

World Meteorological Organization  
Mannava V. K. Sivakumar  
Raymond P. Motha  
Haripada P. Das  
**Natural Disasters and Extreme Events  
in Agriculture**  
Impacts and Mitigation



Mannava V. K. Sivakumar  
Raymond P. Motha  
Haripada P. Das  
(Editors)

# **Natural Disasters and Extreme Events in Agriculture**

**Impacts and Mitigation**

With 93 Figures and 23 Tables

 Springer

Dr. Mannava V. K. Sivakumar  
Agricultural Meteorology Division  
World Meteorological Organization  
7 bis, Avenue de la Paix  
1211 Geneva 2  
Switzerland

Dr. Raymond P. Motha  
USDA/OCE/WAOB  
1400 Independence Ave. SW  
Room 4441, South Building  
Washington DC 20250  
USA

Dr. Haripada P. Das  
Meteorological Office  
Division of Agricultural Meteorology  
Shivajinagar  
Pune 411005  
India

Library of Congress Control Number: 2005921509

ISBN-10 3-540-22490-4 Springer Berlin Heidelberg New York  
ISBN-13 978-3-540-22490-7 Springer Berlin Heidelberg New York

This work is subject to copyright. All rights are reserved, whether the whole or part of this material is concerned, specifically the rights of translation, reprinting, reuse of illustrations, recitations, broadcasting, reproduction on microfilm or in any other way, and storage in data banks. Duplication of this publication or parts thereof is permitted only under the provisions of the German Copyright Law of September 9, 1965, in its current version, and permission for use must always be obtained from Springer-Verlag. Violations are liable to prosecution under the German Copyright Law.

**Springer is a part of Springer Science+Business Media**  
springeronline.com  
© Springer-Verlag Berlin Heidelberg 2005  
Printed in The Netherlands

The use of general descriptive names, registered names, trademarks, etc. in this publication does not imply, even in the absence of a specific statement, that such names are exempt from the relevant protective laws and regulations and therefore free for general use.

Cover Design: E. Kirchner, Heidelberg  
Production: Almas Schimmel  
Typesetting: LE- $\TeX$  Jelonek, Schmidt & Vöckler GbR, Leipzig, Germany  
Printing: Krips bv, Meppel  
Binding: Stürtz AG, Würzburg

Printed on acid free paper 30/3141/as 5 4 3 2 1 0

# 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.

*M.V.K. Sivakumar*  
*Agricultural Meteorology Division*  
*World Meteorological Organization*  
*7 bis, Avenue de la Paix*  
*CP 2300*  
*1211 Geneva 2*  
*Switzerland*

*R.P. Motha*  
*USDA/OCE/WAOB*  
*1400 Independence Ave. SW*  
*Room 4441, South Building*  
*Washington DC 20250*  
*USA*

*H.P. Das*  
*Meteorological Office*  
*Division of Agricultural Meteorology*  
*Shivajinagar*  
*Pune 411005*  
*India*

---

# Contents

<b>1</b>	<b>Impacts of Natural Disasters in Agriculture, Rangeland and Forestry: an Overview</b>	<b>1</b>
	<i>M. V. K. Sivakumar</i>	
1.1	Introduction.....	1
1.2	Natural Disasters – Definitions and Types.....	2
1.3	Natural Disasters – the Rising Trend .....	4
1.4	Impacts of Natural Disasters in Agriculture, Rangeland and Forestry – General Discussion.....	5
	1.4.1 Negative Impacts.....	6
	1.4.2 Positive Impacts .....	10
1.5	Impacts of Specific Natural Disasters in Agriculture, Rangeland and Forestry.....	10
	1.5.1 Droughts.....	10
	1.5.2 Cyclones.....	12
	1.5.3 Floods .....	14
	1.5.4 Forest and Bush Fires .....	15
1.6	Environmental Degradation and Impact of Natural Disasters in Agriculture, Forestry and Rangelands.....	16
1.7	Natural Disasters in Agriculture, Rangeland and Forestry – Some Methodological Issues .....	17
1.8	Mitigating the Impacts of Natural Disasters .....	18
1.9	Conclusions.....	19
	References .....	20
<b>2</b>	<b>The Role of Disaster Preparedness in National Planning with Specific Reference to Droughts</b>	<b>23</b>
	<i>D.A. Wilhite</i>	
2.1	Introduction.....	23
	2.1.1 Monitoring Drought: Unique Challenges and Recommendations.....	25
	2.1.2 Drought Policy and Preparedness .....	27
	2.1.3 Drought Mitigation Planning: Examples and Perspectives.....	28



2.2	Summary and Future Challenges .....	36
	References .....	37
<b>3</b>	<b>The Occurrence and Predictability of Extreme Events over the Southwest Pacific with Particular Reference to ENSO</b>	<b>39</b>
	<i>M.J. Salinger, P. Lefale</i>	
3.1	Introduction.....	39
3.2	Impacts of Extreme Events .....	40
3.3	Trends in Extremes.....	41
3.4	ENSO Impacts on Climate in the Southwest Pacific.....	43
3.5	Predictability of Extreme Events and ENSO.....	45
3.6	Predictability of Southwest Pacific Climate.....	45
3.7	Conclusions.....	47
	References .....	48
<b>4</b>	<b>Accessibility of Database Information to Facilitate Early Detection of Extreme Events to Help Mitigate Their Impacts on Agriculture, Forestry and Fisheries</b>	<b>51</b>
	<i>R.P.R. Guerreiro</i>	
4.1	Introduction.....	51
4.2	The Need for Observational Data and Products .....	53
4.2.1	Floods .....	53
4.2.2	Droughts .....	53
4.2.3	Lightning Storms.....	55
4.2.4	Data Needs for Fisheries .....	55
4.2.5	Automated Weather Stations .....	56
4.2.6	Agrometeorological Databases .....	56
4.3	Database Management .....	57
4.3.1	Database Design.....	57
4.3.2	Real-time Information .....	59
4.3.3	Relational Database Management Systems.....	60
4.4	Remote Sensing .....	61
4.5	Geographical Information Systems .....	63
4.6	Conclusions.....	66
	References .....	67
<b>5</b>	<b>Tools for Forecasting or Warning as well as Hazard Assessment to Reduce Impact of Natural Disasters on Agriculture, Forestry and Fisheries</b>	<b>71</b>
	<i>L. Nuñez</i>	
5.1	Introduction.....	71
5.2	Floods .....	72
5.2.1	Forecasting/Warning of Flood for Reduction of Risk Potential .....	73
5.2.2	Quantification of Risk Potential and Hazard Assessment	73

5.2.3	Forecasting System as a Part of Disaster Management .....	74
5.2.4	Impacts of Flood on Agriculture .....	74
5.3	Droughts.....	75
5.3.1	The Nature and Prediction of ENSO .....	76
5.3.2	Drought and its Forecasts Based on ENSO .....	77
5.3.3	Risk Management .....	80
5.4	Tropical Cyclones .....	81
5.4.1	Cyclone Prediction and Warning .....	82
5.5	Forest Fires .....	85
5.5.1	Fire Danger Ratings .....	85
5.5.2	Fire Behavior Prediction .....	87
5.6	Volcano .....	88
5.6.1	Prediction of Volcanic Eruptions .....	89
5.7	Conclusion .....	89
	References .....	90
<b>6</b>	<b>Agrometeorological Impact Assessment of Natural Disasters and Extreme Events and Agricultural Strategies Adopted in Areas with High Weather Risks</b>	<b>93</b>
	<i>H.P. Das</i>	
6.1	Introduction.....	93
6.2	Agrometeorological Impact of Extreme Events .....	94
6.2.1	Positive Effect on Agriculture of Extreme Events .....	96
6.2.2	Negative Effect on Agriculture of Extreme Events .....	96
6.3	Strategies Adopted in Areas with High Weather Risk .....	102
6.3.1	Drought Management .....	102
6.3.2	Cyclone Preparedness in Agriculture System .....	103
6.3.3	Mitigation of Damage on Agricultural Sector due to Flood and Heavy Rainfall .....	105
6.3.4	Protection of Crop Against Wind .....	106
6.3.5	Protection of Crops from Dust Storm/Sand Storm .....	107
6.3.6	Protection of Crops from Cold Injury and Frost .....	107
6.3.7	Fire Prevention Measures.....	108
6.4	Agricultural Strategies for Community Capacity Building .....	108
6.4.1	Diversification of Crops According to Different Planting Seasons .....	108
6.4.2	Propagation of Disaster Resistant Crops.....	109
6.4.3	Seed Banks and Nurseries.....	109
6.4.4	Post Harvest Facilities .....	110
6.4.5	Encourage Proper Land Use Management and Sustainable Agriculture Practices.....	110
6.4.6	Community Participation for Traditional Rain Water Harvesting .....	110
6.5	Disaster Risk Reduction Through Livelihood Concerns .....	111
6.5.1	Creation of Alternate Livelihood Options .....	112

6.5.2	Livelihood Strategies in Disaster Risk Reduction – A Case Study in Bangladesh .....	113
6.6	Remote Sensing as a Tool for Disaster Risk Management.....	114
6.6.1	Cyclones and Tornadoes .....	115
6.6.2	Drought .....	115
6.6.3	Flood.....	115
6.6.4	Forest Fires.....	116
6.7	Crop Insurance .....	116
6.8	Conclusion.....	117
	References .....	117
<b>7</b>	<b>Damage Assessment of Agrometeorological Relevance from Natural Disasters: Economic and Social Consequences</b>	<b>119</b>
	<i>A.R. Riebau, D.G. Fox</i>	
7.1	Introduction.....	119
7.2	Climate Change and Climate Variability .....	124
7.3	Variability Shifting Continental Ecosystems .....	126
7.4	Interdecadal Climate Variability .....	130
7.5	Economic and Social Consequences .....	132
7.6	Conclusions.....	133
	References .....	134
<b>8</b>	<b>Impacts of Tropical Cyclones on Chinese Lowland Agriculture and Coastal Fisheries</b>	<b>137</b>
	<i>M. Xu, Q. Yang, M. Ying</i>	
8.1	Introduction.....	137
8.2	Destruction Caused by Tropical Storms in Coastal Areas.....	138
8.3	Features of TCs Affecting China and TC Disasters .....	138
8.3.1	High Frequency in Occurrence .....	140
8.3.2	Wide Range of Affecting Areas .....	140
8.3.3	Violent in Sudden Occurrence .....	140
8.3.4	Remarkable in Their Chain Effects .....	140
8.4	Impacts of Tropical Cyclones on Lowland Agriculture and Coastal Fisheries .....	141
	References .....	144
<b>9</b>	<b>Frost and High Temperature Injury in China</b>	<b>145</b>
	<i>D. Yaodong</i>	
9.1	Introduction.....	145
9.2	Frost .....	146
9.2.1	Concept and Harmed Mechanism of Frost.....	146
9.2.2	Frost Area .....	147
9.2.3	Crops Harmed by Frost .....	148
9.2.4	Statistical Characteristics of Frost .....	149
9.2.5	Preventive Measures and Preparedness of Frost .....	154

9.3	High Temperature Injury in China .....	154
9.3.1	Impact on Crops.....	154
9.3.2	Impact on Vegetables .....	155
9.3.3	Impact on Other Plants and Animals in Agriculture.....	155
9.4	Conclusions.....	156
	References .....	156
<b>10</b>	<b>Impacts of Sand Storms/Dust Storms on Agriculture</b>	<b>159</b>
	<i>M.V.K. Sivakumar</i>	
10.1	Introduction.....	159
10.2	Anthropogenic Land Disturbances and Wind Erosion .....	160
10.3	Definition of Sand and Dust Storms .....	162
10.4	Mechanics of Sand and Dust Storms .....	163
10.5	Spatial and Temporal Distribution of Sand and Dust Storms.....	165
10.6	Impacts of Sand and Dust Storms .....	166
10.6.1	Crop Damage .....	166
10.6.2	Soil Productivity Losses.....	167
10.6.3	Economic Losses .....	168
10.6.4	Mass Migration .....	169
10.6.5	Health Impacts.....	169
10.6.6	Impacts on Climate.....	169
10.6.7	Positive Impacts .....	170
10.7	Measures to Combat Sand and Dust Storms .....	171
10.7.1	Use of Wind Breaks or Shelterbelts.....	171
10.7.2	Use of Crop Residues.....	172
10.7.3	Use of Mechanical Tillage .....	172
10.8	Conclusions.....	172
	References .....	173
<b>11</b>	<b>Disaster Reduction Planning and Response: The Example of National Drought Policy in USA</b>	<b>179</b>
	<i>R.P. Motha</i>	
11.1	Introduction.....	179
11.2	Disaster Management: Shift from Reactive to Proactive Management .....	180
11.3	Rationale for a Coordinated National Drought Policy .....	182
11.4	National Drought Policy Commission .....	184
11.5	U.S. Drought Monitor .....	189
11.6	Latest Developments.....	192
	References .....	192
<b>12</b>	<b>Agricultural Drought Policy and Practices in Australia</b>	<b>195</b>
	<i>W.J. Wright</i>	
12.1	Introduction – Past Policy .....	195
12.2	The 1990s – Development of a National Drought Policy .....	197

12.3	Climate Services in Support of the Drought Policy .....	199
12.4	Application of the Exceptional Circumstances Policy .....	201
12.5	Water Management .....	203
	12.5.1 Water, Irrigation and the Environment .....	203
	12.5.2 Urban Water Policy During Droughts .....	204
12.6	The 2002–03 Drought in Australia – a Case Study.....	206
	12.6.1 Lessons Learned .....	208
12.7	Relation to Long-term Climate Fluctuations .....	211
	12.7.1 Cyclical Climate Fluctuations .....	211
	12.7.2 Climatic Trends and Discontinuities .....	213
12.8	Concluding Remarks .....	215
	References .....	216
<b>13</b>	<b>Significance of Training, Education and Communication for Awareness of Potential Hazards in Managing Natural Disaster in Australia</b>	<b>219</b>
	<i>W.J. Wright</i>	
13.1	Introduction.....	220
13.2	Disaster Mitigation Through Education and Training Programmes by Government Agencies .....	221
13.3	Community Awareness and Self-help Programs in Australia .....	221
	13.3.1 Bushfires .....	222
	13.3.2 Tropical Cyclones .....	225
	13.3.3 Public Weather Advice and Alerts .....	227
13.4	Droughts and Flooding Rains – the Effective Use of Climate Information in Managing Extremes of Climate Variability.....	228
	13.4.1 Seasonal Climate Predictions – Educating the User.....	229
	13.4.2 Responses from Farming Community.....	231
	13.4.3 Other Climate Extremes .....	232
	13.4.4 Training in the Application of Seasonal Predictions in the South Pacific .....	233
13.5	Towards Improved Lines of Communication .....	234
	13.5.1 Role of the Media.....	235
13.6	Concluding Remarks .....	236
	References .....	238
<b>14</b>	<b>Agrometeorological Disaster Risk Management in China</b>	<b>241</b>
	<i>W. Shili, H. Zhiguo, G. Jianping, W. Chunyi</i>	
14.1	Introduction.....	241
14.2	Early Warning and Prediction of Agrometeorological Disasters	242
	14.2.1 Improvement in Statistical Prediction Models.....	242
	14.2.2 Prediction Models Based on Climate Prediction and Agrometeorological Models .....	243
	14.2.3 Early Warning for Agrometeorological Disasters Using GIS .....	246

14.3	Risk Assessments of Agro-meteorological Disasters .....	247
14.3.1	Risk Identification of Major Agro-meteorological Disasters .....	247
14.3.2	Risk Assessment of Major Agro-meteorological Disasters .....	248
14.3.3	Comprehensive Risk Division of Major Agro-meteorological Disasters .....	249
14.4	Popularizing Preventive Measures of Agro-meteorological Disasters .....	250
14.4.1	Rational Use of Agro-climatic Resources to Mitigate Disasters .....	250
14.4.2	Adopting Practical Agricultural Measures to Mitigate Disasters .....	251
14.4.3	Preparing and Applying Reagents to Mitigate Agrometeorological Disasters.....	253
14.4.4	Popularizing Agrometeorological Disaster-preventing Techniques .....	254
14.5	Agrometeorological Information Services.....	254
14.5.1	National Level .....	254
14.5.2	Provincial Level.....	255
14.6	Conclusions.....	255
	References .....	256
<b>15</b>	<b>Degradation of Vegetation and Agricultural Productivity due to Natural Disasters and Land Use Strategies to Mitigate Their Impacts on Agriculture, Rangelands and Forestry</b>	<b>259</b>
	<i>B. Gomez</i>	
15.1	Introduction.....	259
15.2	Definitions of Terminologies.....	260
15.3	Natural Disasters.....	260
15.3.1	Tropical Storms (Cyclones, Hurricanes, Typhoons).....	260
15.3.2	Floods .....	262
15.3.3	Drought .....	264
15.3.4	Dust Storms and Sandstorms .....	268
15.3.5	Frost.....	269
15.3.6	Volcanic Eruption.....	271
15.3.7	Landslides .....	271
15.3.8	Bush/Forest Fires.....	273
15.4	Conclusion.....	275
	References .....	276
<b>16</b>	<b>Agricultural Drought Mitigation and Management of Sustained Agricultural Development in India</b>	<b>277</b>
	<i>H.P. Das</i>	
16.1	Introduction.....	277

16.2	Drought Management .....	279
16.2.1	Risk Management .....	280
16.2.2	Drought Management Strategy .....	281
16.3	Drought Planning in Relation to Climate Change .....	291
16.4	Mitigation of Drought .....	292
16.4.1	Drought Mitigation Strategies .....	293
16.4.2	Government Action to Combat Drought .....	294
16.4.3	Development of New Agronomic Practices and Modern Technology .....	295
16.4.4	Education and Training Programmes for Mitigation of Drought .....	295
16.4.5	Farming Systems Approach for Drought Mitigation .....	296
16.4.6	Strategy to Induce Farmer's Participation .....	297
16.5	Strategic Planning for On-farm Research .....	298
16.5.1	Short-term Measures .....	298
16.5.2	Medium-term Measures .....	298
16.5.3	Long-term Measures .....	299
16.6	Drought Management and Remote Sensing .....	299
16.7	Risk Transfer Through Insurance .....	300
16.8	Conclusion .....	301
	References .....	302
<b>17</b>	<b>Early Detection and Monitoring of Drought and Flood in China Using Remote Sensing and GIS</b> .....	<b>305</b>
	<i>Y. Zhao, S. Li, Y. Zhang</i>	
17.1	Introduction .....	305
17.2	Status of Drought and Flood Early Detection and Monitoring in China .....	307
17.2.1	Drought .....	308
17.2.2	Flood .....	311
17.3	Examples of Flood Monitoring by NMSC in 2003 .....	314
17.4	Conclusions .....	315
	References .....	317
<b>18</b>	<b>The Decision of the Center of a Tropical Cyclone over China Coastal Waters Using a Doppler Radar</b> .....	<b>319</b>
	<i>X. Yinglong, J. Meiyan, B. Baogui, C. Tao</i>	
18.1	Introduction .....	319
18.2	Pattern Recognition Technique .....	322
18.3	The Geometric Axisymmetric Center Positioning Method .....	323
18.3.1	The Detection of a Tropical Cyclone Vortex .....	323
18.3.2	The Determination of the Locations of Extreme Doppler Velocity .....	324
18.3.3	The Decision of the Center of a Tropical Cyclone .....	325
18.3.4	The Decision of the Radius Maximum Wind (RMW) .....	325

---

18.4	The Velocity Distance Azimuth Display Positioning Method.....	325
18.5	Simulated Test .....	327
18.5.1	The Building of the Simulated Doppler Radial Velocity....	327
18.5.2	The Result of Simulated Test.....	329
18.6	Actual Test of Typhoon Case .....	330
18.6.1	The Data of a Typhoon Case.....	330
18.6.2	The Result of Actual Test for a Typhoon Case.....	330
18.7	Conclusions and Discussion .....	333
	References .....	334
<b>19</b>	<b>Application of Remote Sensing and GIS for Analysis of Forest Fire Risk and Assessment of Forest Degradation</b>	<b>335</b>
	<i>A.R. Riebau, J.J. Qu</i>	
19.1	Introduction.....	335
19.2	Climate Change, Climate Variability, and Fire Danger.....	341
19.3	Remote Sensing Applications of Fire Fuels Monitoring.....	341
19.4	GIS Applications and Fire Information Mapping.....	344
19.5	Fire Smoke and Air Quality.....	344
19.6	Summary and Conclusions .....	348
	References .....	348
	<b>Conclusions and Recommendations</b>	<b>351</b>
	Conclusions .....	351
	Recommendations .....	352
	<b>Index</b>	<b>357</b>



---

# List of Contributors

## **Bi Baogui**

Weather Forecast Office, National Meteorological Center  
China Meteorological Administration  
46 ZhongGuancun South Avenue, 100081, Beijing, P.R. China  
E-mail: bibg@cma.gov.cn

## **Wang Chunyi**

Chinese Meteorological Society  
No. 46, Zhongguancun Nandajie, 100081, Beijing, China  
E-mail: wcy@cms1924.org

## **Haripada P. Das**

Meteorological Office, Division of Agricultural Meteorology  
Shavajinagar, Pune, 411005 India  
E-mail: hpd\_ag@rediffmail.com

## **Douglas G. Fox**

Center for Investigations and Research of the Atmosphere (CIRA)  
Colorado State University  
Fort Collins, Colorado 80526 USA  
E-mail: dfox@cira.colostate.edu

## **Bernard Gomez**

Department of Water Resources  
Banjul, Gambia  
E-mail: be63gomez@hotmail.com

## **R.P.R. Guerreiro**

Division of Hydrometeorology and Agricultural Meteorology  
Department of Climate and Atmospheric Environment  
Institute of Meteorology  
Lisbon, Portugal  
E-mail: rita.guerreiro@meteo.pt

**Guo Jianping**

Institute of Eco-environment and Agrometeorology  
Chinese Academy of Meteorological Sciences  
No. 46, Zhongguancun Nandajie, 100081, Beijing, China  
E-mail: guojp@cma.gov.cn

**Penehuro Lefale**

National Institute of Water and Atmospheric Research  
P.O. Box 109-695  
Newmarket, Auckland, New Zealand

**Sanmei Li**

National Satellite Meteorological Center of China (NSMC)  
46 Zhongguancun Nandajie, Beijing 100081, China  
E-mail: sanmeili@nsmc.cma.gov.cn

**Jiao Meiyang**

National Meteorological Center, China Meteorological Administration  
46 ZhongGuancun South Avenue, 100081, Beijing, P.R. China  
E-mail: Jiaomy@cma.gov.cn

**Raymond P. Motha**

U.S. Department of Agriculture, World Agricultural Outlook Board  
1400 Independence Avenue, S.W.  
Room 4441, South Building, Washington, D.C. 20250  
E-mail: rmotha@oce.usda.gov

**Liliana Nuñez**

Servicio Meteorológico Nacional  
C.P. 1002  
Buenos Aires, Argentina  
E-mail: lnunez@meteofa.mil.ar

**John Jianhe Qu**

School of Computational Science (SCS)  
GeorgeMasonUniversity (GMU)  
4400 University Drive, MS 5C3  
Fairfax, VA. 220303 USA  
E-mail: jqu@gmu.edu

**Allen.R. Riebau**

USDA Forest Service Research and Development  
Wildlife, Fisheries, Watershed and Air Research (WFWAR)  
14th and Independence, S.W., RPC-4  
Washington, D.C. 20250-1113 USA  
E-mail: ariebau@fs.fed.us

**M. James Salinger**

National Institute of Water and Atmospheric Research  
P.O. Box 109-695  
Newmarket, Auckland, New Zealand  
E-mail: j.salinger@niwa.co.nz

**Wang Shili**

Institute of Eco-environment and Agrometeorology  
Chinese Academy of Meteorological Sciences  
No. 46, Zhongguancun Nandajie, 100081, Beijing, China  
E-mail: wangsl@cma.gov.cn

**Mannava V.K. Sivakumar**

World Meteorological Organization  
7 bis, Avenue de la Paix  
1211 Geneva 2, Switzerland  
E-mail: msivakumar@wmo.int

**Chang Tao**

Weather Forecast Office, National Meteorological Center  
China Meteorological Administration  
46 ZhongGuancun South Avenue, 100081, Beijing, P.R. China  
E-mail: zhangtao@cma.gov.cn

**Donald A. Wilhite**

National Drought Mitigation Center  
and International Drought Information Center  
University of Nebraska  
Lincoln, Nebraska 68583-0749 U.S.A.  
E-mail: dwilhite2@unl.edu

**William J. Wright**

National Climate Centre, Australian Bureau of Meteorology  
GPO Box 1289K, Melbourne, 3001 Australia  
E-mail: w.wright@bom.gov.au

**Ming Xu**

Shanghai Typhoon Institute  
166 Puxi Road, Shanghai, China, 200030  
E-mail: xum@mail.typhoon.gov.cn

**Qiuzhen Yang**

Shanghai Typhoon Institute  
166 Puxi Road, Shanghai, China, 200030  
E-mail: yangqz@mail.typhoon.gov.cn

**Du Yaodong**

Climatic and Agrometeorological Center  
Meteorological Bureau of Guangdong Province  
People's Republic of China  
E-mail: yddu@grmc.gov.cn

**Ming Ying**

Shanghai Typhoon Institute  
166 Puxi Road, Shanghai, China, 200030  
E-mail: yingm@mail.typhoon.gov.cn

**Xu Yinglong**

National Meteorological Center, CMA  
Beijing, China, 100081  
E-mail: xuy1@cma.gov.cn /  
xuyinong\_china@163.com

**Yeping Zhang**

National Satellite Meteorological Center of China (NSMC)  
46 Zhongguancun Nandajie, Beijing 100081, China  
E-mail: yepingzhang@nsmc.cma.gov.cn

**Yanxia Zhao**

Chinese Academy of Meteorological Sciences(CAMS)  
46 Zhongguancun Nandajie, Beijing 100081, China  
E-mail: zyx@cams.cma.gov.cn

**Huo Zhiguo**

Institute of Eco-environment and Agrometeorology  
Chinese Academy of Meteorological Sciences  
No. 46, Zhongguancun Nandajie, 100081, Beijing, China  
E-mail: huozhigg@cams.cma.gov.cn

# 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.



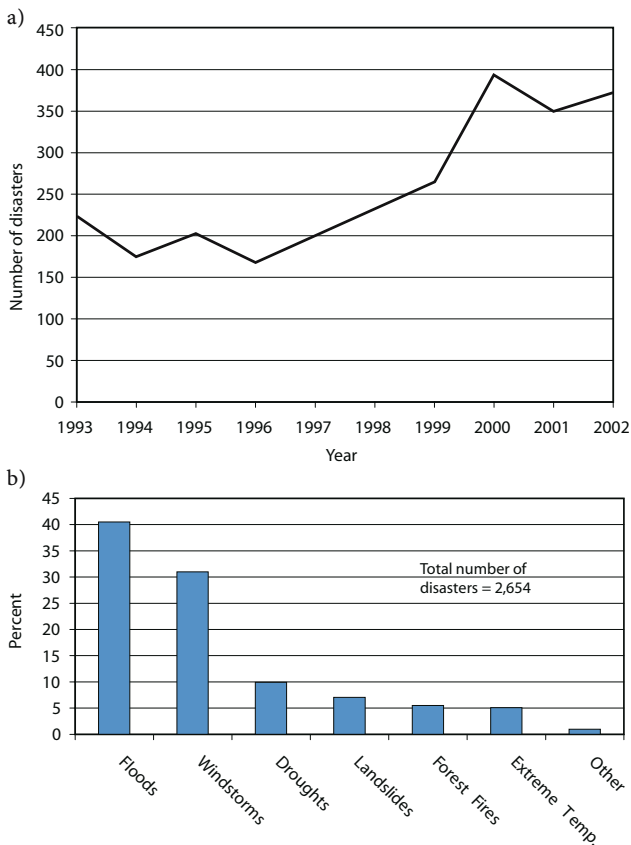


Fig. 1.1. (a) Annual variations in the occurrence of hydro-meteorological disasters during 1993–2002 and (b) the percentage of different hydro-meteorological disasters as a percent of total number of disasters during 1993–2002

## 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).

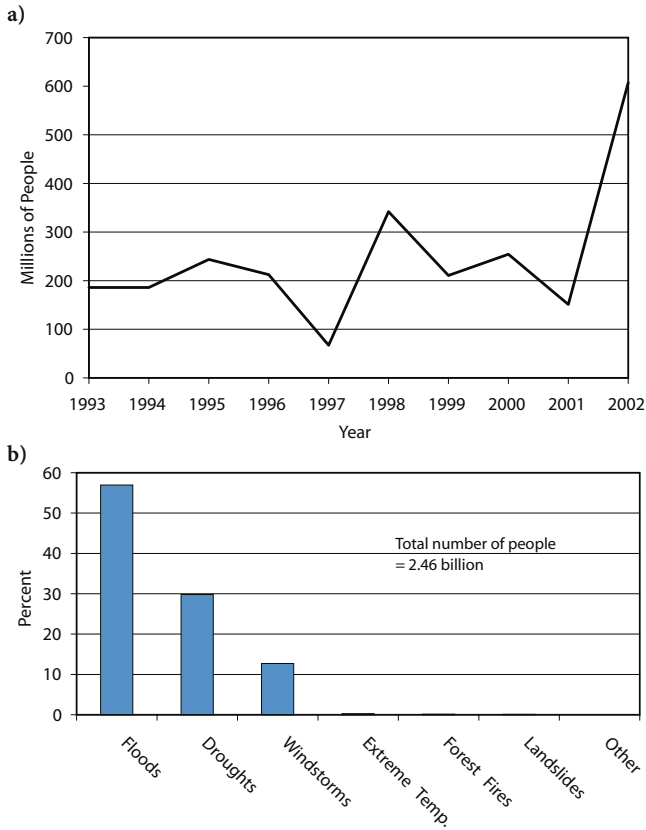


Fig.1.2. (a) Annual variations in the number of people affected by hydro-meteorological disasters during 1993–2002 and (b) the percentage of people affected by different hydro-meteorological disasters during 1993–2002

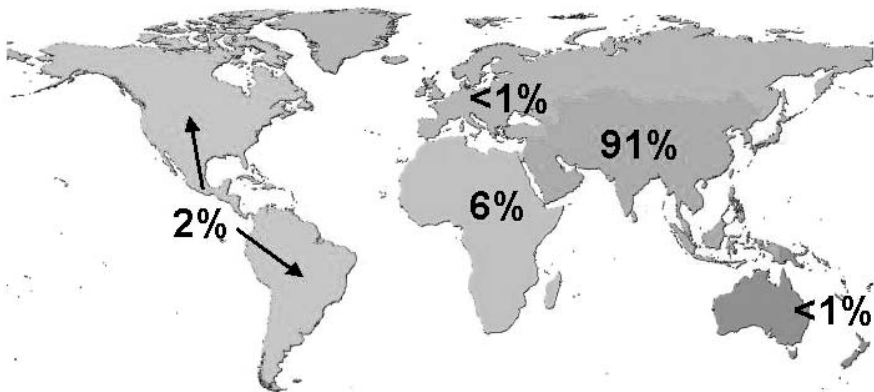


Fig.1.3. Percentage of total number of people reported affected by hydro-meteorological disasters by region

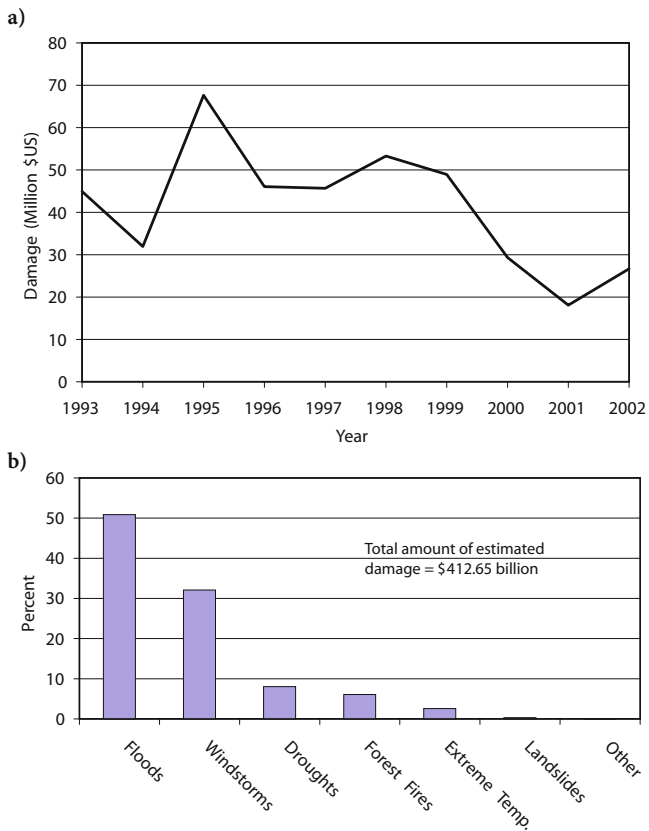


Fig.1.4. (a) Annual variations in the estimated damage due to hydro-meteorological disasters during 1993–2002 and (b) the percentage of damage caused by different hydro-meteorological disasters during 1993–2002

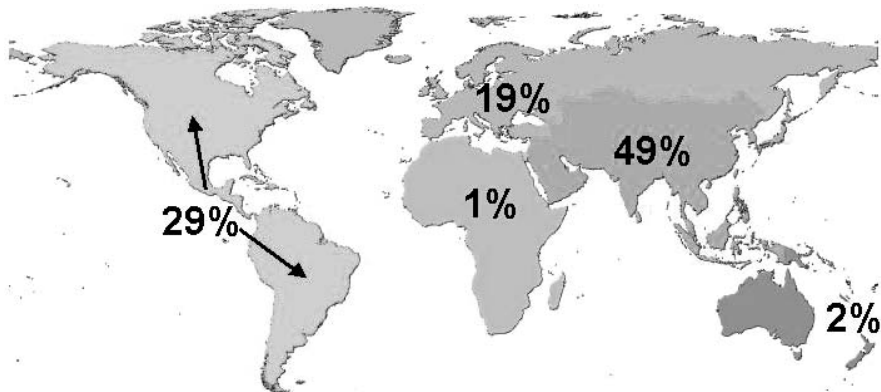


Fig.1.5. Percentage of total amount of disaster estimated damage by region (2002 prices)

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