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DISASTER RESEARCH UNIT

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Natural Hazards in the Windward Islands

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April 1977

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ACKNOWLEDGEMENT

We wish to express our gratitude to Ms. C. Larkin for compiling a disaster history of the Windward Islands from the back editions of 'The Voice of St. Lucia'.

Thanks are also due to all persons who generously gave time to answer our questions.

CONTENTS

1. INTRODUCTION

The Disaster Research Unit was formed within the Project Planning Centre for Developing Countries in the University of Bradford with specific purpose of analysing possible precautions against natural hazard.

In June 1975, the Disaster Research Unit published a report on the Bahamas entitled 'A Study in Predisaster Planning'. The fieldwork for this report had been completed in November and December, 1974, but there was a dearth of statistical material available to quantify either the probability of hazard events or the probable effect of these hazard events. To realistically analyse the economic impact of natural hazards it was thought more field work should be undertaken.

The Windward Islands were chosen as an ideal site for the proposed research programme for three reasons:

a. the islands are multi-hazard including earthquake, volcano, hurricane, flood, drought, landslide and soil erosion;

b. the Disaster Research Unit already had some experience in the Caribbean of the study of island groups;

c. the islands are basically English speaking.

This report is a description of the availability of data to conduct further research, although it necessarily describes the past and present hazards in the Islands. Prior to this reconnaissance trip, library research for the programme was conducted in the British Museum, the FCO, ODM, London University, Royal Commonwealth Society, Commonwealth Institute, the Institute of Tropical Products and other sources. A list of disasters that had occurred in the Windward Islands was compiled from Colonial Reports (Blue Book) and a separate list was compiled from ODM records. This work is discussed in the section on disaster history.

2. THE NATURE OF DISASTER

Disaster occurs at the interface of extreme physical events and a vulnerable population. To adequately comprehend the nature of disasters, it is necessary to consider

a. the nature of the physical event;

b. the vulnerability of the population.

If there is no vulnerable population in an area, there can be no disaster only an extreme event. Without people there is no disaster.

Two elements should be considered when the nature of the physical event is analysed, namely, the risk and intensity of the physical event. Risk can be defined as perjorative probability and intensity as damage force. In the Windward Islands, the risk of earthquake is low but the intensity high. Alternatively the risk of drought is high but the intensity is low. Accumulatively, however, the economic impact of drought tends to be greater than that of earthquakes.

The vulnerability of the population is analysed by considering the current socio-economic conditions pervailing in an area subjected to natural hazards. Such factors as location, standard-of-living, alternative opportunities, etc. are reviewed to determine the vulnerability of the population.

3. DISASTER HISTORY OF WINDWARD ISLANDS

A study of disaster history enables researchers to appreciate the scale of future natura hazards. The following summaries are taken from the data presented in Appendices 1 - 4.

Table I presents summary data of the disaster history of the Windward Islands. The span covered is 169 years although for records of earthquakes and volcanoes data is available from 1673. The total number of hazards recorded is 198, more than one every year. All hazard types, with the exception of volcano and fire, have an expected return frequency of less than 10 years. Earthquakes tend to be over-recorded because these figures contain all readings above Richter IV; many such earthquakes would do minimal damage although it should be noted that recent disasters in Venezuela and Nicaragua were from earthquakes of low intensity (e.g. Richter VI). In terms of lasting repercussions drought is the most common phenomenon. It must be emphasised that when drought occurs it usually affects all islands because the islands lie in the same climatic belt, namely, the Inter-Tropical Convergence Zone (ITCZ), whereas other hazards do not affect all the islands with similar intensity at the same period.

Dominica is remarkable for its higher hurricane frequency (Table II). This is largely due to its northerly position in the Windward Islands belt, a position astride the main hurricane tracks. No past drought information nor volcanic information is recorded as only recent drought is included in this table and there are no available records for volcanic eruptions. No newspaper search was conducted on Dominica although local historians were consulted.

Table III contains the disaster history of Grenada. Hurricane frequency is low because this island lies away from the mean hurricane track. No data was collected from archives or local relief organisations.

Data for the disaster history of St. Lucia is most exact because, besides

TABLE I

WINDWARD ISLANDS

Type	Frequency	Ave. in period studied	First recorded occurrence
Hurricane	27	6.26	1806
Tropical Storm	30	3.37	1874
Drought	33	2.54	1891
Earthquake	100	1.63	1812
Volcano	4	40.75	1812
Fire	4	12.00	1927
Total	198		

TABLE II

DOMINICA

Type	Frequency	Ave. in period studied	First recorded occurrence
Hurricane	14	12.07	1806
Tropical Storm	3	9.00	1948
Drought	6	n.a.	1970
Earthquake	20	7.95	1816
Volcano	0	n.a.	-
Fire	1	n.a.	-
Total	44	3.86	1806

TABLE III

GRENADA

Type	Frequency	Ave. in period studied	First recorded occurrence
Hurricane	3	6.66	1955
Tropical Storm	8	10.12	1894
Drought	9	9.00	1894
Earthquake	24	6.37	1822
Volcano	0	n.a.	-
Fire	0	n.a.	-
Total	44	3.48	

TABLE IV

ST. LUCIA

Type	Frequency	Ave. in period studied	First recorded occurrence
Hurricane	5	16.80	1891
Tropical Storm	12	6.75	1894
Drought	12	7.00	1891
Earthquake	23	6.22	1832
Volcano	0	n.a.	-
Fire	3	16.00	1927
Total	54	2.64	

TABLE V

ST. VINCENT

Type	Frequency	Ave. in period studied	First recorded occurrence
Hurricane	5	15.40	1898
Tropical Storm	7	14.57	1874
Drought	6	n.a.	1970
Earthquake	33	4.94	1812
Volcano	4	40.75	1812
Fire	0	n.a.	-
Total	55	2.94	

the usual sources of information, an extensive library search was conducted. This data is contained in Table IV. Note that the average return period for drought is once every seven years.

The figures for St. Vincent are contained in Table V. Library searches were conducted on St. Vincent although not as intensively as on St. Lucia. St. Vincent has recently experienced a volcanic eruption.

The list below relates to most disastrous hazards in terms of social and economic repercussions and lost lives:

Hurricane	:	1955	Grenada ('Janet')
Tropical Storm	:	1938/9	St. Lucia
Earthquake	:	1843	Dominica
Volcano	:	1902	St. Vincent
Drought	:	1970/5	All Windwards
Fire	:	1943	St. Lucia (Castries)

The disaster history of the Windward Islands contains all the major disasters that can be traced over the last 150 years. The data from St. Lucian newspaper archives provided corroborative evidence not only for St. Lucia but also for the other Windward Islands. Because of the comprehensive nature of the disaster history of the Windward Islands it is not necessary to gather further material on this aspect. The disaster history material is available classified, by island, in Appendices 1 - 4.

4. HAZARD TYPES

To understand the nature of disaster more clearly, it is necessary to review the hazard types experienced in the Windward Islands. This is done by considering geophysical and climatic hazards individually and then by considering those which result from a combination of both these elements such as landslide and soil erosion.

Table VI contains the earthquakes recorded in the islands between 1800-1960 according to the modified Mercalli scale or Richter scale measurements. A copy of the modified Mercalli scheme is enclosed as Appendix V. From similar data, Tomblin has calculated the 50 year probability of earthquake the Windward Islands. These figures are given in Table VII and are calculated from smooth return periods using the formula:

$$P(t) = 100 \left[1 - \exp(-t/R)\right]$$

where, t is the time interval (50 years) and R is the return period in years.

The calculation of earthquake probability should be regarded with a little suspicion. The time period of the observations is only a little over 300 years a time period that is miniscule in terms of the geological age within which this recorded activity occurs. The lower end of intensity for damage is assumed as intensity VI (Tomblin, 1974); this information plus data for recurrence intervals of the different intensities allowed Tomblin to calculate, to a first approximation, the mean annual risk in terms of cost. The calculations were originally intended for Trinidad and Tobago but the recent earthquake in Antigua (October 8, 1974) demonstrated the general reliability of the methodology. Tomblin stresses that the data presented in Table VIII should be regarded as subject to uncertainties of at least a factor of 10. With slight adjustments these figures can be made applicable to the Windward Islands.

Volcanic eruptions are infrequent in the Windward Islands. These

TABLE VI

EARTHQUAKE INTENSITY 1800 - 1960

MM Intensity	IX	VIII	VII	VI	V	IV	III
Dominica	1	1	-	5	17	8	4
Grenada	-	1	2	4	18	10	15
St. Lucia	-	2	4	2	34	16	9
St. Vincent	-	2	3	3	28	13	5

Source: Robson, 1964

TABLE VII

PROBABILITY OF DAMAGING EARTHQUAKES BY MM INTENSITY GRADE FOR WINDWARD ISLANDS

MM Intensity	V	VI	VII	VIII	IX	X
Data interval	1820-1969	1820-1969	1820-1969	1620-1969	1620-1969	1620-1969
50 Year probability %	>99	92	56	27	12	5

Source: Tomblin, 1974

TABLE VIII

ORDER-OF-MAGNITUDE ESTIMATES OF THE EXTENT AND COST OF EARTHQUAKE DAMAGE BY MM INTENSITY GRADE PER ANNUM

MM Intensity	VI	VII	VIII	IX	X
Extent of Damage: % by value of total earthquake susceptible property	0.01	0.09	0.8	7	60
Damage cost T.T.$ p.c.	0.4	4	40	400	4000
Total damage if whole of Trinidad equally affected Millions of T.T.$	0.4	4	40*	400	4000
Return period in years	9	30	100	300	1000
Damage cost/R mean damage per annum. Million T.T.$	0.04	0.13	0.4	1.3	4.0

* Cf. Antigua 1974. E.C. $23 million damage

Source: Tomblin, 1974

eruptions, however, can be destructive typically having a destructive component identified as a hot, high density cloud consisting of lava fragments suspended in gas, pyroclasts. Earthquake, soufrière activity, earth tilting and small volcanic activity usually precede the climax explosion and should allow time for disaster avoidance, e.g. St. Vincent, 1971-72. Fine ash and mud flow are other hazards association with volcanoes.

Because of the infrequency of volcanic eruptions it is meaningless to attempt probability analysis on the events or even begin to view volcanic activity in the area as a calculable risk. Table IX, however, contains a list of dangerous volcanoes in the Windward Islands and dates of recent violent eruptions. It is possible to appreciate the potential damage from such an eruption - in the 1902 eruption of Soufrière volcano 1565 people were killed and the northern third of St. Vincent was devastated.

Tsunami are potentially a hazard because of the four submarine volcanoes in the Eastern Caribbean. A very small wave was generated by a submarine explosion at Kick-'em-Jenny in October 1965. Although no major tsunami has occurred in the last 200 years, it is possible to envisage a future eruption which could be disastrous because many people in the Windward Islands work less then 60 feet above sea level. Tsunami has a different origin from tidal surge associated with hurricane although the overall effect is similar.

Hurricane probabilities for the region have already been calculated. Table X contains an analysis of tropical storms and hurricanes in the 5°, square that covers the Windward Islands (15° - 20°N x 60° - 65°W). It can be readily appreciated, however, that the more northerly islands are more hurricane prone because they lie more closely to the mean track of Atlantic Storms. The local population often refer to tropical storms as hurricanes even though the maximum sustained winds are not over 64 knots. In part the reason for this is that any wind above 30 knots is likely to damage the main cash crop,

TABLE IX

Island	Volcano	Volcanic Eruptions
Dominica	Morne au Diable	?
	Morne Diablotins	?
	Valley of Desolation	26,900 ± 900 B.C.
	Morne Patates	?
Grenada	Mt. St. Catherine	?
St. Lucia	Qualibou	37,500 ± 1,500 B.C.
St. Vincent	Soufriere	A.D. 1718; A.D. 1812; A.D. 1902; A.D. 1971-2

Source: Tomblin, 1974

TABLE X

PROBABILITY OF TROPICAL STORMS AND HURRICANES

Movement/month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Annual Average
Dominant direction	W		S				W	W	W	SW	E		W
Speed(Knots)	12		9				15	14	13	12	15		13
Prevailing direction	SW		S				NW	W	W	W	SW		W
Speed (Knots	6		9				11	14	13	9	12		13
Frequency per annum	1		1				7	35	39	8	2		92
Probability per annum(%)	1		1				8	40	43	11	3		70

bananas. Table XI contains information on such storms.

It is possible to estimate probable future losses from hurricanes for buildings, etc. on the basis of the methodology utilised in 4.3. This, however, does not seem the most pressing problem for, even though no hurricane building code applies, indigenous building practices ameliorate the hurricane effect. More importantly, recurrent damage from wind blow to bananas is accumulatively more destructive than all except the most severe hurricane. Discussion on the costs of wind blow is contained in the banana section.

The most serious recurring haxard in the Windward Islands is drought. A series of six years of drought, 1970-1975, have had a debilitating effect on the mainstay of the economy, namely agriculture. The most important crop, bananas, is particularly affected jeopardising the social and economic stability of more than 33,000 people, the small farmers.

Table XII contains an example of annual rainfall data for the past 14 years on St. Lucia. The mean annual rainfall figure is 50.4 inches, so over the 6 year period of drought the expected average is 302 inches. In fact, the area in the drier leeward north of the island received 288.46 inches which would not imply a drought situation yet fodder for cattle has been greatly reduced and the area, despite 4 catchment wells, is suffering from household water shortage. To understand the position more clearly, it is necessary to look at monthly rainfall figures.

Table XIII contains monthly rainfall figures for Cap Estate for 1970; this year the area received over 72 inches of rainfall, i.e. more than 20 inches above the mean annual rainfall, but still suffered drought. The rainfall is erratically spread over the year, but during the 3 rainy months, June, July and September, much of the 45 inches fell in only 6 days. The geomorphology of the island encourages fast run-off and the surface geology hinders

TABLE XI

FORMATION AND MOVEMENT OF TROPICAL CYCLONES CENTRES WITH TROPICAL STORM INTENSITY WINDSPEED EQUAL TO OR GREATER THAN 34 KNOTS

Movement/month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Annual Average
Dominant direction	W		S				W	W	W	W	W		W
Speed (Knots	12		9				15	14	12	11	11		13
Prevailing direction	SW		S				W-NW	W	W	W-NW	N		W
Speed (Knots	6		9				11-15	14	12	10	10		13
Frequency per annum	1		1				7	46	54	16	4		128
Probability per annum (%)	1		1				6	40	42	15	4		70

TABLE XII

ANNUAL RAINFALL. CAP. ESTATE, ST.LUCIA

1961	40.57
1962	44.92
1963	52.09
1964	42.02
1965	56.63
1966	64.94
1967	65.95
1968	50.62
1969	50.43
1970	72.91
1971	46.22
1972	44.94
1973	34.97
1974	38.99

TABLE XIII

MONTHLY RAINFALL. CAP ESTATE, ST. LUCIA 1970

January	0.39
February	0.56
March	1.31
April	1.59
May	1.92
June	13.32
July	11.35
August	3.55
September	20.19
October	7.14
November	8.96
December	2.63

water storage. This is a serious problem for urban water supply and there is current legislation to prohibit the building of houses without water storage capacity. More importantly, it has serious repercussions on the basic form of economy in the islands, agriculture.

Agricultural drought must be seen as a lack of soil moisture in terms of plant demand. It is possible to measure soil moisture by comparing the loss of water through evapotranspiration with inputs of water through rain. Any deficit in soil moisture can be assumed as drought if the plants are not water retentive. Table XIV contains monthly potential evapotranspiration figures from two different sources. These figures are consistent and both sets clearly show that evaportanspiration throughout the year is constant. This consistency is not true of the available rainfall. Twyford (1975) adapted the figures from column B for weekly and daily needs. These are contained in Table XV. These figures closely parallel those of Pleasance (1975) who computed figures in the following manner:

> 'Figures for Open Pan Evaporation were secured from Beausejour, St. Lucia, and compared with figures from the Caribbean Meteorological Institute, Barbados; both sets of figures were similar.
>
> Total Pan Evaporation was averaged for the year and a daily mean figure of 0.26" was obtained. Using the Penmann formula for converting Open Pan Evaporation to Potential Evapotranspiration, the formula being corrected to X.8 for the Caribbean, an average daily potential evapotranspiration of 0.2" was calculated'.
>
> (Pleasance, 1975)

With the knowledge of the potential evapotranspiration of the Windward Islands available on a daily basis it is imperative to look at moisture requirements not in terms of yearly, monthly or weekly rainfall figures but in terms of daily rainfall statistics. Table XVI contains rainfall data currently available for August 1975 for Union Station, St. Lucia. According to the calculations for potential evapotransporation it is obvious that by the

TABLE XIV

MONTHLY POTENTIAL EVAPOTRANSPIRATION IN WINDWARD ISLANDS

(inches)

	A (Smith)[1]	B (Twyford)[2]
January	3.5	4.91
February	3.3	4.85
March	3.7	4.87
April	4.4	5.07
May	5.6	5.25
June	5.2	5.32
July	5.0	5.32
August	5.2	5.27
September	4.9	5.27
October	4.9	5.21
November	4.0	5.13
December	3.8	4.93

1 = Based on Thornthwaite

2 = Calculated from formula $e = 2.36\ T$

where e = rainfall in inches

and T = mean annual temperature.

TABLE XV

ADAPTED DAILY AND WEEKLY POTENTIAL EVAPOTRANSPIRATION IN WINDWARD ISLANDS

	Weekly	Daily
January	1.13	.161
February	1.11	.159
March	1.12	.160
April	1.16	.166
May	1.20	.172
June	1.23	.175
July	1.23	.175
August	1.21	.173
September	1.21	.173
October	1.20	.171
November	1.18	.168
December	1.13	.162

Source: Twyford, 1975

TABLE XVI

DAILY RAINFALL STATISTICS. UNION STATION, ST. LUCIA

AUGUST 1975

1	.03	14	-
2	.04	15	.12
3	.12	16	.22
4	.30	17	-
5	.46	18	.10
6	.13	19	.81
7	.24	20	1.62
8	.26	21	.96
9	.03	22	-
10	.26	23	.26
11	.07	24	-
12	-	25	.04
13	.30	26	.75

15th August, despite the so-called rainy season, there were drought conditions requiring some alleviative measure, such as irrigation, assuming the constant permeability of surface geology and consequent poor water retention capacity of the soil. Discussion of possible alleviative measures is included in the banana section.

The effect of drought is difficult to quantify. For the urban dweller costs should be measured as inconvenience or extra financial burden. For the rural dweller, orientated towards agriculture, the effect is much more serious.

The economic effect of the drought can be calculated from Table XVII for the banana growers of St. Lucia. The reasonably healthy state of the banana industry can be judged from the 1969 figures where production exceeded projected estimation. The accumulative shortfall in production of 117,268 tons is a serious loss. At 6.20 East Caribbean cents per pound to the producer (mean price for 1970-1975) this loss exceeds EC$16.27 million in producer revenue.

Drought has affected other cash crops. For example, coconut production for 1976 is estimated as 34 per cent below 1975 production. Most importantly the subsistence root crops are severely affected. With an average annual return period of drought less than once every eight years, this hazard is probably the most insidious that the Windward Islands face.

Flash floods, landslide and soil erosion are hazards of largely human origin induced by mismanagement of land. None of these hazards have been effectively measured although, without adequate control and better husbandry techniques, these continuing hazards will destroy the most valuable physical resource of the Windward Islands, namely soil.

TABLE XVII

PROJECTED AND ACTUAL BANANA EXPORT PRODUCTION, ST. LUCIA
1969 - 1975

Year	Forecast (tons)	Actual (tons)	
1969	78.500	85.487	
1970	88.500	50,929	5 months drought
1971	64,750	45,020	5 months drought
1972	56,250	46,998	6 months drought
1973	57,000	35,156	8 months drought
1974	50,000	44,139	5 months drought
1975	50,000	32,000	(estimated) 5 months drought

Source: SLBGA, August 1975

Three land capability classes have been proposed for St. Lucia and it would seem sensible to apply these classes to other areas. These classes are:

1. Land suitable for cultivation with no or only simple conservation measures. All land with a slope of 7° or less is placed in this class. Grass barriers are an example of a simple conservation measure.
2. Land suitable for cultivation but requiring intensive conservation measures. All land with slopes of more than 7° and less than 20° is included in this group. If soils are very shallow, then 10° is the maximum permissible slope. This land will generally require bench terracing or some similar form of treatment.
3. Land unsuitable for cultivation but suitable for tree crops provided a permanent ground cover is maintained. In some areas there would also be a fourth class which would be left in natural forest.

With such classification in mind, it should be possible to encourage farmers, through the agricultural extension programmes, to pursue better husbandry practices that will reduce the risk of flash flooding, landslide and soil erosion. These three hazards exacerbate the problems of lost agricultural production through drought and windblow.

The hazard types associated with the Windward Islands have been briefly discussed. It is apparent that the low risk/high intensity phenomena of earthquake and hurricane can be measured in terms of probability because there are sufficient discrete events over a known time period that can be extrapolated. This is not possible with volcanic eruption or tsunami where insufficient observations exist. Although all these low risk/high intensity phenomena could produce a major disaster, various steps exist to ameliorate the effect of these hazards.

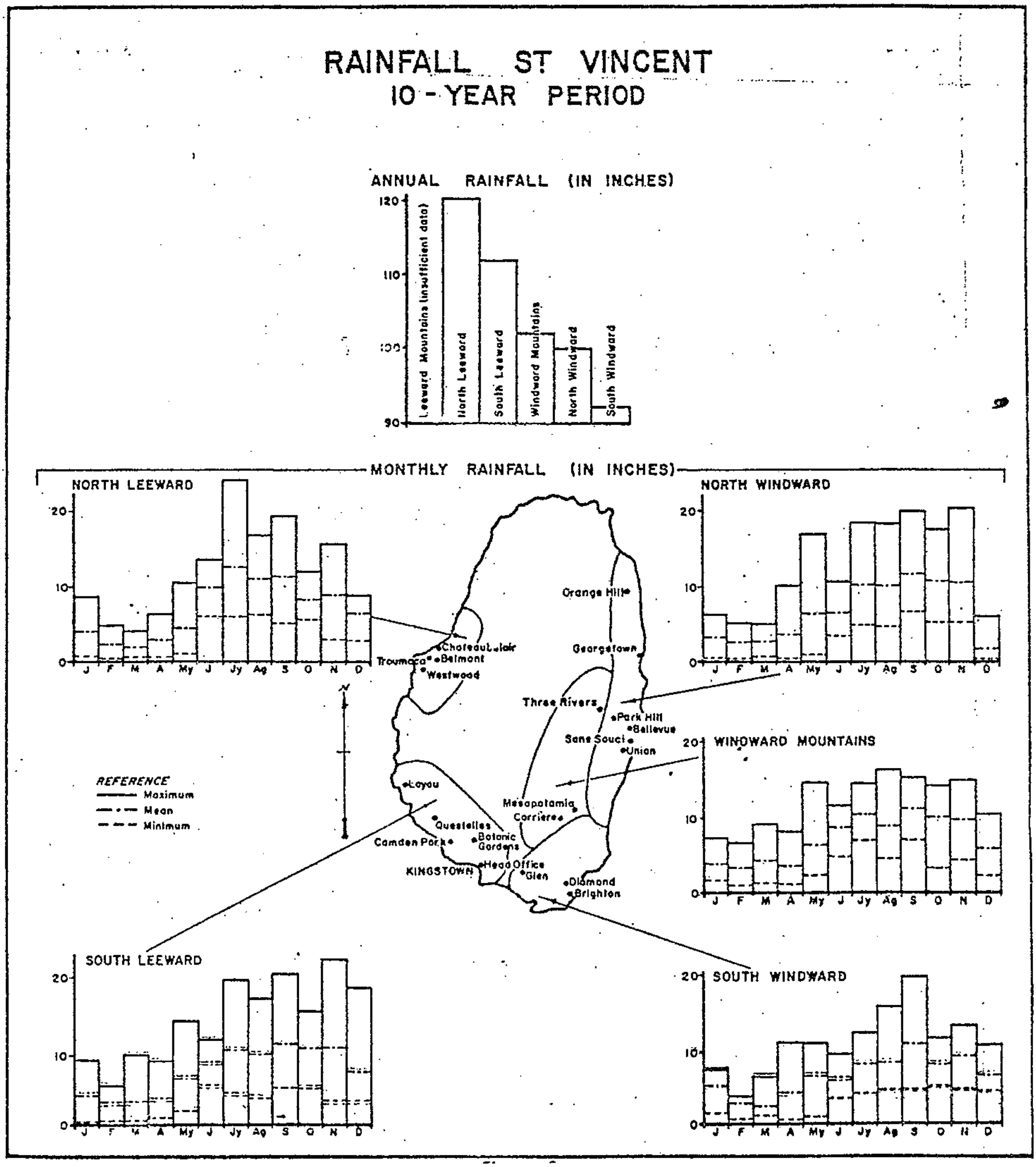
The Seismic Research Unit, UWI, has a long history of dealing with seismic risk. Besides the compilation of data on past earthquakes, volcanoes and tsunamis in the area, the Seismic Research Unit continues to monitor current seismic activity. The Seismic Research Unit is also involved in compiling and publishing reports on Caribbean anti-earthquake building structures, analysing risk for insurance companies, preparing predisaster plans for the islands and pressurizing the governments of the region to become more aware of the local seismic hazard.

The Caribbean Meteorological Institute in Barbados provides parallel information on hurricanes to that provided by the Seismic Research Unit on earthquakes, volcanoes, and tsunami. The CMI provides an early warning system for the area, computes risk data, emphasises the need for adequate building structures, etc. The data on rainfall necessary for a study of drought is available. The central issue for a study of the physical nature of drought is whether it is a recurring phenomenon insufficiently understood because of the different nature of the former agriculture (i.e. sugar instead of bananas) or if there is a major movement of the Inter-Tropical Convergence Zone which is producing a significant and lasting climatic change. This data must be studied over available time period (from 1897) to determine trends but, most importantly, it must be analysed for the last 15 years on a daily basis to appreciate the relationship between rainfall and potential evapotranspiration. It is a long task but it is important that it should be completed if the drought hazard is to be adequately understood. There is no short step to the interpretation of the rainfall data. Rainfall in the Windward Islands is largely orographic so it is possible to determine windward/leeward relationships correlated with a.s.l. This relationship, however, is made largely irrelevant because of the localised effects of orographic rainfall dependent on microtopography (Diagram 1).

Data on wind damage is available from two sources. From the various airports, it is possible to obtain data on sustained windspeeds and gustings. From the Winban Hurricane Insurance Scheme it is possible to determine which windblows were destructive. This aspect is discussed more fully in the banana section.

The man-induced hazards of flash flooding, landslide and soil erosion require field mapping. This programme has already been started by the Regional Soil Conservation Officer and should be expanded in the next year.

DIAGRAM 1



Source: Soil and Landuse Survey:
St. Vincent, 1958

5. MACRO-ECONOMICS OF WINDWARD ISLANDS

Tables XVIII and XIX relate to population and labour force. The present population of each of the Windward Islands is approximately 100,000 although up-to-date figures for Dominica and Grenada are not available from a reliable source for 1973. The age distribution of these islands is heavily biased towards the younger section of the community. In St. Vincent for example, 58.8% of the population are below 20 years of age. When this is coupled with the consistently high unemployment figures (see Table XIX) and allowing for the retired section of the community, it means that those gainfully occupied in the islands only represent about one-third of the total population. That there has been a significant drop in the birth rate (see Table XX), which is borne out in discussions during the visit, is a hopeful sign for the future.

Tables XXI to XXV relate to agriculture and land. Dominica and St. Lucia are significantly larger than the other two, the former being twice St. Vincent's size, and the latter being nearly twice Grenada's size (see Table XXI). This land area is highly polarised on all of the islands (see Table XXII) to the greatest extent in St. Vincent where nine people own 40% of the land. The majority of the farmed land is used to cultivate bananas and the importance of this crop to the islands is shown in Tables XXIII and XXIV. These tables indicate that St. Lucia relies most heavily on bananas whilst Grenada are returning to nutmegs and cocoa following re-growth after hurricane Janet in 1955, when the crops were devastated. Agricultural exports similarly contributing towards the banana revenues can be seen for the other islands in Table XXV, which, apart from coconuts, shows limes for Dominica (where a lime juice factory has recently been built) and arrowroot for St. Vincent (where the secondary crop seems to be declining slightly in importance). Other important industries apart from agriculture in the Windwards are basically: construction, tourism, fishing and light industries associated with agriculture (such as fruit canning and bottling, extracting of oil from fruits, etc.)

TABLE XVIII

TOTAL POPULATION

	1970	1973
Dominica	69,500	70,000
Grenada	95,000	105,000
St. Lucia	99,806	100,580
St. Vincent	86,314	100,300

TABLE XIX

UNEMPLOYMENT 1971

	%
Dominica	7
Grenada	9.3
St. Lucia	10.7
St. Vincent	9.1

TABLE XX

BIRTH RATE - GRENADA

1960	45 per 1000
1965	31.1 per 1000
1969	29.5 per 1000

TABLE XXI

LAND AREA

	Square Miles
Dominica	290
Grenada	120
St. Lucia	238
St. Vincent	133

TABLE XXII

POLARISATION OF LAND OWNERSHIP 1971-1972

Dominica	695 people (1% of total population own 55%
Grenada	Not available
St. Lucia	19 people own 34%
St. Vincent	9 perople own 40.4%

TABLE XXIII

BANANAS AS A % OF AGRICULTURAL EXPORTS

	1968	1971
Dominica	82.3	71.5
Grenada	40.1	17.8
St. Lucia	82.7	77.6
St. Vincent	62.1	70.3

TABLE XXIV

BANANAS AS A % OF TOTAL EXPORTS

	1968	1971
Dominica	76.7	64.0
Grenada	37.1	16.8
St. Lucia	81.8	75.1
St. Vincent	57.4	51.0

TABLE XXV

IMPORTANT AGRICULTURAL EXPORTS OTHER THAN BANANAS 1975

Dominica	Coconuts, limes, other citrus
Grenada	Nutmegs, cocoa
St. Lucia	Coconuts
St. Vincent	Coconust, arrowroot.

Table XXVI relates to Gross Domestic Product. It shows that both in absolute terms and in terms of income per capita, St. Lucia is the richest. St. Vincent is probably the poorest although information relating to the island of Grenada is limited and suspect. These figures do not reveal, however, details of the distribution of this income, although a direct association with the distribution of land (Table XXII) on each island may give some rough indication.

Table XXVII relates to Government Information available on the islands and shows that in 1971 Government Expenditure was on average equal to approximately a third of GDP. Due to the high average propensity to import, the deficits on current account has been exaggerated by the recent inflation but it is unlikely that Government Expenditure will fall in the future in the light of the consistently high unemployment figures (see Table XIX).

In conclusion, the most recent data consistently available for all four islands relates to 1971. Information in Grenada is very poor, aggravated by the lack of a government statistical department. The most up-to-date information was obtained in St. Lucia; St. Vincent only lacked a recent development plan; Dominica has the information available but it was not obtainable at the time due to limited supply. The existence of all this data is summarised in Table XXVIII.

The existence of this macro-economic data means that it is possible to analyse the effect of future disasters upon the national economies in broad terms. But to understand in specific terms the social and economic conditions relating to the islands one must have an understanding of the condition of the people, i.e. micro-economic data. Whilst there is a serious lack of this information, it is only with such data that it would be possible to identify the groups most vulnerable to future disaster.

TABLE XXVI

GDP (EC$) - 1971 (Mill.)

	At Factor Cost	Per Capita
Dominica	39.6	570
Grenada	67.2 (est.)	701
St. Lucia	75.9	749
St. Vincent	39.5	452

TABLE XXVII

GOVERNMENT EXPENDITURE IN RELATION TO GDP - 1971

	GDP (EC$.Mill.)	Government Expenditure (EC$.mill)	%
Dominica	39.6	13.4	34
Grenada	-	-	-
St. Lucia	75.9	25.8	33
St. Vincent	39.5	14.5	35

TABLE XXVIII

SUMMARY - MACRO-ECONOMIC DATA AVAILABLE

DATA	DOMINICA	GRENADA	ST. LUCIA	ST. VINCENT
Agricultural Census 1961	Yes	Yes	Yes	Yes
Banana Growers Reports	For 1974	For 1974	For 1972-1974	For 1972-1974
British Development Division Economic Survey	Yes for 1970-1971	No	Yes for 1970	Yes for 1970
Long-Term Development Plan	For 1971-1974 - Not obtainable at time of visit due to limited supply	None	Unpublished 1973 Plan Not obtainable at time of visit due to current revision. None other.	1947 Plan most recent
Statistical Abstract	For 1971-1972 - Not obtainable at time of visit due to limited supply	None	For 1974	For 1973
Other	-	1970 - 'Situation and Prospects' by British Development Division.	1970 - 'Survey and Projections' by Overseas Development Admin.	1975 - Agricultural Census.
Soon to be available	Agricultural Sector Plan (now being typed) Population Census 1975 (by end of August)	BDD Economic Survey (Date unknown). Population Census 1975.	Updated Development Plan to account for affect of recent inflation. Population Census 1975 (by end of August) Agric. Census 1975	Population Census 1975 (by end of August)

6. NATURAL HAZARDS AND BANANAS

The macro-economic survey of the islands indicated the predominant position of the banana industry. The industry is the most important agricultural export industry in the Windward Islands, a position of importance assumed after the Second World War. The change from sugar to bananas produced something of an economic and social revolution. The growth of the banana industry meant that peasants, largely living as subsistence farmers during the sugar producing era, were able to obtain a regular source of income, particularly if they were small land owners. Previously, the only source of cash was casual labour on the sugar cane estates or the sale of surplus food at local markets.

Table XXIX contains production figures for bananas for the Windward Islands. The table clearly shows the increase of bananas during the late 1950s and early 1960s and the subsequent fall-off in production because of the six year drought from 1970-1975.

The recent significant decrease in banana exports is particularly noticeable in St. Lucia which relies heavily on bananas. In 1969, for example, bananas accounted for about 80% of agricultural exports and employed at least 20,000 workers (Cf. Table XXII). Table XXX contains a breakdown of St. Lucian banana production from 1969-1975.

Before this recent decline, a threefold growth was experienced in St. Lucia with the industry exporting 27.7 thousand tons in 1960 to a peak of 85 thousand tons in 1969, the value of sales rising from EC$3.4 million to EC$10.9 in the same period. This phenomenon of the 'Green Gold Rush' also occurred in the other Windward Islands. It should be noted that after serious crop damage bananas are often planted to protect the growth of other vegetation, e.g. after hurricane Janet to protect new nutmeg trees in Grenada.

The importance of bananas in the Windward Islands disguises the fact that the natural environment of the Windward Islands is, in many ways, marginal for

TABLE XXIX

WINDWARD ISLANDS BANANA EXPORTS (tons)

1954	19,700
1959	88,500
1964	139,400
1969	
1974	

TABLE XXX

ST. LUCIAN BANANA PRODUCTION (Actual tons)

1969	85,487
1970	50,929
1971	45,020
1972	46,998
1973	35,156
1974	44,129
1975	32,000

Source: SLBGA, 1975

the production of bananas. The topography of the Windwards is rugged making communications, and thus the delivery of agricultural inputs, arduous. The same factor means that during transportation of the fruit, a necessarily rapid task, much damage is done and quality lowered. For this reason, among others, much cultivation occurs of the lower hillslopes which suffer from highly variable rainfall. In this sense, banana production in its present form is marginal.

Banana cultivation on such steep slopes is difficult and poor husbandry practices result. Disease and pest control are impossible to achieve by spraying; little surface water is controlled and stored; mechanisation is impossible. In fact, the ecological balance has been disturbed by the production of bananas in these marginal areas and the visible evidence of this is stagnant rivers, low water tables and flash flooding which result from the destruction of the watershed and soil erosion.

The importance of bananas should not be underestimated particularly to the small grower. The weekly income provides some security and stability to the small farmer although the low return per unit yield has resulted in farmers who can afford to wait for an annual return cultivating such crops as citrus and coconut. Table XXXI contains a breakdown of banana cultivation by size of landholding for Dominica, the only island for which these relationships have been computed. It must be remembered that average yield per acre is only 4 tons/acre in the Windward Islands while in neighbouring Martinique, the yield exceeds 10 tons/acre. The importance of this weekly production cannot be over-emphasised and, therefore, the effect of the drought is very severe. Table XXXII contains mean weekly production figures for four week periods in 1969 and 1970. A sharp drop in yields is shown during the early rainy season of 1971.

TABLE XXXI

LANDHOLDINGS AND BANANA PRODUCTION IN DOMINICA

Size of holding (acres)	Number of Growers	%	Total Acres	Sales (tons in 9-month period)	%	Yield per acre (tons)
Above 100	2	0.1	701	3,168	12.0	7.2
50 to 100	9	0.2	610	419	1.6	1.1
10 to 50	123	3.2	2,064	2,602	9.8	2.0
Less than 10	3,688	96.5	8,641	20,182	76.6	3.7
TOTAL	3,822	100.0	12,016	26,371	100.0	

Source: Baker, 1973

TABLE XXXII

BANANA PRODUCTION (LONG TONS) ST. LUCIA

PERIOD	MEAN WEEKLY PRODUCTION PER PERIOD 1969	1970
1	1,544	1,620
2	1,441	1,457
3	1,880	1,415
4	2,004	1,320
5	1,780	1,224
6	1,795	1,018
7	1,563	736
8	1,434	551
9	1,281	641
10	1,376	700
11	1,429	621
12	1,691	662
13	1,555	797

Source: Tench, 1973

The banana industry not only suffers from environmental hazards in a marginal area but from competition from other areas of the economy, particularly construction, engineering and tourism. These sectors offer higher wages and easier working conditions thus attracting both human capital and investment capital as well as services and Government infrastructure from agriculture. These difficulties were particularly acute from 1965-1970 when rising prices in the banana industry coincided with contracting prices in the UK market through price war and as banana consumption dropped from 7.6 kilograms per head in 1960 to 6.4 kilograms per head in 1969. Twyford examined the economics of banana farming in three Windward Islands, using the experience of 5 plots ranging from 1 to 1½ acres over a 5-year period. With the data obtained he considered a grower with 3 acres of bananas, one with 25 acres, and one with 200 acres. In the case of a 3-acre plot, he concluded that if yields of 12 tons per acre in the first year and 16 tons per acre in the 4 subsequent years were maintained, and the yield in 1½ years is halved to allow for bad weather, he would achieve (using all recommended practices) an income of EC 2,000 dollars per year or a monthly income of EC 180 dollars. A monthly income of EC 300 dollars could be attained on a 5-acre farm, and a farm of 20 acres or more should provide an attractive family living.

The industry's problems can be discussed in the short-term and long-term. The immediate problem is to gain increases in production levels to stop the Banana Associations increasing debt and prevent rural exodus. This problem is rapidly becoming intractable because of the prolonged drought. The long-term problem is much more difficult - how can the atomised structure of production on scattered micro-units which only support poor family incomes be made into a viable economic unit?

Drought affects banana growth and fruiting in several ways. At first, because of the folding of the leaves, the plant reduces its transpiration and photosynthesis and thus growth slows. Fruit takes longer to mature and production falls. Slower rates of flowering occur and large plants do not shoot bunches.

The next symptom is that pseudostems fail to elongate and thus leaves are produced in a rosette. Leaves at this stage possess yellow-bronze blotches. Bunches shooting through the rosette tend to have abnormally long stalks which often break and thus bunches fall to the ground ('jumping out of the heart'). Occasionally the bunch cannot emerge from the rosette at all ('choke throat'). Even normal bunches at this stage of drought have excessively short fingers with noticeably tipped tips (drought fruit). The next drought symptom is the collapse of the pseudostem because there is not sufficient water to maintain turgidity.

When adequate rains are experienced after drought, developing bunches mature quickly but if they a e shortfingered they remain that way; shooting off new fruit accelerates. The size of the bunch of the fingers is determined 2-3 months before shooting so new bunches bear poor fruits much of which is rejected. For any mature field, there is a slow recovery over 5-6 months.

Young plants are affected in drought conditions by a great reduction in their rate of growth which often results in their remaining at a fruit differentiation stage for too long. The bunches shot after the drought are frequently contorted and thus valueless. Sometimes fields are cut back after a drought and ratoons allowed to grow, thus the period of recovery is almost one year. Often fields are simply thrown out and replanted. In this case, as when young plants die, the resumption of production only begins after one year.

Full recovery for banana crops alone is calculated as taking one year. However, actual recovery takes longer because the income from banana production drops so that farmers cannot afford large inputs necessary to rehabilitate their

their holdings. Some farmers remain out of banana production while others have to be persuaded to grow bananas again. The problem of increasing production after drought is exacerbated because fertiliser is distributed on the basis of production. A drop in production therefore means a drop in fertiliser supply and a consequently longer recovery period.

The problem of drought is compounded by current husbandry techniques. In some of the larger, former sugar cane, estates the old channels designed to remove water from the fields increases the current drought. The general lack of soil conservation throughout the islands increases the problem. Such simple techniques as mulching with waste blue diothene, used as a protective cover on stems, would greatly reduce the effect of drought. These techniques, however, are not widely practised and, as the situation deteriorates, drought compounds the problem of wind blow.

There are no records of the efficiency of irrigation in the Windward Islands. At Roseau, St. Lucia, irrigation has been carried out using the old sugar bed drains as supply canals into which water was pumped from the river. The quantity of water supplied is not known but significant increases in plants shot were counted. In the irrigated area 8% of the plants shot, while in the non-irrigated area 4.5% of the plants shot.

At Portsmouth Estate on Dominica two types of irrigation have been carried out continuously. Figures can be disputed as ratoon and variety vary with each plot, but increase through irrigation seems significant (Table XXXIII). To minimise discrepancies in ratoon or variety, Pleasance (1975) assumed the mean of the irrigated plots as 16.8 stems/acre as against the non-irrigated mean of 7.8 stems/acre. The irrigated yield is more than 100 per cent above that of non-irrigated yields.

These yields from irrigated and non-irrigated areas can be assessed

TABLE XXXIII

YIELDS AT PORTSMOUTH, DOMINICA

Irrigation Method	Plot Size (acres)	Stems/acre
Overhead sprinkler	7	20.9
Flood Irrigation	26	12.7
Not Irrigated (A)	8	9.9
Not Irrigated (B)	7	5.7

Source: Pleasance, 1975

economically. Assuming that both irrigated and non-irrigated areas produce bunches of comparable weight, i.e. 45 lbs., and assuming that the reject rate and stem weight are 30% of total weight harvested, then based on the Portsmouth trials, production and gross income can be assessed as follows for 50 acres:

		Non-Irrigated	Irrigated
Stems/acre/year		405	873
lbs/acre/year		18225	39285
less 30%		12757	27499
Expressed tons/ acre/year		5.6	12.27
Gross income on 1 acre at current prices (10¢per lb.)	EC$	1275	2750
Gross income on 50 acres at current prices (10¢per lb.)	EC$	63750	137500

Gross income irrigated compared with non-irrigated:

Irrigated	EC$ 137,000.00
Non-irrigated	63,750.00
Difference	64,250.00
Less irrigation cost	22,500.00*
Total gross income	41,750.00

This figure contrasts starkly with Pleasance's estimate, July 1973, of total gross income EC$36,500, when the banana price was lower <u>indicating that as banana prices rise, it becomes more pressing to irrigate the medium size</u> holdings.

Assuming that 1.5" per acre (see Section 4) per week are required, a

* <u>Irrigation Capital Costs</u>
Irrigation cost approximately EC$1440 acre
For 50 acres 72000
Calculated capital recovery on 5 year pump life and sprinkler and 10 years for pipe line and fittings, the figure is 450 acre per year or on 50 acres, $22,500 per year.

50-acre irrigation set would demand 1,695,000 galls. This water would be difficult to provide without the creation of storage facilities which are not included in these costings.

The importance of irrigation as a pre-hazard technique should not be denied. Twyford (1971) plotted monthly rainfall figures against bunch weights. Averaging the rainfall of two-monthly periods gave fluctuations more in line with bunch weight variation. It was seen that peaks and troughs of curves coincided roughly, a few months apart. Correlation coefficients were then calculated for apparently best fit and a month or two on either side. The work was repeated, reducing all very high monthly rainfalls to 6", as values much above this could hardly affect bunch weight positively.

In the case of St. Vincent, with a marked dry season and sandy soils, it was found that bunch weight would be most affected by a particular month's rainfall four and five months ahead and 'r' values adjusted for high rainfall months were better than unadjusted values. Best 'r' values were 0.72 for 4 months ahead and 0.66 for 5 months ahead. In Grenada, with a similar climate to St. Vincent's but heavier soils, the same months gave the best correlations, especially when adjusted, but were not so high as for St. Vincent. In St. Lucia, with a similar climate but much heavier soils, 4, 5 and 6 months ahead correlated best but 'r' values were much lower and there was no benefit from adjustment. In Dominica with light soils but a much wetter climate, especially in banana-producing areas, correlations were very poor, though still best at 4 and 5 months. It was considered that these differences in 'r' value pattern were quite logical having regard to climate and soil moisture storage capacity and that 4 - 5 months before harvest, i.e. 1 - 2 months before shooting, was clearly the critical time for moisture availability, at least as far as bunch size was concerned.

The results of drought are compound. Besides the accumulatively debilitating effect on banana production that means plants are more vulnerable to return drought, the compact soil means that nematode control is difficult to achieve and that fertiliser application, if applied, tends to burn roots. The lack of nematode control makes plants more susceptible to wind blow. The lack of strong roots means that the ground is more susceptible to soil erosion when rain eventually falls.

More importantly, drought also affects the production of food crops. At the present moment few root crops exist and it is estimated that normal yam production will not be resumed until 9 months time. This means that the basic carbohydrate diet of the population will change to plantains/bananas with a consequent drop in the export production of bananas and loss of external revenue. In such a situation theft of bananas becomes a serious problem. This leaves the Windward Islands in a precarious balance of payments position particularly as the area has switched to an agricultural deficit importing EC$100 million worth of foodstuff in 1972.

These developments make the probability of a move away from banana cultivation to foodstuff production a reality. In 1970, the farmer received 5 cents/pound for production of which 2 cents went to inputs; in 1975, the farmer receives 13 cents/pound of which 10 cents go to inputs. In other words, for more than double the risk, the producer is obtaining the same return, 3 cents per pound. In the current drought situation, this does not encourage the farmer to have confidence in banana production.

Wind blow to bananas is a hazard whose affects can be minimized if adequate nematode control is utilised. Winban ran a hurricane insurance scheme on the cess levy raised from individual producers. The cess raised obviously drops with any fall in production (because cess rate is payable on poundage sold) making the revenue to cover claims inadequate. Thus wind blow following drought encourages a rising debt situation for the Banana Growers Association. Dominica left the scheme in 1968 because it felt fertiliser inputs were receiving less attention than the hurricane scheme. The scheme folded on December 31st, 1974 with accusations that St. Lucia was continuously drawing more cash in claims than she was paying in premiums. At the present moment, only Dominica has a scheme which pays out on the basis of 40 per cent excess. St. Vincent are contemplating a scheme with 15 per cent excess which is better than the former Winban scheme of 20 per cent excess. However, Grenada, St. Lucia and St. Vincent will have difficulty establishing a scheme because the shared capital from the former Winban scheme is not liquid.

Table XXXIV contains the number of windstorms reported as causing damage to banana cultivators in Dominica, 1973. For all these a total of 349 claims were received out of which 231 qualified to receive statutory benefits amounting to $23,618 in cash and 166 cwt in fertiliser. The 32 windblows in the other three islands resulted in payments of EC$202,760 in the same year. Assuming that the excess charges were borne, this means that wind blow damage in 1973 cost the Windward Islands more than EC$250,000 for one year, when wind damage was slight. Hurricane Beulah (1967) only did EC$2 million damage to all agricultural crops and the average return period is once every 9 years. More importantly outside aid is available after a serious hurricane but not for the debilitating effects of wind blow which reduce individual capital for possible farm improvement. These claims would be greatly reduced if proper nematode control was implemented.

Other techniques used to reduce wind damage include propping of plants, interplanting with tree crops and windbreaks. Unlike drought, recovery from windblow is swift - if adequate nematode control exists, a hurricane would merely snap the plant cleanly and the production would be back to normal in

TABLE XXXIV

WINDSTORM DAMAGE: DOMINICA, 1973

January	2
February	-
March	3
April	2
May	-
June	2
July	1
August	2
September	2
October	1
November	1
December	-
Total	16

Source: DBGA, 1974

6 - 8 months. This ease of recovery was emphasised by Winban in 1971, the second year of the current six year drought period, when they wrote:

> 'It seems likely that it will take not less than 18 months to recover from the current drought when it ends, assuming no other problems arise.
>
> By comparison, hurricane 'Beulah' in September 1967, dropped mean weekly production from 1,544.8 tons to 1,043.0 tons but in less than seven months (28 weeks) by April, 1968, production had climbed back to the September 1967 level. Thus the hurricane, considered by everyone a serious disaster, cost the industry in St. Lucia some 10,500 tons of bananas but the 1970 drought, by the time it was overtaken by the 1971 drought, had already resulted in the loss of some 34,500 tons and this was at only two-thirds of full recovery. The 1971 drought has exacerbated an already disastrous situation'.
>
> (Winban Office, 27 August 1971)

The availability of information on banana cultivation in the Windward Islands is extensive. Each island banana association has weekly production figures for every single grower since 1958. The figures can be checked against the records of boxing plants operated by BGA. Island production figures from the level of individual grower to that of the national economy are thus available from two sources. Winban has computed these figures into yearly records for the hurricane insurance scheme; these figures obviously do not include Dominica from 1968 onwards. The DBGA, however, has a computer printout on individual growers.

7. PRELIMINARY ASSESSMENT OF INSURANCE AGAINST NATURAL HAZARD

In disaster research, relatively little knowledge is available particularly of the statistical probability of disaster events and their associated costs. The following outlines a possible method of premium calculation applied to the disaster history of St. Lucia. To produce a more exact determination of the natural hazard premium, both return periods and expected losses from natural hazards must be calculated more precisely. This precision will only occur when further scientific knowledge on the probability of natural hazards is available.

The parameters mentioned, the return periods of natural hazards and the loss expected from each natural hazard, are the two most important considerations in the estimation of a premium to cover losses from natural hazard. The accuracy of these parameters is constrained by several factors. The constraints on measuring returned periods are the limited understanding of the physical mechanism of hazard, the unavailability of data and an insufficient knowledge of risk. It is possible to calculate average return periods but rather meaningless to calculate the probability of a return event because the timescale of observation is not statistically valid, e.g. there are 300 years of scientifically recorded earthquake activity but this 300 year period is not a valid sample of the activity of the current geological era in which it occurs. To avoid this difficulty, it is assumed that the average return period accurately reflects the future return frequency of disaster, i.e. that the average return period is a probability assessment of future natural hazard. The constraints on measuring average costs of a natural hazard are the unreliability of the data, particularly as estimations of damage normally exaggerate the cost of disaster, and the continual development of society which means that continually more infrastructure is vulnerable as development occurs. Costs have to be measured at current prices which, in this case, were determined by the Retail Price Index.[1]

To estimate a premium for the insurance of natural hazard, it is necessary to determine what is going to be insured and what value is placed on the insured stock. In this particular example, we are concerned with the banana industry of St. Lucia. In the St. Lucian economy, bananas account for 77.6 per cent of all agricultural exports and 75.1 per cent of all exports (1971). The banana exporting business is the backbone of the St. Lucian economy and, with a per capita income level beneath $500 per annum, its importance can be readily understood. The St. Lucian economy demonstrates the difficulties that face the underdeveloped primary producers particularly those involved in monoculture. Table XXXV indicates the St. Lucian banana production.

Table XXXV

St. Lucian Banana Production (Actual Tons)

1970	50,929
1971	45,020
1972	46,998
1973	35,156
1974	44,129
1975	32,000

Source: SLGBA, 1975

It is assumed that a minimum crop of 50,000 tons is necessary if the economy is not to be seriously affected - the visible decrease in production reflects the effects of drought over the last 6 years. The current average price per pound to the grower is 10 cents (E.C. currency). The

1. Monthly Digest of Statistics, No. 357, Sept. 1975. HMSO

value of 50,000 tons of bananas at 10 cents (E.C.) per pound is £28 million (£1 = $4 E.C.). With a knowledge of the value of bananas to be insured, it is possible to calculate the premium.

The annual premium (P) required to cover this risk, apart from loadings for administration, inflation, etc., is calculated on the basis of the average return period and the average cost per disaster impact. This figure is the average loss expected each year. Expressed as a formula it reads:

$$P = \left(\frac{LE}{RP}\right)$$

where P = average loss per annum

LE = loss expected from hazard

RP = return period in years

Research[1] conducted in the Windward Islands during August 1975 allowed the average return period to be calculated based on a time period from 1832 - 1975. Earthquake, volcano and fire are omitted from these considerations because the influence of earthquake, volcano and fire on banana production is considered slight. If, for example, large scale devastation of banana production were to occur, then the situation would probably result in massive outside relief aid. The purpose of this specific calculation is not to consider every conceivable risk but to assess a minimum premium to allow the continuity of banana production in St. Lucia. Table XXXVI contains the average return period for disasters directly affecting banana production. Windblow is damage from winds of less than 33 knots; tropical storms are from 34-63 knots and hurricanes 64 knots or more. For ease in calculation, storm damage (windblow, tropical storm and hurricane) are separated from drought.

1. 'Natural Hazards in the Windward Islands - A Survey of Available Information. C. Conway and P. O'Keefe. Disaster Research Unit, Bradford University, 106pp. Mimeo.

Table XXXVI

Average Return Period per Disaster in Years

Type	Intensity	Return Period
Windblow	↓ 33 knots	1.0
Tropical storm	34-63 knots	6.75
Hurricane	64 ↑ knots	16.8
Drought*	↓ 0.2"p.d.	7.0

(* The drought figure is assumed to be unrecorded)

The same fieldwork allowed an estimation of the average damage to banana crops per disaster strike. These figures were obtained from the disaster history of St. Lucia and then corrected to current prices. The two prices for drought damage indicate the complexities of assessing drought damage. These figures are presented in Table XXXVII.

Table XXXVII

Average Damage Value per Event

Type		Value (£)
Windblow		62,500
Tropical storm		500,000
Hurricane		2,000,000
Drought	(a)	1,000,000
	(b)	2,400,000

The conservative estimate (a) is obtained by comparing each year's forecasted exports with the actual exports produced (Table XXXV); this method takes into account the effect of the previous year's drought. The estimated exports for 1970-75 were 366,500 tons (approx.) and the actual exports were 254,300 tons (approx.). For simplicity, assume that this total deficit over a six year period is 100,000 tons. At 10 cents (E.C.) per pound the value lost is £5.6 million or almost £1 million per year. The more liberal estimate (b) assumes a maintenance of the level of production before the drought occurred. On this basis, maintenance of the 85,000 tons (approximately equal to the 1969 level) would have been 510,000 tons for the 6 year period. The actual tonnage of 254,300 gives a shortfall of 255,700 tons. Valued at an average of 10 cents (E.C.) per pound, this represents a loss of £14.25 million or almost £2.4 million per annum.

The annual premium (P) required to cover these risks in St. Lucia, calculated from the equation previously presented, is listed below in Table XXXVIII

Table XXXVIII

Calculation of Annual Premium: Results

Type		Annual Premium (£)
Windblow		62,500
Tropical storm		74,000
Hurricane		119,000
Drought	(a)	143,000
	(b)	342,800

It is possible to express the loss expected per disaster not in pounds sterling (when written LE) but as a percentage of the sum insured V, (when written le) and also to express the premium rate in per mille, p, of the sum insured instead of expressing the premium, P, in pounds sterling. In equation form this is:

$$le = \frac{LE}{V} . 100$$

and

$$p = \frac{P}{V} . 1000$$

The calculations for the estimation of loss as a percentage of the sum insured are given in Table XXXIX. The calculation of the premium rate per mille is given in Table XXXIX.

Table XXXIX

Estimation of Loss as a Percentage of Sum Insured

Type		%
Windblow		0.22
Tropical Storm		1.79
Hurricane		7.14
Drought	(a)	3.57
	(b)	8.57

Table XXXX

Premium Rate Expressed per Mille

Type		‰
Windblow		2.232
Tropical storm		2.643
Hurricane		4.25
Drought	(a)	5.107
	(b)	12.243

It is now possible to rewrite the premium calculation to read:

$$p = \left(\frac{le}{RP}\right) \cdot 10$$

This equation means that 'p' is the annual premium rate per mille without loadings for fluctuation for an object which is exposed in the course of RP years to a disaster through which it suffers a loss of 'le'% of its value. The results obtained for the rewritten equation are contained in Table XXXXI.

It is possible to sum the risk of storm hazard, i.e. to cover all storm damage under one policy premium. It is not possible to do the same for drought, for the variation in intensity for drought conditions is not known.

Table XXXXI

Revised Premium Calculation

Type		Premium °/oo
Windblow		2.232
Tropical storm		2.643
Hurricane		4.25
Drought	(a)	5.107
	(b)	12.243

The premium equation is amended for the revised storm premium to read:

$$p = 10 \cdot \sum_{i=1}^{i=3} \left(\frac{l\ddot{e}}{RP}\right)_i$$

This equation represents the average annual loss expected from storms of varying intensity and would correspond to the risk premium. Table XXXXII gives the revised premium for storm damage.

Table XXXXII

Revised Premium for Storm Damage

Intensity	Type	le(%)	RP(Years)
↓33 knots	Windblow	0.25	1
34-63 knots	Tropical storm	2.643	6.75
↑64 knots	Hurricane	4.25	16.8

The equation then reads

$$\dot{p} = 10 \cdot \left(\frac{0.25}{1} + \frac{2.643}{6.75} + \frac{4.25}{16.8}\right)$$

$$= 10 \cdot (0.25 + 0.39 + 0.25)$$

$$= 8.9 \ {}^{o}/oo$$

The results of this premium calculation expressed as costs against the total value of the banana crop (£28 million) are contained in Table XXXXIII.

Table XXXXIII

Annual Cost of Insurance

Type		Value
Windblow		62,500
Tropical storm		74,000
Hurricane		119,000
Total Storm Coverage		255,500
Drought	(a)	143,000
	(b)	342,800
Total hazard coverage (inc. drought (a))		398,500
Total hazard coverage (inc. drought (b))		598,300

These are basic estimated which do not contain any loadings for fluctuation in either intensity or impact. Until better data is obtained, this will be impossible. Commercial insurance companies are likely to overestimate the premium to safeguard against fluctuations. There are no loadings for administration, commission and profit. It is difficult to visualise any company who would underwrite the risk for less than £1 million per annum or more than 3.5% of the annual crop value.

APPENDICES

EXPLANATION OF ABBREVIATIONS USED

(a) : W = damage by wind

(b) : F = damage by water through flooding

(c) : L = damage by water (or by water together with wind) causing landslide

APPENDIX 1

A DISASTER HISTORY OF DOMINICA

Type of Disaster	Date	Details
Hurricane (W,F,L)	1806 (9 Sept)	'River Roseau overflowed and inundated the town causing 31 deaths by drowning and then destruction became general by a most dreadful fall of rain' - 'Every home which obstructed its passage was thrown down or carried away by the stream' - 'Every plantation on the Windward coast from River Tabarie to Morne Paix Bouche is almost entirely destroyed. In general the island offers a scene of devastation and ruin' - total of 136 died.
Hurricane (F)	1813 (23 July)	15ft tidal wave - damage minor.
Hurricane (F)	1813 (25 Aug)	River flooded town of Roseau to a depth of 10 ft although no lives were reported lost.
Earthquake	1816 (15 Aug)	V on Richter Scale - a severe shock.
Hurricane (W,F,L)	1834 (20 Sept)	Governor General reported: 'The planters are ruined - they will never be able to rebuild their works or carry on cultivation unless they get a loan from the Government - Many estates must be abandoned and the negroes will be starving in a few months'.
Earthquake	1838 (June)	V on Richter Scale - several smart shocks.
Earthquake	1839 (21 Sept)	V on Richter Scale - a severe shock.
Earthquake	1843 (8 Feb.)	IX on Richter Scale - In Roseau: 'The walls of most masonry buildings were cracked, some severely. Several old walls and chimneys were thrown down. The intensity here and in the southern part of the island VIII. In the northern part of the island at Londonderry and Melville Hall the sugar works and other stone buildings were destroyed. At Melville Hall the river bed sank by a few inches and the river was diverted twenty feet to the south. Damage to sugar works in the north was estimated at £4,500. One person was killed. Intensity here IX' (Dominican 8.2.1843). Estimated loss of property £8,000 - £10,000 - 'Mountains were visibly crumbling away' - Earthquake of no devastating importance however.

Type of Disaster	Date	Details
Earthquake	1844 (10 Jan)	V on Richter Scale - experienced in all the other Windwards.
Earthquake	1845 (17 Dec)	V on Richter Scale - at 2:10a.m. General alarm in Roseau - no serious damage.
Earthquake	1847 (16 Aug)	V on Richter Scale - at 2:00a.m. Another shock.
Earthquake	1849 (19 Apr)	VIII on Richter Scale - at 5:00p.m. A very severe shock felt in Roseau but was more severe in Grand Bay area. At Geneva Estate the mill house and chimney were severely damaged. At Bericoa Estate stone buildings were severely damaged with partial collapse.
Hurricane	1851	No information available.
Earthquake	1879 (10 Sept)	V on Richter Scale - at 1:20 - a severe shock.
Earthquake	1893 (17 Feb to 18 Mar)	At the northern end of Dominica; occasional shocks were felt from Feb 17th to Mar 12th, then frequent shocks until 18th. No serious damage reported.
Earthquake	1903 (26 Feb)	V on Richter Scale - at 3:10p.m. - a sharp shock from south to north.
Earthquake	1903 (4 Mar)	V on Richter Scale - 2:45p.m. - a severe and prolonged earthquake from the south-west.
Earthquake	1903 (7 Mar)	V on Richter Scale - 4:51 p.m. - a sharp shock
Earthquake	1905 (30 Mar)	V on Richter Scale - at 8:00p.m. in the northern part of the island; a sharp shock.
Earthquake	1906 (16 Feb)	VI on Richter Scale - at 1:32 p.m. - walls were slightly damaged.
Earthquake	1907 (22 Aug)	V on Richter Scale - at 7:53 a.m. - a sharp shock.
Earthquake	1912 (8 Feb)	V on Richter Scale - 3:55 a.m. - a slight prolonged tremor.
Earthquake	1914 (3 Oct)	V in Richter Scale - 1:20p.m. - a severe and prolonged shock.

Type of Disaster	Date	Details
Hurricane (W,F,L)	1916 (28 Aug)	Cash crops of peasants completely destroyed - Roads severely damaged - 200 buildings destroyed or damaged - 8 ships lost - 50 dead.
Earthquake	1921 (12 May)	V on Richter Scale - 9:10p.m. - a sharp shock.
Hurricane	1921	No information available
Hurricane	1924	No information available
Hurricane (W,F,L)	1926 (24 July)	Trees uprooted causing damage to buildings. Roads blocked - Serious damage to electric and telephonic system.
Hurricane	1928 (12 Sept)	Sea front damaged. Extensive damage to buildings and cultivation. Fear of food shortage. Damage estimated locally at £66,000 although Assessment Committee assessed damage at £28,750. Dissatisfaction over Hurricane Relief Fund distribution.
Hurricane (W,F,L)	1930 (1 Sept)	Wind blew from WNW. Whole year's crop lost - 60% estates uprooted. 1,000 houses destroyed - another 850 damaged. General services out of action. 'The valleys are plucked bare of nearly all fruit trees . It is the sea which caused the havoc unprecedented in the history of the island. Never have the waves been so terrific in height and force ... At Mahaut estates have sustained enormous losses. Tens of thousands of pounds will be required to repair all the damage done, and no doubt it will take years to effect the repairs'. (Governor General's Report). 'Dominica was being hit whilst she was already down. Plantations went bankrupt and the peasants resigned themselves to subsistence agriculture ...' (B. Cracknell: Dominica).
Earthquake	1935 (4 Feb)	IV on Richter Scale - at 3:00 p.m. - an earthquake.
Earthquake	1946 (21 May)	VI on Richter Scale - In Roseau; crockery and glassware damaged.
Tropical Storm (F,L)	1948	Heavy rain caused landslides and deforestation

Type of Disaster	Date	Details
Tropical Storm	1949 (Sept)	20 dead - limited information.
Earthquake	1953 (19 Mar)	VI on Richter Scale - 4:30a.m. in Roseau: nearly all were wakened. The Cathedral clock stopped.
Hurricane ('Edith') (W,F,L)	1963 (28 Sept)	Destroyed about 50% of fruit-bearing trees in affected areas - affect only minor and temporary - St. Lucia bore brunt of hurricane. UK aid £60,000 grant and £10,000 loan for fertiliser.
Fire	1964	No information available
Tropical Storms (F,L)	1966 (June onwards)	Minor flooding and storms until Feb. 1967. £10,000 British aid.
Hurricane ('Dorothy') (W,F,L)	1970 (20 Aug)	Mostly wind damage. North and East worst hit areas - southern and central areas only affected by river overflowing. Export figures for bananas fell by an average of 680 tons per week for 24 weeks. Valued at 4.11¢ per lb. this represents a loss of earning of about EC$1.5 million (£300,000). Damage well in excess of £100,000 - British aid £84,000 upwards.
Drought	1970	Lack of sufficient rainfall for 5 months
Drought	1971	Lack of sufficient rainfall for 5 months
Drought	1972	Lack of sufficient rainfall for 6 months
Drought	1973	Lack of sufficient rainfall for 8 months
Drought	1974	Lack of sufficient rainfall for 5 months
Drought	1975	Lack of sufficient rainfall for 5 months

APPENDIX 2

A DISASTER HISTORY OF GRENADA

Type of Disaster	Date	Details
Earthquake	1822 (1 Dec)	VIII on Richter Scale - a violent earthquake - did great damage to buildings.
Earthquake	1822 (29 Dec)	VII - more shocks - enormous rocks were rolled down from mountains.
Earthquake	1831 (4 Dec)	VII - In St. George's Church bells rang. the walls cracked slightly.
Earthquake	1834 (25 Nov)	VI - Slight cracks were caused in the walls of dwelling houses in the north of the island. A considerable amount of minor damage occurred.
Earthquake	1844 (19 Jan)	VII - In St. George's the front wall of the guardroom was damaged and partially collapsed.
Earthquake	1846 (6 Sept)	VI - Much alarm - no reports of serious damage.
Earthquake	1885 (13 Nov)	V - a sharp shock
Earthquake	1886 (2 Feb)	V - a severe shock
Earthquake	1887 (6 May)	V - a sharp shock
Earthquake	1888 (9 Jan)	VIII - In St. George's many stone buildings were seriously damaged. Serious damage to churches..
Earthquake	1890 (6 Oct)	V - a sharp shock.
Earthquake	1892 (17 Feb to 18 Mar)	V - a sharp shock
Drought	1894	
Tropical Storm (F)	1894 (Sept)	Damage to farms and causeway
Tropical Storm (F)	1895	
Tropical Storm (F)	1896	
Earthquake	1896 (26 Nov)	During the night a sharp shock occurred.

Type of Disaster	Date	Details
Tropical Storm (F)	1897	
Earthquake	1898	V - a heavy shock
Drought	1901	
Drought	1904)	Severe drought
Drought	1905)	
Earthquake	1905 (24 Dec)	V - a severe shock
Earthquake	1906	V a strong prolonged shock
Tropical Storm (F,L)	1915	20-25 acres of cocoa damaged. Three bridges, and roads damaged. Reported as being 'the most serious rain damage in living memory'
Earthquake	1918 (24 Feb)	V - a sharp tremor
Tropical Storm (F,L,W)	1921	Heavy winds. Damage to cocoa. Trees brought down. Communications and shipping damaged.
Earthquake	1924 (21 May)	V - a severe and prolonged earthquake
Tropical Storm (F,W)	1954 (7 Oct)	Several trees uprooted. Houses blown down. Electricity and roads damaged.
Earthquake	1954 (4 Dec)	VI - slight cracking of walls in some buildings in St. George's.
Hurricane ('Janet') (W,F,L)	1955 (22 Sept)	Very heavy wind followed by 15" of rain within 9 hours. 95% of nutmeg trees and coconut trees were uprooted. 120 killed. 6,000 dwellings totally destroyed. 20 (out of 50) schools seriously damaged. Agricultural losses absolutely immense. Most serious hurricane by far in history of Grenada.
Hurricane ('Edith')	1963 (24 Sept)	Minor repercussions - St. Lucia bore the brunt of the hurricane. UK aid £48,000 grant for fertiliser.
Hurricane ('Flora') (W,F,L)	1963 (1 Oct)	Airport, bridges and roads damaged. Est. damage £20,000. Over a period of 4 months there was a reduction in average monthly output of 25%. (13,000 stems compared with 20,000 stems)

Type of Disaster	Date	Details
Drought	1970	Lack of sufficient rainfall for 5 months
Drought	1971	Lack of sufficient rainfall for 5 months
Drought	1972	Lack of sufficient rainfall for 6 months
Drought	1973	Lack of sufficient rainfall for 8 months
Drought	1974	Lack of sufficient rainfall for 5 months
Drought	1975	Lack of sufficient rainfall for 5 months

APPENDIX 3

A DISASTER HISTORY OF ST. LUCIA

Type of Disaster	Date	Details
Earthquake	1832 (17 Dec)	V - two violent shocks
Earthquake	1841 (17 Aug)	VI - in the evening a violent shock. Stone buildings were cracked.
Earthquake	1842 (3 Aug)	V - a smart shock
Earthquake	1843 (8 Feb)	VII - in Castries the Roman Catholic Church, Custom House, jail and other masonry buildings were cracked but none were severely damaged.
Earthquake	1844 (10 Jan)	V - felt severely
Earthquake	1888 (9 Jan)	V - in Castries long oscillations from north to south were felt.
Earthquake	1889 (23 July)	V - a sharp shock
Earthquake	1890 (6 Oct)	V - a sharp shock
Drought	1891	No information available
Earthquake	1891 (4 July)	No information available
Hurricane	1891 (18 Aug)	Largely hit Martinique
Earthquake	1893	V - severe shocks reported. No damage
Tropical Storm (F,L,W)	1894	Heavy landslides - 'incalculable damage to crops' - 45 houses at Soufriere carried away - 11 dead.
Drought	1894)	Lack of rainfall
Drought	1895)	
Earthquake	1894 (14 Oct)	V - 2 severe shocks.
Tropical Storm (F,L)	1897 (11 Sept)	14" of rain - damage to property £10,000. Loss of agricultural income £50,000. 'Hundreds of peasant proprietors in total ruin'. Cocoa crop swept away (Re-establishment of trees 5-10 years minimum)
Drought	1906)	15" below mean (period not known)
Drought	1907)	

Type of Disaster	Date	Details
Earthquake	1906 (16 Feb)	VIII - in Castries heavy damage to masonry structures. Cracks in ground at wharf. No lives lost. Damage est. £6,000 - £7,000.
Earthquake	1906 (25 Feb)	V - a sharp shock (movements continued until August of 1908)
Earthquake	1907	
Earthquake	1908 (Aug)	
Earthquake	1911 (20 Nov)	V - a strong and prolonged shock
Earthquake	1914 (3 Oct)	V - a severe and prolonged shock
Earthquake	1916 (17 Jun)	V - a sharp shock
Tropical Storm (F,L,W)	1921 (10 Sept)	Cocoa estates damaged. Trees brought down. Communications and ships damaged - 15 dead.
Fire	1927	in Castries
Tropical Storm (F,L)	1928 (19 Sept)	Main crops at Roseau destroyed - Roads destroyed - in Roseau, fish market and jetty was swept away.
Earthquake	1928 (26 Sept)	V - a sharp tremor .
Drought	1937	Driest year on record
Tropical Storm (F,L)	1938 (21 Nov)	Rainfall for year was 38" above 50 year average - November had 'worst storms in living memory' (Barre de L'Isle, 9.61" in a day). Rainfall distribution irregular and abnormal - 120 dead (mainly through landslides) - Loss to colony est. at £55,000 - Ravine Poisson particularly badly hit.
Tropical Storm (F,L)	1939 (7 Jan)	3 villages destroyed - 100 dead. 250 missing - £16,000 aid from Britain
Tropical Storm (F,L)	1940 (7 Aug)	Ravine Poisson, Barre de L'Isle and L'Abbaye particularly badly hit - extensive damage to livestock and plantations - roads and walls which were rebuilt after 1939 floods were immediately swept away again.

Type of Disaster	Date	Details
Fire	1943	in Castries
Earthquake	1946 (21 May)	VII - in Castries the Roman Catholic Church, Government Buildings, stores and houses were damaged
Earthquake	1953 (19 Mar)	VII - in Castries there was partial collapse of buildings previously damaged by fire (see previous box) and some damage to other buildings. New buildings designed to resist earthquakes were undamaged.
Tropical Storm (F,L)	1954 (12 Dec)	Recorded rainfall for year 128.91". Peasants in south Castries (Ravine Poisson) hard-hit by landslides - whole year's output of staple crops and bananas destroyed in this area.
Fire	1955	in Soufriere - destroyed 3/5th of town. 2000 homeless.
Tropical Storm (W,F,L)	1958 (4 July)	50 mph winds. 2,500 banana trees lost in Dennery, Soufriere and Vieux Fort (the hardest hit areas). Losses were as high as 50%. Loss to farmers est. EC$300,000 (= £60,000). None of the damage was covered by insurance.
Hurricane ('Abbey')	1960 (10 July)	70% of fruiting banana plants destroyed in affected areas - 30% of non-fruiting destroyed - 20% coconuts and 10% cocoa destroyed. Damage to roads, bridges and electricity supply - damage estimated at EC$14 million excluding export shortfall - 6 dead. UK grant EC$1 million.
Hurricane ('Edith')	1963 (24 Sept)	60% of fruiting banana trees destroyed in affected area (mostly northern and eastern districts). Loss of fruit sales about EC$2 mill. Est. damage to roads, bridges and electrical supplies etc. EC$2 mill. UK aid £110,000 for fertiliser
Hurricane ('Flora')	1963 (1 Oct)	Followed a week after 'Edith'. Most damage done to Grenada.
Tropical Storm (W,F,L)	1965 (25 Oct)	40% of all bananas affected in some way. Worst hit area around Castries.
Tropical Storm (F,L)	1966 (June onwards)	Damage mostly in North East. Est. at EC$450,000 - road communications seriously affected.
Hurricane ('Beulah')	1967 (8 Sept)	15" of rain in 24 hours (most of which fell in 12 hours) - 18 dead - collapse of road

Type of Disaster	Date	Details
		system - Millions of tons of top soil washed away therefore hundreds of acres will be unproductive for several years. (St. Lucian 'Voice'). Damage mostly to NE - here 30% of bananas affected (i.e. blown down or washed away). Damage to roads and bridges alone EC$450,000 = (£90,000)
Tropical Storm (F,L)	1970 (2 Oct)	Damage to roads est. EC$50,000 = (£10,000)
Drought	1970	Lack of sufficient rainfall for 5 months
Drought	1971	Lack of sufficient rainfall for 5 months
Drought	1972	Lack of sufficient rainfall for 5 months
Drought	1973	Lack of sufficient rainfall for 6 months
Drought	1974	Lack of sufficient rainfall for 8 months
Drought	1975	Lack of sufficient rainfall for 5 months

APPENDIX 4

A DISASTER HISTORY OF ST. VINCENT

Type of Disaster	Date	Details
Earthquake	1811 (May)	More than 200 shocks were felt between May 1811 and the eruption of the Soufriere Volcano in April 1812.
Volcano	1812 (12 Apr)	1500 people killed - 'The great danger was famine ... but the neighbouring colonies ... hastened to supply the island with provisions'. £2500 UK aid voted for relief - whole island covered with several inches of ashes.
Earthquake	1819 (12 Aug)	IV - severe shock
Earthquake	1825 (20 Aug)	V - severe shock recorded in Kingstown
Earthquake	1830 (1 Jan)	V - a small shock - no damage
Earthquake	1834 (25 Nov)	VIII - slight cracking of walls - considerable amount of minor damage
Earthquake	1844 (30 Aug)	VIII - The walls of some of the buildings in Kingstown cracked. Elsewhere chimneys and out-buildings collapsed.
Tropical Storm (F,L)	1874 (9 Sept)	Heavy rainfall. Destruction heavy in Mesopotamia Valley both to crops and houses - 'The inundation of this district caused lamentable loss of life'
Tropical Storm (F,L)	1876 (1 Jan)	Heavy rain for 2 days - St. David's Parish heavily affected. 'The water unearthed a considerable amount of Soufriere coal; large logs of locust and other wood which were burnt at the time of the 1812 eruption and which 64 years had failed to decay' - 'The caribs and others living at the base of Soufriere and at Morne Ronde were the greatest sufferers'.
Tropical Storm (W,F,L)	1884 (16 Aug)	4 dead - 2000 homeless - Barometer stood at 29.20 'when the fury of the cyclone sudden burst upon Kingstown and the neighbourhood'. It lasted an hour. - 'Torrents of rain continued to fall while the wind blew heavily from the NE till noon' (i.e. for 17 hours). UK aid: St. Vincent £100 - distribution at 50% of est. damage. 1/5th in cash - remainder in building materials.
Earthquake	1885 (13 Nov)	V - sharp knock

Type of Disaster	Date	Details
Earthquake	1886 (2 Feb)	V - a severe shock
Earthquake	1890 (6 Oct)	V - a sharp knock
Earthquake	1892 (4 Mar)	V - a sharp knock
Earthquake	1893 (14 Oct)	V - severe knocks
Earthquake	1894 (30 Oct)	V - severe knock - doors and windows rattled.
Tropical Storms (F,L)	1895 (6 Sept) (15 Sept)	Mesopotamia Bridge destroyed. 5 dead - a few homeless. Rainfall for year 40" above average.
Tropical Storm	1896 (28 Oct)	25 dead - heavy rains esp. in northern part -'trees felled by rivers acted as battering rams and proved formidable weapons of destruction'. Extensive damage everywhere except Kingstown and surroundings. Of 3000 cocoa trees 3 years old, many bearing, on an estate on the leeward district, 9 were left and of 600 nutmeg trees none at all remained. It was said of the estate 'Windsor forest is gone in the sea'. There was widespread devastation of provision grounds and incalculable destruction of livestock.
Tropical Storm (W,F)	1897	Cyclone 'of moderate velocity' passed over the island - thunderstorms followed - 3 dead - damage minor.
Hurricane	1898 (11 Sept)	30,000 homeless and dependent upon 'public charity'. Wind came from N and NW in fitful gusts and lasted 6 hours - Came at time of suffering and hardship following devastation of ground provisions in 1896 (see above). Est. dead 300. UK gave free grant of £25,000 and loan of £50,000 'to inspire confidence'.
Tropical Storm (W)	1901 (20 Aug)	'There was a terrific south-westerly gale which swept into Kingstown harbour with disastrous results' (Gov. General). - damage in effect was minor and short-term.

Type of Disaster	Date	Details
Volcano	1902 (7 May)	Eruption of Soufriere volcano - 2000 dead - had been dormant for 90 years - ⅓ of island very seriously affected - USA despatched food, clothes and medical stores - houses were rebuilt to higher standard - further eruptions occurred on July 7, Sept. 3, Oct. 15 and Mar. 22. 'The "relief" remedy which has had perforce to be so largely applied in these two illnesses, is a dangerous drug, and apt to have ill-enduring effects on the constitution' (Gov. General). UK aid £75,000.
Earthquake	1902 (17 July)	VII Buildings cracked.
Earthquake	1903 (21 July)	V - severe shock
Earthquake	1906 (28 Dec)	V - severe shock
Earthquake	1909 (13 Mar)	V - severe shock
Earthquake	1911 (14 Dec)	V - severe shock
Earthquake	1912 (13 May)	V - severe tremor
Earthquake	1914 (3 Oct)	V - severe tremor
Tropical Storm (F)	1916 (Oct)	Flooding due to heavy rains
Earthquake	1918 (15 Jun)	V - severe shock
Earthquake	1919 (6 Oct)	V - severe shock and prolonged tremors
Hurricane	1921	No details known
Earthquake	1928 (26 Sept)	V - exceptional severity
Earthquake	1939 (20 Apr)	VII - several buildings damaged
Earthquake	1940 (5 Jul)	V - heavy and prolonged tremor

Type of Disaster	Date	Details
Volcano	1946	Earth tremors caused peasants to leave mountain(compare with 1971).
Earthquake	1946 (21 May)	VI - Kingstown public library and other buildings damaged.
Earthquake	1953 (19 Mar)	VII - in Kingstown the hospital, police barracks and stores were damaged. At Gomea the Roman Catholic Church was destroyed
Earthquake	1954 (4 Dec)	Strong tremors
Hurricane ('Janet')	1955 (22 Sept)	Effects on St. Vincent only minor in terms of Grenada - crops were badly damaged and so were coastal roads - no known deaths - not of disaster proportions but serious enough to set back economy.
Tropical Storm (W,F)	1954 (9 Oct)	Hurricane 'Hazel' although missing St. Vincent did some damage to sea walls etc. Roads, bridges etc. damaged to tune of EC$750,000 - damage to livestock and crops not too serious - overall est. damage EC$250,000 = (£50,000)
Earthquake	1958 (15 Oct)	IV - an earthquake
Earthquake	1959 (24 Nov)	IV - an earthquake
Hurricane ('Edith')	1963 (24 Sept)	St. Lucia bore brunt of storm - £50,000 grant from UK for fertiliser.
Hurricane ('Beulah') (F,L)	1967 (17 Sept)	About £33,000 damage estimated. 18" of rain fell in 12 hours (highest amount of rainfall ever recorded in a short period of time), minor repercussions on banana industry - No UK aid given.
Drought	1970	Lack of sufficient rainfall for 5 months
Drought	1971	Lack of sufficient rainfall for 5 months
Volcano	1971 (1 Nov to Jan '72)	Danger of eruption led to evacuation of 10,000 peasants - 2000 of whom became dependent on Govt. - Led to political repercussions in terms of seats held in Parliament.
Drought	1972	Lack of sufficient rainfall for 5 months

Type of Disaster	Date	Details
Drought	1973	Lack of sufficient rainfall for 6 months
Drought	1974	Lack of sufficient rainfall for 8 months
Tropical Storm (F,L)	1974 (2 Oct)	Heavy rain causing landslides and damage to plantations.
Drought	1975	Lack of sufficient rainfall for 5 months

APPENDIX 5

THE MODIFIED MERCALLI SCALE OF EARTHQUAKE INTENSITIES

Source: Seismic Research Unit, University of the West Indies, St. Augustine.

I Not felt. Marginal and long-period effects of large earthquakes.

II Felt by persons at rest, on upper floors, or favourably placed.

III Felt indoors. Hanging objects swing. Vibration like passing of light trucks. Duration estimated. May not be recognised as an earthquake.

IV Hanging objects swing. Vibration like passing of heavy trucks: or sensation of a jolt like a heavy ball striking the walls. Standing motor cars rock. Windows, dishes, doors rattle. Glasses clink. Crockery clashes. In the upper range of IV wooden walls and frames creak.

V Felt outdoors; direction estimated. Sleepers wakened. Liquids disturbed, some spilled. Small unstable objects displaced or upset. Doors swing, close, open. Shutters, pictures move. Pendulum clocks stop, start, change rate.

VI Felt by all. Many frightened and run outdoors. Persons walk unsteadily. Windows, dishes, glassware broken. Knickknacks, books, etc. off shelves. Pictures of walls. Furniture moved or overturned. Weak plaster and masonry D cracked. Small bells ring (church, school). Trees, bushes shaken (visibly, or heard to rustle).

VII Difficult to stand. Noticed by drivers or motorcars. Hanging objects quiver. Furniture broken. Damage to masonry D, including cracks. Weak chimneys broken at roof line. Fall of plaster, loose bricks, stones, tiles, cornices (also unbraced parapets and architectural ornaments). Some cracks in masonry C. Waves on ponds; water turbid with mud. Small slides and caving in along sand or gravel banks. Large bells ring. Concrete irrigation ditches damaged.

VIII Steering of motor cars affected. Damage to masonry C; partial collapse. Some damage to masonry B; none to masonry A. Fall of stucco and some masonry walls. Twisting, fall of chimneys, factory stacks, monuments, towers, elevated tanks. Frame houses moved on foundations if not bolted down; loose panel walls thrown out. Decayed piling broken off. Branches broken from trees. Changes in flow or temperature of springs and wells. Cracks in wet ground and on steep slopes.

IX General panic. Masonry D destroyed; masonry C heavily damaged, sometimes with complete collapse; masonry B seriously damaged. (General damage to foundations). Frame structures, if not bolted, shifted off foundations. Frames racked. Serious damage to reservoirs. Underground pipes broken. Conspicuous cracks on ground. In alluviated areas sand and mud ejected, earthquake fountains, sand craters.

X Most masonry and frame structures destroyed with their foundations. Some well-built wooden structures and bridges destroyed. Serious damage to dams, dikes, embankments. Large landslides. Water thrown on banks of canals, rivers, lakes, etc. Sand mud shifted horizontally on beaches and flat land. Rails bent slightly.

XI Rails bent greatly. Underground pipelines completely out of service.

XII Damage nearly total. Large rock masses displaced. Lines of sight and level distorted. Objects thrown into the air.

Masonry A, B, C, D. To avoid ambiguity of language, the quality of masonry, brick or otherwise, is specified by the following lettering (which has no connection with conventional Class A, B, C construction).

Masonry A. Good workmanship, mortar, and design; reinforced especially laterally, and bound together by using steel, concrete, etc., designed to resist lateral forces.

Masonry B. Good workmanship and mortar; reinforced, but not designed in detail to resist lateral forces.

Masonry C. Ordinary workmanship and mortar; no extreme weaknesses like failing to tie in at corners, but neither reinforced nor designed against horizontal forces.

Masonry D. Weak materials, such as adobe; poor mortar; low standards of workmanship; weak horizontally.

An approximate empirical relation between ground acceleration and intensity on the 1956 Mercalli scale is given by

$$\text{Log } a = \frac{\text{Int}}{3} - 1.5$$

where a is the ground acceleration expressed as a percentage of the acceleration due to gravity and Int. is the intensity.

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