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NATURAL DISASTER REDUCTION AND ENVIRONMENTAL MANAGEMENT: A GEOMORPHOLOGIST'S VIEW

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Natural hazards, threatening many parts of the world, are often ignored in the context of regional planning and environmental management, although this is necessary for avoiding, or at least substantially reducing the recurrence interval and magnitude of the related «natural» disasters. This is particularly the case for «creeping» disasters, related to environmental degradation caused by slow and in many cases almost imperceptible processes, including desertification, salinization, certain forms of soil erosion, pollution, etc. The more spectacular instantaneous disasters, resulting from high-intensity and low-frequency natural events of endogenous or exogenous origin, are nowadays reported about by the media world-wide. They are, however, soon out of focus again and adequate measures to prevent similar disasters in the future do not always remain a high priority of the responsible authorities.

Disaster reduction through environmental management is a complex issue that requires interdisciplinary applied research related to the natural environment as well as to the socio-economic situation of the endangered societies. In fact, sustainability is at stake. For the implementation of adequate protection measures, ranging from «hard» engineering structures to «soft» management improvements, optimal cooperation between the various sectors of the communities concerned is essential. This multisectoral approach should lead up to a master-plan for long term regional management and a disaster scenario specifying tasks and responsibilities of organizations and individuals in case of an emergency situation. Apart from natural disasters, technical-industrial disasters and also the, often neglected, ecological disasters should be considered. Humanitarian disasters are, unfortunately, largely outside the field of science. The UN-IDNDR (International Decade for Natural Disaster Reduction) program of the 19nineties concentrated on natural disasters only. Its follow-up, the UN-ISDR (International Strategy for Disaster Reduction), has a broader scope because technological / industrial disasters are also included.

Examples are given of volcanic disasters in Indonesia, including gas emanations on the Dieng plateau and pyroclastic flows on the densely populated SW slopes of the Merapi volcano in Central Java, Further, the effects of the ill-famed eruption of the Nevado de Ruiz volcano, Colombia in 1985 are discussed in relation to shortcomings in disaster mitigation systems. Drought and desertification studies executed in northern Chad and in Botswana are discussed thereafter as an introduction to the problems of assessing and achieving global sustainability problems.

KEY WORDS: Natural hazards, Disaster reduction, Geomorphology, Sustainability.

INTRODUCTION

Natural disasters are of common occurrence in many parts of the world. Particularly the instantaneous disasters resulting from extreme natural events (Nott, 2006) such as floods, landslides, volcanic eruptions, earthquakes and tsunami, are frequently reported about in the media. Creeping disasters, the other main category of natural disasters have become a focus of attention only in recent years and will be dealt with separately. Some types of instantaneous disasters (volcanic eruptions, earthquakes, tsunami, etc.) are of endogenous origin and society then plays the part of victim only. The causes of disasters of exogenous origin (river floods, cyclones, landslides, etc.) are natural in the first place, but human impact on the environment by way of inadequate agricultural practices, engineering works, etc., often is a triggering or aggravating factor. The «natural» disaster in such cases is not fully natural and society is not only a victim but a causative factor as well (McCall & *alii*, 1992). Hazard zoning and early warnings are the two basic elements of disaster mitigation programmes in endangered areas. Extreme natural events are a fascinating subject of study for earth scientists. They are considered to be disastrous only if they adversely affect society. Creeping processes of land degradation usually concern large areas but frequently remain unnoticed for a long time. Their visual effects often become spectacular only in a late stage when it may be difficult to take the proper remedial measures.

MITIGATING INSTANTANEOUS DISASTERS

Hazard zoning, rooted mostly in geomorphological research, is an important means of reducing the losses of human life and property in case of extreme events because it leads to specifying endangered areas in case of events of specific magnitudes. However, it is only effective if it has been legalized by the responsible authorities and if the en-

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visaged physical planning is a real option. Inadequate governance, economic constraints, social conditions, scarcity of safe ground and the economic importance of endangered sites, preclude the optimum use of hazard zoning in many parts of the world. In the Netherlands, for instance, the outskirts of Rotterdam are situated at seven metres below sea level notwithstanding the risk of dike breach in case of exceptionally high seas, such as during the flood disaster of 1953. Historical and economic reasons account for this situation. On the higher slopes of some active Indonesian volcanoes, many farmers live in severely endangered areas and even in the so-called «prohibited zone», lured by the fertility of the volcanic soils and forced by the lack of other options on the densely populated lower slopes.

Fig. 1 shows an attempt to hazard zoning in a part of the volcanic Dieng plateau in Central Java, Indonesia, where a considerable number of small potential eruption points is situated. Occasional, sudden gas emanations along certain fissures are a particular danger in this area. One of these, for instance, killed 149 school children on their way to school on the occasion of the supposedly mainly phreatic eruption of the SiNila of 1979. Fig. 2 is a ground view of the eruption point, a small, elongated depression bordered by mud deposits.

Population pressure strongly limits the value of hazard zoning also in countries such as Thailand and Bangladesh where the frequent river floods are incorporated in the rural land use system. Farmhouses are built on small artificial mounds, situated on the natural levees and the paddy fields are preferably planted with so-called «floating» rice that grows up with the slowly rising floodwater. The construction of adequate dikes being unaffordable, people live with the floods rather than combating them. Disaster strikes when fields disappear due to a lateral shift of the riverbed, because the family then is condemned to a life in urban slums. The floods are a natural fertilizer and the sediments gradually raise the level of the land and counter the effects of sea level rise. Dike construction thus has its pros and cons. The benefits of hazard zoning are in such densely populated areas mainly in the field of planning infrastructures, such as roads and bridges.

Early warning systems (Zschau & Küpper, 2003) based on constant monitoring of the hazard situation, are the second basic means of reducing instantaneous disasters. although their potential varies from high for river floods to low where earthquakes and sea waves are concerned. In some cases there is no other option for disaster mitigation. The coastal zones of Bangladesh bordering on the Bay of Bengal, for instance, are at times suddenly exposed to several metres high storm surges caused by tropical cyclones. Hazard zoning is hardly of any use and a timely early warning system, combined with the construction of many artificial mounds where people can seek refuge, is the only really effective approach to disaster mitigation. The existence of an adequate, legalized emergency scenario, preparedness of the authorities and awareness of the endangered population are essential prerequisites for successful early warning. Environmental management thus plays a key role also in early warning. Good coordination between the various authorities involved in handling emergency situations is essential. Above all, the warning system should be reliable, quick and if not automated, free of competency disputes as to who is authorized to issue an alarm.

The simple early warning equipment of fig. 3, situated in a village on the lower slopes of the Semeru volcano, East Java, Indonesia, includes not only volcanic mudflows, but also fire, burglary, etc. It is uncertain who is competent to order an alarm and whether it will be given timely.

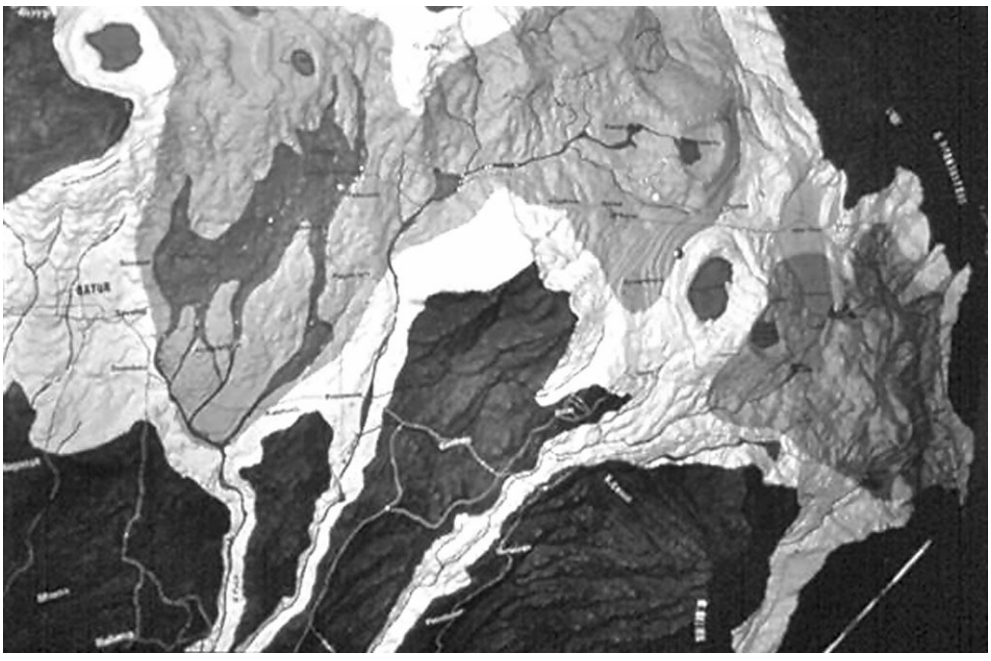

FIG. 1 - Volcanic hazard zoning of the densely populated Dieng Plateau, Central Java, Indonesia.

FIG. 2 - Ground view of one of the fissure-determined sites of occasional phreatic eruptions with gas emanations in the Dieng Plateau, Central Java, Indonesia.

Fig. 4 shows a fully automated early warning system on the SW slopes of the Merapi volcano in central Java, Indonesia. The two steel cables in the concrete construction will snap in case of a pyroclastic flow and thus an alarm will be triggered. More recently the cables have been replaced by a set of laser beams.

EXTREME EVENTS AND SOCIETY

The magnitudes and frequencies of natural disasters are on the rise, as is evident from the statistical data of insurance companies. However, only a relatively small portion of this development results from an increase of extreme natural events due environmental changes. The larger number of victims is primarily due to the increased population density in endangered areas and the rising economic losses are related to urbanization, industrialization and other aspects of modern society. There is thus much more at risk (Blaike & *alii*, 1994).

It is not always easy to define exactly whether a situation arising from an extreme event should be declared a disaster or not. The main criterion is that the local society is unable to handle the situation without outside help. This criterion is valid for the category of local disasters, which encompasses the instantaneous disasters of all types.

The disastrous effects of extreme events on society include death toll, injured people, uprooted population, capital losses and impeded socio-economic development as a result of destroyed infrastructures and production units and of social or family structures. More people are at present adversely affected and the economic losses are higher than ever, notwithstanding the efforts made worldwide. More than 25 percent of the world population is at risk and the number of casualties varies between 50,000 in quiet years and 300,000 or more during a single major flood of seismic event. The economic losses have more than tripled in the last 30-40 years and now amount to more than 100 billion Euro annually. The insurance bill is around 15 billion Euro "only" because of the low insurance density in many affected areas, particularly in developing countries. Windstorms and floods account on the average for about 85 percent of the economic losses but losses due to seismic events peak at irregular intervals. The location, frequency and impact of natural disasters are determined by two main elements: the susceptibility of the land to certain extreme events on the one hand and the vulnerability of the society on the other. These two, interactive, elements determine the orientation of the required research, the scope of the disaster reduction measures and the management strategies (Bohle, 1993).

The mitigation of instantaneous disaster reduction is obviously a complex management subject that requires interdisciplinary applied research related to the natural environment as well as to he socio-economic situation of the endangered societies. For the implementation of adequate protection measures, ranging from «hard» engineering structures to «soft» management improvements, optimal cooperation between the various sectors of the communities concerned is essential. Taking appropriate mitigation measures becomes problematic for instance if the hazard zoning has not been legalized by the authorities. An example is the ill-famed 1985 eruption of the Nevado de Ruiz, Colombia. Mudflows, generated by the sudden melting of the ice cap covering the mountain, swept through the settlements situated in the surrounding valleys on that occasion and caused a death toll of 36,000 people and major structural damage. The fig. 5 and 6 show the ice melt of the glacier by volcanic bombs and the effects of the mudflows in the town of Armero respectively.

LAND DEGRADATION AND GLOBAL, CREEPING DISASTERS

Disasters caused by creeping processes such as sheet and rill erosion, salinization and other forms of environmental degradation, are a second main group of disasters. They have been rather neglected in the past, be-

FIG. 3 - Simple warning device in a village on the SE-slopes of the Semeru volcano, Eastern Java, Indonesia. Four bangs on the gong announce a natural hazard (volcanic mudflow).

cause the effects of these slow and usually diffuse processes may remain unnoticed for decades and no timely appropriate action thus is taken. It has become an important issue in the context of sustainability, however Verstappen, 1996).

Most creeping disasters affect much larger areas than extreme events and in case of an emergency outside help therefore may be problematic. Concerted global action is the only valid approach to developing adequate strategies for ensuring sustainability. The research required for coping with creeping disasters focuses on the interacting elements of the natural environment as affected by human interferences of various kinds. Environmental disasters have been a rather neglected subject in the past

FIG. 4 - Automated warning system at a lahar check dam on the SW slopes of the Merapi volcano, Central Java, Indonesia. The arrow points to the fastening of three thin horizontal steel cables that stretch across the check dam. Note the rise of the valley floor caused by the structure.

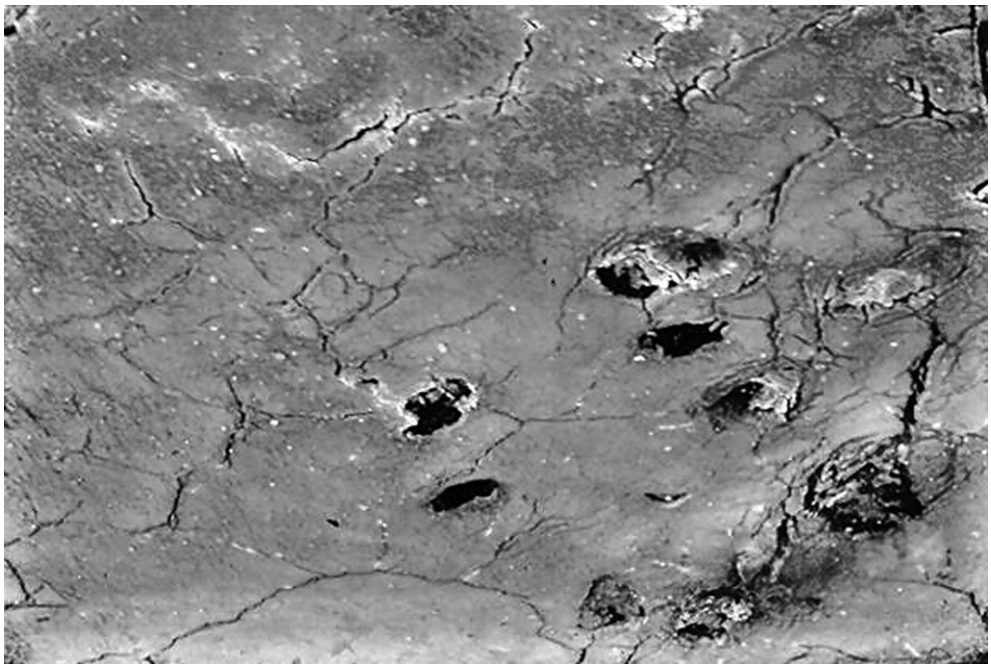

FIG. 5 - Detailed helicopter view of the ash cover on the Nevado de Ruiz glacier, Colombia, (1985), showing deep melting holes caused by hot volcanic bombs. Scale approximately 1:3,000.

and certainly deserve more emphasis. The UN-IDNDR (International Decade for Natural Disaster Reduction) of the 19ninetees concentrated solely on the impact of instantaneous natural disasters on society. Its follow-up, the UN-ISDR (International Strategy for Disaster Reduction) has a somewhat wider mandate because it includes also technical / industrial disasters. The latter are entirely different from a research point of view but rather similar where emergency management is concerned. Environmental disasters, however, are as yet hardly considered. Yet it is now gradually understood that humanity is not a creature apart from nature but forms a part of it. The unprecedented worldwide devastation of our environment is a boomerang with detrimental effects on society and even endangering the future of mankind. We are not only the cause and the victim as well of this threat. The mitigation of humanitarian disasters is in many cases largely a political issue, with good governance in the countries concerned and adequate international action as basic elements.

FIG. 6 - Part of the devastation in the town of Armero resulting from the 1985 Nevado de Ruiz lahar disaster, Colombia.

The mitigation of creeping disasters is nowadays placed in the context of environment, life support systems and sustainability issues. Fig. 7 shows rill erosion developed in a wheat field in the Crati valley, southern Italy. The rills are obliterated every year after the harvest and the field is ploughed as a preparatory for next year's crop. Such slow and almost imperceptible land degradation may ultimately lead to the occurrence and increasing frequency of disasters of exogenous origin such as floods, droughts and slope failures. The consequences of the environmental degradation usually escape attention in average conditions. The timing of the related disasters therefore is often linked to natural climatic fluctuations, covering periods of several years or decades. Uncertainties in predicting them complicate the efforts of combating the resulting disasters, notably flood and drought disasters. The severe droughts that ravage large parts of sub-Saharan and southern Africa at irregular intervals are a dramatic example of this impact. These fluctuations may also affect the tracks of tropical cyclones and lead to extreme floods in other areas as exemplified by the extreme and repeated floods of some European rivers, such as the Meuse, Rhine and Oder, in the 19nineties. They should not be confused with the slowly continuing process of long term global warming and the resulting sea level rise that supposedly result essentially from world wide man-induced, environmental degradation. The effects of global environmental change are an important additional problem (Warrick & *alii*, 1993).

COPING STRATEGIES FOR CREEPING DISASTERS

Traditional, rural societies regularly exposed to drought, have developed specific coping strategies, ranging from techniques of water harvesting and land use adaptation to temporary changes in social organization. The same applies to societies repeatedly subjected to floods. Flood retreat agriculture is a traditional response to these situations notably in Africa while the use of floating rice, capable to grow up with the rising floodwaters, is another kind of indigenous response, especially in SE Asia. Such coping strategies exist also for other types of environmental crises. These indigenous strategies merit our full attention and research because they provide a deep insight into the environmental situation and can assist in finding modern solutions for the present problems in specific endangered parts of the world. During a drought susceptibility survey in northern Botswana (Verstappen, 1983) the author became aware that the drought relief wells, constructed after the catastrophic droughts of the 19seventies and deriving water from a deep-seated artesian basin, are harmful for the environment. They provide water in large quantities at a limited number of localities, thus causing an unbalance with the available grass resources. The small herds previously owned by the villagers were distributed over the whole territory and moved from water eye to water eye. The new situation is that large herds of 50,000 to 100,000 heads of cattle, owned by influential cattle breeders and looked after by the local villagers, are now continuously grazing around the wells and depleting the grass vegetation within a radius of 10 to 20 km from the well. The Landsat image of fig. 8 shows the situation. Another aspect is that the free movement of zebras, antelopes, etc. is impeded by the many anti mouth and claw disease fences. Modern technology has replaced the earlier existing extensive but sustainable mode of herding by an intensive but unsustainable use of the land. The new situation is a far cry from the traditional drought coping strategies of the

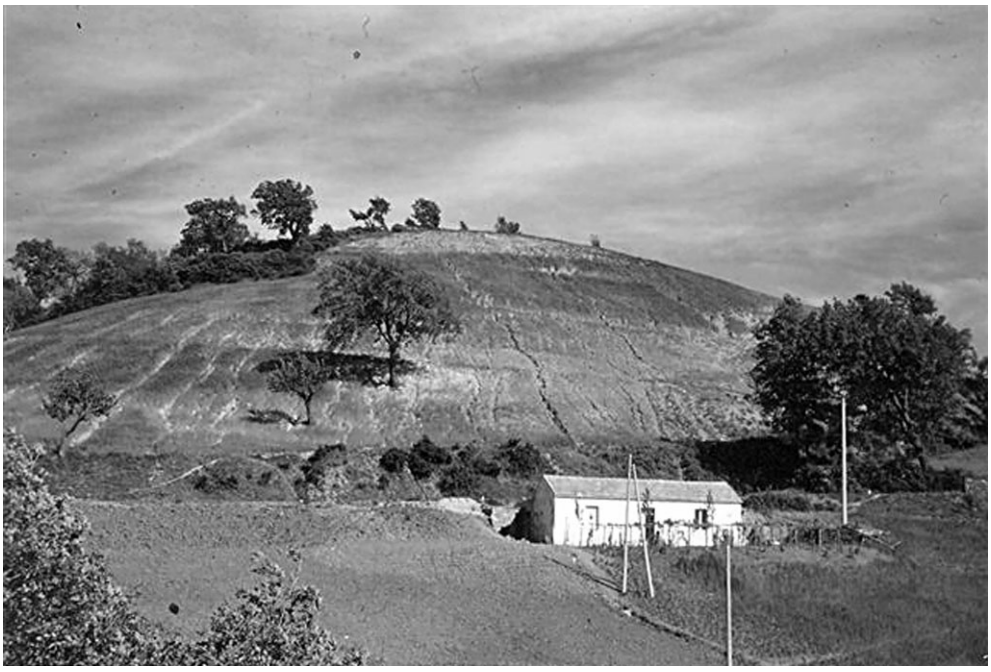

FIG. 7 - Rill erosion in a wheat field, Crati Valley, Calabria, Italy. The rills disappear after ploughing and the ongoing land degradation thus is obliterated.

FIG. 8 - Devastation of grass resources around permanently used drought relief wells in Botswana. Landsat image, band 5, scale 1:1,000,000, 1975. The yellow, affected areas measure 10-20 km across. The red areas are completely barren.

San people, based on storage of green water melons and the use of zip wells.

Changes in modern society are another important field of change that, are on par with, and often the causative factor of, the present changes of the environment in the context of sustainability problems. A major issue is the increasing population density that gives rise to growing pressure on the land in rural areas and to rapid urban growth. The high and still sharply rising per capita consumption in the industrialized world is another main factor of environmental stress that endangers sustainability. However, the desire for a better living is, of course, universal. Today's have-nots want to get a better share in the future. The quality of life of these have-nots is a must for global stability and the solution of the related global economic, social and environmental issues should get top priority. However, these growing demands of the consumption society are incompatible with sustainable development because they surpass the resources of our planet. Certain human impacts probably already have caused irreversible changes while restoring the natural balance in other cases will require centuries even if the causative human impact could be stopped overnight. Concerted action is urgently required because the global environment and the fate of humanity are at stake!

SUSTAINABILITY AND THE DYNAMICS OF PLANET EARTH

The variety of natural ecological conditions prevailing on our planet results from the complex and ever changing interactions between the geosphere and the biosphere where the subtle interactions between the land surface, the oceans and the atmosphere play a leading part. Together these factors form a dynamic system that is generated by a number of driving forces and ultimately by the sun. This system is affected by variations in solar radiation and other extraterrestrial phenomena. It is also very sensitive however for disturbances in the existing ecological equilibria and this makes it extremely vulnerable for the massive interferences with nature by our modern society. We should therefore face the present acute environmental problems and focus on the development of appropriate coping strategies at the global scale. Innovating scientific approaches and the invention and application of new technologies are key elements in this issue but also a change in our priorities and lifestyle will be inevitable to achieve sustainability.

Sustainability implies that human activities should ensure the continuous maintenance of our global life support system. It is a complicated matter particularly because our environment and society are both ever changing dynamic systems. When the word «development» is used in the context of sustainability one should realize that society must get organized within the limits set by our planetary resources. Environmental equity is essential. Emphasis thus should be on the fulfilment of basic needs and a state of well being for all. The increasing demands of our consumption society are, at the global scale, incompatible with the environmental basis of sustainability. Economic, social and environmental elements are the three pillars of sustainability. They are closely related and should be in balance. An efficient economic system is emphasised by those who believe that the social and ecological goals can only be achieved when sufficient financial resources are

available. Others point out that where social balance fails, the have-nots will cause political unrest and uprisings that preclude the creation of a sustainable society. This applies to the world as a whole and on the national level also. The idea that environment comes first as an element in sustainability is increasingly heard. Don't we have the obligation to save our planet for ethical reasons and also for our own sake? In fact environmental, social and economic distress go hand in hand! Fig. 9 gives an example from the Chama Valley, Venezuela.

It is beyond doubt that achieving sustainability requires co-ordinated action at a planetary scale not only in the field of environment but also encompassing society and economy. The call for globalisation thus is justified and irreversible. It is in its present form mainly restricted to economic affairs and therefore lopsided, however. The weak supranational governance is as yet no match for it and environment is a non-issue. Also it disregards the variety opportunities and limitations at the regional and local levels. Replacement of this centralised top-down concept of globalisation by decentralized bottom-up glocalisation, rooted in respect for the rich diversity of our planet and humanity, is an important prerequisite for obtaining worldwide support for the implementation of the changes required to save our planetary resources for future generations.

SCIENCE AND TECHNOLOGY FOR DISASTER REDUCTION

The increasing impact of instantaneous and creeping «natural» disasters on local communities, exposed countries and the world at large, has triggered a massive scientific response. All disaster reduction measures, ranging from «hard» engineering structures to «soft» management programmes, are rooted in thorough scientific research on the local, regional and global levels. Its scope is usually interdisciplinary, the aim being to bridge environmental issues and needs of society. Hazard zoning requires knowledge of the potentially dangerous processes, their extent in case of extreme events and their effects on environment and human life. Risk assessment, quantifying the potential loss of life and property, is an essential follow up. Determining the mode and the location of an adequate early warning system requires a concerted input of scientists and engineers. Assessing and combating creeping disasters is only possible through the study of data of the past and the monitoring of ongoing natural and social processes on the continental and global levels. Satellite technology is a powerful tool in this field.

The research focuses on a number of major issues that urgently require adequate responses by society, such as

1. The risks incurred in large urban/industrial areas where more than half of the world's population is concentrated and large property damage by natural and technological disasters can be expected. Hazard zoning, early warning and innovative engineering are important elements.
2. The effects of changing land use and population patterns on disaster vulnerability. The increasing population density in critical zones and inappropriate land use systems are major factors.
3. The responses required in coastal lowlands all over the world to face the expected sea level rise. Extensive, densely populated and food-producing areas are threatened.

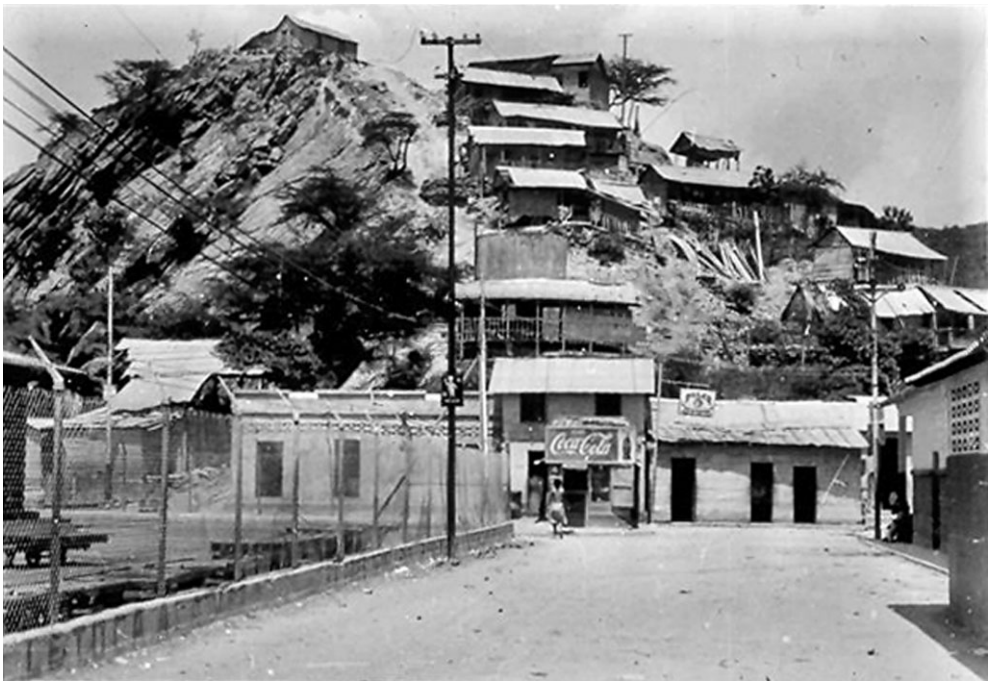

FIG. 9 - Economic, social and environmental stress go hand in hand! Chama valley, Venezuela.

4. The study of Holocene and historical situations, trends and events as to more precisely predict the effects of the now ongoing environmental and land use changes.
5. The effects of climatic fluctuations, such as «El Niño», on magnitude and frequency of extreme events and the creeping processes of land degradation. River floods, mountain hazards and droughts are adversely affected and the related disasters aggravated.
6. The study of climatic and other environmental changes in their human dimension.
7. Global environmental monitoring from aerospace combined with observations on the ground and modelling technology to cope with the enormous amount of data.

Our knowledge of the dynamics of our global environment has made unprecedented progress since the advent of earth observation satellites (Aronoff, 2005). The use of the information so obtained was limited initially by the low spatial resolution of the then available satellite recording systems. However, the present high-resolution satellites provide very detailed information. Some of them have pixels of less than one metre. Fig. 10 exemplifies this and shows an active pyroclastic flow, derived from a lava plug, rushing down at the SW-side of the Mt. Merapi, Central Java, Indonesia. It is a detail of an IKONOS image measuring approximately 2x2 km and has a spatial resolution of about 50 centimetres.

The data so obtained can be used on the global, regional and local levels. They open new vistas for detecting trends of change and for predicting future environmental conditions. The accuracy of these predictions will undoubtedly increase in the coming years, with growing data input and improving modelling techniques. One may wonder, however, whether there is not too much emphasis on environmental changes in view of the fact that the present situation is already unsustainable. Are the observed changes not rather symptoms of the more fundamental causes of growing world population and rising per capita consumption? Monitoring to reveal the fragile dynamic ecosystem of our planet is an important scientific issue that should form the basis of global environmental management. One should realize, however, that it is rather irrelevant for many practical purposes to know whether or not today's global warming and related sea level rise are mostly due to human factors: the disturbances of the planetary dynamic system already are either irrevocable of their remedy requires centuries or millennia. We simply have to face the problems and respond timely by appropriate action. Reaching sustainability is an urgent necessity and an ethical obligation to future generations. It cannot be reached overnight, however!

OUR COMMON FUTURE - A CHALLENGE FOR HUMANITY

It is undeniable that our planet is in peril and that the fate of humanity is at stake. We are facing a global disaster if we continue to ignore the limits of growth that are set by the earth's natural resources. The problem is immense, but we should not forget that humanity has, in the past, always found ways and means for survival. There are two noteworthy positive developments in the present situation. At first we have a powerful scientific and technological potential at our disposal for combating the many, diverse prob-

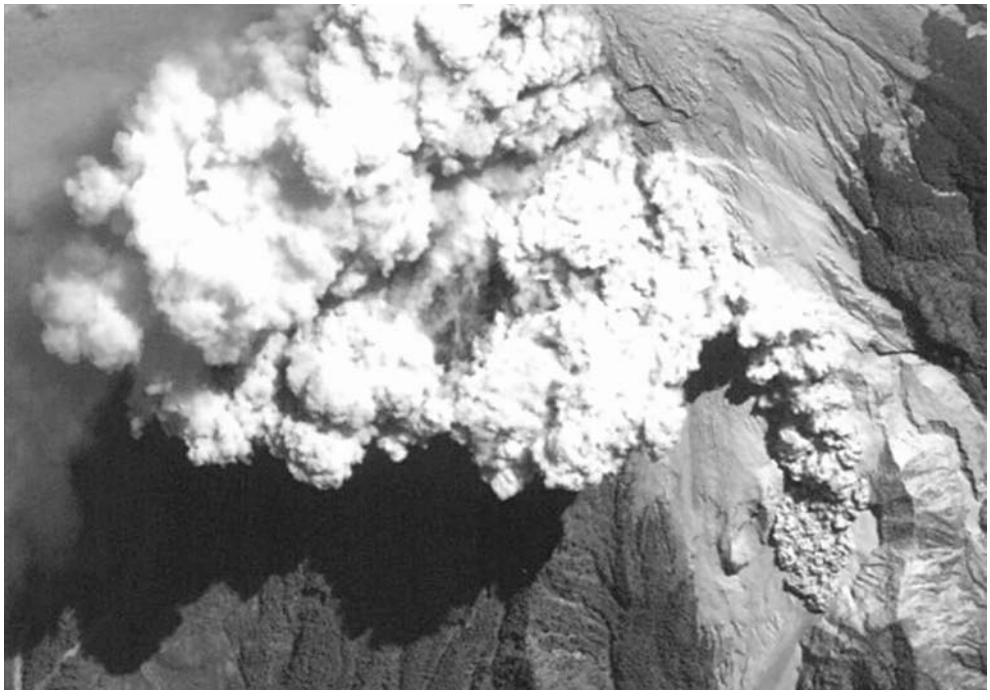

FIG. 10 - Detail of an Ikonos image of a pyroclastic flow rushing down the SW slope of the Merapi volcano, Central Java, Indonesia. June 4, 2006, area covered 2x2 km; resolution 50 cm.

lems (Institution of Civil Engineers, 1995 [a, b]). Secondly the world leaders and the public at large have become aware of the alarming situation and the acute need for action. The scientific community has been very successful in raising global awareness of the alarming situation and in getting the issue high on the political agenda, particularly during the last decades. These developments are very positive indeed and give us hope that society is a sufficiently dynamic system capable to take at last the appropriate decisions and to invent the required changes. The future is in our hands!

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