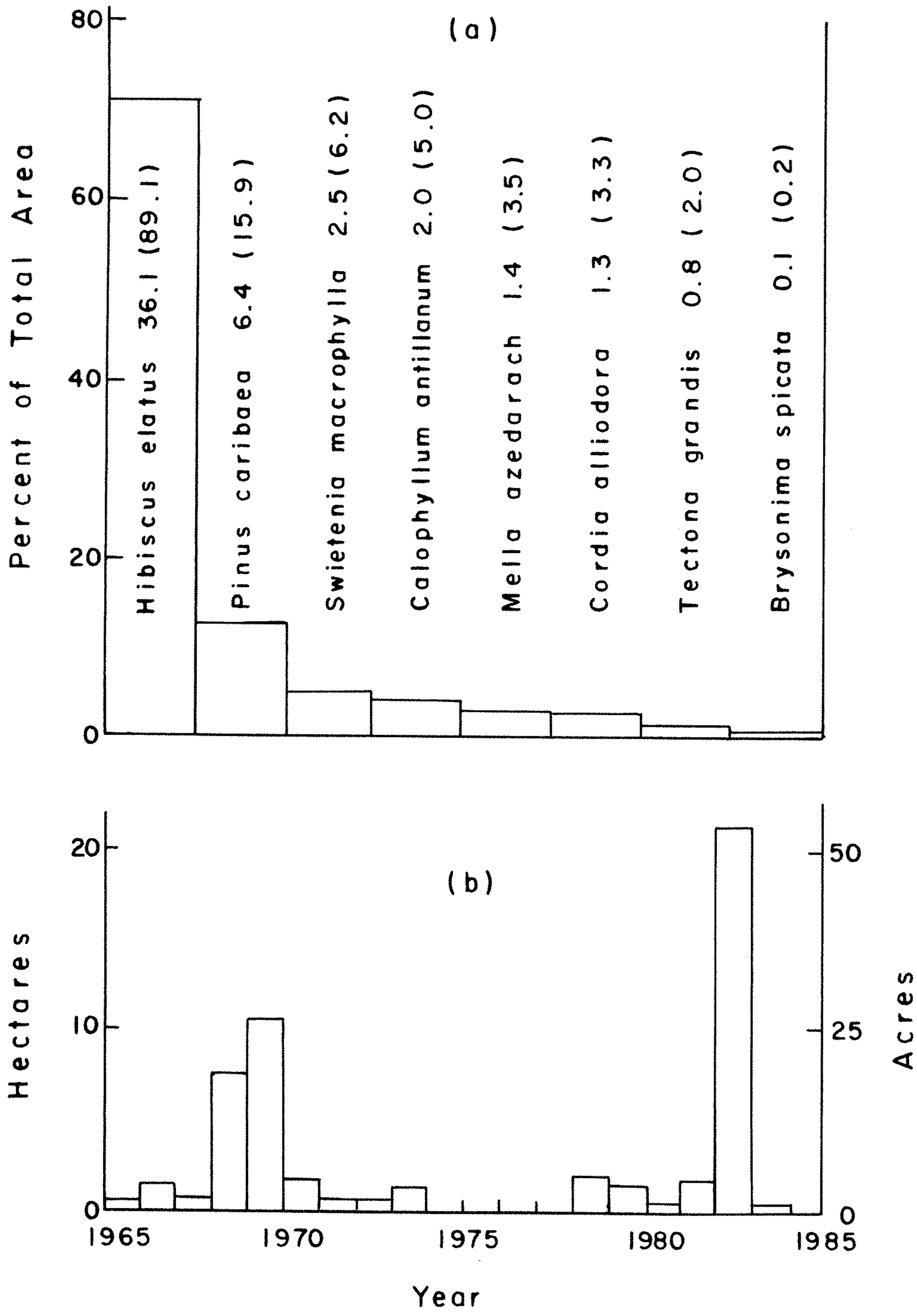

Figure 2. Planting records for St. Vincent. (a) Percent of total area planted by species with actual areas in hectares (acres). (b) Chronology of planting since 1965 without regard to species. Records may not be completed.

Table 1. Summary of species and sites surveyed in January, 1984.[1/]

Site[2/]	Date[3/]		No. Measured		Comments
	Planted	Thinned	Trees	Plots	
Y- Young Man's Valley					
Cordia alliodora	1969	1976	22	3	midslope; stand open
Hibiscus elatus	"	"	20	1	bottomland; stand dense
Pinus caribaea	"	"	28	1	mid to upper slope; stand very dense
H- Hermitage					
Hibiscus elatus	1962-63	1975	25	2	midslope
Pinus caribaea	"	"	18	1	bottom land terrace
Swietenia macrophylla	"	"	19	1	midslope; stand dense
Swietenia macrophylla	"	---	22	1	mid to lower slope; stand very dense
G- Government House					
Cordia alliadora	1975		7	2	midslope; stand open
Swietenia macrophylla	1969-70	1975	28	2	midslope
V- Vermont					
Calophyllum antillanum	1973	---	9	1	midslope; trees branchy, understory dark
Hibiscus elatus	1971-72	---	15	2	midslope
Pinus caribaea	1973	---	33	2	mid to lower slope
M- Montreal					
Hibiscus elatus	1966-67	1974	12	1	steep midslope
Hibiscus elatus	"	"	11	1	bottom land
Pinus caribaea	1967	1979	14	1	gentle midslope
Pinus caribaea	"	"	25	1	gentle midslope
Pinus caribaea	"	1982	20	1	exposed hilltop; considerable wind
C- Camden Park					
Swietenia mahagoni	---	---	96	3[4/]	mid to upper slope
Tabebuia pallida	---	---	32		
Total	---	---	456	27	----------------------------

1/ All are plantations except for Camden Park which is naturally regenerated secondary forest. All plantations were originally planted in 6 x 6 (1.8 x 1.8 m) spacings.

2/ Letters preceeding site name are coded to Figure 1.

3/ Dates derived from records and field personnel. Only years available.

4/ Both species were recorded on 3 x 0.25 ac (0.1 ha) plots.

Table 2. Stand characteristics of the species and sites surveyed in January, 1984.

Sites[1/]	Mean dimensions ± (standard error)							
	Diameter		Height		Basal area[2/]		Total woody volume[3/]	
	cm	in	m	ft	m^2/ha	ft^2/acre	m^3/ha	ft^3/acre
Y- Young Man's Valley								
Cordia alliodora	15.4 (1.0)	6.0 (0.4)	12.8 (0.4)	42.0 (1.4)	16.8	73.2	33.7	481.6
Hibiscus elatus	14.7 (1.0)	5.8 (0.4)	15.5 (0.7)	50.8 (2.2)	45.9	199.9	100.7	1433.3
Pinus caribaea	23.4 (0.8)	9.2 (0.3)	18.4 (0.6)	60.2 (2.0)	64.3	280.1	281.3	4019.8
H- Hermitage								
Hibiscus elatus	23.6 (0.8)	9.3 (0.3)	20.8 (0.4)	68.2 (1.4)	28.7	125.0	172.4	2463.6
Pinus caribaea	35.6 (1.0)	14.0 (0.4)	27.3 (0.7)	89.6 (2.2)	41.3	179.9	575.2	8219.6
Swietenia macrophylla	30.6 (1.4)	12.0 (0.6)	19.2 (0.4)	62.9 (1.5)	43.6	189.9	395.3	5648.8
Swietenia macrophylla	20.4 (1.0)	8.0 (0.4)	18.6 (0.5)	61.1 (1.6)	50.5	217.8	215.2	3075.2
G- Government House[0]								
Cordia alliadora	8.4 (0.7)	3.3 (0.3)	8.8 (0.5)	29.0 (1.6)	8.0	34.8	5.6	80.0
Swietenia macrophylla	23.9 (0.9)	9.4 (0.4)	15.2 (0.3)	49.8 (0.8)	32.4	141.1	149.2	2132.1
Vermont								
Calophyllum antillanum	11.7 (0.7)	4.6 (0.3)	10.8 (0.4)	35.4 (1.4)	20.6	89.7	23.1	328.0
Hibiscus elatus	12.1 (0.8)	4.8 (0.3)	12.7 (0.6)	41.6 (1.9)	17.2	74.9	23.2	331.5
Pinus caribaea	19.6 (0.7)	7.7 (0.3)	17.1 (0.6)	56.2 (1.9)	37.9	165.1	108.6	1551.9
M- Montreal								
Hibiscus elatus	21.0 (1.1)	8.2 (0.4)	20.3 (0.7)	66.6 (2.4)	25.7	111.9	131.1	1873.4
Hibiscus elatus	18.4 (1.4)	7.2 (0.5)	19.0 (0.7)	62.4 (2.3)	25.2	109.8	93.1	1330.4
Pinus caribaea	21.2 (0.8)	8.4 (0.3)	19.2 (0.4)	63.1 (1.3)	32.1	139.8	115.0	1643.4
Pinus caribaea	18.9 (0.4)	7.4 (0.2)	14.8 (0.4)	48.5 (1.3)	57.4	250.0	125.8	1797.7
Pinus caribaea	18.9 (0.4)	7.4 (0.3)	12.0 (0.3)	39.3 (0.8)	45.9	199.9	82.8	1183.2
C- Camden Park								
Swietenia mahagoni	20.9 (0.5)	8.2 (0.2)	10.9 (0.3)	35.8 (0.8)	17.8	77.4	134.8	1926.3
Tabebuia pallida	27.0 (0.8)	10.6 (0.3)	13.1 (0.4)	42.9 (1.4)				

1/ Letters preceeding site name are coded to Figure 1.

2/ Basal areas were read with a BAF 10 prism (each intercepted tree = 10 ft^2/acre or 2.3 m^2/ha) except for Camden Park which was composed of 30.25 ac (0.1 ha) plots.

3/ Above ground, outside bark.

Table 3. Growth rates of the species and sites surveyed in 1984.

Site[1/] Species	Mean annual growth rates ± (standard error) Diameter cm	Diameter in	Height m	Height ft	Total woody volume[2/] m³/ha	ft³/acre
Y- Young Man's Valley						
Cordia alliodora	1.13 (0.07)	0.45 (0.03)	0.95 (0.03)	3.11 (0.10)	2.50	35.73
Hibiscus elatus	1.09 (0.07)	0.42 (0.03)	1.15 (0.05)	3.76 (0.16)	7.44	106.32
Pinus caribaea	1.74 (0.06)	0.68 (0.02)	1.36 (0.05)	4.46 (0.15)	20.84	297.80
H- Hermitage						
Hibiscus elatus	1.17 (0.04)	0.46 (0.02)	1.03 (0.02)	3.41 (0.07)	8.62	123.18
Pinus caribaea	1.78 (0.05)	0.70 (0.02)	1.36 (0.03)	4.48 (0.11)	28.76	410.98
Swietenia macrophylla	1.53 (0.07)	0.60 (0.03)	0.96 (0.02)	3.15 (0.07)	19.76	282.37
Swietenia macrophylla	1.02 (0.05)	0.40 (0.02)	0.93 (0.02)	3.05 (0.08)	10.76	153.76
G- Government House						
Cordia alliodora	1.11 (0.10)	0.44 (0.04)	1.18 (0.07)	3.87 (0.22)	0.75	10.71
Swietenia macrophylla	1.77 (0.07)	0.70 (0.03)	1.12 (0.02)	3.69 (0.06)	11.05	157.90
V- Vermont						
Calophyllum antillanum	1.23 (0.08)	0.48 (0.03)	1.13 (0.05)	3.72 (0.15)	2.43	34.72
Hibiscus elatus	1.10 (0.07)	0.43 (0.03)	1.15 (0.05)	3.78 (0.17)	2.10	30.01
Pinus caribaea	2.06 (0.07)	0.81 (0.03)	1.80 (0.06)	5.91 (0.20)	11.43	163.33
M- Montreal						
Hibiscus elatus	1.27 (0.07)	0.05 (0.03)	1.23 (0.04)	4.03 (0.14)	7.94	113.46
Hibiscus elatus	1.12 (0.08)	0.44 (0.03)	1.15 (0.04)	3.78 (0.14)	5.64	80.60
Pinus caribaea	1.37 (0.05)	0.54 (0.02)	1.24 (0.03)	4.07 (0.08)	7.42	106.03
Pinus caribaea	1.22 (0.03)	0.48 (0.01)	0.95 (0.03)	3.13 (0.09)	8.11	115.89
Pinus caribaea	1.22 (0.04)	0.48 (0.01)	0.77 (0.02)	2.53 (0.05)	5.34	76.31

1/ Letters preceeding site name are coded to Figure 1.

2/ Above ground, outside bark.

Table 4. Names of existing water supply sources and hydropower sites on St. Vincent.[1/]

Number	Name	Number and type of intakes	Intake Capacity Dry	Intake Capacity Wet
			---1,000 gal/day---	
1	Byera	1 Spring	15	15
2	Camel	2 Springs	40	43
3	Chateaubelair	1 River 2 Springs	80	120
4	Cumberland River[3,4/]	1 River	1,000	1,680
5	Dalaway[5/]	2 Rivers	1,500	2,700
6	Fancy	1 River	50	50
7	Georgetown	3 Springs	95	95
8	Greiggs	2 Springs	75	100
9	Higher Lowmans	1 Spring 1 River	100	100
10	John Hill	1 River	170	250
11	Layou	1 Spring	100	150
12	Lively	1 Spring	20	30
13	Majorca	1 River	500	850
14	Maroon	1 River	40	200
15	Montreal	1 Spring 4 Rivers	400	1,000
16	Owia	1 River	50	50
17	Richmond[4/]			
18	Sandy Bay	1 River	90	90

Table 4. (cont'd)

Number	Name	Number and type of intakes	Intake Capacity Dry	Wet
			---1,000 gal/day---	
19	South Rivers[4/]	2 Springs	180	220
20	Spring Village	1 Spring	28	28

1/ Forestry Division, Ministry of Trade and Agriculture, Kingstown, St. Vincent.

2/ Numbers are coded to Figure 1.

3/ Includes Hermitage, Convent, and Grove.

4/ Hydropower sites.

5/ Located in the Vermont area.

Appendix. Dimensions at maturity and uses of the plantation timbers surveyed.[1/]

Species	Dimensions at maturity[2/]				Uses
	Diameter		Height		
	cm	in.	m	ft.	
Calophyllum antillanum	45	18	18	60	general construction and utility wood; canoes, shipbuilding, flooring, interior construction, furniture; charcoal
Cordia alliodora	45	18	20	65	generally resistent to dry wood termites and durable in ground; furniture, cabinet work, general construction, flooring, boat parts
Hibiscus elatus	38	15	25	80	easily worked timber prized for highgrade furniture; cabinet work, interior trim, flooring, door frames, construction; boat masts
Pinus caribaea	60	24	30	100	general utility lumber where native; posts with preservative treatment (preservative easily absorbed without pressure treatment); christmas trees
Swietenia macrophylla	60	24	18	60	cherished cabinet wood, high grade and attractive; highly resistant to decay and insect attack; furniture, interior panelling, planking on yachts, musical instruments, burial caskets
Swietenia mahagoni	90	36	15	50	fine quality timber, easily worked and good polish; resistant to decay and dry wood termites; furniture, cabinet work, veneer; boat building

Appendix (cont'd)

Species	Dimensions at maturity [2/]				Uses
	Diameter		Height		
	cm	in.	m	ft.	
Tabebuia pallida	45	18	18	60	easy to shape and wood turns stronger in salt water; boat building (framing ribs on boats), furniture, cabinet wood, interior trim, veneer, flooring

1/ SOURCES: Longwood 1962; Little and Wadsworth 1964; Little, Woodbury and Wadsworth 1974; Adams 1972, 1973.

2/ All of the species listed may attain greater diameters and heights under favorable conditions.

CONSERVATION OF NATURAL RESOURCES IN ST. LUCIA

Paul Butler
Conservation Advisor
Forestry Division

Wise management and conservation of our limited natural resources are not just esoteric concepts but ones essential for the sustained development of our islands. Be it soil, watersheds, mineral deposits, or wildlife, all have, in one way or another, a vital role to play in our socio-economic well being. However, all too often conservation is seen as an opposing force acting against development, and when this idea is set in the minds of decision makers, irrepricable damage can be done. It has been estimated that worldwide, an area of forest, the size of St. Vincent is destroyed every two days, week after week, year after year. Such indiscriminate removal of natural cover has led to an increase in soil erosion, a reduction in land fertility and to a rapid disappearance of a large number of plant and animal species. If we continue to destroy our environment, man's own survival will be threatened. Without top soil, we will have no food, without water there can be no life.

Conservation, like development, is for people. While development aims to achieve human goals largely through the use of natural resources, conservation aims to achieve them by ensuring that such use can continue.

In St. Lucia, conservation of the environment in general, and of wildlife in particular, is based upon four cornerstones. As the term implies, each is as important as the other, and all are integrated. They are: legislation, environmental education, research/captive breeding, establisment of reserves.

LEGISLATION

Legislation is the "big stick" with which those policies that Government has deemed essential to the well being of the country as a whole are implemented. For legislation to be effective it must be a real deterrent; penalties and fines should be in line with the cost of living and should be amended at regular intervals to prevent inflation eroding into the deterrent value; laws should be rigidly enforced and in an unbiased fashion.

Legislation must also be fair inasmuch as its "clauses" should be well publicized so that the general public is aware not just of penalties imposed for the various legal infringements, but also the reasons behind the legislation itself.

The protection of St. Lucia's terrestrial wildlife falls under the broad umbrella of the Forestry Division's Wildlife Protection Ordinance of 1983. This Act is divided into "Absolutely Protected Species" (37) "Partially Protected Species" and unprotected species (rats, mice, mongoose and fer-de-lance). However, Section 9 (2) Reads, "The powers of the

Minister......shall include the power to declare, for any period not exceeding three years, a closed season in respect of any or all species of wildlife in the second/partially protected schedule". With the habitat devastation resulting from the recent passage of Hurricane "Allen" and the resultant adverse effects on wildlife populations, this clause was applied, and today all but the four unprotected species are "absolutely protected".

The penalties for infringement of this Ordinance are stiff with a maximum fine of $5,000.EC ($1,886.US) or one year in jail. Knowledge of this ordinance is widespead among the population. To date we have had very few legal infringements and most have involved the collection and possession of reptile species.

This wildlife ordinance is complimented by:

-"Forest, Soil and Water Conservation Act" and its 1983 Amendment, which protects our forests, habitat for so many of the native wildlife species;

-"Turtle and Lobster Protection Ordinance", of the Fisheries Department that provides legislative coverage for a range of marine species.

Our Wildlife Protection Ordinance is further complimented by our Government having ratified CITES (Convention on International Trade in Endangered Species). CITES entered into force in 1975 and has since been ratified by more than 85 countries. Its prime objective is to attempt to regulate international trade in rare or threatened species of wild animals or plants and to prevent their over exploitation and their ultimate extinction. CITES operates on a system of permits and those species which are subject to trade controls are listed in three appendices.

-Appendix I: Includes species presently threatened with extinction. All shipments of such species including their parts and derivatives require two permits. One from the country of export and one from the country of import. These permits will be issued only when such shipment will not be detrimental to the survival of that species. This appendix includes St. Lucia Parrot, St. Vincent Parrot, and both Dominican Parrots, as well as most Caribbean Sea Turtles.

-Appendix II: Includes species not presently threatened with extinction but may become so unless their trade is regulated. Import permits are not required for Appendix II species but an export or re-export permit must accompany each shipment. Included in Appendix II is black coral and the boa constrictor.

-Appendix III: Includes species which do not fall into Appendix I or II but are regulated for conservation purposes by a party nation. International shipment of these species requires either an export or re-export from any other country. No import permit is required.

ENVIRONMENTAL EDUCATION

It is quite obvious that the plight of the Caribbean's wildlife is intimately linked to habitat destruction. This is in turn is due to short term economic goals and a general lack of understanding as to both the value and fragility of the resource. Environmental education has a valuable role to play in awakening an interest and understanding of our natural, cultural and historical resources. The potential of environmental education is tremendous, especially in small island states such as ours, for several reasons:

- -A limited population size enables programmes, backed with only limited financial support, to reach the majority of the people;
- -The distribution of age groups is such that a large proportion of the population is attending some form of academic institution (29% in St. Lucia) and can therefore be relatively easily reached;
- -The lack of teaching aids and curriculum development materials makes the donation of educational handouts/booklets especially welcomed by teachers and parents alike;
- -Large family size results in quite a small number of households within the population, making distribution of materials less difficult; and
- -The mass media is often limited to a small number of newspapers, radio and television programmes many of which are quasi-government and this assists in gaining complete coverage.

An environmental education package should: be interesting as well as informative; reach the entire community rather than only a particular segment of it; build upon initial successes and be guided by pre-determined goals as to what a specific education project is attempting to achieve.

The Forestry Division in St. Lucia has placed considerable emphasis on environmental education and the Division regularly holds film shows, slidetalks and publishes articles in our newspaper. Visual aids such as billboards, posters, t-shirts, and bumper stickers have also featured in our work. A small interpretive centre has been constructed in the forest for tourists and locals alike, and a self guide trail is currently under construction.

The Forestry Division has printed a booklet entitled "A-Z of St. Lucia's Wildlife" and this has been distributed to schools and is available for sale to the public. A second series on the A-Z of trees has also been featured in the Voice newspaper.

A monthly environmental broadsheet entitled "Bush Talk" now plays a major role in our programme. "Bush Talk" was originally conceived as a teaching aid for children aged between 8-13 years, and it set itself the aim of covering a different topic monthly from a broad range of environmental concerns. To further involve the community it was decided to also reproduce this broadsheet in the weekend issue of our national newspaper, and to seek production costs from public sponsorship.

Now in its 28th issue "Bush Talk" appears on a monthly basis and has covered a diverse range of topics including: water, indigenous wildlife, soil erosion, plantations, family life, mangroves, coral reefs, town birds, turtles, litter, bananas, illegal forest squatting, hurricanes, coconuts, and forest folklore.

The response from both schools and the public has been excellent; today it is read not just by the children but by a broad cross section of the community and the desired changes in attitude are becoming evident. In a survey carried out under the "Man and Biosphere Programme" a questionnaire asked the public to comment on the perceive seriousness of certain environmental problems - some 73% of St. Lucians questioned defined deforestation as a "very serious hazard" (second only hurricanes at 79%), compared to 26.4% on St. Vincent).

Questionnaires circulated to teachers were enthusiastically returned, complete with constructive criticisms, suggestions and comments that "Bush Talk" is being widely used and appreciated by children with an age range of 5-15 years. An essay competition was held, and the winners published in an anniversary issue. A second competition is currently being held. If funds can be located it is hoped to publish "Bush Talk" in book form for permanent use by our nation's school children and for sale to the public.

RESEARCH

Wise management goes hand in hand with research, and each is intimately linked, for without an accurate data base, management cannot exist on a scientific basis. Wildlife research consists of:

-A Bird Banding Programme: Bird banding is a sampling technique used to census wild birds to obtain a rough index of species composition, species diversity, bird densities and population fluctuations. Sixteen mist nets are placed in a straight line, each net being 2.5 m high and 12 m long. Individual birds are captured as they fly into the nets and get entangled in the fine 30 mm nylon mesh. Each bird is "ringed" with a numbered metal band. Birds are weighed and measure before being released unharmed. Standard measurements taken include body weight and bill, leg and tail lengths. These measurements together with observations on plumage aid scientists in determining variations in geographical populations of the same species. Trapped birds are also examined for signs of disease and parasites.

-A Captive Breeding Programme for Endangered Indigenous Species: Because of a lack of finances and lack of adequately trained manpower, our captive breeding programmes are currently run in collaboration with internationally recognized zoological institutions. Captive breeding programmes can act as a valuable safety net for endangered species, for when animal populations reach a critically low level, the conservationist must become concerned with the fate of individuals. Captive breeding programmes should always be: established in a manner not detrimental to the survival of the species in the wild; maintained without augumentation from the wild, except for the occasional addition of animals from wild populations to prevent deterioration in breeding; and managed in a manner designed to maintain the breeding stock indefinitely.

The goal of any captive breeding programme should be to re-introduce or supplement existing wild stocks and to improve the species survival chances in the wild.

St. Lucia is currently participating in two captive breeding programmes:

-St. Lucian Parrot, Amazona versicolor, programme at Jersey Zoo where a single chick was successfully hatched in 1982.

-Maria Island Lizard, Cnemidophorus vanzoi, programme recently established at the San Diego Zoo in the USA.

ESTABLISHMENT OF RESERVES AND PROTECTED AREAS

To counter continued habitat destruction, the steady decline in species diversity or abundance, and damage to soil and water supplies, it has become the tradition of Governments, St. Lucia included, to declare areas of critical habitats as national parks, forest reserves or wildlife sanctuaries. In small territories, these often serve many purposes, including protection of critical watersheds, protected wildlife habitats and as recreation areas. Discussion on watershed areas can be found elsewhere in this volume, and thus this section will concentrate on areas for wildlife conservation and amenity.

Nature Reserves must have a people component and should not be areas set aside solely for wildlife protection, as this may alienate them in the eyes of the local population. The citizens of many third world communities are often "environmentally unaware" having lacked the priviledges of an advanced education and easy access to the media. Further, they have little time of from their labours, and even less "free" money to spend on visiting their country's protected areas. More often than not, they see them as areas set aside for foreign visitors. Conservation, to them, is therefore an abstract concept, with little or no bearing on their day to day life, and may even be seen as a barrier to their material progress.

Education/Interpretive Centres, self guiding trials, school and community visits all have a role to play in making the people understand the value of protected areas.

Within the St. Lucia Forestry Division's Central Forest Reserve, an area of approximately 1,600 acres (648 ha) has been set aside as a Nature Reserve to protect the St. Lucia Parrot and other forest wildlife. Artificial nest boxes have been erected and the planting of preferred tree species has occured on a limited basis.

Two small islets (Maria Islands), lying off the southeast coast of St. Lucia have been declared a Nature Reserve to protect the indeginous Maria island lizard and snake, unique to the 30 acres (12 ha) that the island's comprise.

Savannes Bay, lying on the southeast coast near Micoud is an area of mangrove that has been declared a Nature Reserve, although at present its development as a reserve has been stalled due to a lack of funds.

Other areas recommended for protection include Marigot Bay, (mangrove), The Pitons (scenic area), Bois D'Orange Swamp (fresh water swamp) and Dennery Knob. Official recognition of these and development funds have yet to be obtained.

The Forestry Division actively encourages children and youth groups to participate in field studies as these both stimulate the child's curiousity as well as re-inforce their classroom activities. To date, approximately 12% of the island's school population have participated in the guided forest tours. Other tours are operated for the benefit of our foreign tourists and a per person levy of $17.50 EC (US$6.6) is charged. To date, since its conception in 1979, an excess of $71,250 EC (US $26,886) has been raised for conservation and a total of 5,547 tourists have visited the forest.

Today, the concern of the Forestry Division for conservation and sustained management extends from the restricted confines of the forest itself, to encompass the broader environment. Part of the reason for this broader interest stems from the fact that the forest is intimately linked to other ecosystems (consider that deforestation results in the silting of rivers, and the fouling of reefs, that trees can form valuable windbreaks or that mangroves are only forests of a single tree type),and that of the personal interest of senior members of the Division.

Such an interest for the wider environment has manifested itself in the fact that the Forestry Division has played a key role in the formation of the following:

-<u>Environmental Commission</u>: A multi-disciplinary group of Government and non-Government representatives who meet to discuss wide ranging problems impinging on the wider environment, and who offer advise and impact assessments to the planning and development authorities.

-<u>Parks and Beaches Commission</u>: A commission set up to protect, enhance and develop St.Lucia's beaches and parklands for the benefit of tourists and locals alike, and to advise Government on policies related to the same.

-<u>St. Lucia Naturalists' Society</u>: A non-Governmental body open to interested members of the public whose objectives are education and research, as well as to act as a "conservation pressure group" if the need arises.

The Forestry Division is also represented on the following:

-St. Lucia National Trust
-Central Water Authority

-Timber Industry Development Board
-Urban Beautification Committee
-Caribbean Conservation Association

People everywhere must learn to appreciate the meaning of CONSERVATION, within the context of their own lives, and the lives of their children and their children's children. Our approach towards stimulating this appreciation must be balanced and appropriate. We must not emphasize conservation to the exclusion of development; but rather seek to foster an understanding that there can be NO long term development without teaching the community why it is needed. Nor must we undertake grand management programmes founded without an accurate data base. It is always better to start small and to achieve one's aims than to have grand programmes that fail.

THE FOREST ECOSYSTEM IN FRENCH GUYANA
ECOLOGICAL STUDY ON ITS EVOLUTION UNDER MAN-MADE CHANGES

Francois Wencelius
Directeur Regional
Office National des Forests

INTRODUCTION

One of the main projects for developing French Guyana is industrial pulp-milling. This will be supplied, at first, by a large scale clear-felling of natural forest. Small areas of the cleared forests will be established with plantations of fast growing species, the remainder will be used for agriculture and for natural regeneration of the forest.

Such transformations of the original forest ecosystem will bring about heavy risks with predictable and worrying consequences: erosion, modification of watei economy, various biological damages and presumingly a fast reduction of yields in these newly created ecosystems. Accordingly, the French Government has decided to finance studies and experiments, called Program ECEREX, whose objectives are: to have a precise and comprehensive knowledge of the initial ecosystem, to define ways of its exploitation and transformation as well as new simplified ecosystems, to assess the effects of the changes of the various yield factors of the natural balance, to give an estimate of the new systems yields and draw land management schemes to be extended on a large scale.

METHODOLOGY

The research and studies will be multidisciplinary so as to collect most of the basic data and information and to interpret them for practical use. Thus the whole operation, belonging to the UNESCO Program MAB 1 (Ecological Effects of Human Activities on Tropical and Sub-tropical Ecosystems) involves various research institutes (ORSTOB, INRA, MUSEUM, NATIONAL D' HISTOIRE NATURELLE AND CTFT) the leadership being given to the CTFT. The project activities are led in close connection with the Development Services: DDA and ONF.

The initial ecosystem has to be precisely known in order to accurately compare the initial situation with the modified ones. Thus, a first set of studies deals with the various natural factors (soil, water, climate, botany, zoology, etc.) and a second one with the hydrological behaviour of the catchment basins. The studies will be performed during the two years preceding the modifications.

The experimental design for testing these modifications has to cover the variable conditions of the project area and allow for extension of the results to a large scale. Observations and measurements must be carried out within a long-term program.

EXPERIMENTAL LAY-OUT

The experiment is located beneath the town of Sinnamary, on the so-called "Bonidoro Schists", in a landscape of low altitude hills. The drainage conditions of the different soil types vary from a free vertical drainage (FVD), with no land use problems, to a locked vertical drainage (LVD) situation whose value for agriculture is unclear.

The different land uses considered for the experiment are: natural regrowth, *Pinus* and *Eucalyptus* plantations, orchard, pastures and foodcrop by shifting cultivation. They are tested within 10 different catchment basins, each one having a 1 to 1.5 ha area, after clearing by "pulp" standards: logging, wind-rowing of the remaining vegetation and burning of the wind-rows. Considering the different drainage conditions, the "treatments" were assessed, from 1979 to 1982, (Table 1).

PRELIMINARY RESULTS

The data collected to date mainly deal with the initial ecosystem. Those on clearing effects are not yet available. Very briefly summarized, the present results are as follows:

- *Soils*: An analytic map of catchment basins has made it possible to determine the soils of the initial covertype. The pedological characteristics of a catchment basin may now be precisely known by only indicating its evolution grade. Organic matter, carbon and nitrogen components linked with biological activities strongly decrease after clearing; the C/N ratio increases significantly after cultivation. The biological evolution of the soil is deeply stressed by burning; its recovery after burning depends on the litter from neighbouring regrowth.

- *Water balance and erosion*: In the natural forest, with an annual rainfall of 3,320 mm, 7% of the water is intercepted by the canopy, 1% returns as stemflow, and 1,470 mm is evapotranspired. The amount of run-off and erosion depends on the soil type:

	Run-off (%)	Internal flow (%)	Mechanical erosion (t/ha)
FVD	4	10	0.24
LVD	16	15	0.24
LVD + Thalweg	24	41	0.5

After clearing, the flow (average and peak) increases by a factor varying from 1.5 to 2 even when the pastures or the orchard (with its grasses) are established. Mechanical erosion amounts to 3.2 t/ha on a "FVD" soil and to 11.2 t/ha on a "LVD" soil.

Water run-off varies from 60% on poorly established pastures to 30% only on the good ones (Digitaria swazilandensis, Brachiaria decumbens). Erosion on these land use types after a very high peak during establishment is reduced to 0.5 t/ha.

-Flora: Within the trees over 20 cm diameter, 45 families have been identified. The lecythidaceae represent 26% of the total and the caesal piniaceae 22%. Drainage conditions of the soil have significant effects on the composition of the flora, on the basal area and the size of the largest trees but not on stand density.

The biomass amounts to 323 t/ha ± 30%. During the natural regeneration after clearing, the dominating species (size and density) are few; they are fast growing and require strong light. Within six years after clearing, the basal area amounts to 23 m^2/ha compared to 38 m^2/ha in the natural forest before clearing.

Species having an economical value, Goupia glabra, is the most promising.

-Crop yields: Pastures with Digitaria swazilandensis and Brachiaria decumbens behave well and, three years after establishment, still give an annual yield of 12 t/ha dry matter on "LVD" soils.

-Pinus growth does not yet depend on the soil type; the hydromorphic parts of "LVD" soils only have a depleting effect.

Accumulation and wind-rowing zones are favourable to Eucalyptus and Pinus growth.

CONCLUSION

The ECEREX program has resulted in a greater understanding of the forest ecosystem in French Guyana and of its behaviour in relation to soil moisture. This program is now able to give various data for establishing a development policy for the country. It deals with the industrial outlook for using the land after forest clearing (pastures, orchards, fast growing trees plantation) and also with traditional shifting cultivation and natural regeneration. The program should prove a great value even outside French Guyana.

Table 1. Experimental treatments by drainage condition under various land uses.

	FVD	Intermediate	LVD	Total
Natural forest (control)	-	1	1	2
Natural regrowth	-	2	-	2
Pinus plantation	-	-	1	1
Eucalyptus plantation	-	-	1	1
Orchard	1	-	-	1
Pastures	-	1	1	2
Food crop	-	1	-	1
Total	1	5	4	10

PRELIMINARY RESULTS ON VOLUME TABLES OF BLUE MAHOE (*Hibiscus elatus*) AND HONDURAS MAHOGANY (*Swietenia macrophylla*) IN ST. LUCIA

William Butler
Peace Corps Volunteer

Permanent plantation sample plots were begun in St. Lucia in 1980 by Peace Corps Volunteer Tom Ward. Ward was not able to complete his programme, so subsequent plots were established by Verna Slane (three), and William Butler (five). Fourteen 500 m^2 sample plots for Honduras mahogany have been established. Of these, three plots were established at Edmund Forest (approximate elevation 1,500 ft or 457 m), two at Quilesse (1,000 ft or 305 m), one at Union (250 ft or 76 m), and two at Barre de L'Isle (1,000 ft or 305 m). For blue mahoe, fifteen 500 m^2 sample plots have been established: nine at Edmund Forest, two at La Sorciere, two at Marc (1,000 ft), one at Barre de L'Isle, and one at Union (Whitman 1980).

METHODS

The plots were established by running a 50 m (horizontal distance) string line through a portion of the stand. Each end of the centerline was permanently marked with a piece of orange painted steel rebar driven into the ground. Trees within 5 m on either side of the centerline were measured. Each plot is therefore 10 m wide and 50 m long or 500 m^2 (0.05 ha or 0.124). A 4 m buffer strip was also established on all sides of the plot (Ward 1982).

After the plot was established and all qualifying trees tagged and measured, the stand was marked for thinning if it was found necessary. The thinning regime used was based on opening up the crown, which varied from stand to stand.

Tree volumes were determined by felling those trees marked to be thinned and measuring both the over-bark and under-bark diameters of the midpoint of each 3 meter log. Volumes were measured to a top diameter of (7.62 cm) (3 inch). Volumes of the remainder of the standing crop after thinning was also determined. The standing crop was separated into large, medium and small diameter classes. Two representatives trees for each size class outside the plot were found, felled, and the volume of 3 meter logs determined. The volumes of these representative trees were then extrapolated to give a final volume of those treees left on the plot.

Ward's measurement techniques were altered after he left. Where Ward chose trees >5 cm DBH, plots measured by Slane and Butler used a 10 cm DBH minimum for trees to qualify for measurement. Ward also counted all trees with DBH $\geq$ 6 cm as having merchantable volume. Calculations from Slane and Butler and all future calculations will assume that only trees over 21 cm (8 inches) DBH will have merchantable volume. These measurement changes will help to reduce field work time and thus allow the research forester to establish more plots across the island.

RESULTS

The local volume tables presented here for blue mahoe and Honduras mahogany are strictly of a preliminary nature. They were constructed from all the tree volume results currently available from the permanent sample plots established since 1980. The volume results shown here (Tables 1-4, Fig. 1-4) should only be used as a rough comparison with results from other countries of the tropics. Future harvests in St. Lucia will have a research forester on hand to measure the volumes of more trees. Only then can volumes be separated according to site class.

The data base was so small that volumes of all three site classes had no definitive variations. It was only when all three site classes were combined that an adequate volume curve could be constructed. Because many of the measured stands were of similar age groups, there were several tree volumes for one diameter class, while another diameter class would not be represented at all. For instance, blue mahoe had eleven trees of 14 cm DBH that were measured for volume, while no trees were measured for 26 cm DBH (Table 1). Similar gaps can be seen in the Honduras mahogany data, where no tree volume data were gathered for 33, 35 adn 37 cm DBH classes (Table 2). The combined data did allow for constructing an initial curve for estimating individual volumes for blue mahoe (Fig. 3) and Honduras mahogany (Fig. 4).

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Ward, T. 1982. Provisional yield tables from blue mahoe (Hibiscus elatus) in St. Lucia. Report on file at the Ministry of Agriculture, Forestry Division, Castries, St. Lucia. 10 p.

Whitman, D. 1980. St. Lucia compartment maps with accompanying table of acreages and elevations. Available at Ministry of Agriculture, Forestry Division, Castries, St. Lucia.

Table 1. Volumes* of blue mahoe (Hibiscus elatus) arranged by diameter classes.

DBH (cm)	Volume under bark§ (cm^3)							Average volume (cm^3)
8.00-8.99	.023	.007	.022	.013	.015			0.016
9	.013	.021	.017	.018	.026	.029	.011	
	.008	.019						0.018
10	.029	.030	.042					0.034
11	.024	.029	.019	.049	.040	.013	.011	0.026
12	.024	.029	.081	.042	.084	.064	.000	
	.056	.057	.059					0.058
13	.078							0.078
14	.099	.121	.054	.079	.097	.150	.074	
	.060	.135	.043	.095				0.092
15	.115	.069	.103	.085	.044	.075	.142	
	.095							0.091
16	.162	.200	.142	.084	.109	.073	.089	
	.138	.195	.125					0.132
17	.202	.170	.135					0.169
18	.169	.195	.240	.200	.144	.047	.119	
	.118	.185						0.157
19	.259	.078	.131	.194	.198	.294	.277	0.204
20	.225	.351	.203	.233	.222	.137	.153	
	.334							0.232
21	.278	.231	.293	.279	.170	.140		0.231
22	.255	.361						0.308
23	.448	.362	.210	.179	.395	.375	.399	
	.398							0.346
24	.439	.448	.383	.323				0.398
25	.424	.441	.464	.459	.397			0.437

Table 1. (cont'd)

DBH (cm)	Volume under bark[§] (cm^3)							Average volume (cm^3)
26	-							-
27	.578	.382	.452	.618	.563	.323	.229	
	.538							0.460
28	.509	.556						0.533
29	.854	.734						0.794
30	.567	.756	.655					0.659
31	-							-
32	.677							0.677
33	.897	1.025						0.961

* Volume to a 7.6 cm top diameter.
§ Each value represents a tree.

Table 2. Volumes* of Honduras mahogany (Swietenia macrophylla) arranged by diameter classes.

DBH (cm)	Volume under bark§ (cm^3)							Average volume (cm^3)
9.00-9.99	.015	.017						0.016
10	.020	.029	.025					0.025
11	.034	.029	.030					0.031
12	.058	.041						0.050
13	.064	.058	.048	.045				0.054
14	.057	.054	.059	.082	.039	.048		0.057
15	.028	.083	.063	.083				0.064
16	.084	.090	.065					0.080
17	.124	.085						0.105
18	.121	.104	.142	.088	.136	.127	.160	
	.110	.080	.143	.175				0.126
19	.143	.157	.096	.155	.164	.134	.079	0.133
20	.114	.170	.212	.130	.169	.147	.159	
	.147							0.156
21	.204	.153	.164	.190	.269			0.196
22	.117	.314	.218	.248	.303	.185		0.231
23	.204	.206	.172	.274	.228	.368	.399	
	.398							0.260
24	.254	.167	.253	.277	.335	.387	.232	0.272
25	.337	.366	.205	.183				0.273
26	.372	.262						0.317
27	.302	.206	.463	.186				0.289
28	.393	.551	.525	.422				0.473
29	.665							0.665

Table 2. (cont'd)

DBH (cm)	Volume under bark[§] (cm^3)						Average volume (cm^3)
30	.273	.581					0.427
31	.562	.690					0.626
32	.735	.621					0.678
33	-						-
34	.582	.473	.481	.549	.664	.637	0.564
35	-						-
36	.720	.978	.946				0.881
37	-						-
38	1.074	.976	.908				0.986
39	1.383	1.170	1.126				1.226
44	1.374						1.374
45	1.146	1.422					1.284
46	1.866						1.866
48	2.484						2.484
64	3.701						3.701
65	3.932						3.932

* Volume to a 7.6 cm top diameter.
§ Each value represent a tree.

Table 3. Volume of blue mahoe trees based on curve projections of data for 134 trees measured island-wide.

DBH		Volume under bark	
(cm)	(inches)	(m^3)	(ft^3)
10	3.94	0.033	0.472
11	4.33	0.044	0.629
12	4.72	0.055	0.786
13	5.12	0.068	0.972
14	5.51	0.084	1.201
15	5.91	0.100	1.430
16	6.30	0.120	1.716
17	6.69	0.141	2.016
18	7.09	0.163	2.331
19	7.48	0.188	2.680
20	7.87	0.215	3.074
21	8.27	0.246	3.518
22	8.66	0.279	3.989
23	9.06	0.315	4.504
24	9.45	0.355	5.076
25	9.84	0.393	5.620
26	10.24	0.436	6.234
27	10.63	0.475	6.792
28	11.02	0.513	7.335
29	11.42	0.553	7.907
30	11.81	0.593	8.479

Table 4. Volume of Honduras mahogany trees based on curve projections of data for 122 trees.

DBH		Volume under bark	
(cm)	(inches)	(m^3)	(ft^3)
10	3.94	0.020	0.206
11	4.33	0.030	0.429
12	4.72	0.040	0.572
13	5.12	0.050	0.715
14	5.91	0.065	0.929
15	5.91	0.800	1.144
16	6.30	0.095	1.358
17	6.69	0.110	1.573
18	7.09	0.125	1.787
19	7.48	0.145	2.073
20	7.87	0.165	2.359
21	8.27	0.185	2.645
22	8.66	0.210	3.003
23	9.06	0.235	3.360
24	9.45	0.265	3.789
25	9.84	0.295	4.218
26	10.24	0.325	4.647
27	10.63	0.360	5.148
28	11.02	0.400	5.720
29	11.42	0.440	6.292
30	11.81	0.485	6.935
31	12.21	0.535	7.650

Table 4. (cont'd)

DBH		Volume under bark	
(cm)	(inches)	(m^3)	(ft^3)
32	12.60	0.585	8.365
33	12.99	0.635	9.080
34	13.39	0.690	9.866
35	13.78	0.750	10.724
36	14.17	0.810	11.582
37	11.57	0.870	12.440
38	14.96	0.940	13.441
39	15.35	1.010	14.442
40	15.75	1.090	15.586
41	16.14	1.180	16.873
42	16.54	1.270	18.160
43	16.93	1.360	19.447
44	17.32	1.455	20.805
45	17.72	1.560	22.306

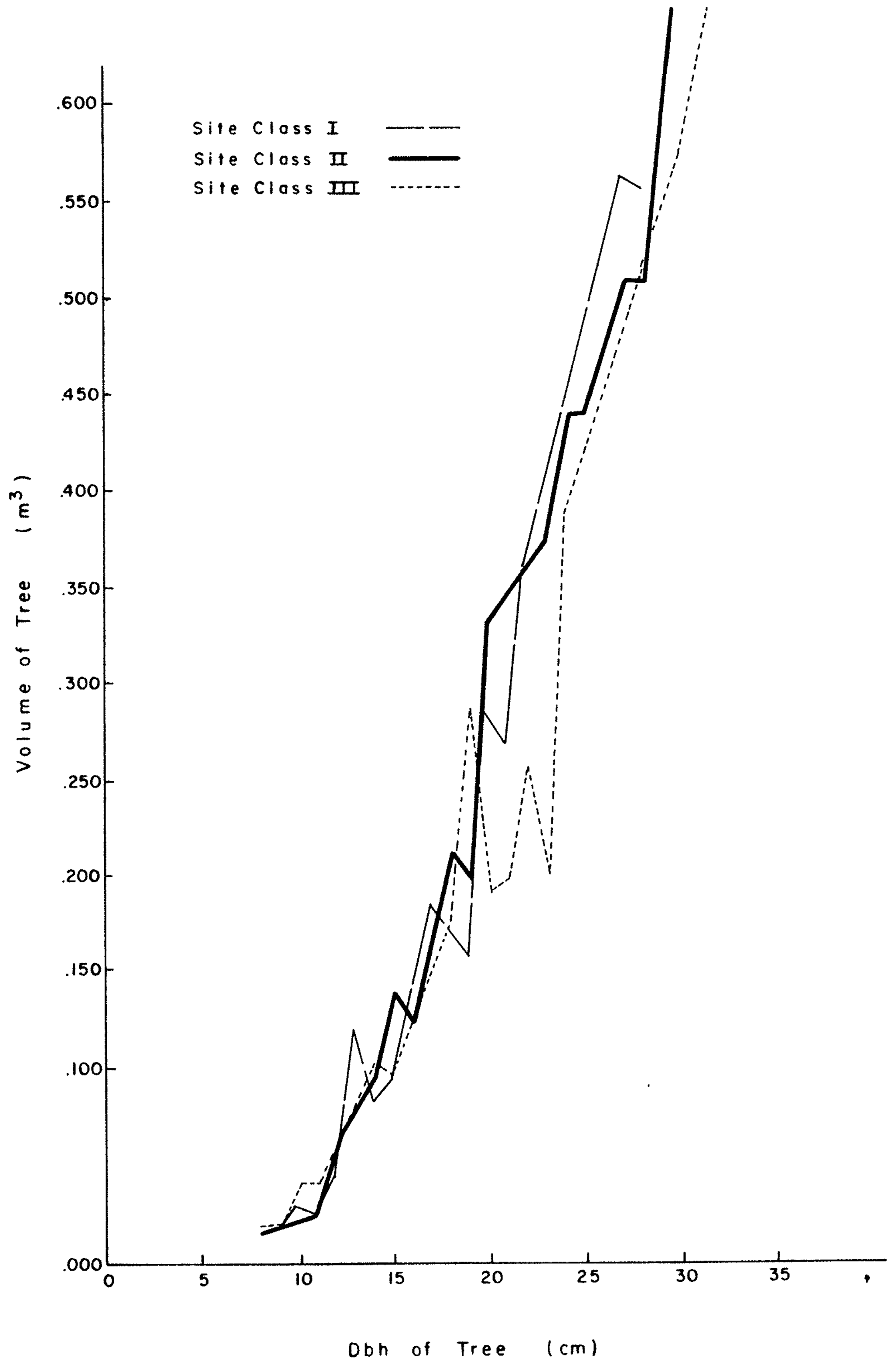

Figure 1. Comparison of blue mahoe volumes (under bark) from the thr site classes fround on St. Lucia. (Volumes measured to a 7.6 cm top diameter).

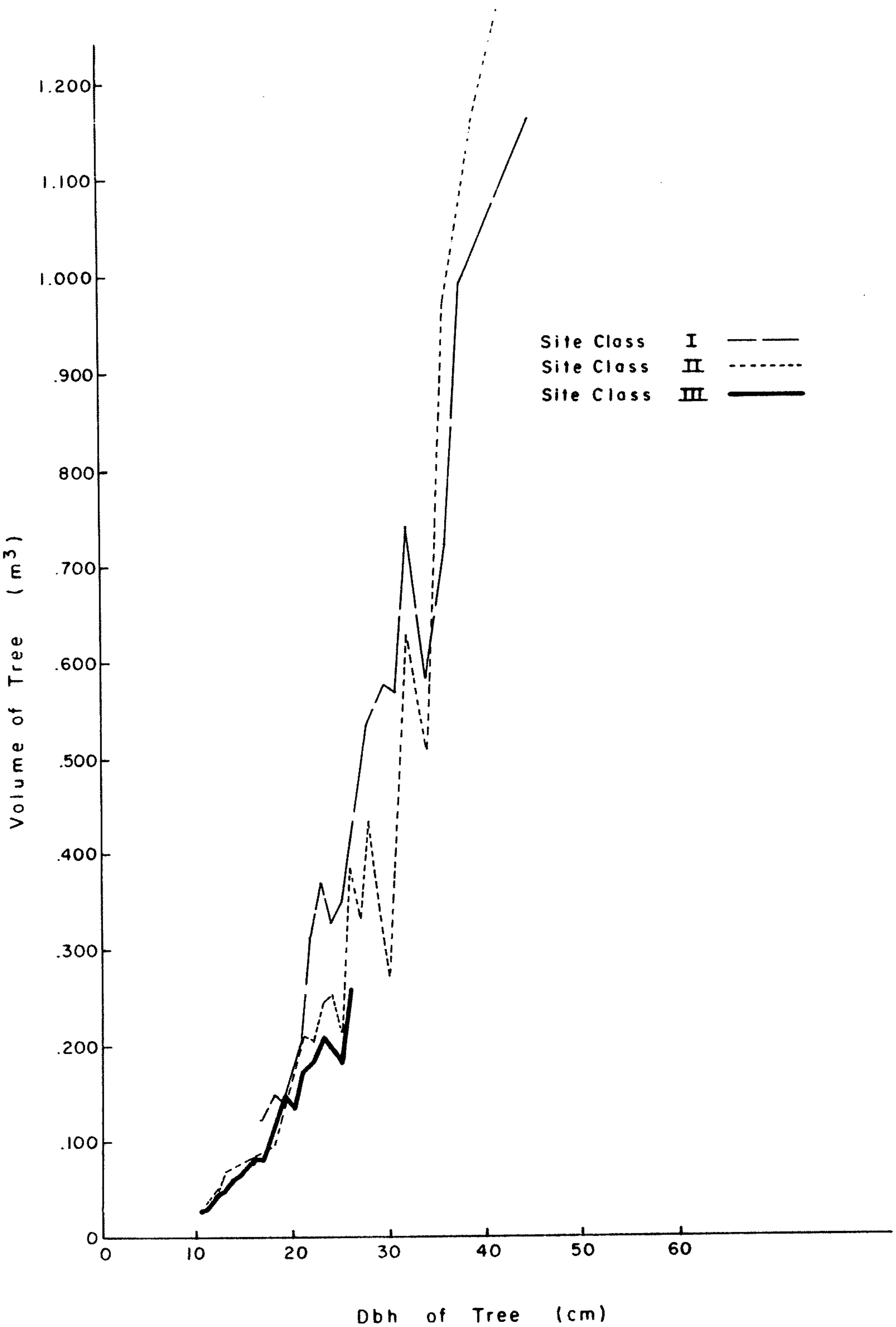

Figure 2. Comparison of Honduras mahogany volumes (under bark) from the three site classes found on St. Lucia. (Volumes measured to a 7.6 cm top diameter).

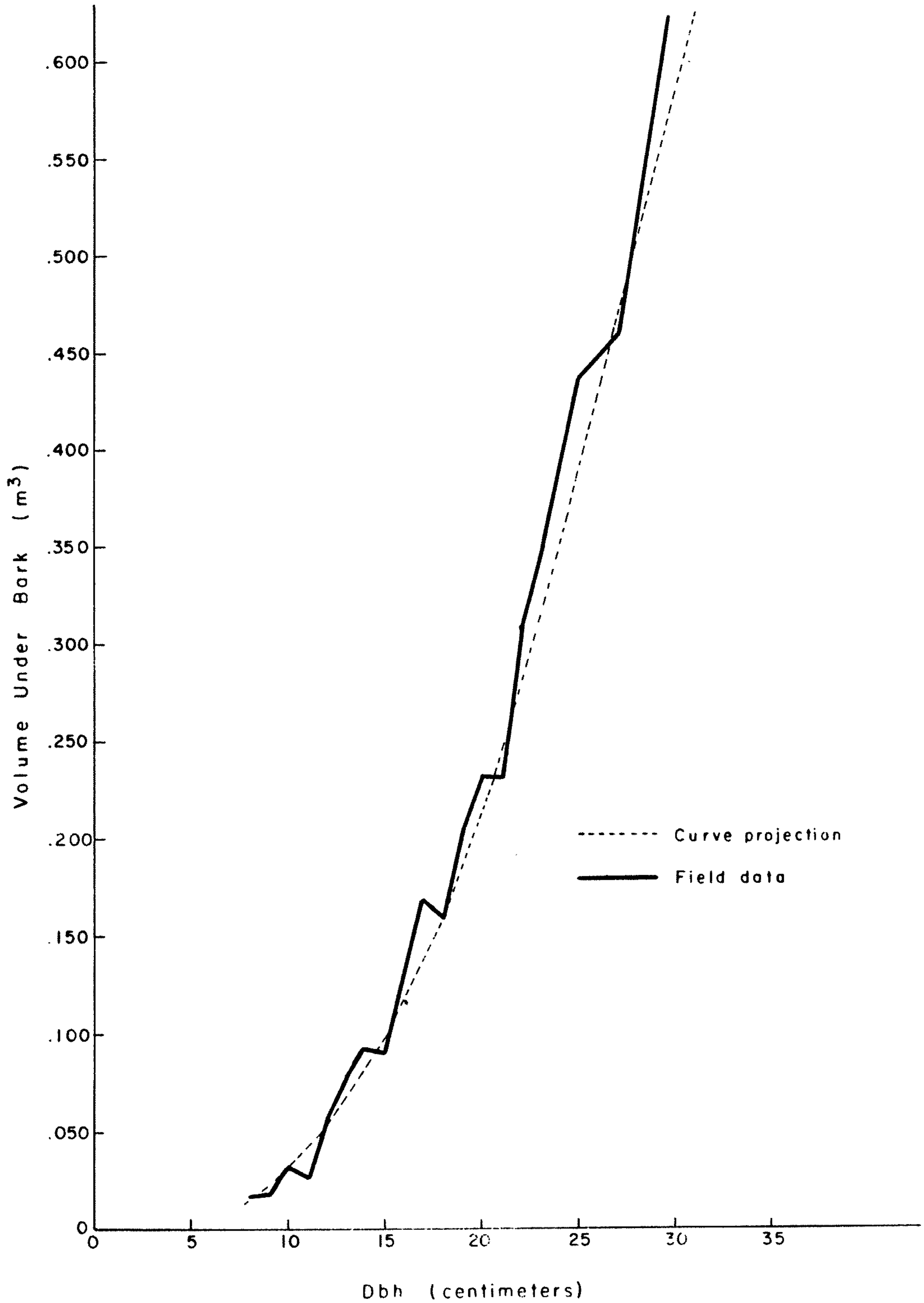

Figure 3. Comparison of the volumes of blue mahoe based on field measurements (all sites combined) with those based on curve projections.

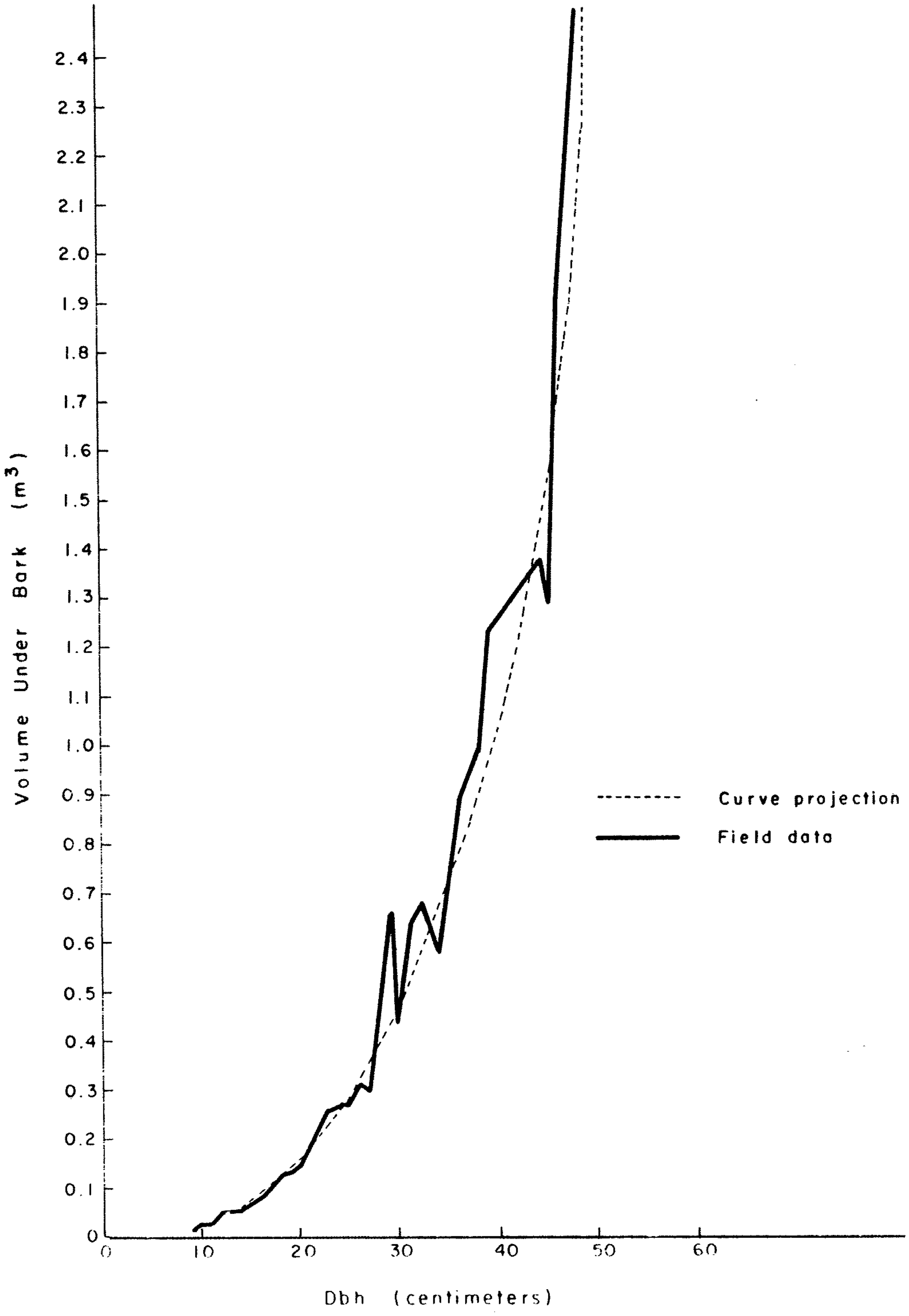

Figure 4. Comparison of the volumes of Honduras mahogany based on field measurements (all sites combined) with those based on curve projections.

TIMBER STAND MANAGEMENT INITIATION ON ST. VINCENT WITH SPECIAL REFERENCE TO SWIETENIA mahagoni/TABEBUIA pallida MANAGEMENT AND UTILIZATION

J. T. Valenta
Peace Corps Officer

INTRODUCTION

Plantation initiation on St. Vincent dates back to 1949 with the establishment of approximately 15 acres (6 ha) at Eyry Hill of Honduras mahogany (Swietenia macrophylla) and teak (Tectona grandis). Tree planting leveled off during the 1950's. During the 1960's and 1970's an upsurge of plantation establishment took place, in response to a growing need for watershed protection. Operations were based around three watershed areas, Montreal, Buccament Valley and Cumberland Valley. The early 1980's reafforestation activities were focused towards the Colonaire River, in which a hydroelectric plant has been established at South Rivers. Approximately 75% of plantations established on St. Vincent are within water-catchment areas. Recorded description of these plantations are not available. In addition, thinning schedules have not been incorporated. Watershed reafforestation serves a two-fold purpose: water conservation and timber production.

In response to the initiation of a timber management scheme, a two phase project has been incorporated.

-PHASE I - plantation and natural stand area measurement and mapping. Natural stands will be measured if recognized by the forestry division.

-PHASE II - plantation and natural stand inventory. Upon initiation, this phase will select specific forest management operations that correspond with specific stands. Eventually every stand will be inventoried to determine stand structure for incorporating specific silvicultural prescriptions.

METHODS

Stand area measurement incorporates traversing procedures to determine total area. Traversing implements a lead person measuring slope for correction purposes and back azimuth, and a rear person measuring azimuth. A chain is stretched between persons at distances of 33, 66, 99 or 123 ft (10, 20, 30 or 37 m) and both points are marked. The lead person's point is utilized to sight in the next lead point. This procedure is continued until the stand boundary is measured. Traverse data are plotted at a 1:10,000 scale, the stand areas are divided into triangles for area measurement. Stand outlines are transferred into 1:10,000 scale maps, utilizing specific land locations on the map to accurately locate the stand. Traverse error of 5% and less is acceptable.

Traversing Considerations

To date a total of 42.42 acre (17.2 ha) have been traversed and calculated. The efficiency of traversing is questionable because of the considerable amount of field hours for data collection. Aerial photographic area determination has been considered, but not accepted because of the large number of shadowed photos. However, I feel traversing implements basic concepts and field procedures necessary for a developing forestry programme.

Camden Park Secondary *Swietenia mahagoni*/*Tabebuia pallida* Stand

Camden Park, located on the southwestern coast of St. Vincent, was formerly cultivated in arrowroot and sugar cane under estate ownership. Cultivation was abandoned around 1925 and seeds of *Swietenia mahagoni* and *Tabebuia pallida* were planted. This deciduous seasonal forest (Beard 1949) Swietenia - Tabebuia formation receives a mean rainfall 79 in (1,990 mm). The rainfall rate is high for this formation. Soils within the stand are shallow, steeply sloping clays with rock-out crops, hence influencing dryness of the site (Watson *et al*. 1958). The forestry division first recognized this 16.3 acre (6.6 ha) stand in 1955 and various forms of thinnings have been incorporated with no management objectives. Illegal cutting along with haphazard thinnings has caused a hygradation of well formed trees in the stand. Species composition is 75% *S. mahagoni* and 25% *T. pallida**. Trees are poorly formed, averaging 13 well-formed seed trees per acre (32/ha). Another consideration related to poor-formed *S. mahagoni* is shoot borer (*Hysipyla* spp.) attack at early age. Evidence of *Hysipyla* spp. does not exist within the regenerating stand at present. Studies done in Puerto Rico and St. Croix indicate *S. mahagoni* resistance to *Hysipyla grandella* attack (Geary *et al*. 1973, Geary and Nobles 1980). *Hysipyla* spp. considerations for the management of *S. mahagoni* could be eliminated from this stand if future indicators stay the same.

T. pallida have typical sweeping characteristics, ideal for boat building (Adams 1973). Natural seed germination is abundant as exhibited by the large number of saplings and seedlings.

Silvicultural Considerations

Silviculture of Camden Park *S. mahagoni*/*T. pallida* stand consists of an irregular sheltered wood, seed tree system, incorporating a series of secondary fellings and a final felling being administered with full establishment of the reproductive seed tree crop. With the present establishment of seedlings and saplings in the stand, regeneration fellings are not required. Secondary fellings consist of two cuttings, at a seven year

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* Data were taken from the first three plots established within this stand, data could change upon completion of the inventory.

interval, adjustments will be administered according to results of the first release, scheduled to start with the completion of plot sampling.

If results indicate the presence of Hysipyla spp., secondary fellings will be increased and years between fellings extended.

Plot Sampling

Sixteen 0.25 acre (0.10 ha) permanent plots will be established within each plot. Trees are measured for total height with a clinometer and diameter at breast high. Tree damage will be also be recorded. Each tree will be numbered, coded with paint, and tagged for easy identification in future samplings. Seed tree selection recognizes well crowned and good seed producing trees as residuals. Specifications for minimum bole measurements will be determined for commercial volume estimations. Establisment of perminent plots will determine volume of growth rate values and also evaluate results of silvicultural operations.

Diagnostic samples of 0.25 acre (0.10 ha) are located in the north east section of each plot where stand regeneration will be determined. Both seddlings (4 ft or 1.3 m tall) and saplings (4 to 15 ft or 1.3-4.6 m tall) are recorded. Four corners of the diagnostic samples will be permanently marked for future sampling.

RESULTS

Three plots are completed and limited information acquired (Tables 1 and 2): 128 trees have been measured and seven S. mahagoni and three T. pallida seed trees selected indicating an abundance of poorly formed individuals in the stand. Commercial tree volume methods will be adapted from the US Forest Service Southern Forest Experiment Station inventory work plan (1983) with modifications, and parameters include: bole length (minimum 8 feet), bole top diameter outside bark-minimum 4 inches, cubic foot cull, and tree class. Volume measurements were postponed so that methods correspond with stand conditions, determined from field reconnaisance and initial plot samples.

As would be expected seedlings outnumber saplings, although sapling occurence is high. Plot 2 partially occurs inside a burned area and T. pallida seedlings outnumber S. mahagoni seedlings by over 220%. The February 1983 fire covered 0.25 acre in Camden Park. Sapling destruction was very high. T. pallida were also affected by fire scars and adventitious rooting was observed within the fire scarred sections of the trees.

Dry Woodland Timber Utilization

Camden Park's S. mahagoni/T. pallida stand is a typical deciduous seasonal forest located on the coastal leeward side of St. Vincent. Only a very small percent is available to the forestry division irregardless of the considerable value placed on these species, especially S. mahagoni. Recognized as a premier cabinet wood, S. mahagoni is used locally for furniture, carving and charcoal burning. The wood's high resistance to marine borers and decay, makes it an ideal boat building wood. T. pallida is still considered excellent wood for the boat building industry on St. Vincent and the Grenadines. The majority of boat building occurs on Bequia in the Grenadines where T. pallida supply is dwindling. On Union Island, in the southern Grenadines, the boat building industry is almost non-existent due to the over-exploitation of T. pallida. Camden Park's S. mahagoni/T. pallida stand, if properly managed, could supply the Grenadines with adequate seeds for both S. mahagoni and T. pallida plantation establishment. Boat builders on Bequia declare white cedar (T. pallida) grown on St. Vincent possess inferior strength quality resulting from higher rainfall (Matthes 1983). This contention could be valid, for rainfall in Camden Park, a dry site on St. Vincent, has an annual mean rainfall of 15.0 in (381 mm) more than Bequia. Figure 1 shows rainfall distribution on three possible S. mahagoni/T. pallida plantation sites. The graph indicates Camden Park's wet season, when growth rate accelerates, well above Bequia's. Matthes (1983) contends that wooden boat building within St. Vincent and the Grenadines will continue into future generations but a gradual shift towards fiberglass boats can be expected.

CONCLUSION

Proper forest management incorporates organized record keeping in order that timber resources are utilized efficiently. This organizations starts with basic knowledge of where, how much and what kind of plantations and natural stand exist within a forestry division's management plan. Project phase I, stand area measurement will provide basic information for St. Vincent's Forestry Division. Project phase II, plot sampling, will evaluate stand areas in detail and management proposals will be submitted according to sampling results. Management considerations must also be given to timber resource, objectives to coincide with national demand. With the establishment of this project, timber resource planning will affect silvicultural practices for proper site utilization and thus timber resource availability.

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Table 1. Camden Park sampling data for plots 1, 2, and 3.

Plot #	*Swietenia mahagoni*				*Tabebuia pallida*			
	Total trees measured	Mean DBH (cm)	Mean height (m)	# of seed trees	Total trees measured	Mean DBH (cm)	Mean height (m)	# of seed trees
1	34	22.3	11.5	2	1	23.4	9.8	1
2	22	23.6	11.5	2	19	28.7	13.6	2
3	40	18.5	10.3	3	12	24.9	12.6	-
Total	96	20.8	10.9	7	32	26.9	13.1	2

Table 2. Diagnostic sampling summary for plots 1, 2, and 3.

Plot #	Seedling species	Number	Sampling species	Number
1	Swietenia mahagoni	96	Swietenia mahagoni	62
1	Tabebuia pallida	2	Tabebuia pallida	1
2*	Swietenia mahagoni	177	Tabebuia pallida	1
2*	Tabebuia pallida	388	Swietenia mahagoni	20
3	Swietenia mahagoni	21.8	Swietenia mahagoni	34
	Albizia lebbek	17	Albizia lebbek	14

* Plot partially affected by fire.

Additional tree species occuring in the diagnostic samplings include: Bursera simaruba, Tabebuia glomerata, Citharexylum spinosum and Lanchocarpus latifolius.

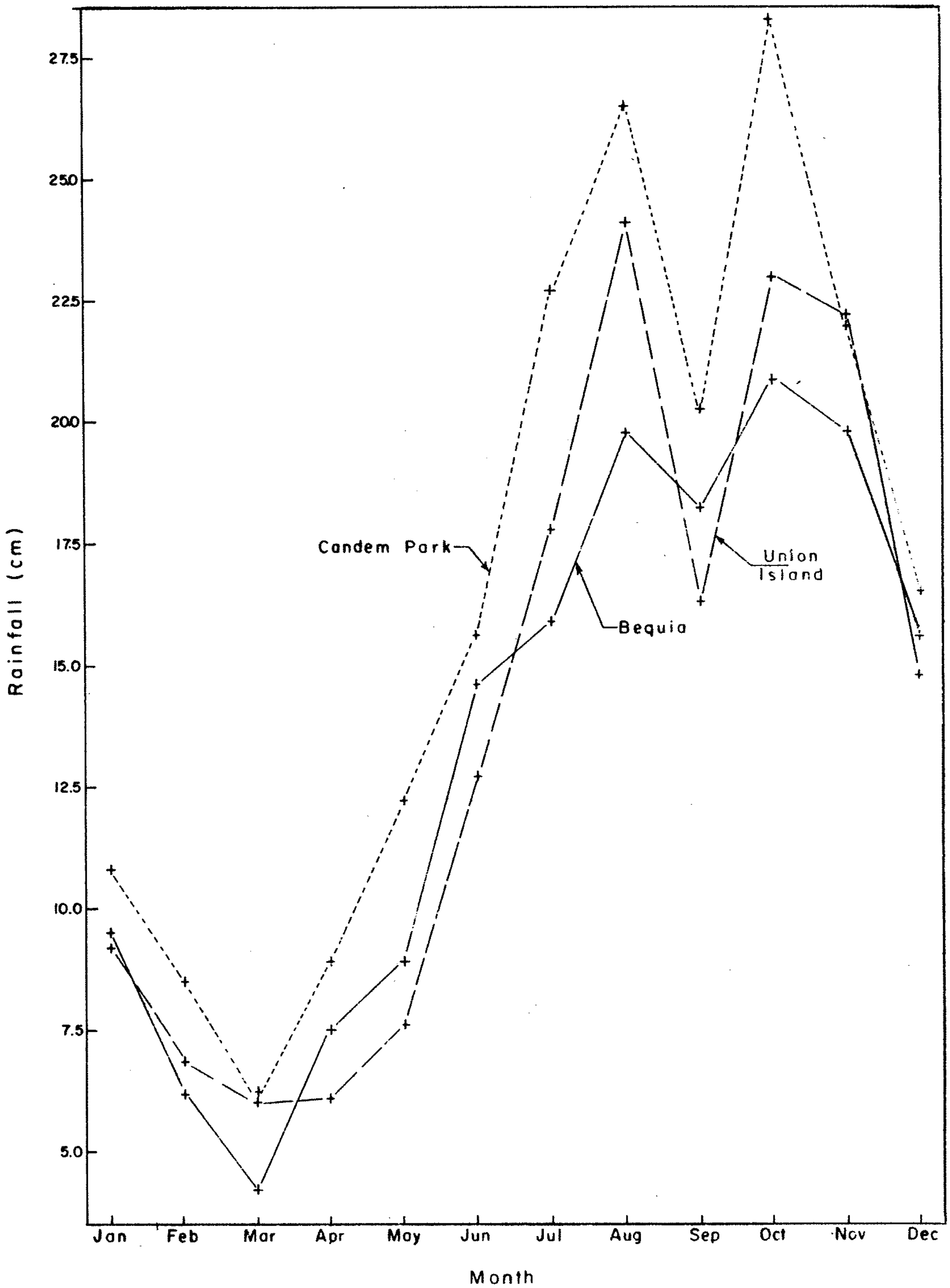

Figure 1. Rainfall comparisons between three Swietenia mahagoni, Tabebuia pallida sites; 10 year mean.

CHARCOAL PRODUCTION AND LEUCAENA IN ST. LUCIA

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Charcoal has traditionally been the major fuel source for cooking in St. Lucia. It is produced by the earth pit method which is inefficient in terms of yield but acceptable in terms of quality and texture produced. Between 1934 and 1942, St. Lucia was an important exporter of charcoal, exporting a total of 25,600 tonnes mainly to Barbados. However, since then the export trade declined to very low levels, due, among other things, to a decline of nearly 60% of the area under natural forest. The present industry is carried out by some 3,000 households of which perhaps 25 - 30% rely on charcoal production as a major source of cash income.

Due to the constant changes in the prices of kerosene and liquid petroleum gas (LPG), there is greater demand for charcoal and to a lesser extent fuel-wood by rural and a few urban communities. This has created greater pressure on the forest reserve, resulting in devastation of forest lands, an increase in rill and gully erosion, destruction of watersheds and the reduction in water quality and quantity. In view of this, the Forestry Division of St. Lucia have made some positive steps towards solving these existing problems and rehabilitating the charcoal industry.

The following is an outline of projects undertaken and workshops attended by forestry staff to derive valuable information concerning charcoal production and identification of fast growing species. Most projects are in their preliminary stages.

In late 1979 a research project was undertaken to identify fast growing species. These would be used to revegetate denuded forest lands and establish plantations on marginal forest lands and shrubland areas, specificially for charcoal production and fuel wood. The result of this project was the discovery of a versatile leguminous species, *Leucaena leucocephala*. It is one of the fastest growing species known in the sub-tropical and tropical world (e.g., growth rate in St. Lucia at one provenance trial given in Table 1).

In 1980, two departamental staff of the Ministry of Agriculture were trained in Dominica in the operation of portable metal kilns. That same year the Forestry Division received two charcoal metal kilns donated by British Development Division Tropical Products Institute (T.P.I.). The trained personnel have been involved in demonstrations on kiln operation at exhibitions, on forest lands and private estates. Very soon, the T.P.I. kilns will be loaned to private farms at a fee to be decided upon and under the guidance of the Charcoal Promotion Officer (C.P.O.).

The introduction of the transportable metal kilns for the production of charcoal will approximately double the yield of charcoal from a given quantity of wood. These kilns are also less time consuming and allow the largely wasted fallen trees to be brought into productive use. There is also potential to manufacture charcoal from coconut shells as a by-product of copra processing.

In 1981, a feasibility study for a charcoal enterprise using nontraditional methods of production was carried out by Tropical Products Institute and Industrial Development Unit. This was requested by the National Development Corporation of St. Lucia. The result of this study was compiled into an informative booklet titled "St. Lucia, the Manufacture of Charcoal".

Between 1981-1982, kiln produced charcoal was undertaken in different parts of the island by the Forestry Division. The raw material used was mainly branches and defected wood from white cedar (Tabebuia pallida). The aim was to check the quality and quantity of charcoal obtained because most of the shrublands identified for charcoal enterprise consisted of these species.

Results: There were 21 burnings, yielding 238 bags (i.e. 50lb fertilizer bags) of charcoal.

In 1983, a Leucaena Pilot Project was initiated. A 25 ac (10 ha) plot was selected in the drier southern area of St. Lucia, consisting of dense shrub following cultivation many years ago. The area chosen is accessible and fencing is provided for the plot. Management of the plot will be based on a rotation period of 5 yr which is suitable for charcoal production. Actual volume growth expected is unknown for now, however, from experiments it varies between 30 m^3 - 80 m^3/ha.yr. An average value of 52.5 m^3/ha.yr (or 750 ft^3/ac.yr) has been used for an estimate for this project.

The project is the first of many expected to be carried out to replenish and promote the charcoal industry or enterprise. To date 1,223 ac (495 ha) have been planted and maintained.

This on-going project is funded jointly by the Government of St. Lucia and O.A.S., with St. Lucia Government investing $10,000 E.C. and the O.A.S. $16,000 E.C., respectively, for the first six months. The O.A.S. is expected to invest $18,360 annually for the next five years.

An additional pilot project using Leucaena was also established late 1983 with 5 acres (2 ha) planted to date. This was done in the southeastern part of the island at Mon Repos.

Another Leucaena project has been started in the northern section of the island. Already 3 acres (1.2 ha) have been planted with other planting to be done during the rainy season. The aim of this Leucaena plantation is slightly different from the previous pilot projects. In the charcoal project, the spacing is 6' x 6' (or 1.8 m x 1.8 m) with rotation age 5 yr. But in this plantation project the spacing is 9' x 9' (or 2.7 m x 2.7 m) with unknown rotation age. The aim is to develop good timber trees.

The first regional fuelwood/charcoal/cookstove workshop was held in Montserrat in September 1983. One member of the St. Lucia Forestry Division attended the workshop and reports shows that it was successful.

The highlight of the workshop was the Montserrat Project which dealt with four main components:

-Fuelwood Species Trials - to determine the most suitable species to grow on a plantation scale or small farm wood lots;

-Resource Assessment - to determine locations, species and quantities of fuelwood available in given areas;

-Cookstove - to determine the most desirable wood fuel and charcoal cookstoves from the standpoint of efficiency, acceptability and low cost investment; and

-Charcoal Production - to determine the most suitable method for charcoal production so as to derive the highest efficiency, acceptability and low economic investment.

Some 21 species were tried at two different sites and results for the first six months showed good performance from: Leucaena leucocephala, Sesbania grandiflora, Gliricidia sepoim (seedlings) and Enterolobium cyclocarpum. In relation to the other areas of the project, more work and time is needed for better evaluation. Nevertheless, the earth pit method used for charcoal production is still considered to be the number one method.

The recently completed Forest Management Workplan for 1984-1994 caters for the establishment of 325 acres (131.5 ha) of timber for promoting the charcoal industry.

Table 1. Summary of results from *Leucaena* plots in St. Lucia

Location	Plot	Age of plot (yr)	Average height (m)	Average DBH (cm)
Union Nursery, northwest	Plot A_1	4	10.8	16
	Plot A_{11}	3	9.2	15
Vieux Fort, southern	Plot B	0.5	1.4	
Mon Repos, southwest	Plot C	0.25	1.2	
Louvet, northeast	Plot D	0.5	1.5	

ISSUES OF PLANTATION FORESTRY IN WATERSHED MANAGEMENT ON SMALL CARIBBEAN ISLANDS IN THE 1980's

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INTRODUCTION

Two years ago I listed some advantages and disadvantages of plantation forestry compared to alternatives for natural forest management. The conclusion was that either plantations or natural forests can meet a country's specific wood needs depending on local circumstances such as inherent site fertility, native flora and fauna complexity and specific economic-marketing-social welfare considerations (Liegel 1982). A successful reforestation project attempts to balance all factors as judiciously as time, money, and personnel permit.

Issues of plantation forestry versus natural forest management practices on watershed objectives are particularly complicated. On any one island, conflicting watershed objectives frequently exist for major or populated drainage basins. Thus, issues cannot be summarized adequately by simply listing advantages and disadvantages of either forest management system. The purpose of this paper is fourfold:

- to quickly review the standard or traditional role of forests in protecting watershed values,

- to explain several phenomena that complicate applying traditional viewpoints to many situations in humid temperate and tropical areas,

- to list some advantages and disadvantages of plantation establishment in meeting basic watershed goals, and

- to review three key restraints that I believe must be considered when deciding forestry watershed project alternatives on small Caribbean islands in the 1980's.

TRADITIONAL VALUES OF FORESTED WATERSHEDS

Forested watersheds are traditionally viewed as producing less sediment than tilled cropland, pasture and grasslands, and exposed sites such as unreclaimed mine spoils and newly developed residential and industrial sites. The protective nature of a forest rests in its extensive canopy and continuous litter layer (Patric el al. 1984, Wischmeier 1975). This relationship can be expressed in equation form as:

Closed forest canopy and reduced force of raindrops on ground	+	continuous litter layer and resultant large porous surface	=	high infiltration and little overland flow to cause erosion

Other benefits of forest trees and forest cover in watersheds are:

- deep root systems that aid infiltration and increase percolation to greater depths, and

- a shaded overstory that reduces evaporation of water from the soil surface and keeps stream (surface) temperatures lower.

If forest trees facilitate infiltration, increase percolation, and reduce evaporation, then there is little difference, at least traditionally, between natural forests and planted forests in producing similar results: producing far less sediment than do nonforested watersheds. This is true within a wide range of forest types where local geology, climate, and physiography are also diverse (Patric et al. 1984).

SPECIAL PROBLEMS IN ASSESSING FORESTED WATERSHEDS

Overland Flow Phenomena

Primary erosional processes on (exposed) agricultural lands are sheet, rill, and gully erosion. All three are products of increased overland flow caused by high-intensity storms and restricted infiltration, the latter quite common for compacted farm soils (Eschner and Patric 1982). Other factors modifying actual soil loss per unit area for given storm intensities are soil type, land slope, and past/present tillage practices. Soil loss by overland flow in forested lands is usually considered small to nonexistent because raindrops falling from a forest canopy normally have less erosive power and forest litter increases infiltration and reduces runoff velocity if and when overland flow occurs. Because the Universal Soil Loss Equation (USLE) was developed primarily for relatively open farmland conditions, difficulties arise when using it to predict soil losses from forested (covered) watersheds (Wischmeier 1975). Thus, special cover-management subfactors must be considered when estimating sediment yields from forest environments (Dissmeyer and Foster 1980).

A recent study in the eastern United States postulated that overland flow and subsequent debris landslide phenomena in upland forested watersheds are much more common and less phenomenal than previously thought possible (Eschner and Patric 1982). Individual storms produced slides with soil losses amounting to hundreds of tons per ha and ankle-deep overland flow on 70% slopes. According to the theory, heavy rains from intense convection or long-duration cyclonic storms saturate soil over bedrock and other impermeable soil strata. As the rains continue, saturated layers expand, with water sometimes coming to the surface and causing overland flow on the forest floor. As soil and water float over impermeable layers, shear stresses are exceeded and debris avalanches occur. The visible effects of frequent large landslides in mountainous areas of humid tropical countries are all to common for foresters working on the small or large islands (Ford and Liegel 1981) and elsewhere in the Caribbean (Ulate and Morales 1966). If overland flow/debris landslide phenomena are widespread in humid tropical forests, then such forested areas must be viewed as significant non-point sources of sediment and related lower water quality standards.

Qualitative versus Quantitative Data

Data on effects of plantation and natural forests on water and sediment yields in tropical regions are scarce. When available, such data are usually qualitative (e.g., estimated percentage of A and B horizons or vegetative cover lost in accelerated erosion along poorly constructed logging roads). When quantitative data are available, many units of expression are used: tons/ha.yr (tons/acre.yr), tons/km^2, tons/km stream length, and acre-ft/mi^2. Without standard units of measurement, comparisons of water and sediment yields between countries must be left to hydrologists who have similar technical vocabularies.

Greater availability of quantitative watershed data from temperate than tropical regions must not be interpreted as watershed methodologies being different in temperate and tropical areas (Hamilton 1983). Basic physical and chemical laws of equilibria are the same in any environment. Intensity and magnitude, however, of particular processes will vary with local circumstances. Such reasoning justifies the successful technology transfer of several important agronomic management systems (e.g. soybeans and tobacco) from temperate low base, low pH, high aluminum Ultisols to areas of similar soils in tropical areas. The similarity of overland flow/debris landslide phenomena in humid temperate and tropical areas also suggests that other watershed phenomena in the two regions may be more similar than dissimilar. Scientists and practitioners from tropical and temperate areas can readily learn from one another. Obtaining quantitative data from forested watersheds in tropical areas can be done cheaply and effectively, if planning and ingenuity are used (Dissmeyer 1982).

Timber Harvesting Influences on Water/Sediment Yield

Some generalizations about harvesting influences on water and sediment yields may or may not be similar for tropical and temperate forests. Cutting usually increases water yields because evapotranspiration is reduced. Water yields are higher in areas with higher annual rainfall and increases in yield are usually greatest immediately after cutting and diminish as the replacement forest grows back. However, where forest regrowth is slow, as in drier tropical areas, or soils are deep, increased water yields after cutting will persist longer (Anderson *et al*. 1976).

Cutting can, but does not always, increase flood runoff and sediment yields, even after clearcutting, the most severe harvesting technique. Even in clearcuts, overland flow does not generally occur unless the forest floor is severely disturbed by skid trails, access roads, or yarding areas. Good planning can minimize these problem areas. Clearcutting can be scheduled so that only a small percentage of a major drainage area is affected at any one point in time. In humid tropical areas, where rainfall is high and uniformly distributed throughout the year, vegetative regrowth is fast and complete; invading grasses and shrubs effectively intercept rainfall and protect the ground against raindrop impact (Anderson *et al*. 1976). In drier tropical areas and those with shallow and fragile soil cover, these generalizations must be modified.

Tree Planting and Type Conversion Influences on Water/Sediment Yields

Planting and natural regeneration of cutover areas usually reverse hydrological processes observed after harvesting: reduction of water yields, flood flows, erosion, and sedimentation of downstream reservoirs. Topography, soil, slope, rainfall and other climatic factors influence vegetative regrowth and therefore determine rates of reduction in water and sediment yields. Unfortunately, certain site preparation techniques increase erosion on some forested sites. On other sites, brush and secondary forest regrowth are as effective and cheaper than planting to improve water quality in formerly farmed watersheds.

In humid tropical areas where rainfall is high and uniformly distributed, hardwood and conifer vegetation transpire all year long. Short- or long-term differences in water yields for both kinds of vegetation occurring on the same site have not yet been documented. Also, in areas where soils are almost always at full field moisture capacity, problems of maintaining water quality are usually greater than problems in maintaining or increasing water yields.

ADVANTAGES/DISADVANTAGES OF PLANTATION FORESTS IN WATERSHED MANAGEMENT

As stated in the Introduction, I presented a detailed explanation in 1982 on advantages and disadvantages of plantation management systems compared with natural forest systems. The following discussion therefore focuses only on those factors where plantation establishment will have a substantial impact on local watershed objectives as well as social and cultural expectations.

Advantages

Economics

Large reforestation projects with conifers or hardwoods are usually undertaken because they anticipate future economic returns, either in local or export markets. Truly integrated forest development projects will provide year-around employment in depressed rural areas. If planned properly, such integrated projects can turn former highly eroded wastelands into productive forests that reduce sediment and stabilize water yields for downstream urban centers.

Regeneration

After cutting, certain forest species especially eucalyptus, regenerate by coppicing. Additional wood crops are obtained without costly replanting. This plantation system minimizes site disturbance in successive rotations and reduces exposure of the ground to erosive elements.

Tree Improvement Potential

Fast-growing plantations of exotic trees are desirable because tree improvement techniques are easily employed to improve wood volume growth and insect and disease resistance. It is also possible to breed trees with root systems that are tolerant of high aluminum or other chemicals found on errosive mine spoils (e.g., bauxite areas). Aluminum-tolerant grasses have been developed for revegetating acid soil roadbanks. The implications for converting useless and highly erosive, acid mine spoil or borrow pit sites in the tropics to productive forest lands are positive and enormous.

Disturbed Sites

Planting trees and grasses stabilizes landslides and areas devastated by hurricanes and volcanoes more quickly than natural revegetation processes. Experience in Puerto Rico shows that seeded grasses (and presumably trees) modify the harshness of disturbed sites so that native grasses and shrubs are established more quickly (Ford and Liegel 1981). Where stream water quality in disturbed areas must be improved and maintained quickly to provide potable water to downstream cities, planting trees for protective purposes and simultaneous building of various mechanical controls (e.g., check dams) seem more practical than relying on natural revegetation processes alone. However, on really large slides with actively eroding headwalls and sidewalls, check dams and revegetation work are a waste of time and money. In such cases, erosion control work should not be started until either nature- or man-induced processes have created a more stable angle or repose over the entire slide area.

Disadvantages

Economics

Replacing natural forest with plantations is costly and wastes large volumes of wood and fiber. Site disturbance in such operations will be great unless time-consuming precautions are taken that reduce erosion/potential on the site. If large clearing or harvesting operations are done prior to the start of rainy seasons, damage risks from floods and erosion after long-duration, high-intensity storms, of frequent incidence in rainy seasons, are minimized.

Biological Considerations

When plantations replace existing virgin natural forests, local ecological diversity in flora and fauna can be reduced. However, reforestation of open savannas and highly-eroded wastelands may actually improve wildlife and vegetative habitat diversity. There are increased hazards of insects and diseases in plantation monocultures but supposed problems may be highly overrated; even natural coniferous temperate forests and native tropical pine forests are subjected to periodic insect or disease outbreaks.

Site Productivity Decline

It is often asserted that successive rotations of fast-growing tree species increase nutrient removals from a site. Unfortunately, there are great difficulties in quantifying nutrient removals by different species. Only certain species perform well on infertile and dry sites. Observed long-term poor growth on such sites is probably the result more of improper species selection and improper planting/tending technique than a result of site and productivity decline.

KEY RESTRAINTS IN USING PLANTATION MANAGEMENT IN WATERSHEDS ON SMALL ISLANDS

Conflicting Objectives

The most obvious restraint for deciding to use or not use plantations in watershed management on small Caribbean islands is the amount of conflicting, usually competing, watershed objectives that exist. Watersheds that must provide drinking water to cities frequently have crown lands or other public lands that are also managed for wood production. The same watershed may be dotted with small landowners who indiscriminantly use pesticides and herbicides on their cash crops; excess chemicals are easily washed into nearby streams polluting them for human and animal use. And, the same watershed may be the most important source of large amounts of irrigation water used for mechanized coastal agricultural/horticultural projects. In such instances where there are so many uses for water in relatively small, finite watersheds, effective planning seems an impossibility.

Soils/Topography

Most small and large Caribbean islands have steep and rugged topography. This factor plus the high clay, slow-infiltration capacity of many soils combine to create very high natural erosional losses, even under forested conditions. When farm, road, and urban development go unchecked on such upland sites, erosional processes are accelerated on the exposed areas. When experiments are contemplated to monitor disturbed and undisturbed areas, steep topography can limit accessibility to areas that are truly representative of a country's overall watershed problems.

Because all people need to eat, need homes to live in, and need to travel between farms and cities, effective control measures that regulate land clearing are hard to legislate, implement, and enforce. One noteworthy exception to this generalization is a law passed in the U.S. Virgin Islands in 1971. It requires that an "earth change permit" be issued before starting construction activities for private, industrial, or government buildings and projects. Violators are subject to fines or imprisonment and there have been successful prosecutions.

Disturbances

All Caribbean islands yearly face the dangers of hurricanes and other cyclonic storms. These storms create havoc by washing away topsoil and bridges as well as by blowing down homes and entire plantations. Just as catastrophic is loss of experiments designed to monitor short- and long-term sediment and water yields from watersheds receiving different management treatments. If continuity of watershed research in the Caribbean islands is to be maintained, then all studies must be replicated on several sites in individual countries. Experimental replication in space is needed to protect the integrity and investment of projects that are costly and time-consuming to install and maintain.

CONCLUSIONS

Under comparable conditions, watershed research from temperate areas is transferable to tropical regions. The closed canopy, continuous litter cover, and deep rooting habit of plantation or natural forests reduce raindrop erosive forces and promote high infiltration rates. However, steep and humid watersheds in tropical areas face considerable soil loss and long-term reduction of other water-quality factors because of overland flow/debris ladslide phenomena, even in forested watersheds. Depending on local watershed objectives, environmental and climatic factors, and existing social, cultural, and economical realities; plantation forests may or may not offer suitable alternatives for combining wood production with reducing sediment yields or stabilizing long-term water yields. Each watershed presents a unique case of human and natural elements. Failure to recognize these and possible results from periodic catastrophic disturbances will mean eventual failure of any short- or long-term watershed project.

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