



Indicators of Disaster Risk and Risk Management

**Program for Latin America and
the Caribbean**

BARBADOS

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INTRODUCTION

Disaster risk is not only associated with the occurrence of intense physical phenomenon but also with the vulnerability conditions that favour or facilitate disaster when such phenomenon occur. Vulnerability is intimately related to social processes in disaster prone areas and is usually related to the fragility, susceptibility or lack of resilience of the population when faced with different hazards. In other words, disasters are socio-environmental by nature and their materialization is the result of the social construction of risk. Therefore, their reduction must be part of decision making processes. This is the case not only with post disaster reconstruction but also with public policy formulation and development planning. Due to this, institutional development must be strengthened and investment stimulated in vulnerability reduction in order to contribute to the sustainable development process in different countries.

In order to improve disaster risk understanding and disaster risk management performance a transparent, representative and robust System of Indicators, easily understood by public policymakers, relatively easy to update periodically and that allow cluster and comparison between countries was developed by the Institute of Environmental Studies (IDEA in Spanish) of the National University of Colombia, Manizales. This System of Indicators was designed between 2003 and 2005 with the support of the Operation ATN/JF-7906/07-RG “Information and Indicators Program for Disaster Risk Management” of the Inter-American Development Bank (IDB).

This System of Indicators had three specific objectives: *i*) improvement in the use and presentation of information on risk. This assists policymakers in identifying investment priorities to reduce risk (such as prevention and mitigation measures), and directs the post disaster recovery process; *ii*) to provide a way to measure key elements of vulnerability for countries facing natural phenomena. It also provides a way to identify national risk management capacities, as well as comparative data for evaluating the effects of policies and investments on risk management; and *iii*) application of this methodology should promote the exchange of technical information for public policy formulation and risk management programs throughout the region. The System of Indicators was developed to be useful not only for the countries but also for the Bank, facilitating the individual monitoring of each country and the comparison between the countries of the region.

The first phase of the Program of Indicators IDB-IDEA involved the methodological development, the formulation of the indicators and the evaluation of twelve countries from 1985 to 2000. Subsequently, two additional countries were evaluated with the support of the Regional Policy Dialogue on Natural Disasters. In 2008 a methodological review and the updating of the indicators for twelve countries was made in the framework of the Operation RG-T1579; ATN/MD-11238-RG. Indicators were updated to 2005 and for the most recent date according to information availability (2007 or 2008) for Argentina, Bolivia, Chile, Colombia, Ecuador, Jamaica, Mexico, Peru, Dominican Republic and

Trinidad and Tobago¹. In addition, Barbados and Panama were included in the program. This report has been made using –with some adjustments that in each case are referenced– the methodologies formulated in the first phase of the Program of Indicators IDB-IDEA²

The System of Indicators abovementioned attempts risk and vulnerability benchmarking using relative indicators in order to facilitate access to relevant information by national level decision makers which facilitates the identification and proposal of effective disaster risk management policies and actions. Their underlying models seek to represent risk and risk management at a national scale, allowing the identification of its essential economic and social characteristics and a comparison of these aspects and the risk context in different countries.

The System of Indicators proposed permits the benchmarking of the evaluations of each country in different periods. It assists the move toward a more analytically rigorous and data driven approach to risk management decision-making. This measurement approach enables:

- Representation of disaster risk at the national level, allowing the identification of key issues relating to their characterization from an economic and social point of view.
- Risk management performance benchmarking of the different countries to determine performance targets for improving management effectiveness.

Due to a lack of parameters, the need to suggest some qualitative indicators measured on subjective scales is unavoidable. This is the case with risk management indicators. The weighting or pondering of some indices has been undertaken using expert opinion and informants at the national level. Analysis has been achieved using numerical techniques that are consistent from the theoretical and statistical perspectives.

Four components or composite indicators reflect the principal elements that represent vulnerability and show the advance of different countries in risk management. This is achieved in the following way:

1. The Disaster Deficit Index, DDI, measures country risk from a macro-economic and financial perspective when faced with possible catastrophic events. This requires an estimation of critical impacts during a given exposure time and of the capacity of the country to face up to this situation financially.
2. The Local Disaster Index, LDI, identify the social and environmental risk that derives from more recurrent lower level events which are often chronic at the local and sub

¹ Last period, in general, is considered tentative or preliminary because usually, most recent values are not totally confirmed and it is common that some of them change, such as it has been verified in this updating with values that were used in the previous evaluation (2005).

² More information and details of methodologies can be found in IDEA (2005). “System of Indicators of Disaster Risk and Risk Management: Main Technical Report”. Program of Indicators for Disaster Risk and Risk Management IDB – IDEA, Universidad Nacional de Colombia, Manizales. <http://idea.unalmzl.edu.co>

national levels. These particularly affect the more socially and economically fragile population and generate a highly damaging impact on the country's development.

3. The Prevalent Vulnerability Index, PVI, is made up of a series of indicators that characterize prevailing vulnerability conditions reflected in exposure in prone areas, socioeconomic fragility and lack of resilience in general.
4. The Risk Management Index, RMI, brings together a group of indicators related to the risk management performance of the country. These reflect the organizational, development, capacity and institutional action taken to reduce vulnerability and losses, to prepare for crisis and efficiently recover.

In this way, the System of Indicators covers different aspects of the risk problematic and takes into account aspects such as: potential damage and loss due to the probability of extreme events, recurrent disasters or losses, socio-environmental conditions that facilitate disasters, capacity for macroeconomic recovery, behaviour of key services, institutional capacity and the effectiveness of basic risk management instruments such as risk identification, prevention and mitigation measures, financial mechanisms and risk transfer, emergency response levels and preparedness and recovery capacity (Cardona 2008). Each index has a number of variables that are associated with it and empirically measured. The choice of variables was driven by a consideration of a number of factors including: country coverage, the soundness of the data, direct relevance to the phenomenon that the indicators are intended to measure, and quality. Wherever possible it is sought to use direct measures of the phenomena is wanted to capture. But in some cases, "proxies" had to be employed. In general it is sought variables with extensive country coverage but chose in some cases to make use of variables with narrow coverage if they measured critical aspects of risk that would otherwise be overlooked.

This report presents only the updated or new results for the country and detailed methodological explanations are not included because they are not the scope of this report. Information related to the methodology and the previous results of the System of Indicators can be found at: <http://idea.unalmzl.edu.co>, where details on conceptual framework, methodological support, data treatment and statistical techniques used in the modelling are presented (Cardona *et al* 2003a/b; 2004 a/b; Cardona 2005; IDEA 2005).

SYSTEM OF INDICATORS FOR BARBADOS

1 NATIONAL CONTEXT

Barbados is located at the most easterly of the Caribbean chain of Islands, stretching from Florida on the North American mainland to the Guianas on the northern mainland of South America. It is a mere 416 square kilometers (166 square miles). Most of the island is made up of soft marine deposits of coral limestone.

According to the world factbook CIA, population of Barbados estimated for 2009 is 284,589 and the population growth rate estimated for 2009 is 0.383%. Figure 1 presents an estimative of population in thousands of inhabitants for the different parishes and their variation since 1980.

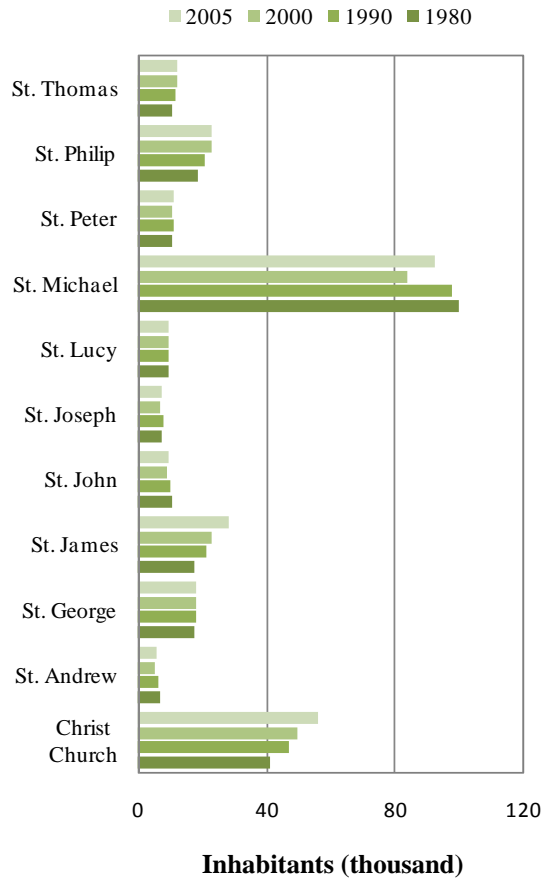


Figure 1. Population by parishes (Source <http://www.citypopulation.de/Barbados.html>)

Regarding its economy, GDP of Barbados is of the order of US\$3 billion in 2005; its growth rate was 2% in 2000 and it was negative (-2%) for 2002. Current account and trade balance was near to -6% and 13% of GDP for 2000 and 2005 respectively. The inflation rate is over 7% and the unemployment rate is estimated of the order of 9.9 (2009). The gross capital formation as proportion of GDP has risen since 2000 and it is closer to 25% in

2005. The exchange rate in 2008 fluctuates around BBD 2 per dollar. Table 1 presents a summary of macroeconomic variables of the country. Concerning the social characteristics of the country, the illiteracy rate of the population over 15 years old is around 0.3% in 2005. The number of hospital beds per one thousand inhabitants is 1.9.

Table 1. Main macroeconomic and social indicators

Indicator	1995	2000	2005
GDP (USD million)	1,859.15	2,544.47	3,043.95
Trade balance (% GDP)	2.35	-5.70	-12.65
Total debt service (% Exports and income)	**	**	**
Unemployment (%)	19.7	9.2	9.1
Population living lower the poverty line	**	**	**
Human Development Index	**	**	0.89

Sources: *The World Bank, ECLAC*

** *Data not available*

2 NATURAL HAZARDS

Figure 2 presents the percentages of the influence area and the severity level of the different hazards in the country. Likewise, Figure 3 presents the classification by mortality risk established by the International Strategy for Disaster Reduction, ISDR. These figures illustrate the events that can be considered as triggers for the estimation of the Disaster Deficit Index, DDI. Other frequent and punctual phenomena such as landslides and floods, less visible at national level, are the causes of recurrent effects at local level and may have an important accumulative impact. For this reason they are considered in the estimation of the Local Disaster Index³. Appendix I presents a general description of the country's hazards.

³ The Local Disaster Index could not be determined for Barbados because

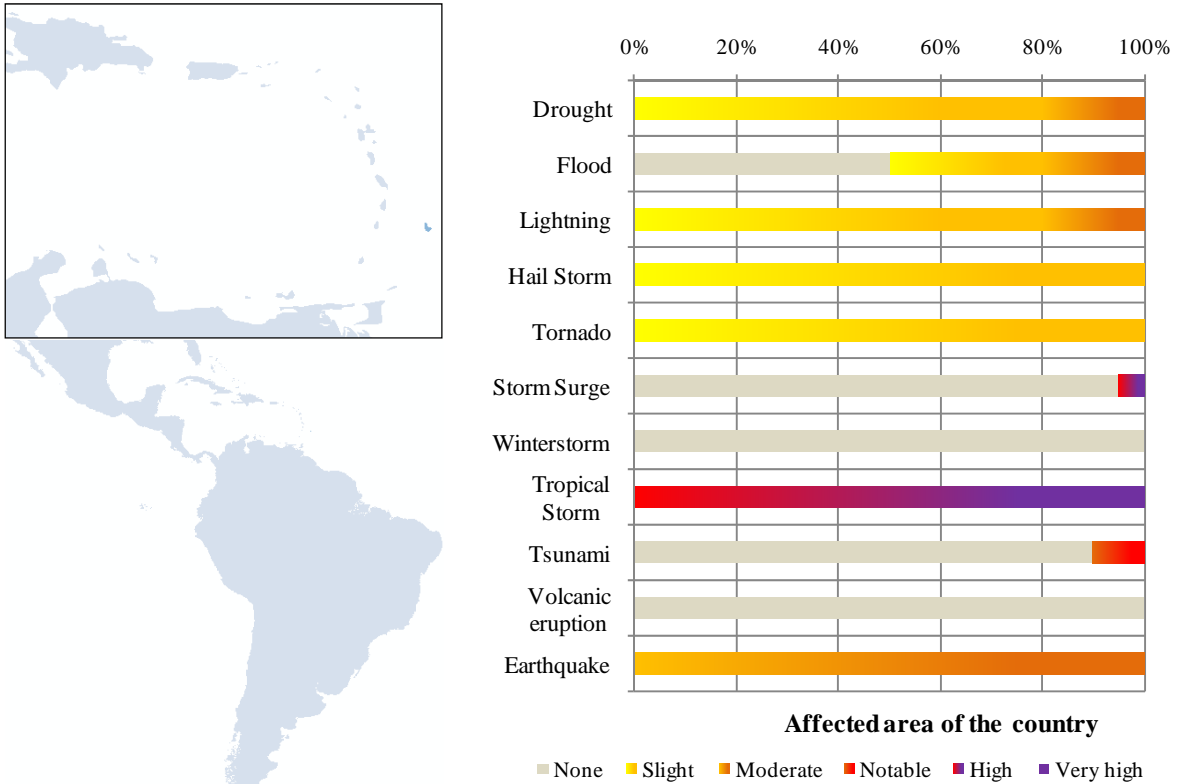


Figure 2. Percentages of the influence area by hazard (Source: Munich Re⁴)

The most important natural hazards to the country are the tropical storms. These are extreme events that would cause the major losses in the future in Barbados. There are other natural phenomena that have lower probability of affecting the country such as storm surges, tsunamis, earthquakes, droughts, lightning, flood, hail storms and tornados; however they are able to cause a significant damage. This information is especially important for the estimation of the Disaster Deficit Index, DDI. On the other hand, most recurrent and isolated phenomena, such as landslides and floods, cause frequent effects at the local level, without being noticed. These events have also great impacts over population, and, if they are cumulative can be important too. Information about these events is especially important for the estimation of the Local Disaster Index, LDI.

⁴ <http://mrnathan.munichre.com/>

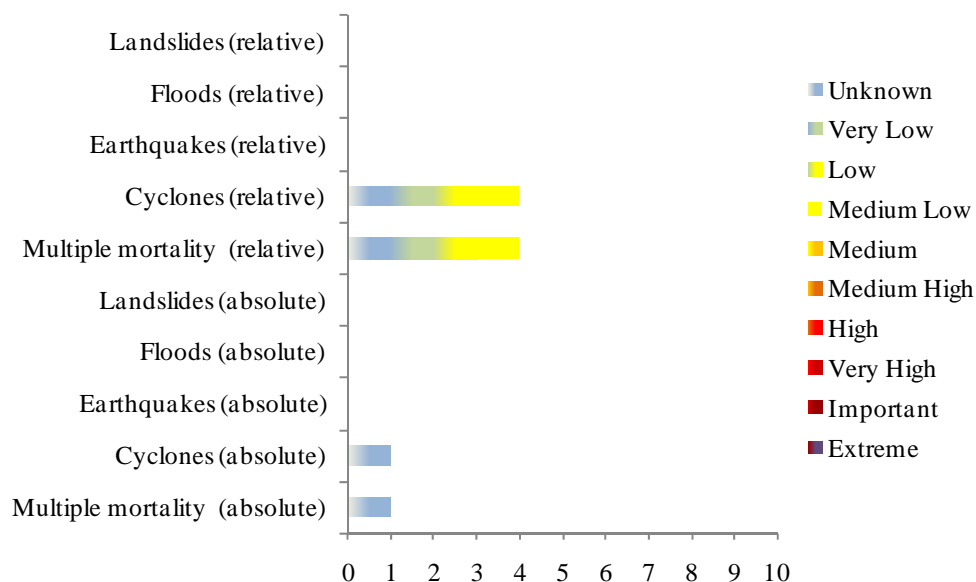


Figure 3. Classification by mortality risk (Source ISDR 2009)

The mortality risk index established by the International Strategy for Disaster Reduction (ISDR), is based on hazard modeling (tropical cyclones, flooding, earthquakes and landslides) taking into account the frequency and severity of hazard events, the human exposure and vulnerability identification. The absolute mortality risk index refers to the average of deaths per year; the relative mortality risk index refers to the average of deaths in proportion to the national population. According to Figure 3, relative values indicate that mortality risk is medium-low concentrated due to cyclones. The other hazards do not have any participation in the index.

3 INDICATORS OF DISASTER RISK AND RISK MANAGEMENT

A summary of the results obtained from the System of Indicators application for Barbados for the period 2001-2005 and later to 2005, as far as information allows, is presented in this section. These results are useful to analyze risk and risk management performance in the country, based on information supplied by different national institutions.

3.1 DISASTER DEFICIT INDEX (DDI)

The DDI measures the economic loss that a particular country could suffer when a catastrophic event takes place, and the implications in terms of resources needed to address the situation. This index captures the relationship between the demand for contingent resources to cover the losses that the public sector must assume as result of its fiscal responsibility caused by the Maximum Considered Event (MCE) and the public sector's economic resilience (ER).

Losses caused by the MCE are calculated with a model that takes into account, on the one hand, different natural hazards, calculated in probabilistic terms according to historical

registers of intensities of the phenomena; and on the other hand, the current physical vulnerability that present the exposed elements to those phenomena. The ER is obtained from the estimation of the possible internal or external funds that government, as the entity responsible for recovery or as owner of the affected goods, may access or has available at the time of the evaluation.

A DDI greater than 1.0 reflects the country's inability to cope with extreme disasters even by going into as much debt as possible. The greater the DDI, the greater the gap. Also, an estimation of a complementary indicator, DDI'_{CE} has been made, to illustrate the portion of a country's annual Capital Expenditure that corresponds to the expected annual loss or the pure risk premium. That is, what percentage of the annual investment budget would be needed to pay for future disasters (IDEA 2005; Cardona 2005). The DDI'_{IS} is also estimated with respect to the amount of sustainable resources due to inter-temporal surplus; i.e. the savings which the government can employ, calculated over a ten year period, in order to best attend the impacts of disasters. The DDI'_{IS} is the percentage of a country's potential savings at present values that corresponds to the pure risk premium.

3.1.1 Reference parameters for the model

Even though there is not detailed data useful for modelling public and private inventories, it is possible to use general information about built areas and/or on the population to make estimations of these inventories of exposed elements. This technique or proxy method allows a *coarse grain* assessment of the volume and cost of the exposed elements required for the analysis. The parameters for shaping a homogeneous and consistent information structure for the project specific objectives are detailed below. They are the cost of square meter of some construction classes, built area (in each city related to the number of inhabitants) and distribution of built areas in basic groups for analysis such as the public and private components, which would be in charge or would be fiscal liabilities of the government in case of disaster. In addition, the rest of private goods, that constitute capital stocks, are considered as well to provide a general view of the potential impact in the country.

Figure 4 shows estimations of built areas in different components and their variation over the most recent periods of analysis. Figure 5 presents a similar graphic regarding the exposed values for the whole country. The technique for the country's exposure estimation, vulnerability assessment and the hazard and risk models used are explained in Ordaz & Yamin (2004) and Velásquez (2009). These technical explanations are available in <http://idea.unalmzl.edu.co>.

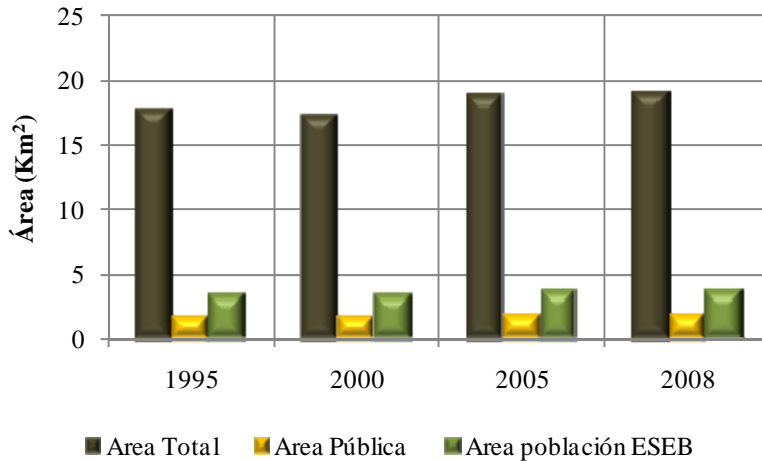


Figure 4. Total built areas by component in square km

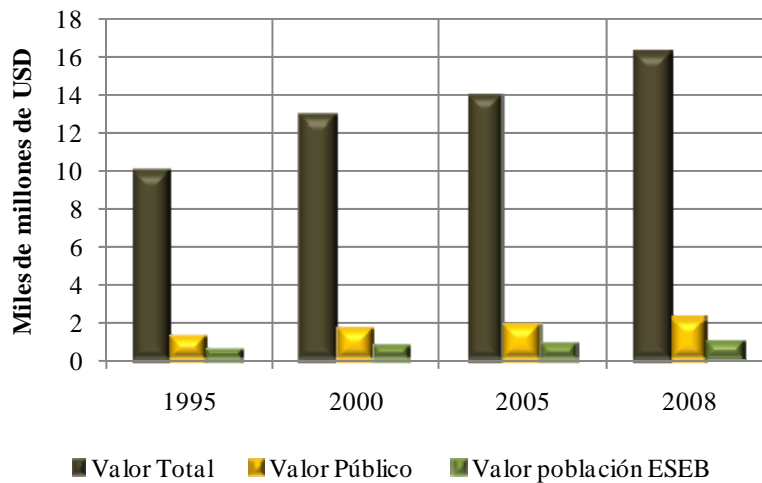


Figure 5. Exposed value by component in billion dollars

Technique for exposure estimation for the country, vulnerability of exposed elements and hazard and risk model is explained in Ordaz & Yamin (2004) and Velásquez (2009).

3.1.2 Estimation of the indicators

Table 2 shows the DDI for 1995, 2000, 2005 and 2008 for the Maximum Considered Event (MCE) of 50, 100 and 500 years of return period.⁵

Table 2. DDI for different return periods

<i>DDI</i>	2000	2005	2008
<i>DDI</i> ₅₀	1.00	1.30	1.49
<i>DDI</i> ₁₀₀	2.30	2.84	3.15
<i>DDI</i> ₅₀₀	5.22	5.58	5.75

⁵ Events that can occur in any moment and they have a probability of occurrence of 18%, 10% and 2% in 10 years.

For extreme events in 50, 100 and 500 years in each period, the DDI is greater than 1.0; this means the country does not have enough resources to cover losses and/or feasible financial capacity to face losses and replace the capital stock affected. Table 3 shows DDI' values, which corresponds to annual expected loss related to capital expenditure (annual budget of investment), and related to possible savings for inter-temporal surplus to 10 years, expressed in percentages. DDI'_{CE} illustrates that if contingent liabilities to the country were covered by insurance (annual pure premium), the country would have to invest annually close to 12% of 2008's capital expenditure to cover future disasters. The DDI' with respect to the amount of sustainable resources due to inter-temporal surplus indicates that for 2005 and 2008 saving were greater than 100%, that is, annual pure premium value would increase the deficit. Values of DDI'_{IS} in 2000 were lower indicating that there would be annual average savings for covering the losses in the country.

Table 3. DDI' related to capital expenditure and inter-temporal surplus

<i>DDI'</i>	2000	2005	2008
<i>DDI'_{CE}</i>	7%	10%	12%
<i>DDI'_{IS}</i>	4%	>100%	>100%

Figure 6 illustrates DDI and DDI' values related to capital expenditure. The graphics illustrate that from 2000 to 2008 DDI increased gradually. The DDI', according to the budget of investment, also increased from 2000 to 2008. This illustrates that if contingent liabilities to the country were covered by insurance (annual pure premium), the country would have to invest 12% approximately of its capital annual expenditure in 2008 to cover future disasters. The DDI' with respect to the amount of sustainable resources due to inter-temporal surplus indicates that for 2005 and 2008 saving was greater than 100%, that is, although the country have access to some resources for coverage some amount of the annual pure premium they are not enough for coverage the total amount of the annual average loss.

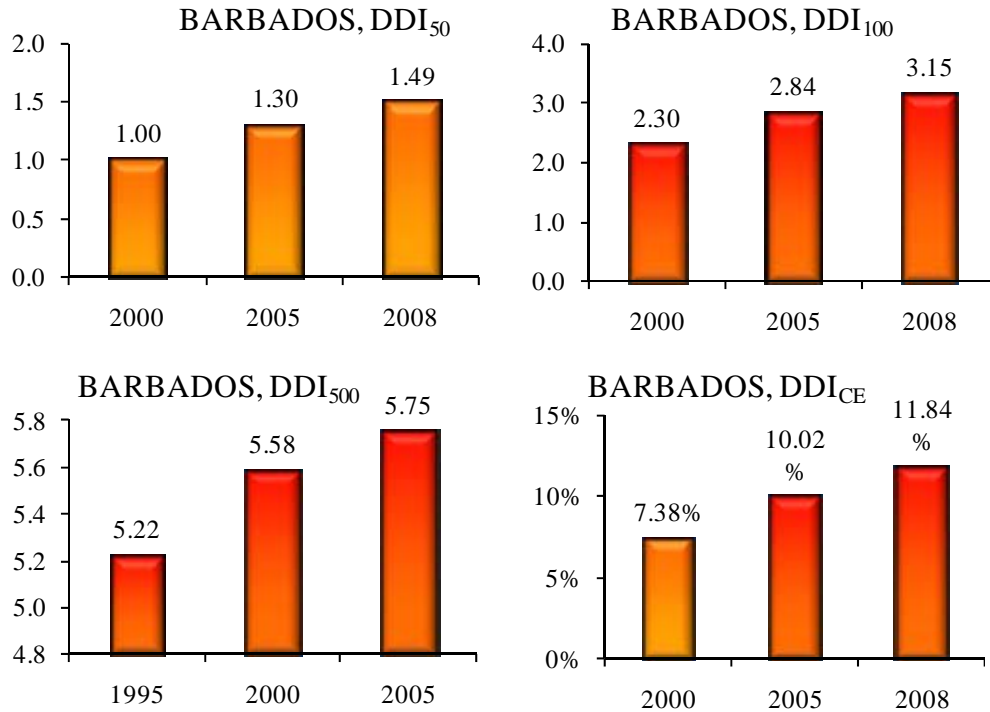


Figure 6. DDI₅₀, DDI₁₀₀, DDI₅₀₀, DDI'_{CE}

Due to the importance of the numbers used to evaluate the DDI and the DDI' in each period and considering the extreme disasters of reference, Table 4 shows the values of the potential losses for the country for the Maximum Considered Event, MCE, with 50, 100 and 500 year return period. This estimation in retrospective took into account the exposure level of the country every five years, from 2000 to 2008. In addition,

Table 4 presents the values of the pure premium i.e. the annual amount required to cover future disasters in each period. The DDI and DDI' for the five year-period (2000 to 2008) were calculated based on the estimations of the potential maximum losses and expected annual losses respectively (numerator of the indicators).

These indicators can be estimated every five years and can be useful to identify the reduction or increase in the potential deficit due to disasters. Clearly, investments in mitigation (retrofitting of vulnerable structures) that would reduce potential losses; or increasing of insurance coverage of exposed elements that would enhance economic resilience; could be reflected in a future DDI evaluation for the country.

Table 4. Probable loss and pure premium for DDI and DDI' calculations

<i>L50</i>	2000	2005	2008
Total - Million US\$	126.2	138.3	164.1
Government - Million US\$	46.1	49.6	57.8
Poor - Million US\$	29.8	32.0	37.3
Total - %GDP	4.93%	4.47%	4.13%
Government - %GDP	1.80%	1.60%	1.46%
Poor- %GDP	1.16%	1.04%	0.94%
<i>L100</i>			
Total - Million US\$	327.8	358.1	423.4
Government - Million US\$	100.6	108.2	126.2
Poor - Million US\$	106.2	114.3	133.2
Total - %GDP	12.81%	11.58%	10.65%
Government - %GDP	3.93%	3.50%	3.17%
Poor- %GDP	4.15%	3.70%	3.35%
<i>L500</i>			
Total - Million US\$	2,302.3	2,499.6	2,939.0
Government - Million US\$	534.5	575.2	670.5
Poor - Million US\$	597.2	642.7	749.1
Total - %GDP	89.97%	80.84%	73.94%
Government - %GDP	20.89%	18.60%	16.87%
Poor- %GDP	23.34%	20.78%	18.85%
<i>Ly</i>			
Total - Million US\$	19.0	20.7	24.4
Government - Million US\$	5.0	5.3	6.2
Poor - Million US\$	3.3	3.6	4.1
Total - %GDP	0.7%	0.7%	0.6%
Government - %GDP	0.2%	0.2%	0.2%
Poor- %GDP	0.1%	0.1%	0.1%

Table 5 presents possible internal and external funds that the government needs to access at the time of the evaluation in order to face the losses in case of an extreme disaster. The sum of these available or usable possible funds corresponds to the economic resilience between 2000 and 2008 every five years. Based on these estimations (denominator of the indicator) the DDI was calculated for the different periods.

Table 5. Economic resilience, funds and resources for DDI calculations

Funds	2000	2005	2008
Insurance premiums - % GDP	3.0	3.3	3.3
Insurance/ reinsurance.50 - <i>F1p</i>	2.3	2.7	3.2
Insurance/ reinsurance.100 - <i>F1p</i>	6.3	7.3	8.7
Insurance/ reinsurance.500 - <i>F1p</i>	34.5	39.9	47.4
Disaster reserves - <i>F2p</i>	0.0	0.0	0.0
Aid/donations.50 - <i>F3p</i>	6.3	6.9	8.2
Aid/donations.100 - <i>F3p</i>	16.4	17.9	21.2
Aid/donations.500 - <i>F3p</i>	115.1	125.0	147.0
New taxes - <i>F4p</i>	0.0	0.0	0
Capital expenditure - % GDP	4.4	2.9	2.2
Budgetary reallocations. - <i>F5p</i>	67.1	53.2	52
External credit. - <i>F6p</i>	0.0	0.0	0.0
Internal credit - <i>F7p</i>	0.0	0.0	0.0
Inter-temp surplus. <i>d</i> *- % GDP	7.6	0.1	0.1
Inter-temp surplus. - <i>F8p</i>	193.7	3.7	0.6
RE.50			
Total - Million US\$	76	63	64
Total - %GDP	2.96%	2.03%	1.61%
RE.100			
Total - Million US\$	90	78	82
Total - %GDP	3.51%	2.54%	2.07%
RE.500			
Total - Million US\$	217	218	247
Total - %GDP	8.47%	7.05%	6.21%

DDI for 2008 was calculated based on the most recent available information on exposed elements, references of the built areas and their cost values. They have been established according to still tentative data and statistical information that may change in the future. In addition, the economic resilience (denominator of the index) was estimated in terms of GDP for each fund taking as reference economic information available for 2006 and 2007 due to current gaps; i.e. information that have not yet been incorporated in the databases. This means that the recent results of DDI may vary once the data is consolidated.

In conclusion, based on the results obtained, the country has become worse as the DDI values have been increasing along the years. Disasters in general, imply an obligation or non explicit contingent liability that can mean an impact to fiscal sustainability, given that most of the resources that government could access represent its own funds and new possible debts. In other words, government retains significant losses and its financing represent a high opportunity cost given other needs of investment and the country's existing budget restrictions.

3.2 PREVALENT VULNERABILITY INDEX (PVI)

PVI characterizes predominating vulnerability conditions reflected in exposure in prone areas, socioeconomic fragility and lack of social resilience; aspects that favour the direct impact and the indirect and intangible impact in case of the occurrence of a hazard event. This index is a composite indicator that depicts comparatively a situation or *pattern* in a country and its causes or factors. This is so to the extent that the vulnerability conditions that underlie the notion of risk are, on the one hand, problems caused by inadequate economic growth and, on the other hand, deficiencies that may be intervened via adequate development processes. PVI reflects susceptibility due to the level of physical exposure of goods and people, PVI_{ES} that favours direct impact in case of hazard events. It also reflects social and economic conditions that favour indirect and intangible impact, PVI_{SF} . And it reflects lack of capacity to anticipate, to absorb consequences, to efficiently respond and to recover, PVI_{LR} (IDEA 2005; Cardona 2005).

PVI varies between 0 and 100, a value of 80 means very high vulnerability, from 40 to 80 means high, from 20 to 40 is a medium value and less than 20 means low. In the new phase of the Program of Indicators, for the countries already evaluated, the PVI was calculated again for all the periods, as various values of the databases that were not known, are either currently available or have been modified as a result of revisions that were made after the previous evaluation of the index. Modifications in maximum and minimum reference values were also made for this new evaluation in order to standardize the values of the subindicators in a uniform manner for old and new countries evaluated.

3.2.1 Indicators of exposure and susceptibility

In the case of exposure and/or physical susceptibility, PVI_{ES} , the indicators that best represent this function are those that represent susceptible population, assets, investment, production, livelihoods, essential patrimony, and human activities. Other indicators of this type may be found with population, agricultural and urban growth and densification rates. These indicators are detailed below:

- ES1. Population growth, avg. annual rate, %
- ES2. Urban growth, avg. annual rate, %
- ES3. Population density, people (5 Km²)
- ES4. Poverty-population below US\$ 1 per day PPP
- ES5. Capital stock, million US\$ dollar/1000 km²
- ES6. Imports and exports of goods and services, % GDP
- ES7. Gross domestic fixed investment, % of GDP
- ES8. Arable land and permanent crops, % land area.

These indicators are variables that reflect a notion of susceptibility when faced with dangerous events, irrespective of the nature or severity of these. “To be exposed and susceptible is a necessary condition for the existence of risk”. Despite the fact that in any strict sense it would be necessary to establish if the exposure is relevant when faced with each feasible type of event, it is possible to assert that certain variables comprise a

comparatively adverse situation where we suppose that natural hazards exist as a permanent external factor, even without establishing precisely their characteristics.

3.2.2 Indicators of socio-economic fragility

Socio-economic fragility, PVI_{SF} , may be represented by indicators such as poverty, human insecurity, dependency, illiteracy, social disparities, unemployment, inflation, debt and environmental deterioration. These are indicators that reflect relative weaknesses and conditions of deterioration that would increase the direct effects associated with dangerous phenomenon. Even though such effects are not necessarily accumulative and in some cases may be redundant or correlated, their influence is especially important at the social and economic levels. Those indicators are the following:

- SF1. Human Poverty Index, HPI-1.
- SF2. Dependents as proportion of working age population
- SF3. Social disparity, concentration of income measured using Gini index.
- SF4. Unemployment, as % of total labour force.
- SF5. Inflation, food prices, annual %
- SF6. Dependency of GDP growth of agriculture, annual %
- SF7. Debt servicing, % of GDP.
- SF8. Human-induced Soil Degradation (GLASOD).

These indicators are variables that reflect, in general, an adverse and intrinsic ⁶ predisposition of society when faced with a dangerous phenomenon, irrespective of the nature and intensity of these events. “The predisposition to be affected” is a vulnerability condition although in a strict sense it would be necessary to establish the relevance of this affirmation when faced with all and individual feasible types of hazard. Nevertheless, as is the case with exposure, it is possible to suggest that certain variables reflect a comparatively unfavourable situation, supposing that the natural hazards exist as a permanent external factor irrespective of their exact characteristics.

3.2.3 Indicators of resilience (lack of)

The lack of resilience, PVI_{LR} , seen as a vulnerability factor, may be represented at all levels by means of the complementary or inverted⁷ treatment of a number of variables related to human development levels, human capital, economic redistribution, governance, financial protection, collective perceptions, preparedness to face crisis situations, and environmental protection. This collection of indicators on their own and particularly where they are disaggregated at the local level could help in the identification and orientation of actions that should be promoted, strengthened or prioritized in order to increase human security.

- LR1. Human Development Index, HDI [Inv]
- LR2. Gender-related Development Index, GDI [Inv]
- LR3. Social expenditure; on pensions, health, and education, % of GDP [Inv]

⁶ Also it is denominated as inherent vulnerability. It means, own socio-economic conditions of the communities that favour or facilitate the occurrence of effects on them.

⁷ The symbol [Inv] is used here to indicate a reverse or inverted dealing of the variable ($-R = 1 - R$).

- LR4. Governance Index (Kaufmann) [Inv]
- LR5. Insurance of infrastructure and housing, % of GD [Inv]
- LR6. Television sets per 1000 people [Inv]
- LR7. Hospital beds per 1000 people [Inv]
- LR8. Environmental Sustainability Index, ESI [Inv]

These indicators are variables that capture in a macro fashion the capacity to recover from or absorb the impact of dangerous phenomena, irrespective of their nature and severity. “To not be in the capacity to” adequately face disasters is a vulnerability condition, although in a strict sense it is necessary to establish this with reference to all feasible types of hazard. Nevertheless, as with exposure and fragility, it is possible to admit that certain economic and social variables reflect a comparatively unfavourable situation supposing that natural hazards exist as permanent external factors without establishing their precise characteristics.

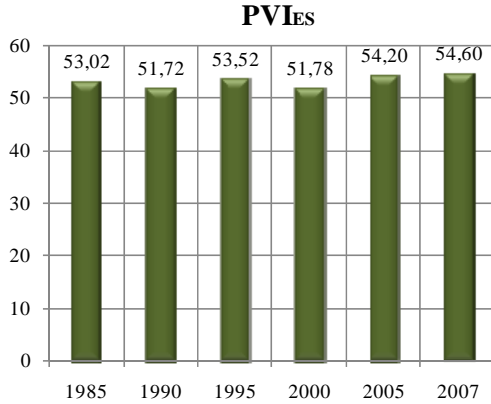
3.2.4 Estimation of indicators

In general, PVI reflects susceptibility due to the degree of physical exposure of goods and people, PVI_{ES} , that favour the direct impact in case of hazard events. In the same way, it reflects conditions of socioeconomic fragility that favour the indirect and intangible impact, PVI_{SF} . Also, it reflects lack of capacity to absorb consequences, for efficient response and recovering, PVI_{LR} . Reduction of these kinds of factors, as the purpose of the human sustainable development process and explicit policies for risk reduction, is one of the aspects that should be emphasized. Table 6 shows the total PVI and its components related to exposure and susceptibility, socio-economic fragility and lack of resilience. It is important to point out that, for participation of subindicators which do not have a recent value, we opted to use the same value in all periods, in order to avoid affecting relative value of indices and with the hope that in future the value of these subindicators will be published.

Table 6. PVI values

	1985	1990	1995	2000	2005	2007
PVI_{ES}	53,020	51,722	53,524	51,783	54,200	54,603
PVI_{SF}	30,989	29,934	33,751	25,223	25,550	25,036
PVI_{LR}	52,471	48,873	43,375	44,271	34,237	38,386
PVI	45,493	43,510	43,550	40,426	37,996	39,342

Figure 7 shows non scaled subindicators values that compose PVI_{ES} and their respective weights, which were obtained using Analytic Hierarchy Process (AHP).

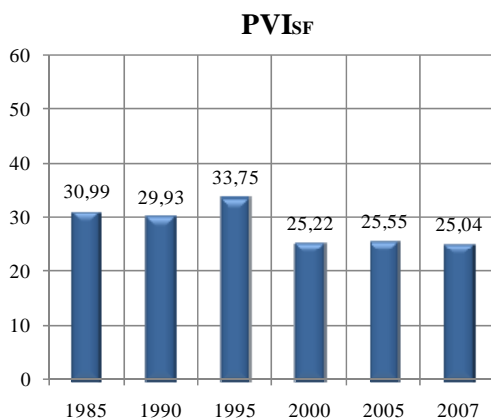


	1985	1990	1995	2000	2005	2007	W _{AHP}
ES.1	0,94	0,77	0,55	0,42	0,35	0,34	5,01
ES.2	-1,04	-1,23	1,60	1,41	1,45	1,57	12,37
ES.3	3023,28	3154,27	3254,97	3330,66	3394,57	3417,93	8,99
ES.4	19,09	18,02	19,01	15,14	11,90	11,90	25,39
ES.5	5634,06	6564,08	7950,70	8568,77	11414,30	13966,43	12,35
ES.6	127,82	100,83	118,22	107,51	117,77	117,77	11,71
ES.7	15,43	18,84	15,13	18,50	24,39	24,39	12,38
ES.8	39,53	39,53	39,53	39,53	39,53	39,53	11,82

Figure 7. PVI_{ES}

Vulnerability due to exposure and susceptibility in the country was relatively constant in every period. Slight decreases can be observed during 1990 and 2000. The changes for these years are the result of a decrease in some indicators such as the urban growth (ES2), which was negative for 1985, and then decreased further for 1990; the reduction in poverty population (ES4), which even had an important assigned weight and can have a significant influence on the total of the index; the imports and exports of goods and services (ES6), which presented a positive change from 1985 to 1990. Some of the subindices increased for 1995 but they decreased again for 2000. However, for the next years they presented some increases, although the ES4 which has an important weight decreased and the Capital Stock (ES5) had a notable decrease. There were other indicators such as ES6, the Gross Domestic fixed investment (ES7), the population density (ES3) and the urban growth (ES2) that increased for the next years, and in combination they represented a large portion of the weight that influenced the increase in the total index.

Figure 8 shows non scaled subindicators values that compose PVI_{SF} and their respective weights, which were obtained using Analytic Hierarchy Process (AHP).



	1985	1990	1995	2000	2005	2007	W _{AHP}
SF.1	3,00	3,00	3,00	3,00	3,00	3,00	20,91
SF.2	58,03	50,10	47,00	42,77	39,02	37,80	8,50
SF.3	47,66	48,51	57,07	49,84	51,72	51,30	16,40
SF.4	18,70	15,03	19,66	9,34	10,99	10,99	12,52
SF.5	3,92	3,07	1,88	2,44	6,08	4,03	9,44
SF.6	6,24	7,40	6,30	4,29	3,68	3,68	9,58
SF.7	5,65	8,20	5,65	5,65	3,10	3,10	9,63
SF.8	26,50	26,50	26,50	26,50	26,50	26,50	13,02

Figure 8. PVI_{SF}

Vulnerability due to socio-economic fragility in the country has a slight constant decrease over the period evaluated, with exception of 1995 where it increased, especially because of

the increase in social disparity (SF3) and unemployment (SP4). In the following years there was a decrease because of the decrease of the named subindicators and also of others such as the dependents as proportion of working age population (SF2), and dependency of GDP growth of agriculture (SF6). Human Poverty Index presents an important assigned weight but it had not changed during the period of evaluation, hence the reason why it did not have any influence on the total value of the index.

Figure 9 shows the figures of non scaled subindicators that compose PVI_{LR} and their respective weights, which were obtained using Analytic Hierarchy Process (AHP).

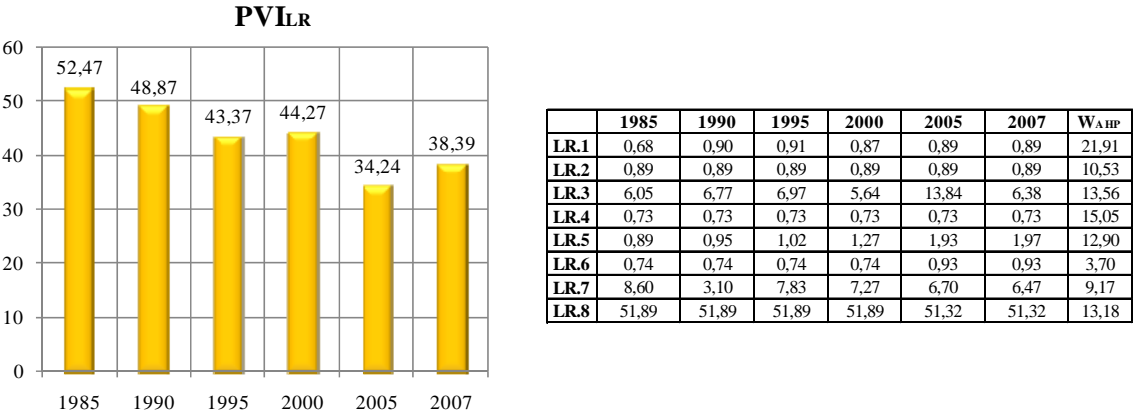


Figure 9. PVI_{LR}

Vulnerability due to lack of resilience is the complementary or inverted treatment of resilience or capacity, obtained for selected subindicators. In this case most of subindicators show relative steady values in all the periods. For this reason, a continued and slight decrease is detected in the PVI_{LR} ; this indicates resilience has been improving, with the exception of year 2000 in which a slight increase of the PVI_{LR} can be detected. In comparison to the other countries of the region, Barbados has a low vulnerability due to lack of resilience; nevertheless, the general indicator value is high and this is the indicator with more contribution to the country’s vulnerability.

Figure 10 shows total PVI obtained with average of its component indicators, and its aggregated presentation in order to illustrate their contributions.

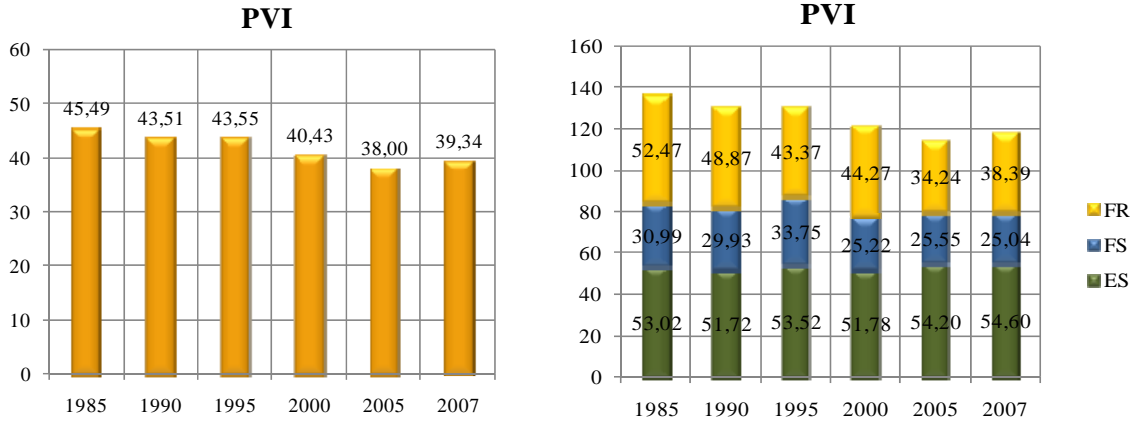


Figure 10. PVI

PVI figures illustrate a reduction in the prevalent vulnerability over the years until 2005; in 2007 it presented a slight increase of the vulnerability. The decrease from 1985 to 1990 was due to the reduction in the three components of the index. From 1995 to 2000 the decrease was due to the social fragility and to a lesser degree the exposure and susceptibility. And in 2005 it was due to the significant decrease of the lack of resilience. For 2007, the PVI increase, due to the growing of the lack of resilience. The growth in the index shows risk prevention-mitigation has been little considered, regarding both physical and socio-economic vulnerability reduction in the country. Comparing the three indicators, the lack of resilience is the indicator with the greatest contribution to prevalent vulnerability; a situation that also occurs in other countries in the region. In general, this indicator has the main incidence in developing countries.

PVI illustrates relationship between risk and development, either because the development model adopted reduces it or increases it. This aspect makes evident the convenience of explicit risk reduction measures; because development actions do not reduce vulnerability automatically. This evaluation can be useful to institutions related to housing and urban development, environment, agriculture, health and social care, and economics and planning, to mention a few.

3.3 RISK MANAGEMENT INDEX (RMI)

The main objective of the RMI is to measure the performance of risk management. This index is a qualitative measurement of risk based on pre-established levels (targets) or desirable references (benchmarking) towards which risk management should be directed, according to its level of advance. For RMI formulation, four components or public policies are considered: risk identification (RI), risk reduction (RR), disaster management (DM) and governance and financial protection (FP).

Estimation of each public policy takes into account six subindicators that characterize the performance of management in the country. Assessment of each subindicator is made using five performance levels: *low*, *incipient*, *significant*, *outstanding* and *optimal*, that corresponds to a range from 1 to 5, where 1 is the lowest level and 5 the highest. This methodological focus allows using each reference level simultaneously with the “performance objective” and,

thus, allows the comparison and identification of results or achievements, towards which governments should direct their efforts of formulation, implementation and evaluation of policies in each case.

Once performance levels of each subindicator have been evaluated, through a non-linear aggregation model, the value of each component of RMI is determined (IDEA 2005; Cardona 2005). The value of each composed element is between 0 and 100, where 0 is the minimum performance level and 100 is the maximum level. The total RMI is the average of the four composed indicators that represent each public policy. When the value of the RMI is high, performance of risk management in the country is better.

3.3.1 Institutional Organisation

The Central Emergency Relief Organization (CERO) is the national multi-sectoral coordinator, responsible for activating the national disaster plan. It is composed by a National Disaster Committee, an Emergency Operations Center, Emergency Management Teams, government ministries and departments, NGOs, Sectoral Standing Committees and District Emergency Organisations.

Risk analysis, prevention, preparedness and response plans are responsibility of the National Disaster Committee, and, each District Emergency Organisation of the 30 political constituencies provide education and training and develop plans for initial emergency response.

A specific national code is being designed and a Barbados Building Authority is being set up in order to monitor and enforce the code that is currently used as the national model: The Caribbean Uniform Building Code. Some hazard mapping has been conducted, yet updating remains a challenge. Vulnerability and capacity assessments have been done for shelters, police stations, fire stations and hospitals. As for early warning, the meteorological office serves as a weather systems monitor and flood gauges have been established in areas at risk. Likewise, the Barbados Government Information Service facilitates the public awareness programme on national disaster management. Other public awareness initiatives are being undertaken by mass media institutions as well as schools. Disaster education programs exist at primary and secondary level, regularly aided by presentations from disaster agencies. (Source: ISDR/the Americas)

3.3.2 Indicators of risk identification

The identification of risk generally includes the need to understand individual perceptions and social representations and provide objective estimates. In order to intervene in risk it is necessary to recognize its existence⁸, dimension it (measurement) and represent it, for example by means of models, maps and indices that are significant for society and decision makers. Methodologically, it includes the evaluation of hazards, the different aspects of

⁸ That is to say, it has to be a problem for someone. Risk may exist but not perceived in its real dimensions by individuals, decision makers and society in general. To measure or dimension risk in an appropriate manner is to make it apparent and recognized, which in itself means that something has to be done about it. Without adequate identification of risk it is impossible to carry out anticipatory preventive actions.

vulnerability when faced with these hazards and estimations as regards the occurrence of possible consequences during a particular exposure time. The measurement of risk seen as a basis for intervention is relevant when the population recognizes and understands that risk. The indicators that represent risk identification, RI, are the following:

- RI1. Systematic disaster and loss inventory
- RI2. Hazard monitoring and forecasting
- RI3. Hazard evaluation and mapping
- RI4. Vulnerability and risk assessment
- RI5. Public information and community participation
- RI6. Training and education on risk management

3.3.3 Indicators of risk reduction

Risk management aims particularly to reduce risk. In general, this requires the execution of structural and non structural prevention-mitigation measures. It is the act of anticipating with the aim of avoiding or diminishing the economic, social and environmental impact of potentially dangerous physical phenomena. It implies planning processes but, fundamentally, the execution of measures that modify existing risk conditions through corrective and prospective interventions of existing and potential future vulnerability, and hazard control when feasible. The indicators that represent risk reduction, RR, are the following:

- RR1. Risk consideration in land use and urban planning
- RR2. Hydrological basin intervention and environmental protection
- RR3. Implementation of hazard-event control and protection techniques
- RR4. Housing improvement and human settlement relocation from prone-areas
- RR5. Updating and enforcement of safety standards and construction codes
- RR6. Reinforcement and retrofitting of public and private assets

3.3.4 Indicators of disaster management

Disaster management should provide appropriate response and recovery post disaster and depends on the level of preparation of operational institutions and the community. This public policy searches to respond efficiently and appropriately when risk has been materialized and it has not been possible to impede the impact of dangerous phenomena. Effectiveness implies organization, capacity and operative planning of institutions and other diverse actors involved in disasters. The indicators that represent the capacity for disaster management, DM, are the following:

- DM1. Organization and coordination of emergency operations
- DM2. Emergency response planning and implementation of warning systems
- DM3. Endowment of equipments, tools and infrastructure
- DM4. Simulation, updating and test of inter institutional response
- DM5. Community preparedness and training
- DM6. Rehabilitation and reconstruction planning

3.3.5 Indicators of governance and financial protection

Governance and financial protection is fundamental for the sustainability of development and economic growth in a country. This implies, on the one hand, coordination between different social actors that necessarily are guided by different disciplinary approaches, values, interests and strategies. Effectiveness is related to the level of interdisciplinarity and integration of institutional actions and social participation. On the other hand, governance depends on an adequate allocation and use of financial resources for the management and implementation of appropriate strategies for the retention and transference of disaster losses. The indicators that represent governance and financial protection, FP, are the following:

- FP1. Interinstitutional, multisectoral and decentralizing organization
- FP2. Reserve funds for institutional strengthening
- FP3. Budget allocation and mobilization
- FP4. Implementation of social safety nets and funds response
- FP5. Insurance coverage and loss transfer strategies of public assets.
- FP6. Housing and private sector insurance and reinsurance coverage

3.3.6 Estimation of indicators

RMI results have been obtained from detailed surveys designed for experts and representatives of different institutions related to risk management. Thus, this index reflects performance of risk management based on evaluations of academic, professional and officials of the country. Results for 1995, 2000, 2005 and 2008 are presented.

Table 7 shows total RMI and its components, for each period. These are risk identification, RMI_{RI} ; risk reduction, RMI_{RR} ; disaster management, RMI_{DM} ; and governance and financial protection, RMI_{FP} .

Table 7. RMI values

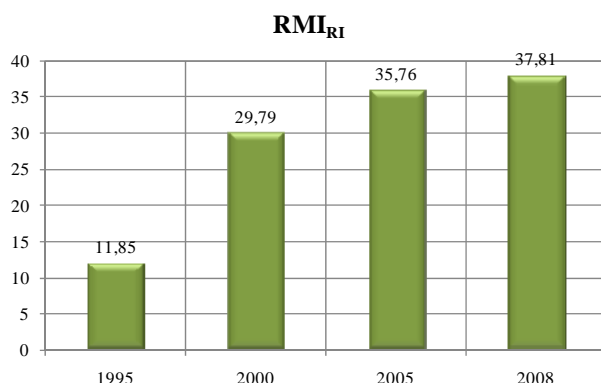
Index	1995	2000	2005	2008
RMI_{RI}	11,85	29,79	35,76	37,81
RMI_{RR}	17,21	38,78	38,78	50,61
RMI_{DM}	13,61	35,46	55,41	55,41
RMI_{FP}	5,25	11,35	13,65	35,78
RMI	11,98	28,84	35,9	44,9

Figure 11 shows the qualification of subindicators⁹ which composed RMI_{RI} and its respective weights, obtained using Analytic Hierarchy Process (AHP).

Management related to risk identification has an important and progressive advance from 1995 to 2008. It can be observed that the country had an improvement from incipient to significant level in systematic disaster and loss inventory (RI1), hazard evaluation and mapping (RI3) and vulnerability and risk assessment (RI4). The hazard monitoring and forecasting (RI2) and the public information and community participation (RI5) subindicators

⁹ Qualification is linguistic and it does not use defined numbers. With reference to the tables: 1: *low*, 2: *incipient*, 3: *significant*, 4: *outstanding* and 5: *optimal*.

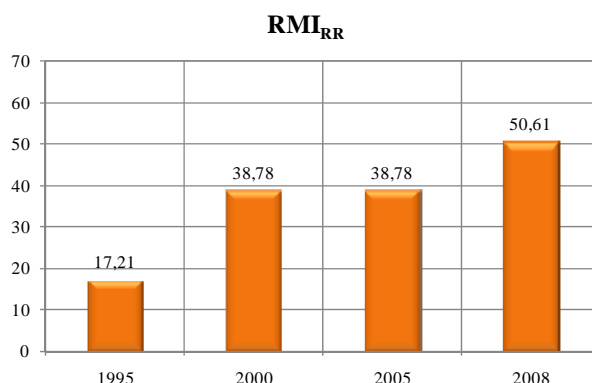
have progressed from incipient to significant level and in training and education in risk management (RI6) passed from low to incipient.



	1995	2000	2005	2008	Weight
RI1	1	2	3	3	13,56
RI2	2	2	3	3	18,14
RI3	1	2	2	3	15,06
RI4	1	2	2	3	20,95
RI5	2	3	3	3	15,13
RI6	1	1	2	2	17,16

Figure 11. RMI_{RI}

Figure 12 shows qualification of subindicators which composed RMI_{RR} and its respective weights, obtained using Analytic Hierarchy Process (AHP).



	1995	2000	2005	2008	Weight
RR1	2	3	3	3	27,19
RR2	2	3	3	3	16,44
RR3	2	3	3	4	10,13
RR4	2	2	3	3	13,65
RR5	2	2	2	3	18,58
RR6	2	2	3	3	14,01

Figure 12. RMI_{RR}

Management related to risk reduction indicates that the country had an important progress from 1995 to 2000 due to the changes from incipient to significant in the performance level in actions such as risk consideration in land use and urban planning (RR1), hydrographic basin intervention and environmental protection (RR2) and implementation of hazard-event control and protection techniques (RR3). Also, this notable progress in these years can be due to the important weights (more than 50 of the total index) that RR1 and RR2 have. Between 2000 and 2005 there were no changes in the public policy of risk reduction management although there were some advances from incipient to significant in housing improvement and human settlement relocation from prone-areas (RR4) and reinforcement and retrofitting of public and private assets (RR6). In 2008 the RMI_{RR} advanced especially due to the change of the performance level that moved from significant to outstanding in the implementation of hazard-event control and protection techniques (RR3) and from incipient to significant in the updating and enforcement of safety standards and construction codes (RR6).

Figure 13 shows qualification of subindicators which composed RMI_{DM} and its respective weights, obtained using Analytic Hierarchy Process (AHP).

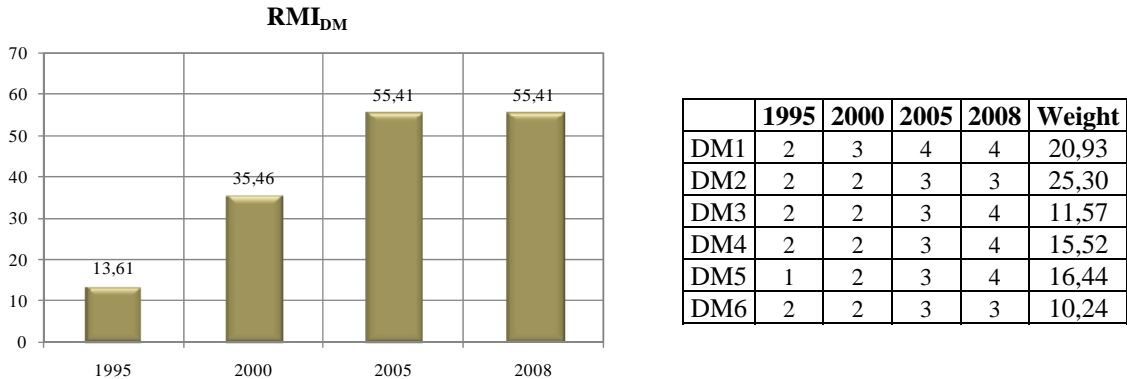


Figure 13. RMI_{DM}

Management related to disaster management indicates important progress in the country over the years evaluated. Notable changes can be observed in all the indicators from 1995 to 2008. From 1995 to 2000 the reason of this improvement is due to the increased of level from incipient to significant of the organization and coordination of emergency operations (DM1) and from low to incipient of the community preparedness and training (DM5). The 2005 advance is due to the fact that all the subindicators passed from incipient performance level to significant with the exception of the organization and coordination of emergency operations that reflected an outstanding advance. In 2008 there were improvements from significant to outstanding of the endowment of equipments, tools and infrastructure (DM3), simulation, updating and test of interinstitutional response (DM4) and community preparedness and training (DM5).

Figure 14 shows qualification of subindicators qualifications which composed RMI_{FP} and its respective weights, obtained using Analytic Hierarchy Process (AHP).

Management related to financial protection and governance has also showed notable changes from 1995 to 2008. The most notable improvement has been from 2005 to 2008 because the interinstitutional, multisectoral and decentralizing organization (FP1) and housing and private sector insurance and reinsurance coverage (FP6) reached a significant performance level. The reserve funds for institutional strengthening (FP2), implementation of social safety nets and funds response (FP4) and insurance coverage and loss transfer strategies of public assets (FP5) achieved an incipient performance level in 2008 while they presented a low level in 1995. The only indicator that did not present any progress during the years of study was the budget allocation and mobilization (FP3) that remain at a low level of performance.

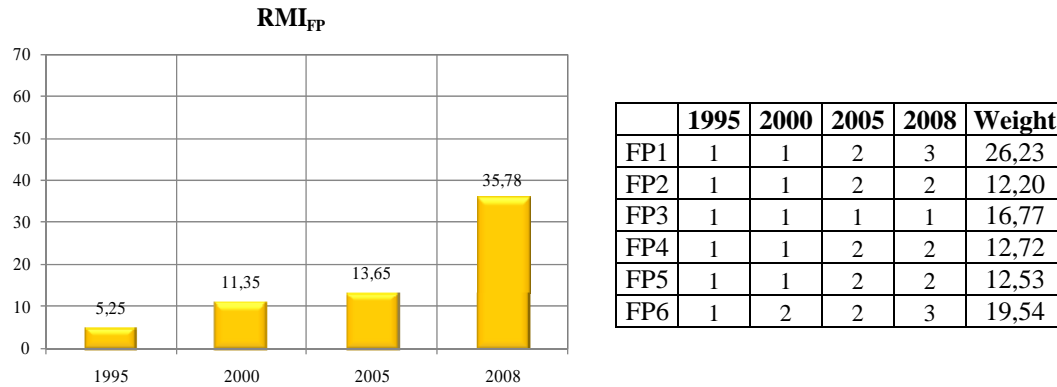


Figure 14. RMI_{FP}

Figure 15 shows the total RMI value obtained from the average of the component indicators and its aggregated version with the objective of illustrating their contributions.

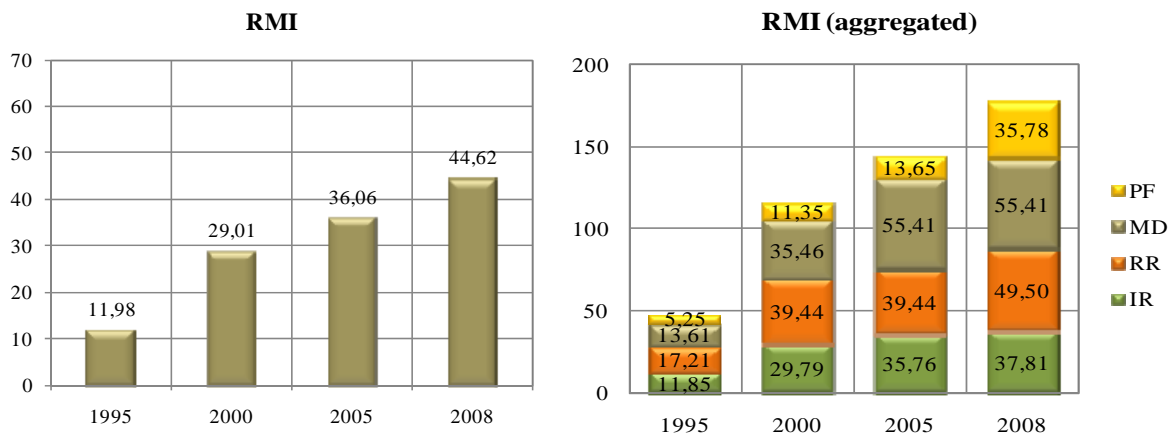


Figure 15. Total RMI

In the RMI graphics it is possible to observe that disaster risk management, in general, had a gradual progress since 1995 to 2008. Indicators which vary more considerably in the first years were the RMI_{RI} of risk identification, RMI_{RR} of risk reduction and RMI_{DM} of disaster management. From 2000 to 2005 there was a slighter increase than in 2000 with the exception of the RMI_{DM} that presented a notable improvement. And in 2008 the RMI of financial protection and risk reduction improved and showed a higher performance in comparison to previous years. Progressive variation in the RMI illustrates a general advance of the country in risk management and it is superior, in comparison, to the majority of the countries of the region. Nevertheless, the country's average RMI represents a current significant level of performance, as can be deduced from the value of 45 in the Figure 15. This implies there is still much work to do in order to achieve sustainability in risk management at high performance levels.

Table 8 presents, in a more illustrative form, the changes of the performance levels of the indicators that composed the aspects of the four policies related to risk management, between the first and the last period.

Table 8. Differences between first and last period for RMI subindicators functions performance

Values of the performance functions of subindicators

1995	RI.	5	RR.1	17	DM.1	17	FP.1	5
	RI.	17	RR.2	17	DM.2	17	FP.2	5
	RI.	5	RR.3	17	DM.3	17	FP.3	5
	RI.	5	RR.4	17	DM.4	17	FP.4	5
	RI.	17	RR.5	17	DM.5	5	FP.5	5
	RI.	5	RR.6	17	DM.6	17	FP.6	5
	R	11.85	RMI _{RR}	17.21	RMI _{DM}	13.61	RMI _{FP}	5.25
	R	11.98						

2008	RI.	45	RR.1	45	DM.1	77	FP.1	45
	RI.	45	RR.2	45	DM.2	45	FP.2	17
	RI.	45	RR.3	77	DM.3	77	FP.3	5
	RI.	45	RR.4	45	DM.4	77	FP.4	17
	RI.	45	RR.5	45	DM.5	77	FP.5	17
	RI.	17	RR.6	45	DM.6	45	FP.6	45
	R	37.81	RMI _{RR}	49.5	RMI _{DM}	55.41	RMI _{FP}	35.78
	R	44.62						

Change	RI.	40	RR.1	28	DM.1	60	FP.1	40
	RI.	28	RR.2	28	DM.2	28	FP.2	12
	RI.	40	RR.3	60	DM.3	60	FP.3	0
	RI.	40	RR.4	28	DM.4	60	FP.4	12
	RI.	28	RR.5	28	DM.5	72	FP.5	12
	RI.	12	RR.6	28	DM.6	28	FP.6	40
	R							
	R	32.64						

In summary, Table 8 shows that during the period 1995-2008 there were important developments in risk management in Barbados. The indicator that reflected the greatest improvements was the disaster management (DM) with the best progress in community preparedness and training (DM5), but also significant evolution in organization and coordination of emergency operations (DM1), endowment of equipments, tools and infrastructure (DM3) and simulation, updating and test of inter institutional response (DM4).

The other index with notable changes was the risk reduction that showed changes of 60 in implementation of hazard-event control and protection techniques (RR3). The other indicators that compose the risk reduction index showed changes of 28.

The indicators related to risk identification (RI) and governance and financial protection (FP) had a lower advance than the two previously mentioned. Some indicators such as the systematic disaster and loss inventory (RI1), hazard evaluation and mapping (RI3), vulnerability and risk assessment (RI4), interinstitutional, multisectoral and decentralizing

organization (FP1) and housing and private sector insurance and reinsurance coverage (FP6) showed a growth of 40. The others showed a lower increase and only the budget allocation and mobilization did not show any change in the period of time evaluated.

4 CONCLUSIONS

DDI illustrates economic implications of a major disaster, estimated on the basis of the potential of feasible extreme events; LDI identifies social and environmental risk as a result of the recurrence of small events; PVI accounts for susceptibility and aggravation factors of the direct effects of the disasters due to deficiencies in development; and RMI indicates what has been achieved and what needs to be done in order to improve risk management.

From these results it is possible to conclude that in Barbados there was an increase of the DDI and an increase in the PVI except from 2005 to 2008. The RMI from 2000 is better than before and based on these results it is possible to conclude that Barbados has a better disaster risk performance. Notwithstanding, the effectiveness of risk management is incipient and therefore it is necessary to improve the capacity to anticipate, to cope and to recover.

Making the comparison of trends in indicators it is possible to conclude that the system of indicators presents results generally consistent or appropriate to the reality of the country. In any case, it is important to disaggregate these indicators and identify areas where improvements can be made through actions, projects and specific activities by the central government with the participation of different sectoral agencies, parishes and communities; and thus achieve further progress and greater sustainability. Decision makers and stakeholders, besides identifying the weaknesses as reflected in the indicators, must take into account other characteristics that are not revealed or expressed by the evaluation presented. Indicators provide a situational analysis from which it is possible to extract a set of actions that must be done without details for a strategic plan, which should be the next step. The aim of the indicator system is to assist in the formulation of general recommendations for planning.

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APPENDIX I

NATURAL HAZARDS OF THE COUNTRY

Barbados is exposed to few natural hazards. The island is located in the southern portion of the Caribbean and hurricanes are not a great threat. However, Barbados is brushed by tropical depressions, tropical storms or hurricanes every 3.07 years. Hurricane Lily was the most recent in September 2002 that passed to the south of the island blowing the roofs off some 135 houses. During the last century, Barbados has been hit by five systems, the most devastating being Hurricane Janet in 1955, which killed 35 people, destroyed 8,100 homes and left 20,000 homeless.

However, the effects of hurricanes and tropical storms such as wind damage, inland flooding and coastal surge are still of concern. Some areas of the island are prone to landslides. In addition, Barbados has experienced periods of drought and soil erosion is an issue. Fresh water shortage and sea level rise are also of concern to the country.

The island is also prone to manmade hazards such as hazardous waste. Illegal solid waste disposal threatens to contaminate aquifers. The pollution of coastal waters from waste disposal by ships is an issue. Oil spills are considered to be a major threat because of the importance of the environment to tourism and the economy.

The active submarine volcano, Kick 'em Jenny, located 9 km northeast of Grenada, and about 260 km (100 miles) southwest of Barbados poses a threat of tsunamis, which is of great concern to Barbados.

AI.1 SEISMIC HAZARD

Seismic events in the Eastern Caribbean are principally associated with a subduction zone at the junction of the Caribbean Plate and the North American Plate. The North American Plate dips from east to west beneath the Caribbean Plate along a north-south line just east of the main island arc. This leads to a moderate level of inter-plate seismicity. Superimposed on this is a pattern of intra-plate activity. There is a concentration of such activity in the Leeward Islands where the subduction of the Barracuda Rise imposes additional stresses on both the "subducted" North American Plate and the overriding Caribbean Plate. The earthquakes there are generally shallow. In the region north-west of Trinidad there is another concentration of earthquake activity where the strike of the plate boundary changes direction. These earthquakes are of intermediate depth.¹⁰

Figure A.1. shows a seismic hazard map for Barbados with a 10% probability of exceedance in 50 years.

¹⁰ Organization of American States, OAS <http://www.oas.org/pgdm>

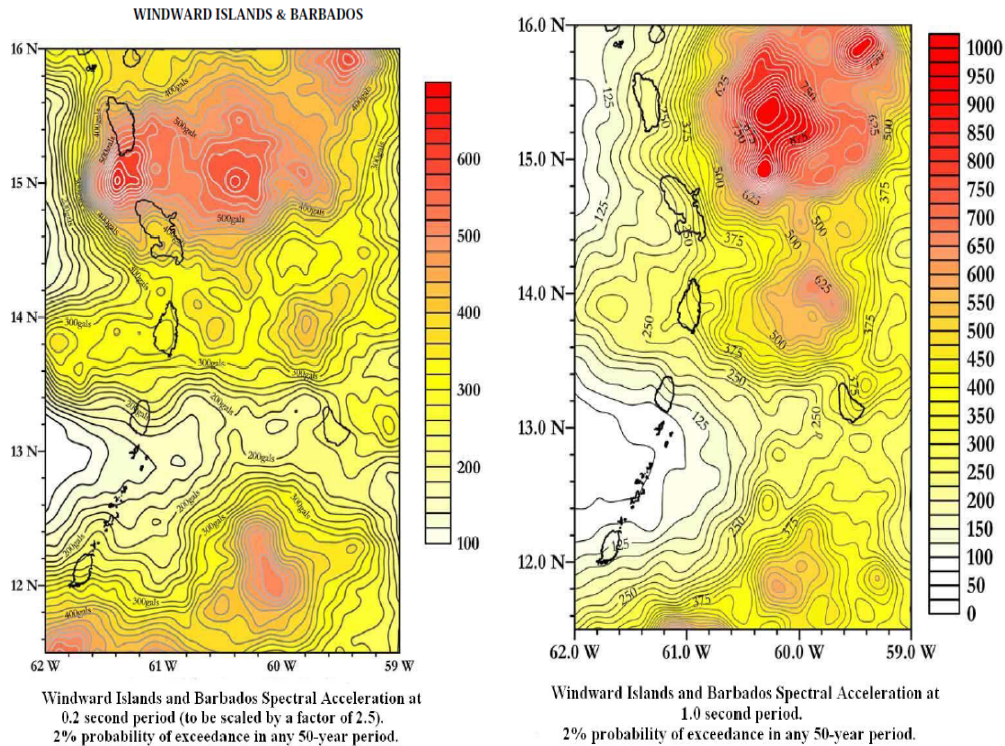


Figure A.1 Seismic hazard map. Source: University of the West Indies¹¹

AI.2 TSUNAMI HAZARD

In the past 500 years there have been ten confirmed earthquake-generated tsunamis in the Caribbean Basin, with four causing fatalities. An estimated 350 people in the Caribbean were killed by these events.

All known sources capable of causing tsunamis occur within striking distance of the Eastern Caribbean, and there are also distant sources across the Atlantic. Since the islands lie in an area of relatively high earthquake activity for the Caribbean, the most likely tsunamis to affect the region are those which can be triggered by shallow earthquakes (<50km depth), in the region, greater than magnitude 6.5. The recurrence rate for tsunamis in the Caribbean is approximately one destructive tsunami per century for local earthquakes and one destructive tsunami per 200 years for distant earthquakes.¹²

AI.3 VOLCANIC HAZARD

Several of the islands of the Eastern Caribbean are volcanic in origin. The volcanoes there are considered to be either active or dormant. There are 19 'live' (likely to erupt again) volcanoes in the Eastern Caribbean. Every island from Grenada to Saba is subject to the direct threat of volcanic eruptions (see map below). Islands such as Grenada, St. Vincent,

¹¹ The University of the West Indies, Seismic Research Center. www.uwiseismic.com

¹² The University of the West Indies. <http://www.uwiseismic.com>

St. Lucia, Martinique, Dominica, Guadeloupe, Montserrat, Nevis, St. Kitts, St. Eustatius and Saba have 'live' volcanic centers, while other islands such as Anguilla, Antigua, Barbuda, Barbados, British Virgin Islands, most of the Grenadines and Trinidad & Tobago (which are not volcanic) are close to volcanic islands and are, therefore, subject to volcanic hazards such as severe ash-fall and volcanically-generated tsunamis.¹³

AI.4 HYDROMETEOROLOGICAL HAZARDS

The official hurricane season in the Greater Caribbean region begins the first of June and lasts through November 30, with 84 percent of all hurricanes occurring during August and September. The greatest risk in Mexico and the western Caribbean is at the beginning and end of the season, and in the eastern Caribbean during mid-season.

The figures A.2 and A.3 show the tropical cyclone tracks for August and September in the Caribbean region. Every year over 100 tropical depressions or potential hurricanes are monitored, but an average of only ten reach tropical storm strength and six become hurricanes. These overall averages suggest that activity is uniform from year to year but historical records indicate a high degree of variance, with long periods of tranquility and activity.

Hurricanes are by far the most frequent hazardous phenomena in the Caribbean. In the last 250 years the West Indies has been devastated by 3 volcanic eruptions, 8 earthquakes, and 21 major hurricanes. If tropical storms are also taken into account, the Greater Caribbean area has suffered from hundreds of such events.¹⁴

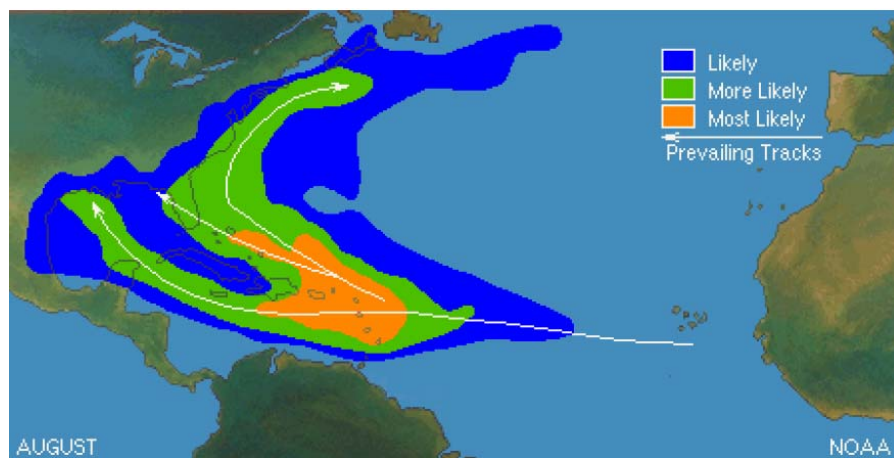


Figure A.2 Tropical cyclone tracks for August in the Caribbean region. Source: National Oceanic Atmospheric Administration

¹³ Seismic Research Center, The University of the West Indies. <http://www.uwiseismic.com>

¹⁴ Organization of American States, OAS. Department of Sustainable Development. <http://www.oas.org/dsd>

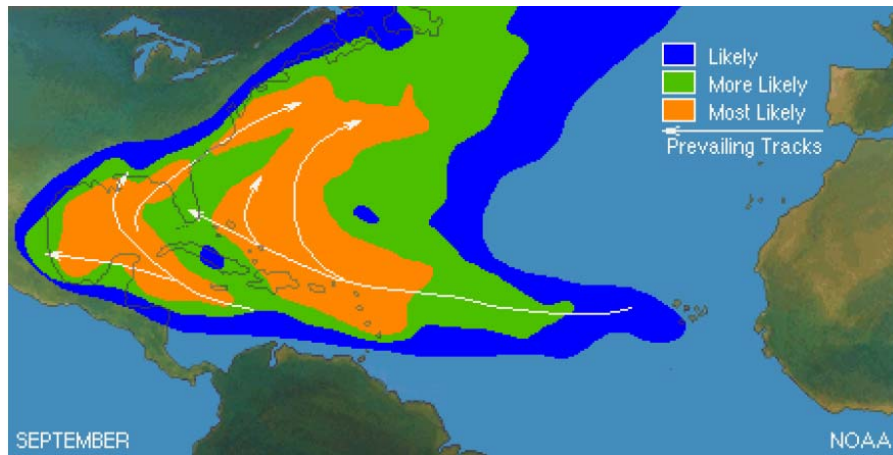


Figure A.3 Tropical cyclone tracks for September in the Caribbean region. Source: National Oceanic Atmospheric Administration

AI.5 LANDSLIDES

Small-scale land sliding is associated with coastal escarpments where instability results from undercutting by wave-action. However, the principal landslide activity on Barbados is confined to the Scotland District on the northeast part of the island.

Earth flows, slumps, and debris flows are the main landslide types present in the Scotland District. They are directly related to the response of clay present in the Joes River Formation and Scotland Beds. Where this clay is present in significant quantities, the landslides tend to exhibit a greater tendency for flowage. Failures occur when the clay-rich soil experiences a decrease in strength resulting from increased pore-water pressure. Increased pore-water pressure may be in direct response to intense rainfall. In other instances, pore-water pressure builds on perched water tables associated with the bedding within the bedrock or older clay-sealed slip surfaces.

Economic impacts attributable to landslides are limited to the Scotland District. Roads within the Scotland District incur damage where undermined by failing slopes and blocked by displaced slide material. Agriculture is the other primary economic impact. Ground cracking, scarps, and gully development are some of the consequences of landslides which render land unusable for farming. Other locations are threatened by active landslides. Concern is expressed for yet other areas where the circumstances associated with active landslides are present but no land sliding is evident.¹⁵

¹⁵ Department of Geography and Geology, The University of the West Indies at Mona, Jamaica. <http://www.mona.uwi.edu>