Journal of the Korean Geographical Society, Vol 33, Special Edition, 1998 (721~728)

Recent Contributions by Geographers to Natural Hazards Mapping and Mitigation

Charles L. Rosenfeld*

자연재해의 지도화와 피해경감 방안에 관한 지리학자들의 최근 성과

Abstract : The United Nations designated the 1990's as the International Decade for Natural Disaster Reduction (IDNDR), establishing a secretariat for that purpose in Geneva. In response, the Interaltional Council of Scientific Unions has sponsored geographical research in several areas through the International Geographical Union (IGU) By establishing a commission on Natural Hazards Studies (CONAHA) at the 27th IGC in 1992, IGU began an effort to involve geographers in a variety of natural hazards projects with an emphasis on emerging new technologies in geography

Geographers have made important contributions to the IDNDR, especially in the areas of geographic information systems for hazard management, remote sensing for mapping and disaster assessment, and the use of the Global Positioning System for disaster response. Geographers are taking more important roles in mapping and mitigation efforts, and in planning the recovery of affected areas CONAHA will conclude its role in support of the UN initiative at the 29th IGC in Seoul in 2000. Among the permanent contributions will be a book series on natural hazards, which began with the 1998 publication of the book on Mountain Hazards, and the section on natural hazards of the Encyclopedia of Life Support Systems to be published by UNESCO at that time.

Key Words Hazards, Natural disasters, Physical geography, Geographic information systems, Remote sensing, Preparedness

요약 : UN은 1990년대를 전세계적인 자연재해 감소를 위한 10년(IDNDR)으로 지정하고 이러한 취지로 제네바에 사무국을 개설했다. 그에 대한 반응으로 국제 과학 연합회는 IGU를 통해 여러 지역에서의 지리적 연구를 지원하고 있다 IGU는 1992년에 개최된 제 27차 IGC에서 자연재해연구 분과를 개설하여 지리학에 있어서 새로운 기술을 개발하는데 강조를 두는 다양한 자연재해 프로젝트에 지리학자들을 포함시키려는 노력을 시작했다

지리학자들은 IDNDR에 중요한 공헌을 하고 있는데, 특히 재해 관리를 위한 GIS의 영역과 지도화와 재해 평가를 위한 원격탐사, 재해 반응에 대한 GPS의 이용 등이 이에 포함된다.

지리학자들은 지도화와 재해를 경감시키려는 노력에 중요한 역할을 하고 있으며, 이미 재해를 입은 지역에 대해 복구 계획을 세우고 있다. CONAHA는 2000년에 서울에서 개최되는 제 29차 IGU에서 UN에 의해 시작된 안건을 지지하게 됨으로 그 역할을 마무리하게 될 것이다 영구적인 공헌 중에는 1998년에 산악 재해에 관한 발간을 시작으로 자연재해에 관한 책 시리즈와 UNESCO에 의해 발간된 Life Support Systems 백과사전 내용 중 자연재해에 대한 부분이 포함된다는 것이다

주요어 위험, 자연재해, 자연지리학, 지리정보체계, 원격탐사, 대책

The United Nations designated the 1990's as the International Decade for Natural Disaster Reduction(IDNDR), establishing a secretariat for that purpose in Geneva. In response, the Interaltional Council of Scientific Unions has sponsored geographical research in several areas through the International Geographical Union (IGU). By establishing a commission on Natural Hazards Studies(CONAHA) at the 27th International Geographical Congress(IGC) in 1992, IGU began an

* Chair of IGU Commission on Natural Hazards Studies, Professor(Ph.D.), Dept. of Geosciences, Oregon State University, U.S.A.

effort to involve geographers in a variety of natural hazards projects with an emphasis on emerging new technologies in geography.

Geographers have made important contributions to the IDNDR, especially in the areas of geographic information systems for hazard management, remote sensing for mapping and disaster assessment, and the use of the Global Positioning System for disaster response. Geographers are taking more important roles in mapping and mitigation efforts, and in planning the recovery of affected areas. CONAHA will conclude its role in support of the UN initiative at the 29th IGC in Seoul in 2000. Among the permanent contributions will be a book series on natural hazards, which began with the 1998 publication of the book on Mountain Hazards, and the section on natural hazards of the Encyclopedia of Life Support Systems to be published by UNESCO at that time.

1. Summary

The dramatic increase in losses and casualtiesdue to natural disasters during the past three decades has prompted a major international scientific initiative into the probable causes and possible mitigation strategies. The damage has increased three-fold from the 1960's through the 1980's, leaving more than three million dead and causing the displacement of more than 800 million persons during that period. Many of the crucial questions are geographical in nature, therefore the International Council of Scientific Unions(ICSU) has tasked the IGU with specific scientific themes during the International Decade of Natural Disaster Reduction(IDNDR). The U.S. National Academy of Sciences(NAS), prompted by the ominous trend of disaster losses, presented an initiative to the United Nations' in December of 1987[1]. The UN subsequently established a secretariat for the IDNDR in April of 1989[2], located in Geneva, Switzerland along with the UN Disaster Relief Organization(UNDRO). The work of CONAHA will conclude with a symposium on geographical contributions to the IDNDR ath the 29th International Geographical Congress at Seoul, Korea in August, 2000.

As the population of the Earth has doubled from the three billion of 1960, the annual losses due to disaster has grown almost ten-fold' . At least part of the problem can be traced to the increase in population density of many regions, which often results in the human occupance of hazard prone lands that were previously avoided. But many states and cultures have not emphasized 'flood-proofing' buildings in floodplains or coastal areas, earthquake design standards in seismic hazard areas, or building codes to withstand windstorm or fire dangers. Often it has not been for lack of knowledge or vigilance, but for lack of resources or willingness to divert limited national wealth to such causes, especially in rapidly developing economies. Even in developed countries, governments have been reluctant to impose costly building standards and zoning regulations in the most vulnerable areas- what if Hurricane Andrew, which struck the United States in 1993 had focused a few kilometers to the north and struck downtown Miami?

Another perplexing question centers upon the apparent increase in frequency of natural disasters.Accurate statistical analyses of such infrequent occurrences requires an observation period well in excess of a century' , while the consistent reporting of most disaster types has a much shorter history. Monitoring techniques, measurement scales(Richter, Beaufort), and communications have only recently allowed the global reporting of events in comparable terms. A study of volcanic eruptions by Simpkin et al[3]. concludes that the reported increase in volcanic activity over the past 120 years is almost certainly due to improved reporting and communications technology; they even cite a reduction in 'apparent' activity during the two world wars. Despite the growing influence of global databases, scientific consortia and the news media, additional factors may be influencing the growing number of reported disasters.

While considerable scientific debate lingers around the issue of global climatic change, we are well aware of other indirect effects of human activity. Certainly the deforestation of large areas has caused landslides and increased both the frequency and peak flows of flood events in many areas, while over-grazing has accelerated drought effects and erosion. Groundwater withdrawal and irrigation diversions have affected the natural vegetation and micro-climates of some regions, and has even induced earthquakes in some cases. As global climate models become increasingly realistic, their mathematical results consistently pointto a more hazardous world in the future'. That increasing concentrations of greenhouse gases in the atmosphere, primarily resulting from the burning of fossil fuels, is changing the radiation balance and perhaps the climate is consistent with recent disaster experience. There is general agreement among atmospheric scientists that a 'warmer' world would be a 'wetter' world, with no increase in the number of days with rain, but with more intense rainfall. This situation could lead to dramatic increases in the severity of flooding and storm-induced mass wasting and mudflow events. Combined with the hydrologic effects of landuse changes, the frequency and affect of floods would surely increase, especially in the monsoon climates of South Asia where flooding already reaches catastrophic proportions. Drought effects in sub-Saharan Africa, South America and Australasia could occur more frequently and be more severe as a result of intensified El Nino-Southern Oscillation events.

Resultant sea level rise could pose additional storm surge or tsunami risk to low-lying coastal regions like Egypt or Bangladesh, and many Pacific islands, with the loss of most fresh groundwater resources in the later case. Regardless of the causes, the impacts of anticipated changes in extreme weather hazards as a result of global climatic change, and their implications for human activity, demands our immediate attention.

Recent experience has shown that disaster planning and early warning systems have resulted in variable success. In Japan, major landslides (primarily debris flows) triggered by heavy typhoon rains were responsible for the loss of more than 30,000 homes and nearly 500 lives in 1938. But in 1976, following the government's comprehensive landslide control program, the worst storm-produced landslide year in over two decades cost less than 2,000 homes and fewer than 125 lives- and this reduction trend is still improving[4]. In Bangladesh a cyclonic storm pushed a 3 to 8 meter storm surge through Sandwhip and other coastal islands killing more than 10,000 people in 1985. However, a satellite-based early warning system aided evacuation of island and coastal dwellers to points further inland, which reduced the toll by 30 to 50 times from that of a similar storm in 1970. Despite these successes, and more than 50 years of comprehensive flood control development, the 1993 floods along the Mississippi valley in the American mid-west were the costliest flood events in U S. history. In the Philippines, flooding triggered by Typhoon Uring in November 1991 struck Ormoc City[5] in Leyete Provence with a 3-meter flood crest. Although the storm itself was monitored, the lack of hazard zoning, and poor infrastructure design in the urban area left nearly 7,000 people dead or missing.

In some instances, disaster mitigation strategies and international relief efforts may actually be partially responsible for the rising losses. In many developed countries, state-backed hazard insurance programs are designed to encourage the use of hazard zoning and the implementation of damage resistant building codes and a reduction in the demand for structural control measures, however this may have actually encouraged the development of hazard prone areas through the combined effect of lower land costs and cheap indemnity. Thus the 'insured' actually transfers the risk to the 'insurer', and may dismiss the risk or reduce the individual concern for loss prevention measures[6]. One critical problem is that insurance rates are calculated based upon the loss experience of the past, however, given the escalating nature of both frequency and magnitude of disaster losses this may not be appropriate. Likewise, many lesser developed countries have developed adependence on international disaster relief, whereby they become less willing to divert their limited national resources to immediate relief or recovery efforts.

The IGU is directing its collective expertise in the areas of drought and famine, flood, and the vulnerability of megacities, with many of its members also contributing to studies of earthquakes, volcanic eruption, landslides and many other hazards. The Commission on Natural Hazards Studies(CONAHA) is directing a flood hazard research program in Bangladesh, and at organizing and co-sponsoring numerous regional and international symposia, and contributing expertise to many projects[7]. Geographer's are well equipped with new tools and methodologies to answer many of the critical questions facing the world's problem areas. The broad expertise of geographers in analyzing the spatial aspects of various phenomena is particularly appropriate to the study of natural disasters. Physical geographers are increasingly engaged in the mapping of geophysical, geomorphic and hydrological characteristics which expose areas to rupture, failure, fire, inundation, drought, erosion or submergence. Coupled with landuse and infrastructure analyses they examine the location, value, exposure and vulnerability of the structural environment to hazard damage, failure, loss of function, and release of hazardous materials. When population density and demographics are added, potential casualties and emergency services needs can be forecast. This, of course involves the integration of human geographers whose focus upon social, technical, administrative, political, legal and economic forces which structure a society's strategiesand policies for risk management(i.e; prevention, mitigation, preparedness, prediction and warning, and recovery), public awareness, training, regulation and social insurance. Such a comprehensive approach would have been nearly inconceivable in the past, but with the advent of computerized geographic information systems(GIS) such mapping, modeling, and decision support systems are becomming more common place". While satellite remote sensing has become a routine tool for land surface classification and mapping, the more recent fusion of these methods with the Global Positioning System(GPS), and integration with GIS technology marks a catalytic changeinour approach togeo graphic data collection.

Modem field-portable(lap-top) computers can now be equipped with GPS receivers to accurately provide field locations anywhere on earth from a 'constellation' of 26 Navstar satellites. As the computer displays the location on a digital map or remotely sensed image, the researcher can map or update a GIS data base in the field[8]. The use of such technology will undoubtedly expand rapidly in the near future as more applications develop and as the costs of the required equipment drop The United Nations Institute for Training and Research(UNITAR) has sponsored several training workshops entitled 'Explorations in Geographic Information Systems Technology', operated by the Graduate School of Geography of Clark University(USA). A similar program is operated by the International Institute for Aerospace Survey and Earth Sciences(ITC) in the Netherlands. CONAHA and the ITC have coordinated the trainig of five students from Bangladesh in the earth survey program, where the curriculum has been fashioned to meet the needs of research work with the flood problems in their country.

At this writing, a 'pen-based' laptop computer, appropriate software and an attached GPS receiver costs about US$5,000. Six computer manufacturers have announced plans to release similar computers withbuilt-in GPS receivers. Such computers do not require a keyboard as they are designed to 'recognize' mapping symbols and handwriting from an electronic 'pen'. Field data from numerous field research teams can quickly be merged electronically into a comprehensive GIS. Other aspects of digital data technology are emerging as significant future contributors to natural hazards studies; the Digital Chart of the World" makes digital cartographic databases available on low-cost compact discs, and may other geophysical and hydrologic data resources are also available in this format, enabling researchers to access long-term records of hazard activity. A significant 'bridging function' by the IGU is resulting in the collaboration of diverse scientificunions under IDNDR. Unfortunately, other UN global scientific programs, such as the International Geosphere-Biosphere Program(IGBP) and the Human Dimension of Global change Program(HDGP) were independently structured and funded resulting in separate program functions with limited interaction. IDNDR considers both the physical aspects of hazards as well as their social consequences, and IGU provides the scientific lead for three IDNDR projects involving five IGU Commissions and several ISCU member unions, as well as cooperation with the IGBP and HDGP. The geographic approach to natural hazards studies may be graphically portrayed as a pyramid, Figure 1, incorporating a temporal scale of the duration of hazard events, a spatial scale proportional to the relative areas affected by each type of hazard event, an economic scale relative to the level of development of the society affected, proportional casualties and economic losses, and levels of response required to meet the impacts. The duration, recurrence interval and areal extent of natural hazards affects both our observation base and our understanding of such events. While the mechanics of mass wasting are well understood, their 'triggers' are often less clear,and the antecedent conditions of their occurance may be too widespread and numerous to monitor effectively. However, adequate safety measures are possible, as seen in Japan's example, provided thateconomic and social circumstances warrant them.

The ability of a society to deal with the effects of disasters to some extent varies with the size of the area affected and the degree to which the infrastructure can retain its function. The 1972 earthquake which struck Managua, Nicaragua caused 10,000 deaths, 20,000 injuries and caused such damage to the infrastructure that three quarters of the city's 400,000 inhabitants were left homeless. Given the Nicaragua's state of economic development, the losses exceeded the nation's entire gross national product. To explore the role of economic development upon the effects and response to natural disasters, we divide states into lesser developed countries(LDC's), transitioning economies(TE's), and developed countries(DC's). While some economists have observed a growing gap between the rich and poor nations of the world, there has been an increase in the number of industrializing transitional economies. The losses sustained by states at varying levels of economic development is shown on the left face of our pyramid: as the severity of disasters increase, there is an exponential rise in the number of casualties among the poorer nations, while the developed countries, with better warning systems, planning and construction regulations, and public services suffer fewer fatalities. At the same time, property losses can be extreme under similar circumstances

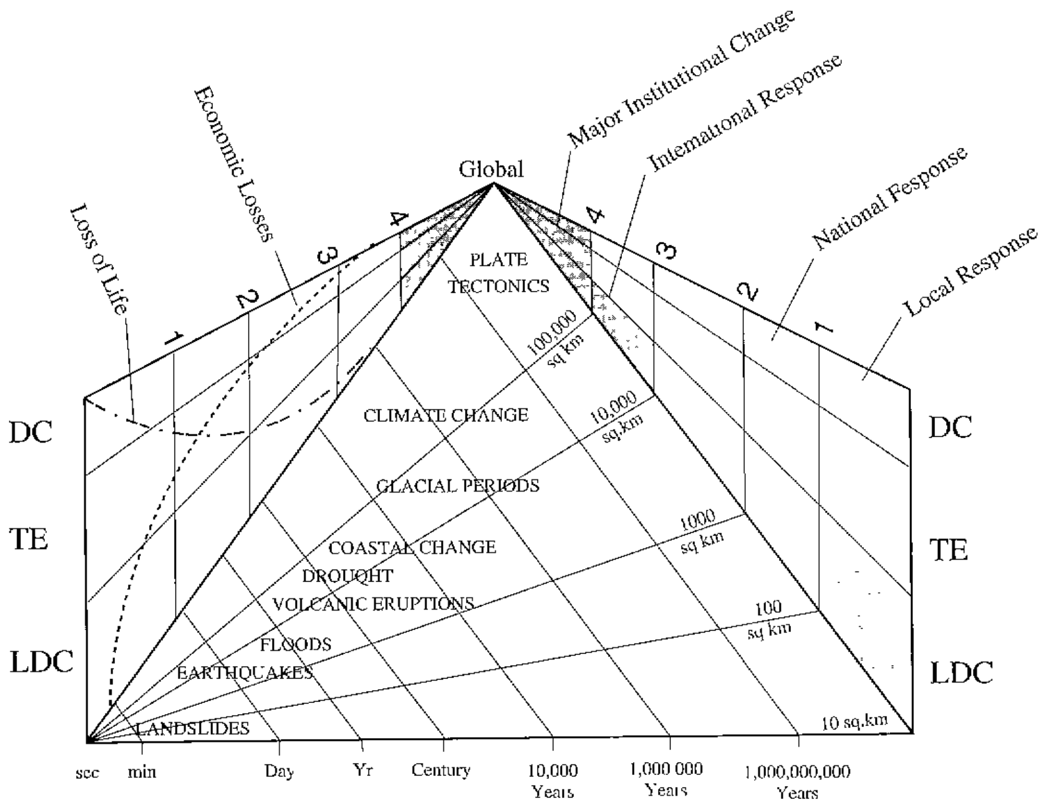

Figure 1. A model of the relation between natural hazards, their severity, and the potential effects upon human societies at varying economic levels of development.

in those developed countries. The 1994 San Fernando valley earthquake which centered in urban Los Angeles caused billions of dollars of property damage, with the loss of less than 70 lives. The casualty and economic loss curves converge in transitioning economies, such as Korea ,where new investment in industrialization often takes higher priority than the costs of hazard mitigation. Awareness of the risks of natural hazards to economic development are essential among the leaders of these nations, as the general population has a heritage of enduring such events, with recovery left to personal initiative- this doesn' t work in the more complex econcmy of the industrialized world. The losses which resulted from flooding in Korea in 1998 presented a significant challenge to the government, where the cost of relief and recovery was added a a time of severe economic reconstruction. There is, however, a threshold of extreme events beyond which cataclysmic losses occur, regardless of a nation' s wealth. The opposite face of our pyramid depicts the levels of emergency response that are generally required for recovery at the various severity levels of disaster. Once again, our relative severity scale ascends from (1) significant events, moderately exceeding 'normal' conditions, (2) exceptional events, beyond the required design standards for routine construction, but below those set for 'key' facilities, (3) catastrophic events which exceed any cost-effective design strengths, and (4) extreme events yielding almost total destruction of structures and support systems. Level I events can usually be ccommodated within 'normal' risk management capabilities, except in the least aware societies, and level 4 is beyond the maximum recovery capability of even the wealthiest of states. Beyond the obvious relation between response containment and level of economic development there is an institutional dimension that is frequently overlooked by major national and international hazards research programs: geologic and geophysical hazards can be identified at large scales, affecting nations or regions, but vulnerability and risk assessments need to be carried out at the detail of human activities, generally at scales of 1: 1,000 to 1: 50,000. Priority for hazards assessment needs to center on those impacts and response options at the local level, as they are the most immediate, and potentially the most crucial at severity 2 and 3. Major social and institutional changes often result when losses far exceed the best available recovery mechanisms, severity 4.

The IGU Commission on Natural Hazards Studies in its flood hazard project in Bangladesh has endeavored to incorporate this model. Using regional climatic forcing models and hydrologic data, the physical scale of flood severity is established. This is then combined with geomorphological mapping and satellite imagery to delineate the hazard regions. Flood forecasting and flood-alert schemes areconstructed using weather satellites and monitoring stations. Vulnerability and potential damage mapping techniques are taught at training workshops to local field mapping technicians, with the idea that local involvement in risk management fosters an increased awareness of the flood hazard among authorities and the population, which inevitably leads to local 'adjustments' in landuse patterns and population densities. Evacuation strategies, flood refuge sites, and relief distribution points are identified using GIS technology, and key facilities and major urban areas are evaluated as candidates for cost-effective flood control structures. Finally, since flood mitigation is cost-limited at certain severity levels, planning consideration must be given to events which could possibly exceed the mitigation efforts. Natural hazards research is obviously an interdisciplinary field involving a range of natural scientists with social scientists assessing the human dimension of the problems. Given the limited observed record of hazard events in most regions, a geomorphological approach, where the areal extent(and possibly the frequency) of events can be determined from the landscape is essential. The geomorphological approach may also encourage the ,nature knows best' approach to designing hazard mitigation strategies in balance with the dynamics of processes within the region. In the final analysis, occupance of hazard-prone areas is both physically and economically self-regulating. It is the function of science, as a servant of society, to identify those limitations and point the way toward minimizing the disastrous consequences of 'learning our lessons' in nature's way.

Acknowledgements

The author is grateful to the Korean Geographical Society, and especially its President, Professor Hyoun-Young Lee for the opportunity to bring this research to the attention of geographers in Korea at the International Geographical Symposium on Human Culture and Environment held at Seoul National University on November 6, 1998. In particular I would like to thank Professor Woo-ik Yu, of the IGC Organizing Committee and the Korean Research Foundation and the Korean Federation of Science and Technology Societies for sponsorship of this program.

Notes

1) Advisory Committee on the International Decade for Natural Hazard Reduction, 1987, "Confronting Natural

Disasters", National Academy Press, Washington, 60pp.

2) An AdHoc Group of experts formulated the so-called Tokyo Declaration, and a UN Committee for the IDNDR was founded. Since then a Select Committee of the International Council of Scientific Unions has been established at Paris for coordination of scientific projects in support of the IDNDR The International Geographical Union has focused on flood hazard and mitigation. drought and famine and the vulnerability of megacities.

3) Simpkin, T , Seibert, L., McClelland, L., Bridge. D., Newhall, C . Latter, J.. 1981,"Volcanoes of the World". Smithsonian Institution, Washington. 232pp.

4) Ministry of Construction, Japan, 1983, "Reference Manual on Erosion control Works, Erosion control Depart,emt.

5) Pearson. M.L and Oliver. J G. 1992, Reconnaissance Report: flooding resulting from Typhoon Uring in Ormoc City, the Philippines, Waterways Experiment Station, Misc. Paper GL-92, Corps of engineers, Washington 49pp.

6) Bretz, G . 1993, 'The Insurance Industry and the IDNDR: Common Interests and Tasks' . workshop on Cooperation of the Construction and Insurance Industries with the IDNDR, Frankfurt

7) The CONAHA project in Bangladesh is funded by the International Council of Scientific Unions. and is in cooperation with the Geography Department of the University of Dhaka

8) The use of such a system was demonstrated during recent flooding in Bangladesh, see Rosenfeld, C.,1994, 'Flood Hazard Reduction: GIS Maps Survival Strategies in Bangladesh'. GeoInfo Systems. Vol. 4(5), 30-37.