CHAPTER 1

NATURAL HAZARDS AND DEVELOPMENT

1.1 Introduction

The idea of writing this book originated during the occurrence of a sequence of natural disasters on the island of Luzon (Philippines). These included the July 1990 earthquake, the June 1991 Mount Pinatubo eruption and the related primary and secondary effects. The two disasters, their consequences on the economy of the Philippines and the lessons learned are described in detail.

An important aspect of the book is the connection between disasters, human development and the environment. Human activities in general have a major change potential on the troposphere and their influence is unique since it consists of a multitude of local impacts simultaneously affecting a wide range of natural realms. Human use and manipulation of environment and resources can significantly alter natural processes and aggravate the impact of extreme natural phenomena.

An example of how anthropic activities can cause major environmental change has been provided by Crosby (1992) in his research on the biological and cultural consequences (and vice-versa) of the European colonization of the Americas. In the case of the Philippines the widespread deforestation during the last decades in Luzon heavily contributed to some of the devastating effects of the 1990-91 disasters.

Description and analysis of the natural phenomena that occurred in Luzon, their strict sequence and effects on human beings, property and the country's economy should help researchers, geoscientists, decision makers, administrators and planners in various ways. Through the description of the 1990-91 geological events and the impacts associated with them, this book should contribute to enhance the knowledge on natural disasters and improve society's response to them. It seeks also to draw special attention to the need for the introduction of natural hazard assessment and mitigation measures into the development planning process as a major step in risk reduction.

The general framework of disasters, as well as interactions with the present global crisis are described in Chapter 1. Past disasters in the Philippines and recent events in Luzon are summarized in Chapter 2. Tectonics and Geology of Luzon, with emphasis on aspects directly related to the recent disasters, are described in Chapter 3. Chapters 4, 5, 6 and 7 deal with the 1990 earthquake, liquefaction in the Central Plain, landslides in Central Cordillera and Caraballo Mountains, and the aftershock swarm, in that sequence. Chapter 8 is devoted to the Pinatubo eruption and its consequences in Central Luzon. Chapter 9 gives an overview of damage caused by the events of 1990-1991 and their effects on the economy of the Philippines. Chapter 10 describes the lessons learned from Luzon's disasters, focusing on general as well as on specific aspects.

1.2 Extreme phenomena and natural disasters

Extreme natural phenomena may occur anywhere in the world and every area of the planet has probably been affected by some of them during part of its geological history. When extreme events take

place in a populated area they are referred to as hazards and termed disasters if they cause numerous casualties, widespread human suffering and considerable property damage. According to UNESCO a disaster occurs when a natural hazard seriously disrupts the functioning of a community, causing widespread human, material and environmental losses that exceed the community's capability to cope without external relief. As the human population increases disasters became more frequent.

Various natural phenomena that turn into disasters are characterized by the occurrence of isolated peak-events, in comparison to the regular magnitude and frequency of the majority of episodes of the same nature: typical is the case of a strong earthquake with a recurrence period of centuries for instance, compared to the myriad of small and harmless tremors that normally hit the same area. Most common disasters include earthquakes, volcanic eruptions, tsunamis, landslides, windstorms, floods, droughts, wildfires, insect infestation and the gradual but progressive degradation of natural resources. Some of them occur suddenly, others are advanced by early signs, others take place slowly.

The majority of earthquakes, tsunamis, and floods belong to the first group (the July 1990 quake, for example, struck Luzon suddenly). The 1991 eruption of Pinatubo, which belongs to the second group, was heralded a few months earlier by premonitory signs, thus the volcanic district was under observation long before the critical episode. A number of disasters, by contrast, belong to the third group since they display their effects during long timespans. Prolonged drought, or the progressive degradation of the land at a regional level, due to deforestation, soil erosion, and inappropriate land use, are typical examples.

Compared to natural phenomena that can recur after decades ar centuries (for example strong earthquakes), some disasters related to climate are characterized by short return periods. Typhoons hit tropical regions with frequencies estimated in years, increasingly provoking disasters as the affected areas become more densely populated and human activities more widespread.

Disasters are characterized by primary effects and in many cases they also have secondary, medium to long-term consequences. The primary effect of the Mount Pinatubo 1991 eruption in the Philippines consisted of the deposition of a vast ash blanket throughout Central Luzon with severe consequences for human activities and for the natural environment. The secondary medium- to long-term impacts were caused by devastating mudflows during the rainy seasons that followed the eruption. In this case the secondary effects were less destructive than the eruption, but the damage to agricultural and other productive activities induced by the recurring mudflows has continued for years.

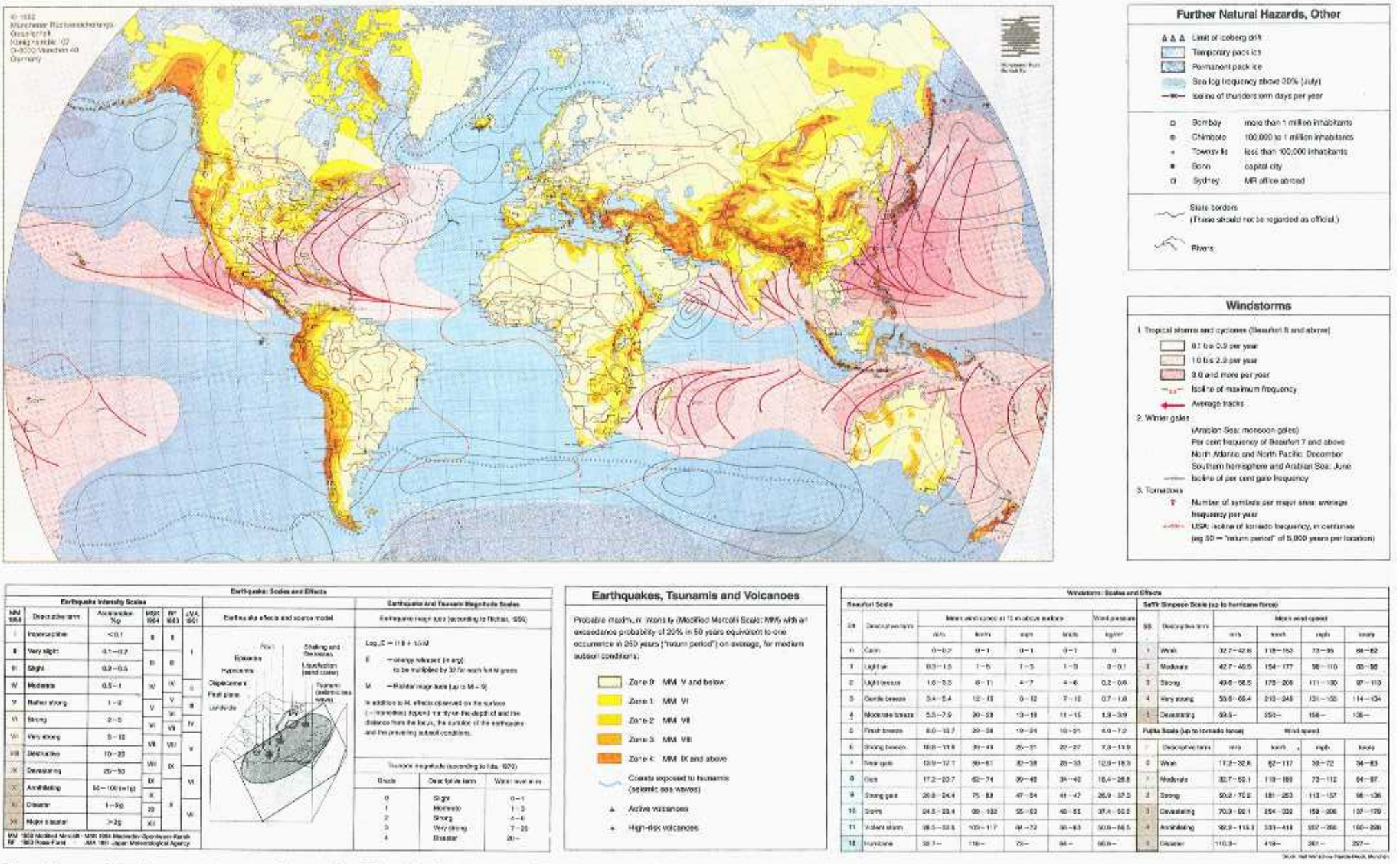
Climate, geological phenomena and their combined effects are sources of disasters in numerous areas of the planet. In this context, the Caribbean and the Philippine-Indonesia regions share a most hazardous location.

Figure 1.1 shows a world map of natural hazards (1988), classed as two groups: the first includes earthquakes, tsunamis and volcanic eruptions (related to lithosphere dynamics), the second consists of tropical storms and cyclones, winter gales and tornadoes (related to climate). The map appears to over-emphasize the zone affected by tropical cyclones, since most of the area in violet is ocean where the population is minimal; by contrast, it does not portray flood and drought hazards, which affect many more people than cyclones and earthquakes do.

Natural hazards are not likely to change in the near future, thus their destructive potential will definitely increase. United Nations predictions indicate that by the year 2000 there will be worldwide 31 megacities of over 8 million people and 67 smaller cities with 2.5 to 8 million people. The on-going massive urbanization and industrialization processes are likely to increase the vulnerability of populations and human activities in the areas at risk.

1.3 Disasters and developing countries

The cost of the damage caused by natural disasters, which was estimated at about US$ 400 million during the 1950-1959 period, increased ninety times to 36 billion in the decade 1980-1989 (World Bank, 1990).



Earthquakes: Scales and Effects

Earthquake Intensity Scales

MM 1964	Descriptive term	Acceleration %g	MSK 1964	RF 1963	JMA 1951
I	Imperceptible	<0.1	I	I	0
II	Very slight	0.1–0.7	II	II	I
III	Slight	0.3–0.5	III	III	
IV	Moderate	0.5–1	IV	IV	II
V	Rather strong	1–2	V	V	III
VI	Strong	2–5	VI	VI	IV
VII	Very strong	5–10	VII	VII	V
VIII	Destructive	10–20	VIII	VIII	
IX	Devastating	20–50	IX	IX	VI
X	Annihilating	50–100 (=1g)	X	X	
XI	Disaster	1–2g	XI	XI	VII
XII	Major disaster	>2g	XII	XII	

MM = 1902 Modified Mercalli · MSK 1964 Medvedev-Sponheuer-Karnik
RF = 1963 Rossi-Forel · JMA 1951 Japan Meteorological Agency

Earthquake effects and source model

Earthquake and Tsunami Magnitude Scales

Earthquake magnitude (according to Richter, 1956)

$\log_{10} E = 11.8 + 1.5\,M$

E = energy released (in erg) to be multiplied by 32 for each full M given

M = Richter magnitude (up to M = 9)

In addition to M, effects observed on the surface (= intensities) depend mainly on the depth of and the distance from the focus, the duration of the earthquake and the prevailing subsoil conditions.

Tsunami magnitude (according to Iida, 1970)

Grade	Descriptive term	Wave height in m
0	Slight	0–1
1	Moderate	1–3
2	Strong	3–6
3	Very strong	7–20
4	Disaster	20–

Earthquakes, Tsunamis and Volcanoes

Probable maximum intensity (Modified Mercalli Scale: MMI) with an exceedance probability of 20% in 50 years equivalent to one occurrence in 250 years ("return period") on average, for medium subsoil conditions:

Zone 0: MMI V and below
Zone 1: MMI VI
Zone 2: MMI VII
Zone 3: MMI VIII
Zone 4: MMI IX and above

Coasts exposed to tsunamis (seismic sea waves)

Active volcanoes

High-risk volcanoes

Windstorms: Scales and Effects

Beaufort Scale

Bft	Descriptive term	Mean wind speed at 10 m above surface: m/s	km/h	mph	knots	Wind pressure kg/m²
0	Calm	0–0.2	0–1	0–1	0–1	0
1	Light air	0.3–1.5	1–5	1–3	1–3	0–0.1
2	Light breeze	1.6–3.3	6–11	4–7	4–6	0.2–0.6
3	Gentle breeze	3.4–5.4	12–19	8–12	7–10	0.7–1.8
4	Moderate breeze	5.5–7.9	20–28	13–18	11–15	1.9–3.9
5	Fresh breeze	8.0–10.7	29–38	19–24	16–21	4.0–7.2
6	Strong breeze	10.8–13.8	39–49	25–31	22–27	7.3–11.9
7	Near gale	13.9–17.1	50–61	32–38	28–33	12.0–18.3
8	Gale	17.2–20.7	62–74	39–46	34–40	18.4–26.8
9	Strong gale	20.8–24.4	75–88	47–54	41–47	26.9–37.3
10	Storm	24.5–28.4	89–102	55–63	48–55	37.4–50.5
11	Violent storm	28.5–32.6	103–117	64–72	56–63	50.6–66.5
12	Hurricane	32.7–	118–	73–	64–	66.6–

Saffir Simpson Scale (up to hurricane force)

SS	Descriptive term	Mean wind speed: km/h	mph	knots
1	Weak	122–152	118–153	73–95	64–82
2	Moderate	154–177	154–177	96–110	83–96
3	Strong	179–208	178–209	111–130	97–113
4	Very strong	210–248	210–249	131–155	114–134
5	Devastating	250–	250–	156–	135–

Fujita Scale (up to tornado force)

F	Descriptive term	Wind speed: km/h	mph	knots
0	Weak	117–182	73–112	64–97
1	Moderate	183–253	113–157	98–136
2	Strong	254–332	158–206	137–179
3	Devastating	333–418	207–260	180–226
4	Annihilating	419–	261–	227–
5	Disaster			

Fig. 1.1 – *World map of natural hazards (Munich Reinsurance Company, 1988).*

Developed countries have already proved able to cope with many types of vulnerability of the physical and human environments to disasters. In a number of cases government authorities have successfully and cost-effectively dealt with the problems created by extreme natural phenomena by a combination of prevention, reconstruction and rehabilitation programs. The number of casualties was limited, for instance, during the January 1994 earthquake in Northridge, near Los Angeles, where experts had learned much about construction techniques and strengthening of old structures. The earthquake which struck Friuli (northeastern Italy) in 1976 was followed by complete reconstruction after the adoption of adequate techniques and standards.

Developing countries do not have in general sufficient financial resources so that the disaster emergency period can be followed by post-disaster havoc. In some cases the devastated area and its feeble economy do not succeed in recovering and thus revert to higher poverty levels. Whenever the affected country has limited financial resources, the public expenditure is usually redirected to rehabilitation and reconstruction projects, leaving most of the pre-disaster problems unattended. A number of poor countries urgently needs foreign help to reduce losses from natural disasters and strengthen the difficult path towards a sustainable development.

The economies of developing countries are the most heavily affected by the immediate impact on physical assets and employment and by the consequent slowing down of their development. The physical effect of hazardous events is often exacerbated by fragile environmental conditions. Poverty, high rates of population growth, environmental destruction through deforestation and inappropriate land use, inadequate infrastructure and policies, and lack of investments are often associated with this scenario.

According to Anderson (World Bank, 1990) development in some cases increases disaster proneness, and poor countries are comparatively more vulnerable since the environment has often already undergone significant degradation and a sizable depletion of resources has occurred. The effect of local development projects that attract more and more people to areas prone to seismic, volcanic or flooding hazards, can aggravate the consequences of natural disasters. Thus, it can be concluded that vulnerability to disasters needs to be considered as an essential aspect in development programs. Disaster costs can be reduced by proper and timely investments, centered on prevention and mitigation. Despite the huge destruction caused by recent disasters in the Philippines, a significant reduction of damage and casualties was achieved by the work of government organizations (such as NDCC, PHIVOLCS and others) with a background in early warning, organization of disaster emergency, preparedness and mitigation.

1.4 Human development and global hazard

Life and the environment on the planet have been conditioned by a number of phenomena that have recurred in the past. Impacts from the outer space (over 120 astroblemes have been discovered on Earth), critical plate tectonics periods and sudden variations in climate and the environment are natural phenomena with an immense destructive potential.

Whereas these events occurred over a period of several hundred million years, some alarming phenomena associated with the recent human development have become evident today, such as the loss of biodiversity or pollution, and some others will develop in the near future. These include the green house warming and the ozone layer depletion. In the course of the next century heat trapping due to the increasing presence of green house gases can reach much higher levels compared to the preindustrial period. The resulting global warming can significantly influence climate and have severe effects on human development.

Since the 1985 discovery of the ozone reduction over Antarctica, ozone depletion has gone on faster than expected and harmful effects on human beings and life may begin to occur during the next decades (World Development Report, 1992).

Despite the great efforts of scientists to model the earth's climate, the variety of scenarios and uncertainties about feedback effects still preclude prediction of the conditions that might be expected during the next 20-30 years. Many questions are still unanswered, while scientists strongly disagree with each other over some major issues. A number of facts, however, are clear:

– the natural resource base of the planet is finite; however, the consumption/production patterns shaped by the current global economic relationships lead to increasing demand and consumption rates even though these are likely to prove unsustainable.

– world population is now about 5.4 billion. According to the World Development Report (1992), between 1990 and 2030 world population is expected to grow by 3.7 billion, while the need for food will double and industrial production and energy consumption will be three times greater. This implies heavier and more widespread impacts on nature, the environment and resources.

– poverty, political uncertainty and local wars will most probably continue during the next century and negatively affect developed and developing countries.

Thus, many of the present problems related to resource depletion and degradation, poverty and insecurity will increase in magnitude. Under these conditions, the occurrence of natural disasters is likely to have a far more dramatic impact than at present on people, the environment and life in general.

1.5 Disaster distribution and effects during the last decades

The trend towards a sustainable development strategy certainly calls for an integrated approach, since not only do the effects of disasters need to be reduced but also harmful global impacts, such as the human-induced strengthening of the greenhouse effect and the depletion of the ozone layer, the responsibility for which rests mainly with the developed countries. Figure 1.2 shows the evolution of disasters during recent decades.

According to Boutros Boutros-Ghali, United Nations Secretary-General, in constant (1990) dollars economic losses due to disasters have tripled in the last thirty years: $40 billion in the 60s, $70 billion in the 70s, $120 billion in the 80s. Without disaster reduction measures the cost will rise to at least $280 billion in the 1990s (Stop Disasters, N. 17, 1994).

An assessment of natural disasters on earth, over a 25 year period (1966-1990) is presented in the May-June 1993 issue of Stop Disasters. Figure 1.3 shows (top left) the number of deaths due to high winds, earthquakes, floods and volcanic eruptions and the number of people affected (top right). Floodings account for three quarters of the number of people generally affected by disasters; this percentage reflects their great destructive potential. The bottom part of the figure illustrates the Spatial Risk Ratio (SRR) of Countries by type of disaster: New Zealand, Bangladesh and Philippines are the three countries most affected by floods, while Philippines and Bangladesh share the most hazardous locations as far as high winds are concerned. The SRR might be more meaningful if applied within countries rather than between countries: floods, cyclones and other types of disasters generally affect specific areas, not whole countries or populations.

1.6 International decade for the reduction of natural disasters

The correlation between poverty, population growth, degradation of the environment, depletion of natural resources and deterioration in the quality of life is a major issue for present and future generations.

Emerging environmental ethics, ecological associations, Green parties, ecologically oriented NGOs and individuals play a prime role in the transition from indiscriminate growth to equilibrium and the reduction of consequences of natural hazards.

At its 44th session (December 1989), the General Assembly of the United Nations proclaimed the International Decade for Natural Disasters Reduction (IDNDR, 1990-2000), and a variety of steps were taken in various fields, at national and international levels.

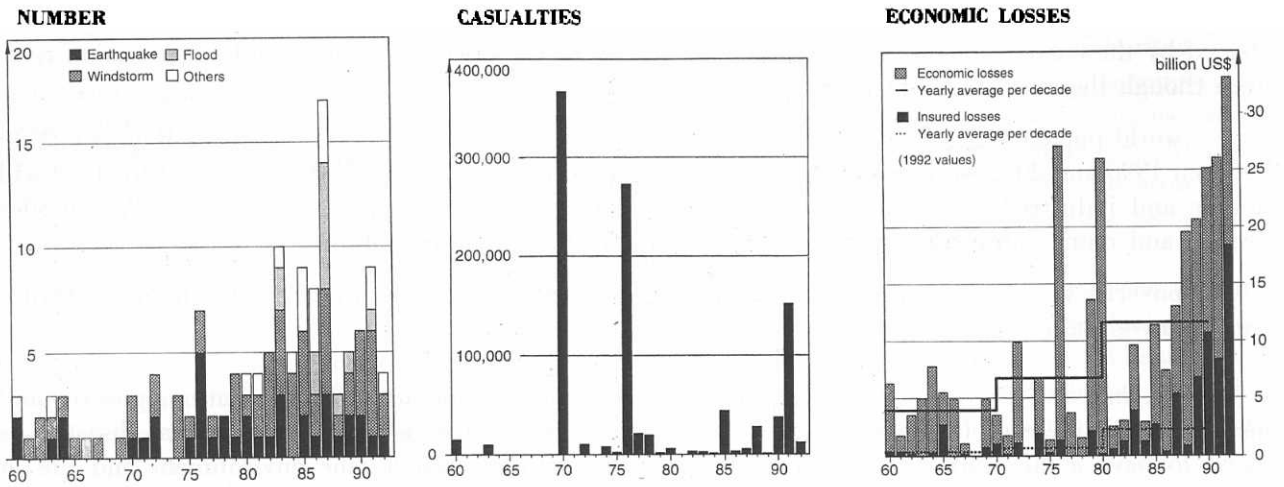


Fig. 1.2 – *Disasters during the last decades (number, casualties and economic losses), Geoscience Research Group, Munich Reinsurance Company (Stop Disasters, N. 17, 1994).*

The initiative «has the objective of substantially cutting the impact of natural hazards in human casualties, property damage and social and economic disruption» (UN/IDNDR, Report 1990-91, United Nations Declaration, 1988). Thus, the general objective of the Decade is the reduction of human and economic losses resulting from the occurrence of natural hazards. By the year 2000 all countries should have achieved:

– comprehensive national assessments of risks from natural hazards, with these assessments taken into account in development plans;

– mitigation plans at national and/or local levels, involving long-term prevention and preparedness and community awareness;

– ready access to global, regional, national and local warning systems and broad dissemination of warnings.

An important aspect links the 1992 Earth Summit in Rio and the 1994 Yokohama Conference on Natural Disoster Redaction: the need to halt and reverse environmental degradation and promote environmentally sustainable development. Reduction of disaster impacts can be considered a first step in meeting some of the major requirements of the Agenda 21 action plan and an investment for future generations.

1.7 Conclusion remarks

Natural phenomena as such do not necessarily carry negative implications, and their change potential is the force through which the planet has evolved through geological times. As a result a planet with life and a balanced environment has been delivered to us. Human activities have recently started altering the environment in more major ways than ever before.

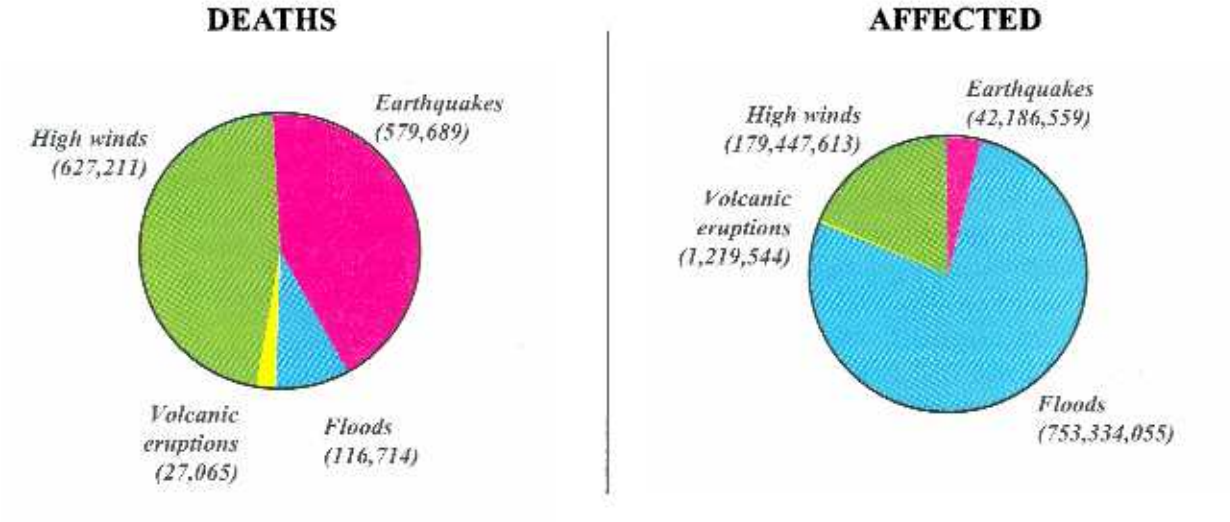
Since then extreme phenomena, which are inherent aspects of natural evolution and which also repeatedly occurred in the past, have begun to turn into disasters. Major natural events are beyond our control, therefore human development has to be modified and addressed in such a way as to minimize the impacts of disasters.

The first lesson to be learned is that human responses to natural hazards need to be integrated into the development planning of present and future generations. The second major aspect is that vulnerability of human settlements, structures and working activities can be reduced by a proper management of natural hazards.

Disaster Ranking Over 25 Years

Total deaths and affected by type of disasters 1966 - 1990

Data from CRED Disaster Events Database (EM-DAT)



Spatial Risk Ratio of Countries by Type of Disasters

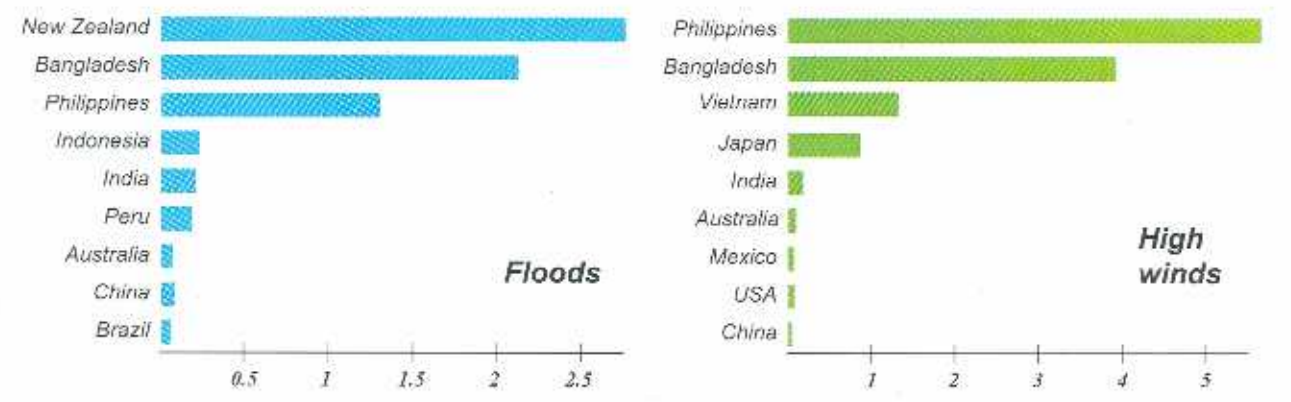


Fig. 1.3 – *Disasters ranking over the period 1966 - 1990. Spatial Risk Index has been calculated by dividing the number of disasters by land and water area of the affected country since the larger the land surface, the higher the overall probability of exposure to geological and meteorological events (Stop Disasters, N. 13, 1993).*