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Natural Disasters and Extreme Events in Agriculture

Impacts and Mitigation

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(Editors)

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With 93 Figures and 23 Tables

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Foreword

Natural disasters cause heavy loss of life and property, forcing humankind to "learn to live" with these calamities. During the period 1992–2001, floods, droughts, tropical cyclones, hurricanes, typhoons, storm surges, landslides and wild fires and other weather- and climate-related calamities have killed over 622,000 people and affected over 2 billion people. For the same period, losses from natural disasters of hydrometeorological origin were estimated at US$ 446 billion, accounting for about 65% of damages due to all natural disasters.

Natural disasters also affect socio-economic activities. Of these, agricultural production is highly dependent on weather, climate and water availability and is adversely affected by the weather- and climate-related disasters. Failure of rains and occurrences of natural disasters such as floods and tropical cyclones could lead to crop failures, flood insecurity, famine, loss of property and life, mass migration and decline in national economy. The growing concern with the possible impact of natural disasters and extreme events on agriculture and forestry has created new demands for information from, and assessment by agrometeorologists. The need for reorienting and recasting meteorological information, fine-tuning of climatic analysis and presentation in forms suitable for agricultural decision-making and helping marginal farmers cope with the adverse impact of natural disasters and extreme events has become more pressing.

Due to recent advances in science and technology, it is now possible to forecast the occurrence of extreme events and the nature of devastation that they may cause with a greater degree of accuracy and with longer lead time. Availability of such crucial information in advance greatly helps in taking effective measures for prevention and mitigation of loss of life and property and avoid human suffering.

Awareness of the need to give greater attention to disaster mitigation, preparedness and management has been growing among decision-makers. Pre-disaster preparedness now forms an integral part of national development planning in many countries. The Commission for Agricultural Meteorology (CAgM) of WMO at its thirteenth session formed an Expert Team on "Reduction of the Impact of Natural Disasters and Mitigation of Extreme Events in Agriculture, Forestry and Fisheries". The Team was invited to provide guidance on the strategies to reduce the destructive effects of the extreme events by stimulating data acquisition for forecasting and early warning systems, and by making improvements in disaster preparedness.

The China Meteorological Administration (CMA) hosted a meeting of the CAgM Expert Team in Beijing, China from 16 to 20 February 2004. The meeting reviewed and discussed the papers prepared by the members of the expert team and developed appropriate recommendations to reduce the impact of natural disasters and mitigate extreme events in agriculture, forestry and fisheries. I hope that the proceedings of this meeting will serve as a useful source of information to all institutions and agencies interested in this subject.

(M. Jarraud)
Secretary-General
World Meteorological Organization

Preface

Over the past few decades, there is an increasing intensity and frequency of natural disasters around the world with severe socio-economic impacts, especially in the developing world. Agriculture is one of the most important sectors heavily impacted by the natural disasters and the challenge in front of the agrometeorologists around the world is that more than ever before, there is a great need to more effectively integrate and deploy the skills to use climate information and products successfully in natural disaster preparedness strategies. There is also a need to develop locally agrometeorological adaptation strategies to reduce the effect of natural disasters especially in vulnerable regions where food and fibre production is most sensitive and vulnerable to climate fluctuations.

The Commission for Agricultural Meteorology (CAgM) of WMO at its thirteenth session held in Ljubljana, Slovenia established an Expert Team (ET) on Reducing the Impact of Natural Disasters and Mitigation of Extreme Events in Agriculture, Rangelands, Forestry and Fisheries. A meeting of this ET was held in Beijing, China from 16 to 20 February 2004 at the kind invitation of the Chinese Meteorological Administration (CMA). The decision to organize this meeting at this point of time is largely due to the increasing concerns with the impact of natural disasters in recent times as highlighted by Mr M. Jarraud in the Foreword. Fifty-four participants from eight countries, including forty-five from China, attended the meeting. In addition to the experts from CAgM, three experts nominated by the Joint Commission on Marine Meteorology (JCOMM) also participated in the meeting. The specific objectives of the meeting were:

- To review the current status of application of climate and weather information in reducing the impacts of natural disasters and mitigation of extreme events in agriculture, forestry and fisheries.
- To assess the potential for improved disaster reduction strategies and relevant agrometeorological applications in different countries for sustainable agricultural development.
- To identify the shortcomings and limitations of current disaster management and mitigation strategies in reducing the risks associated with natural disasters.
- To discuss the resources and strategies, including education and training, required for promotion of sustained efforts in disaster reduction and mit-

igation of extreme events and research activities to better understand the potential risks to agriculture from natural disasters and extreme events.

Altogether there were 10 sessions (including opening and closing session) in the meeting during which 21 invited papers were presented dealing with various aspects on reducing the impact of natural disasters and mitigation of extreme events in agriculture, rangelands, forestry and fisheries. All the participants in the meeting were engaged in discussions on these papers and developed several useful recommendations for all organizations involved in disaster reduction and mitigation of extreme events, in particular the National Meteorological and Hydrological Services. It should be noted that the recommendations listed reflect the considered opinions of the participants at the meeting and we are aware that these recommendations do not address the totality of the needs. We do hope that these will encourage others to suggest further ways in which the science and applications of agricultural meteorology could contribute to reducing the impacts of natural disasters and extreme events in agriculture.

As Editors of this volume, we would like to thank all the authors for their efforts and for their cooperation in bringing out this volume in time. We are most grateful to the Chinese Meteorological Administration (CMA) for hosting this meeting and to the Secretary-General of WMO for his continuous support and encouragement.

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Impacts of Natural Disasters in Agriculture, Rangeland and Forestry: an Overview

Mannava V. K. Sivakumar

Abstract Natural disasters play a major role in agricultural development and the economic cost associated with all natural disasters has increased 14 fold since the 1950s. Natural disasters are classified into hydro-meteorological and geophysical disasters. Definitions of various types of hydrometeorological disasters such as floods, droughts, cyclones, forest fires, heatwaves were presented. Evidence available from different parts of the world showed that there is a rising trend in the occurrence of natural disasters from 1993 to 2002. Impacts of droughts, cyclones, floods, forest and bush fires on agriculture, rangeland and forestry were described with suitable examples. While the predominant impacts from these disasters are negative, there are some positive impacts as well. Environmental degradation is one of the major factors contributing to the vulnerability of agriculture, forestry and rangelands to natural disasters because it directly magnifies the risk of natural disasters. Some methodological issues concerning the characterization of the impacts of natural disasters in agriculture, rangeland and forestry were described. There is an urgent need to mitigate the effects hydro-meteorological disasters through improved use of climate and weather information and forecasts, early warning systems, and appropriate methods of management of land and natural resources.

1.1 Introduction

Throughout human history, natural disasters have played a major role in the economic development and survival of humanity. Historians now believe that an unusually long and severe drought was a primary cause of the disappearance of the Maya civilization (Hodell et al. 1995).

During the past four decades, natural hazards such as droughts, floods, storms and tropical cyclones and wildland fires have caused major loss of human lives and livelihoods, the destruction of economic and social infrastructure, as well as environmental damages. Deaths since the 1950s increased 50 percent each decade, whereas the corresponding population growth rate was only 20 percent (Kreimer and Munasinghe 1991).

The economic cost associated with all natural disasters has increased 14 fold since the 1950s (World Disasters Report 2001). World wide, annual economic costs related to natural disasters have been estimated at about $ 50 to 100 billion. According to China's Ministry of Civil affairs, natural disaster costs have averaged US$ 12 billion or so annually during the past 10 years with an estimated 200 million or so people affected annually. By the year 2050 it is predicted that globally 100,000 lives will be lost each year to natural disasters and the global cost could top $ 300 billion annually (SEI, IUCN, IISD 2001).

The world land use data (FAO 1999) show that 70% of the global land use is for agriculture, rangeland and forestry with 12% of the land used for arable and permanent crops, 31% for forest and woodlands and 27% for permanent pasture. Agriculture is also the essential source of income in most developing countries. For example, agriculture accounts for 70 percent of full-time employment in Africa, 33 percent of total GDP, and 40 percent of total export earnings. Agricultural production is highly dependent on weather, climate and water availability, and is adversely affected by weather- and climate-related disasters.

In order to ensure sustainable agricultural production and assure the livelihood of millions of people, especially in the developing countries, a better understanding of the natural disasters that impact agriculture, forestry and rangelands is essential. This paper provides an overview of the major issues involved.

1.2 Natural Disasters – Definitions and Types

In simple terms, a natural disaster is a natural event with catastrophic consequences for living things in the vicinity. But, different definitions of natural disasters are often used and some of them are based primarily on loss of life.

The emergencies database (EM-DAT) operated by the Centre for Research on the Epidemiology of Disasters (CRED) classifies an event as a disaster if at least "10 people are killed and/or 100 or more are affected and/or an appeal for international assistance is made or a state of emergency declared" (CRED 2000). Clearly, for agricultural purposes only the last part of this definition is applicable.

According to a 1992 disaster training programme, United Nations (UN) defines a disaster as "a serious disruption of the functioning of society, causing widespread human, material or environmental losses which exceed the capacity of the affected society to cope using only its own resources". With suitable interpretation of some parts, this definition could be used by agriculture.

Anderson (1990) defines natural disasters as temporary events triggered by natural hazards that overwhelm local response capacity and seriously affect the social and economic development of a region.

Susman et al. (1983) describe disasters as the interface between an extreme physical environment and a vulnerable human population. Such definitions emphasize the fact that the socio-economic and political factors are of paramount importance in understanding why populations are vulnerable to the environment and experience disasters.

According to World Disaster Report (2003), natural disasters include hydro-meteorological disasters and geophysical disasters. The hydro-meteorological disasters include landslides/avalanches; droughts/famines; extreme temperatures and heat waves; floods; hurricanes; forest/scrub fires; windstorms; and others (insect infestation and waves/surges). The geophysical disasters include earthquakes and volcanic eruptions. In this paper, only the hydro-meteorological disasters impacting agriculture, rangeland and forestry are dealt with. Definitions of each of these disasters primarily from are given below.

A landslide is a geological phenomenon which includes a wide range of ground movement, such as rock falls, deep failure of slopes, and shallow debris flow. Although gravity acting on an over steepened slope is the primary reason for a landslide, there are other contributing factors. An avalanche is caused when a build up of snow is released down a slope, and is one of the major dangers faced in the mountains in winter. An avalanche is a type of gravity current.

Drought is the consequence of a natural reduction in the amount of precipitation over an extended period of time, usually a season or more in length, often associated with other climatic factors (such as high temperatures, high winds and low relative humidity) that can aggravate the severity of the event. Drought is not a purely physical phenomenon, but instead is an interplay between natural water availability and human demands for water supply. The precise definition of drought is made complex due to political considerations, but there are generally three types of conditions that are referred to as drought.

- Meteorological drought is brought about when there is a prolonged period with below average precipitation.
- Agricultural drought is brought about when there is insufficient moisture for average crop or range production. This condition can arise, even in times of average precipitation, due to soil conditions or agricultural techniques.
- Hydrologic drought is brought about when the water reserves available in sources such as aquifers, lakes, and reservoirs falls below the statistical average. This condition can arise, even in times of average (or above average) precipitation, when increased usage of water diminishes the reserves.

A heat wave is a prolonged period of excessively hot weather, which may be accompanied by excessive humidity. The term is relative to the usual weather in the area, so temperatures that people from a hotter climate find normal can be a heat wave if they are outside the normal pattern for a cooler area. The term is applied both to "ordinary" weather variations and to extraordinary spells of heat which may only occur once a century.

Flood is defined as the condition that occurs when water overflows the natural or artificial confines of a stream of other body of water, or accumulates by drainage over low-lying areas. A flood is a temporary inundation of normally dry land with water, suspended matter and/or rubble caused by overflowing of rivers, precipitation, storm surge, tsunami, waves, mudflow, lahar, failure of water retaining structures, groundwater seepage and water backup in sewer systems.

Forest fire (or bushfire in Australasia) is an uncontrolled fires occurring in vegetation more than 6 feet (1.8 m) in height. These fires often reach the proportions of a major conflagration and are sometimes begun by combustion and heat from surface and ground fires.

Tropical cyclones, hurricanes and typhoons are regional names for what is essentially the same phenomenon. Depressions in the tropics which develop into storms are called tropical cyclones in the south-west Indian Ocean, the Bay of Bengal, and the Arabian Sea, parts of the south Pacific and along the northern coasts of Australia. These storms are called typhoons in the north-west Pacific and are known as hurricanes in the Caribbean, south-east United States and Central America.

Tsunami (in Japanese, big wave in port), often incorrectly called a tidal wave, is a series of massive waves that occur after an earthquake, a seaquake, volcanic activity, slumps or meteorite impacts in or near the sea. Since the constant energy of the tsunami is defined by height and speed, its height increases once its speed is reduced where the wave approaches land. The waves travel at high speed, more or less unnoticed where crossing deep water, but raising to a height of 30 m and more. Tsunamis can cause severe destruction on coasts and islands.

1.3 Natural Disasters – the Rising Trend

Information on natural disasters and trends is basically available from global databases that provide essential information on the occurrence, recurrence and location of disasters and disaster trends over time (World Disasters Report 2003). The emergencies database (EM-DAT), referred to earlier, serves the global community. Other databases such as Sigma and Natcat are operated by insurance companies Swiss Re and Munich Re respectively, but are not always accessible to the public.

There is evidence available from different parts of the world that there is a rising trend of natural disasters from 1993 to 2002 (Fig. 1.1a). Of a grand total of 2,654 disasters during this period, floods and windstorms account for about 70% of the disasters while the remaining 30% of the disasters are accounted for by droughts, landslides, forest fires, heat waves and others (Fig. 1.1b).

At the regional level, in South East Asia and Bangladesh, over the last century, 700 disasters have occurred of which 158 (23%) occurred between 1900 and 1979, and 542 (77%) between 1972 and 1996. For the Latin American and Caribbean region, Charveriat (2000) showed a noticeable trend of increase in the frequency of disasters.

At the national level, Roy et al. (2002) showed that the Orissa state of India has been disaster affected for 90 years; floods have occurred for 49 years, droughts for 30 and cyclones have hit the state for 11 years.

These data together with that of deaths and affected people appear to show that the natural disasters are becoming more frequent and are also causing heavier and heavier consequences.

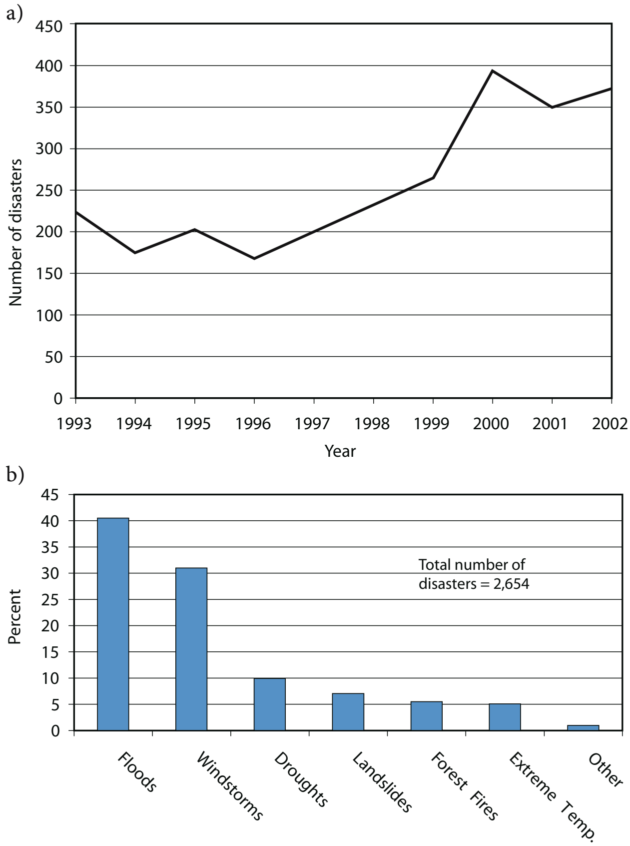

Fig. 1.1. (**a**) Annual variations in the occurrence of hydro-meteorological disasters during 1993–2002 and (**b**) the percentage of different hydro-meteorological disasters as a percent of total number of disasters during 1993–2002

1.4 Impacts of Natural Disasters in Agriculture, Rangeland and Forestry – General Discussion

Impacts from natural disasters on agriculture, rangeland and forestry can be positive or negative. While the impacts are predominantly negative and do affect human society significantly (Joy 1991), there are some positive impacts or benefits that need to be pointed out as well in any discussion on impacts of natural disasters.

As Das (2003a) explained, the impact of natural disasters on agriculture, rangeland and forestry can be direct or indirect in their effect. Direct impacts arise from the direct physical damage on crops, animals and trees caused by the extreme hydro-meteorological event. The impacts may be considered in terms of short-term temporary damage at a particular crop stage to complete crop loss. Within hours of their occurrence, natural disasters produce direct damage to agriculture in terms of total or partial destruction of farm buildings, installations, machinery, equipment, means of transport, storage as well as damage to crop land, irrigation works, dams and destruction of crops ready for harvesting.

Disasters also cause indirect damage which refers to loss of potential production due to disturbed flow of goods and services, lost production capacities, and increased costs of production. Such indirect impacts appear progressively as a result of low incomes, decreases in production, environmental degradation and other factors related to the disaster (Das 2003a).

Anaman (2003) pointed out that the impacts of natural disasters can also be classified as tangible or intangible. Tangible impacts are those that can be easily measured in monetary terms. Intangible impacts are often difficult to measure in monetary terms since they are not purchased or sold in well defined markets and hence direct market values do not exist eg., anxiety or fear of future natural disasters (Oliver 1989), inconvenience and disruption to farm work and stress-induced ill health and human fatalities.

1.4.1 Negative Impacts

Many famines in pre-20th-century Africa, Asia and Europe were triggered by natural disasters – drought, extreme cold, pests and diseases – that devastated crops and livestock (Devereux 2000). According to the EM/DAT data quoted in the World Disasters Report 2003, on average, 246 million people were affected by hydro-meteorological disasters globally each year, between 1993 and 2002. During the same period, these disasters claimed 46,000 lives per year.

Annual variations in the number of people affected by hydro-meteorological disasters during this period (Fig. 1.2a) showed a significant rise in 2002. Data on the percentage of people affected by different hydro-meteorological disasters (Fig. 1.2b) showed that about 56.9% of the 2.46 billion people were affected by floods, 29.8% by droughts, 12.7% by windstorms and 0.6% by the rest of the disasters. On a regional basis (Fig. 1.3), 91% of the people affected were in Asia, due to its huge population. Africa accounted for 6% of the affected people, followed by Americas (2%), Europe ($< 1\%$) and Oceania ($< 1\%$).

During 1993/2002, hydro-meteorological disasters caused an estimated damage of US$ 41.3 billion per year on average. Estimated damage on annual basis during this period (Fig. 1.4a) varied from a high of US$ 67.7 billion in 1995 to a low of US$ 18.1 billion in 2001. Ranking of the different hydro-meteorological disasters according to the percentage of damage caused by them (Fig. 1.4b) is as follows: floods, windstorms, droughts, forest fires, extreme temperatures, landslides and others. On a regional basis (Fig. 1.5), maximum damage occurred in Asia (49%), followed by Americas (29%), Europe (19%), Oceania (2%) and Africa (1%).

Loss of perennial crops such as banana trees or forests has long-term consequences on the ability to generate income. In the case of agricultural income generating assets, the loss might be temporary or permanent (Charveriat 2000).

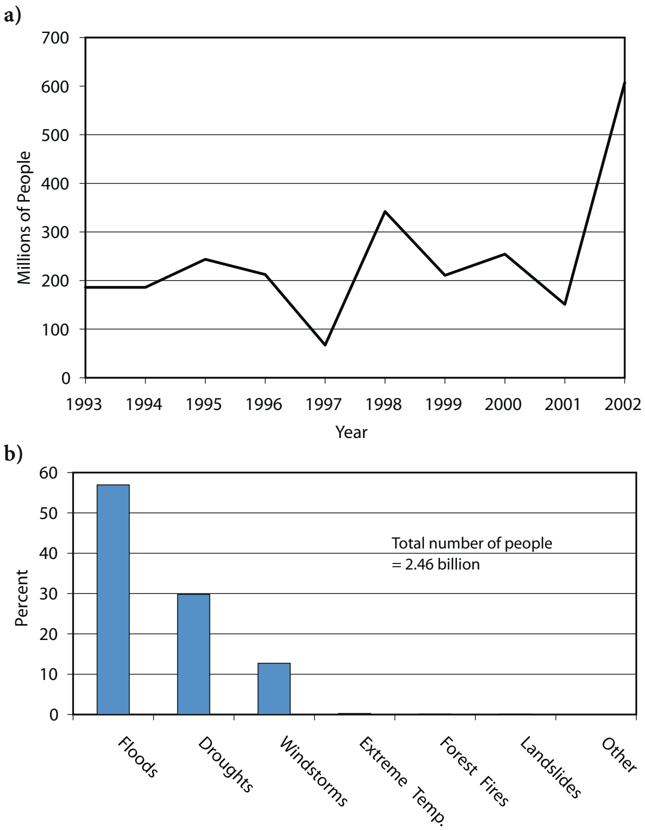

Fig. 1.2. (**a**) Annual variations in the number of people affected by hydro-meteorological disasters during 1993–2002 and (**b**) the percentage of people affected by different hydro-meteorological disasters during 1993–2002

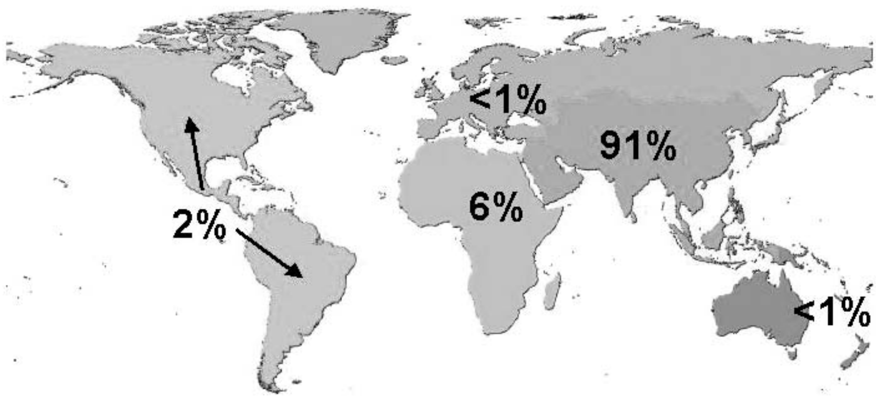

Fig. 1.3. Percentage of total number of people reported affected by hydro-meteorological disasters by region

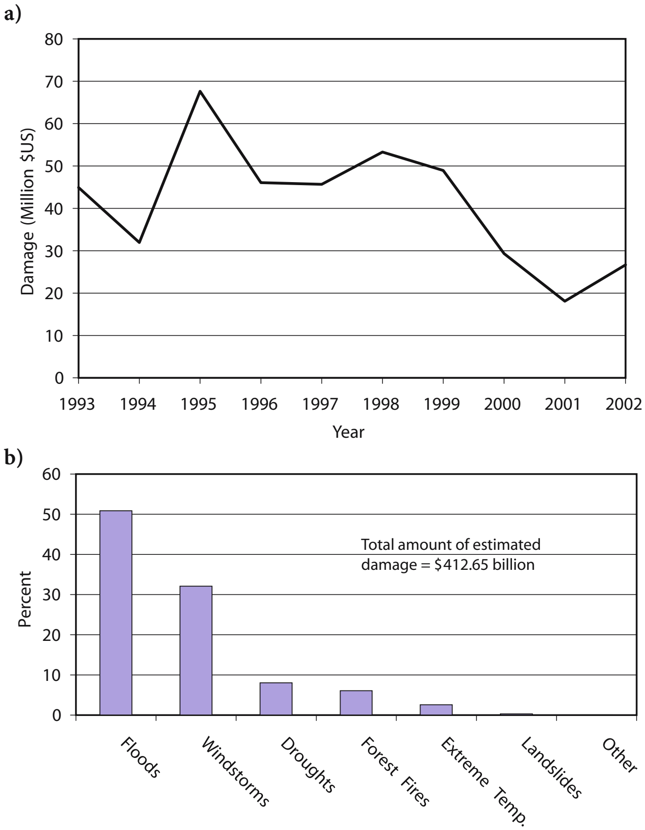

Fig. 1.4. (**a**) Annual variations in the estimated damage due to hydro-meteorological disasters during 1993–2002 and (**b**) the percentage of damage caused by different hydro-meteorological disasters during 1993–2002

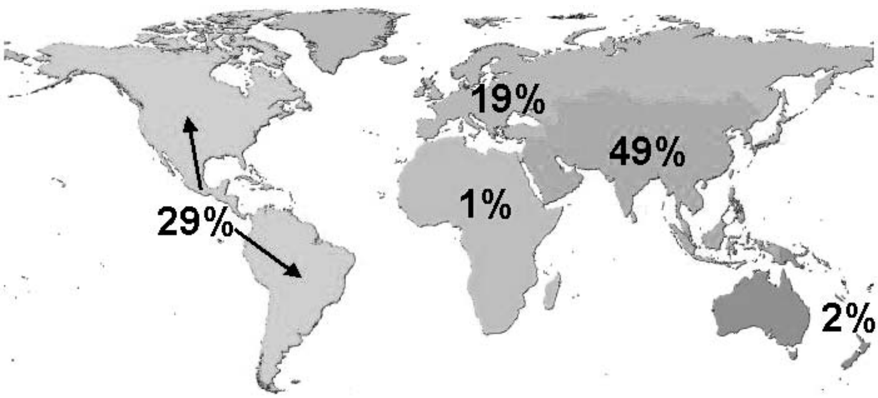

Fig. 1.5. Percentage of total amount of disaster estimated damage by region (2002 prices)

Floods make land unsuitable for agricultural production until waters recede, while hurricanes might wash out arable land or permanently increase its salinity through storm surges and flash floods. Indirect impacts include the evacuation of people in the event of cyclone landfall, disruption to households, stress induced sickness and apprehension (Handmer and Smith 1992; Anaman 1996).

The duration and geographical size of the disaster is an important factor. Localized disasters tend to produce limited aggregate impacts, unlike countrywide natural events such as Hurricane Mitch (Charveriat 2000). Sudden hazards such as storms usually have fewer long/lasting effects than droughts, which are often described as creeping in nature because of the slow rate at which they develop.

Recurrent disasters in the same geographical area might lead to reduced investment due to the perceived risk of asset loss or emigration from stricken areas. Regions repeatedly hit by natural disasters, such as Northeast Brazil, or the coasts of Peru and Ecuador, are usually poorer on average than less hazard-prone areas in a given country.

Poor nations suffer the most from the natural disasters. As Devereux (2000) explained, poor people are more exposed because they tend to live in marginal areas and depend on high-risk, low return livelihood systems such as rainfed agriculture and face many sources of economic vulnerability including little physical infrastructure. Vos et al. (1999) estimated that the poverty incidence in affected municipalities in the coastal province of Ecuador, which already reached 73% before El Niño, rose by 10 percentage points in 1998 due to loss of harvests of poor farmers and rising unemployment among agricultural workers. The UNDP reports that 24 out of 49 least developed nations face a high risk of natural disasters. At least 6 of them have been hit by between 2 to 8 major disasters per year in the last 15 years, with long-term consequences for human development (UNDP 2001).

While damages related with natural disasters are greater in absolute value in developed countries, loss/GDP rates are 20% higher in the developing countries (Funaro 1982). United States experienced more disasters between 1970 and 1999 than any other region, but the impact on national development was not as severe as in some of the developing countries. For example, Hurricane Andrew in 1992 caused a total damage of $ 26.5 billions in the United States, but it was a mere 0.4% of GDP.

Beyond the direct or indirect losses, the economic consequences are of major importance given the repercussions they have on the economic development of the countries (GDP, public finances, foreign trade, price indices). Because of the important role it plays considering the creation of national wealth and the population needs, the agricultural sector appears as a highly vulnerable one. For example, 30.9% of the GNP in Bangladesh was attributed to agricultural activities in Bangladesh while in Cambodia and Laos, it was 44.6 and 54.3% respectively. During the last El Niño in Ecuador, Vos et al. (1999) estimated that around 12,000 workers on banana and sugar cane plantations in the lowlands temporarily lost their jobs. In Honduras, the press reported that the rate of unemployment in the immediate aftermath of Hurricane Mitch had reached an estimated 32%, according to the firm, Asesorias Economicos.

The economic consequences also concern the activities related to international trade, which have become indispensable because of national debt. Export agriculture, tourism, crafts and industrial activities are assumed to bring in foreign currency that is indispensable for the equilibrium of the balance of payments.

The agricultural products hold an even more significant place in exportations. Free zones can be affected by cyclones and floods, with greater probability as they are situated in the coastal plains and on the principal deltas. In Bangladesh, the Chittagong free zone was very seriously affected by the 1991 cyclone (Normand 1991).

1.4.2 Positive Impacts

The positive impacts of natural disasters include increased rainfall to inland areas from tropical cyclones along coastal areas (Ryan 1993), the fixing of atmospheric nitrogen by thunderstorms, the germination of many native plant species as a result of bushfires and the maintenance of fertility of flood-plain soils due to flooding (Blong 1992). The influx of funds into disaster-relief activities after the occurrence of natural disasters can sometimes be positive to local communities, as was shown for the city of Mobile, Alabama after Hurricane Federic (Chang 1984).

1.5 Impacts of Specific Natural Disasters in Agriculture, Rangeland and Forestry

According to Johnson (2003), in a survey of the impacts of extreme weather and climate events on agriculture, the events which were reported by most of the 57 countries around the world which responded included drought (91 per cent), local severe storms (83 per cent), floods (79 per cent), frost (74 per cent) and high winds (72 per cent).

1.5.1 Droughts

Seasonal droughts occur in climates that have well defined annual rainy and dry seasons. Numerous studies have been conducted on the impacts of droughts on crop growth and development at different levels including soil moisture uptake, root growth, shoot growth, various plant processes such as photosynthesis, respiration, plant water uptake and final yield and literature is replete with several good examples. But it is to be understood that the effects of droughts are seriously worsened by human factors such as population growth that forces people into drier and drier regions and inappropriate cropping and herding practices. The impacts of drought are likely to become ever more severe as a result of development processes and population increases (Squires