Natural Disasters and Their Mitigation for Sustainable Agricultural Development

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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 hydro-meteorological disasters such as floods, droughts, cyclones, forest fires, and heat waves were presented. Evidence available from different parts of the world showed that there is a rising trend in the occurrence of natural disasters from 1950 to 2005. Impacts of natural disasters on agriculture, rangeland, and forestry were described. 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. Traditional definitions of sustainable development focussed on balancing agricultural productivity and environmental concerns. Today, however, it is important that the idea of sustainable development be extended beyond the notion of minimizing environmental impact; it should address issues such as managing vulnerability and enhancing the capacity to adapt and respond to natural disasters. In this sense, the sustainable agricultural development matrix should include a component of disaster risk management and reduction. There is an urgent need to mitigate the effects of hydro-meteorological disasters through the improved use of climate and weather information and forecasts, early warning systems, and appropriate methods of land management and natural resources.

Introduction

Agriculture is a complex system, within which changes are driven by the joint effects of economic, environmental, political, and social forces (Olmstead, 1970; Bryant and Johnston, 1992). It is very well known that agriculture is inherently sensitive to climate conditions and is among the sectors most vulnerable to weather and climate risks.

One of the major development issues in agricultural meteorology, which is also linked to humanitarian aid, are natural disasters which have a major impact on agricultural productivity since the economic cost associated with all natural disasters has increased 14-fold since the 1950s.

According to statistics in the Emergency Events Data base (EM-DAT), compiled by the U.S. Agency for International Development Office of Foreign Disaster Assistance (USAID/OFDA) and the Center for Research in the Epidemiology of Disasters (CRED), the number of weather-related natural disasters has risen sharply during the past 50 years (CRED, 2000). The incidence of weather-related disasters per decade has risen from approximately 100 to 1,600 events during the past 50 years in less developed countries, with the number of people impacted or killed per decade rising steadily from 15 million during the 1950s to four billion during the 1990s. These trends are a result of changes in the nature of natural hazards and demographic factors bringing greater numbers of people into harm's way.

During the past 4 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. Höppe (2007) showed the development in the number of great natural disasters (causing billion dollar losses and/or thousands of fatalities) since 1950 (Figure 1), which is broken down into the different perils**:** floods, windstorms, geophysical disasters (earthquakes, tsunamis, volcanic eruptions) and other weather-related events (heat waves, forest fires, droughts). Figure 1 clearly shows a steep increase in the number of such events. Deaths since the 1950s increased 50 percent each decade, whereas the corresponding population growth rate was only 20 percent (Kreimer and Munasinghe, 1991). For the period of 1974-2003, Guha and Sapir, et al., (2004) estimated the cumulative number of casualties at 2 million with 182 million people becoming homeless.

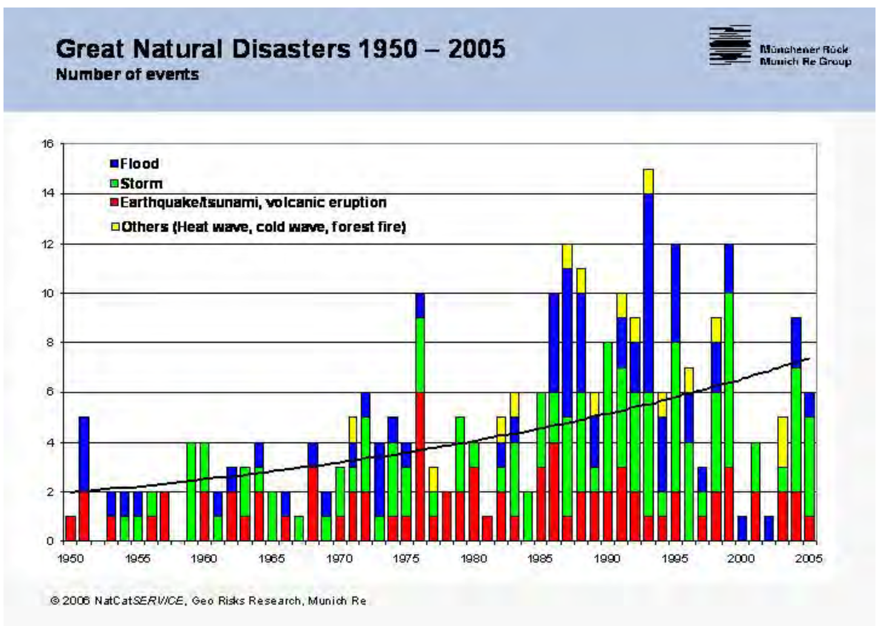

Figure 1. Development of the number of Great Natural Disasters between 1950 and 2005 (Source: Höppe, 2007).

Losses from natural disasters have increased dramatically (Höppe, 2007). In the second half of the 20th century the number of large natural catastrophes doubled and yearly damages in monetary terms increased by more than a factor of six (Munich Re, 2006). From 1980 through 2003, the economic costs of all weather-related natural disasters totaled $1 trillion, divided approximately 40/60 between wealthy and poor countries, respectively (Munich Re, 2004). Although all losses have increased in absolute terms, the rise in the relative incidence of weather-related events (such as wildfire, extreme temperature episodes, and epidemics) compared to non weather-related ones (such as volcano eruptions or earthquakes) is particularly notable (Vellinga, et al., 2001).

As Figure 2 shows, at the global level there has been an exponential increase in both overall economic and insured losses (both adjusted for inflation) since the 1950s, reaching a record level in 2004, which was topped again by new loss records in 2005. In 1995, the year of the Kobe earthquake in Japan, record losses of about U.S. $178 billion were recorded, the equivalent of 0.7 percent of global gross domestic product (Munich Re, 2002). The largest loss from a single event in history occurred in 2005, caused by Hurricane Katrina, with overall economic losses of U.S. $125 billion and insured losses of U.S. $60 billion.

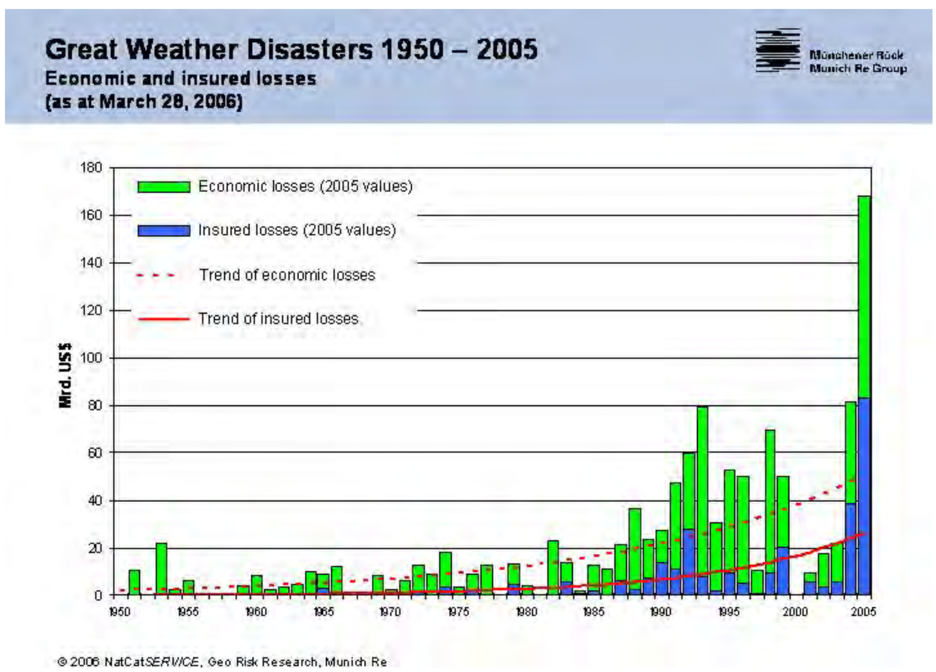

Figure 2. Development of economic and insured losses from Great Weather Disasters between 1950 and 2005 (Höppe, 2007).

Models of future changes in extreme weather events predict particularly large impacts in the developing world from flooding and drought as well as a likely increase in tropical cyclones. The impacts on the agricultural sector are projected to be more intense because developing countries are often closer to the margin of tolerance for temperature and precipitation changes (drought as well as flooding). According to a global insurance industry group studying the issue, economic costs associated with weather-related events are projected to triple to $150 billion/year by the year 2020 (UNEP and Innovest, 2002).

Impoverished people are more exposed to natural disasters because they tend to live in marginal areas and depend on high-risk, low-return livelihood systems, such as rain-fed agriculture, and face many sources of economic vulnerability including limited physical infrastructure.

Environmental degradation and the destruction of natural barriers is one of the major factors contributing to the vulnerability of agriculture, forestry, and rangelands.

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. 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.

Agriculture and Natural Disasters

Agriculture and the rural sector, as a source of food, raw materials, employment, and markets have crucial backward and forward linkages with virtually every other part of the economy. In fact, the poorer the country, the larger the share of agriculture in terms of gross domestic product (GDP), total employment, and exports. Rural poverty is one of the key factors that shapes the risk to natural disasters. The situation is quite disturbing in the Least Developed Countries (LDCs) since agricultural production has not kept pace with population growth in the LDCs as a whole. Although agricultural output in 1990-99 rose at an annual average rate of 2.5 percent, exceeding the rate of 1.6 percent in the previous decade, in per capita terms there was virtually no increase in output, even a slight decline occurred (IFAD, 2001). While more than 25 LDCs experienced negative per capital growth rates during 1990-99, only five countries had positive growth.

IFAD (2001) and World Bank (1997) estimate that about three quarters of the extreme poor currently live in rural areas and depend on agriculture and related activities for their livelihood. Even under high assumptions of economic development and rural-to-urban migration, 60 percent of the extreme poor are likely to be in rural areas in 2020 and 50 percent in 2035. Hence the implication is that low agricultural productivity combined with extreme poverty makes the populations living in LDCs the most vulnerable to natural disasters. Disruption of economic activity and diversion of government funds to prepare for and recover from natural disasters constrains development.

According to UNISDR (2003), the economic impacts of natural disasters are greater in poorer nations; the costs of natural disasters between 1985 and 1999 equaled 13 percent of GDP in the poorest countries versus only two percent in the wealthiest countries. In a striking illustration of the potential adverse impacts of extreme weather events, the Honduran prime minister stated that Hurricane Mitch – which killed up to 20,000 Central Americans in 1998 – set the country's economic development back 20 years (IFRC/RCS, 2003). Losses in Honduras from Hurricane Fifi amounted to 50 percent of GDP (Hooke, 2000).

In addressing the impacts of natural disasters, the agricultural sector has not received the attention that it deserves from the policy makers since most of the economic impacts in this sector are attributable to relatively "small" events. Often it is the large headline-catching disasters that receive the attention of the public and policy makers. In the words of Swiss Re (2002), "unspectacular climatic anomalies, which the general public perceives as 'unusual,' rather than ‘catastrophic’ weather conditions, can cause losses on a scale normally associated with natural catastrophes.” The cost of coping with such climatic anomalies is rising because of a combination of changes in the nature of natural disasters and the increasing vulnerability of society to these disasters (IPCC, 2001). Costs not absorbed by national governments, foreign aid, or insurance fall on the poor farmers.

The poorest in the rural areas occupy the most marginal lands and this forces people to rely on precarious and highly vulnerable livelihoods in areas prone to natural disasters such as droughts, floods, etc. (UNDP, 2004). The ability to adapt to extreme weather events is lowest in the poorest segments of society and in countries where resources, information, and skills are limited; technology is often unavailable; institutions are unstable or weak; and empowerment and access to resources is inequitable (Smit, et al., 2001).

In the light of the issues mentioned above, it is important to reassess the issue of sustainable agricultural development. The traditional definitions of sustainable development focus on balancing agricultural productivity and environmental concerns. Swindale (1988) explained that sustainability conveys the idea of a balance between human needs and environmental concerns. Sustainable agricultural systems should provide for the needs of current, as well as future generations, while conserving natural resources (Natural Research Council, 1991). The enhancement of the environmental quality and careful use of the resource base on which agriculture depends is viewed as a requisite to sustained agricultural productivity (American Society of Agronomy, 1989).

Today, however, it is important that the idea of sustainable development be extended beyond the notion of minimizing environmental impact; it should address issues such as managing vulnerability and enhancing the capacity to adapt and respond to natural disasters. In this sense, the sustainable agricultural development matrix should include a component of disaster risk management and reduction.

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 International Federation of Red Cross and Red Crescent Societies (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. Sivakumar (2005) provided a description of the definitions of each of these disasters which is 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 overly 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 inter-play between natural water availability and human demands for the 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 fire occurring in vegetation more than 6 feet (1.8 meter [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 southwest Indian Ocean, the Bay of Bengal, the Arabian Sea, parts of the south Pacific, and along the northern coast of Australia. These storms are called typhoons in the northwest Pacific and are known as hurricanes in the Caribbean, southeast United States, and Central America.

A tsunami (Japanese for big wave in port), which is 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 rising to a height of 30 m and more when approaching land. Tsunamis can cause severe destruction on coasts and islands.

Impacts of Natural Disasters in Agriculture, Rangeland, and Forestry

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, there are some positive impacts or benefits that can occur (Joy, 1991).

As Das (2003) explained, the impact of natural disasters on agriculture, rangeland, and forestry can be direct or indirect in their effect. Direct impacts arise from 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, 2003).

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, e.g., anxiety or fear of future natural disasters (Olive, 1989), inconvenience and disruption to farm work, and stress-induced ill health and human fatalities.

Many famines in pre-20th century Africa, Asia, and Europe were triggered by natural disasters, including drought, extreme cold, pests, and diseases that devastated crops and livestock (Devereux, 2000). 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). 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).

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 rain-fed agriculture and face many sources of economic vulnerability including little physical infrastructure. 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, GDP loss rates are 20 percent higher in the developing countries (Funaro, 1982). 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 percent of the Gross National Product (GNP) in Bangladesh was attributed to agricultural activities in Bangladesh while in Cambodia and Laos, it was 44.6 and 54.3 percent 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 percent, 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.

Agricultural export products hold an even more significant place. 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).

Mitigating the Impacts of Natural Disasters

Communities that are most exposed to risk from climate extremes and natural disasters and potentially at risk from climate change, are those with limited access to technological resources and with limited development of infrastructure. Countries, especially the geographically smaller ones, cannot be expected to cope alone because each one needs to have information on the full extent and magnitude of natural disasters. Socio-economic losses cannot be entirely eliminated, but timely and appropriate mitigation measures can certainly reduce the impacts.

The Plan of Implementation of the World Summit on Sustainable Development (WSSD) held in Johannesburg in 2002 highlighted the need to mitigate the effects of droughts and floods through such measures as improved use of climate and weather information and forecasts, early warning systems, land and natural resource management, agricultural practices, and ecosystem conservation in order to reverse the current trends and minimize degradation of land and water resources. WSSD noted the need to promote the access and transfer of technology related to early warning systems and to mitigation programmes to developing countries affected by natural disasters.

Improved use of Climate and Weather Information and Forecasts

The interaction between weather and agricultural production is so complex (Hoogenboom, 2000) that it is not just a case of developing a simple solution and expecting farmers to implement it. Each year or season will bring a different set of circumstances and hence the farmers have to make their decisions based on each situation. Hence a participatory approach involving the representatives of the National Meteorological and Hydrological Services (NMHSs), the agricultural extension agencies, and the farmers is necessary. One basic requirement is the awareness of the influence of weather and climate parameters on sustainable agricultural production. In many cases, this awareness is acutely present and many farmers often look for intelligent, low-risk solutions. This should stimulate an interest among the farmers to evaluate the forecast products produced by the NMHSs.

In the past 2 decades, significant advances have been made in the science and applications of seasonal climate forecasting. The principal scientific basis of seasonal forecasting is founded on the premise that lower-boundary forcing, which evolves on a slower timescale than that of weather systems, can give rise to significant predictability of atmospheric developments. These boundary conditions include sea surface temperature (SST), sea-ice cover and temperature, land-surface temperature and albedo, soil moisture, and snow cover, although they are not all believed to be generally of equal importance. Climate variations, also called anomalies, are differences in the state of the climate system from normal conditions (averaged over many years, usually a 30-year period) for that time of the year. The strongest evidence for long-term predictability comes largely from the influence of persistent SST anomalies on the atmospheric circulation which, in turn, induces seasonal climate anomalies.

The key weather variables for crop prediction are rainfall, temperature, and solar radiation, with humidity and wind speed playing also a role. As Doblas-Reyes, et al., (2006) explained, seasonal climate forecasts are able to provide insight into the future climate evolution on timescales of seasons and longer because slowly-evolving variability in the oceans significantly influences variations in weather statistics. The climate forecast community is now capable of providing an end-to-end multi-scale (in space and time) integrated prediction system that provides skilful, useful predictions of variables with socio-economic interest.

Seasonal forecasts can be produced using mathematical models of the climate system. A wide range of forecast methods, both empirical-statistical techniques and dynamical methods, are employed in climate forecasting at regional and national levels (WMO, 2003). Operational empirical-statistical methods, based on statistical links between current observations and weather conditions in the future, include analysis of general circulation patterns; analogue methods; time series, correlation, discriminant, and canonical correlation analyses; multiple linear regression; optimal climate normals; and analysis of climatic anomalies associated with El Niño-Southern Oscillation (ENSO) events.

Dynamical methods (used principally in major international climate prediction centers) are model-based, using either atmospheric the General Circulation Models (GCMs) in a two-tiered prediction system, or the dynamically coupled atmosphere-ocean GCMs. These dynamical forecast models – an extension of the numerical methods used to predict the weather a few days ahead – are based on systems of equations that predict the evolution of the global climate system in response to initial atmospheric conditions and boundary forcing from the underlying ocean and land surfaces.

The forecasts of future trends in precipitation, 3 months or more in advance, could be extremely important to agriculture, forestry, and land management by potentially forecasting drought or heat waves. These outlooks have strategic relevance to national policy with respect to planning to help alleviate food shortages, lessen the impact of droughts, and provide distribution of energy. Seasonal forecasts, provided they are reliable enough, are already being successfully used in developed countries at the farm level to adapt seasonal crop planning (Meinke and Stone, 2005), but there is still a deficit when it comes to making such information usable for farmers in low-input systems (Salinger, et al., 2005). However, seasonal forecasts are already being used in developing countries for yield forecasting to support policy decision making (Hansen and Indeje, 2004) and the MARS project of the European Union, which has been extended to the African regions (Rojas, et al., 2005).

Early Warning Systems

A fundamental condition for disaster preparedness is the availability of risk assessments and well functioning early warning systems that deliver accurate and useful information in a timely and dependable manner to decision makers and the population at risk. While natural hazards may not be avoided, the integration of risk assessment and early warnings with prevention and mitigation measures can stop many hazards from becoming disasters. This means that action can be taken to considerably reduce the resulting loss of life and socio-economic damages. Without doubt, a fundamental pre-condition for disaster preparedness is a well-functioning early warning system, capable of delivering accurate information to the population at risk, dependably, and in a timely manner.

There is a growing global awareness of the importance of early warning systems. During the Second World Conference on Disaster Reduction (Hyogo, Kobe, Japan, January 2005), 168 countries adopted the Hyogo Framework for Action 2005-2015 (HFA) and identified five high priority areas, of which the second stressed the need for “identifying, assessing, and monitoring disaster risks and enhancing early warnings,” as a critical component of disaster risk reduction.

From 1980 to 2005, over 7,000 natural disasters worldwide have taken the lives of nearly two million people and produced economic losses of over one trillion U.S. dollars. However, as the number of disasters and their economic impacts increased during the period, the number of fatalities was diminishing. For example, for disasters related to weather-, water-, and climate-related hazards, there has been nearly a 4-fold increase in the number of disasters and a 5-fold increase in the economic losses, but nearly a 3-fold decrease in loss of lives. This noteworthy achievement is due to several factors, one of which is the development of specific end-to-end early warning systems (Jarraud, 2006).

WMO is working with its partners at the international, regional, and national levels to improve early warning capabilities further and ensure that these systems are available to all countries, particularly those with the least resources. The scientific programmes of WMO have been vital in expanding knowledge of the climate system. The systematic observations carried out using standardized methods have provided worldwide data for analysis, research, and modelling of the atmosphere and its changing patterns of weather systems. WMO coordinates a global network for the acquisition and exchange of observational data under the Global Observing System of its World Weather Watch Programme. The system comprises some 10,000 stations on land, 1,000 upper-air stations, 7,000 ships, some 3,000 aircraft providing over 150,000 observations daily and a constellation of 16 meteorological, environmental, operational, and research satellites. WMO also coordinates a network of three World Meteorological Centres, 35 Regional Specialized Meteorological Centres, and 187 National Meteorological Centres. Specialized programmes of observations, including those for chemical constituents of the atmosphere and characteristics of the oceans and their circulations, have led to a better understanding of interactions between the domains of the climate system (the atmosphere, the oceans, the land surface, and the cryosphere) and of climate variability and change.

Over the recent years, new technologies have brought about an accelerated increase in our knowledge of the climate system. Satellites for monitoring aspects of the oceans and sparsely populated parts of the globe; ocean buoys, and expendable bathythermographs for monitoring the physical and chemical properties of the oceans; hundreds of specially equipped commercial aircraft; and manned and automatic weather stations on land, are all expanding the volume of data and contributing to knowledge base.

In relation to any kind of hazard, such as flash floods, disaster mitigation can only be successful provided that there is enough lead-time for appropriate measures to be taken, in order to save lives and to reduce the impacts. The use of numerical weather prediction (NWP) products is a way to provide an increase in the lead-times to a greater degree than could be achieved by the use of radars alone. Today, state-of-the art technologies include improved terrestrial and space-based observation systems, as well as increasingly accurate models and the necessary telecommunication means to relay observations, in near real-time, to the forecasting and warning centers. This is especially true in the area of medium-range weather forecasting, which with the development of ensemble prediction systems (EPS), permit evaluation of the uncertainty in the forecast. Such systems need to be adapted to local circumstances and to be fully utilized, in order to extend the lead-time, especially in the developing countries.

With the aim to improve flood forecasting, WMO has launched its Flood Forecasting Initiative with the objective of further improving the capacity to deliver timely and more accurate flood forecasting products and services. This is occurring through effective cooperation of the National Meteorological Services (NMSs) and National Hydrological Services (NHSs) as well as capacity building activities in collaboration with the disaster managers.

Major advances in technology, notable progress in scientific understanding, and the accuracy and timeliness of weather and flood warnings have significantly improved over the last few decades. Today the accuracy of forecasts of large-scale weather patterns for 7 days in advance is the same as those for 2 days in advance only 25 years ago (Obasi, 1998). Now forecasts up to 10 days are showing remarkable accuracy, and there is now capability to provide some skillful information on expected weather patterns several seasons in advance.

For example, early information on El Niño episodes is now allowing advanced national planning, with considerable advantage in many sectors of the economy, such as in water resources management, tourism, fisheries, and agricultural production (Obasi, 1996). In the case of the 1997-98 El Niño event, advances in El Niño related science and in monitoring the sea-surface temperatures in the Pacific Ocean, enabled scientists in the NMHSs to predict its formation longer in advance than all the previous events. With recent developments in communication technology, including use of the Internet, information on the El Niño is disseminated in a rapid and timely manner throughout the world. These have enabled many governments to take appropriate measures, stimulated international cooperation, and integrated efforts to address the associated impacts.

The accuracy of tropical cyclone track forecasts and the timeliness of warnings have been steadily improving in the past few years. Global efforts, especially within the context of the Tropical Cyclone Programme of WMO, have resulted in a noticeable improvement in the warning systems in many parts of the world and resulted in saving a lot of lives and limiting property damage. For example, the decrease in the death toll in Bangladesh, from about 130,000 to 500 caused by similar tropical cyclones in 1991 and 1994 respectively was attributed, in large part by government sources, to improvements in early warning, and evacuation systems (Obasi, 1997).

The evolving Internet has proven to be an invaluable tool in facilitating the exchange of global and regional climate monitoring and prediction information. However many users require assistance in the selection, interpretation, and application of appropriate information. Effective early warning systems coupled with community education for protective action have reduced the potential human loss from these events. Floods as a disaster also lend themselves well for preparedness measures both structural and legislative (land use laws, zoning plans, and urbanization). Preparedness of life-saving techniques and evacuation plans should be promoted actively in these high risk zones.

More Efficient Management of Land and Water Resources

When prolonged natural disasters such as droughts occur, the high temperatures and low precipitation in the dry lands lead to poor organic matter production and rapid oxidation. Low organic matter leads to poor soil aggregation and low aggregate stability leads to a high potential for wind and water erosion. For example, wind and water erosion is extensive in many parts of Africa. Excluding the current deserts, which occupy about 46 percent of the landmass, about 25 percent of the land is prone to water erosion and about 22 percent to wind erosion.

On the contrary, during periods of heavy rainfall, eg., during cyclones, rainfall can erode soil by the force of raindrops, surface and subsurface runoff, and river flooding. The velocity of rain hitting the soil surface produces a large amount of kinetic energy which can dislodge soil particles. Erosion at this micro-scale can also be caused by easily dissoluble soil material made water soluble by weak acids in the rainwater. The breaking apart and splashing of soil particles due to raindrops is only the first stage of the process, being followed by the washing away of soil particles and further erosion caused by flowing water. The greater the intensity of rainfall and subsequent surface runoff, the larger the soil particles carried away.

Hence it should be apparent that natural disasters have a great impact on soils and the prevailing agricultural production systems, so farm technologies and management options have to be adapted to maintain soil functions for crop production to secure sustainable agricultural production. Agricultural practices adopted in regions that are continuously prone to natural disasters such as droughts and floods can strongly impact soil functions in the short term, and farming technologies and management can play an important role in these processes. For example, improper irrigation schemes and use of irrigation water with high salt content can increase salinity of soils, making them unusable for agricultural production. Other examples are overgrazing in the Sahel zone and other semi-arid regions which for various reasons can lead to wind erosion and desertification. In temperate regions with high-input systems, heavy machinery use, often in combination with slowly developing crops and soil cover, contributes to soil compaction; which can decrease water infiltration, increase runoff, and result in water erosion.

New farm technologies and those that have been established for many generations – indigenous technologies – offer many opportunities to mitigate the impact of natural disasters. Because of the projected climate change, the optimization of farm technologies becomes even more important for the productivity of various agricultural production systems at different input levels (Sivakumar, et al., 2005). Farmers cannot only change crops and cultivars but also modify crop management, for example, by changing the sowing date according to the expected seasonal weather. The seasonal precipitation pattern (onset of rain, duration of rainy season, and distribution during crop-growing period) is one of the most important pieces of information for farmers in semi-arid regions using rain-fed cropping, especially for low-input systems in developing countries, which enables them to adapt their sowing dates and crop selection (Stigter, et al., 2005; Ingram, et al., 2002; Mati, 2000). Matthews, et al., (1997) reported that for rice production in Asia the modification of sowing dates at high latitudes, where higher temperatures allowed a longer potential crop-growing season, permitted a transition from single cropping to double cropping in some locations, which could had a significant effect on regional production. Two shorter ripening varieties might be a better strategy than a longer maturing variety because the grain formation and ripening periods are pushed to less favorable conditions later in the season.

The ever-increasing water demand in contrast to the slow increase in water supply is leading to unsustainable water use and competition for water resources in agriculture. This trend has serious implications for sustainable agricultural development, especially in the developing countries. Proper management of water resources by application of appropriate farm technologies plays and will play a major role in both developed and developing countries in regions with limited resources for agricultural production. For example, irrigated agriculture in the Mediterranean area was introduced in ancient times and has been improved over time with experience. However, irrigation techniques have been maintained in the same way for centuries in most Mediterranean countries. Inefficient flooding irrigation systems, for example, can be still found in many areas of Spain and Egypt (El Gindy, et al., 2001; Neira, et al., 2005). Modern sprinkler and drip-irrigation systems have been introduced at great expense in some Mediterranean European regions such as Spain (MAPA, 2005). These new techniques significantly reduce water use. The productivity of irrigated crops, such as maize, in Spain has increased in the last 15 years, compared with countries like Egypt, despite the fact that the total production is lower. The differences between Spain and Egypt may have many causes, but the new engineering irrigation infrastructures that have been introduced in Spain certainly have a strong influence on the yield increases reported (ANPC, 2003).

Improved management of watersheds through establishment of water spreading, harvesting, and storage facilities as well as the use of supplementary irrigation techniques are needed to improve and develop rain-fed agriculture. Techniques such as "deficit irrigation" should be considered as an option in the next decades, or irrigated agriculture will become unaffordable (Fereres, 2005). At the same time, it is also essential to curtail losses of conveyance and on-farm use of irrigation water through appropriate measures. Guidelines need to be developed for the rational use and proper management of the vast but mostly non-renewable groundwater resources that are available in varied water qualities in huge aquifers.

Conclusion

According to the International Federation of Red Cross and Red Crescent Societies (2003), natural disasters are on the rise and they continue to target the world's poorest and least-developed and there must be greater investment in disaster reduction rather than high-profile response efforts. Improved data on past disasters would help inform investment and policy decisions and thus help secure more appropriate levels and forms of disaster prevention, mitigation, and preparedness. Historical studies would also help inform the development of appropriate methodologies for the assessment of future disasters.

Despite a long history of disasters affecting agriculture, rangelands, and forestry, comprehensive documentation of these disasters at the national, regional, and international levels has been weak; and it is important to develop mechanisms for more efficient assessment and documentation of natural disaster impacts in agriculture. A comprehensive assessment of impacts of natural disasters on agriculture requires a multi-sectoral and integral approach involving key organizations.

Priority should be given to supporting research with practical applications since research is needed to understand the physical and biological factors that contribute to disasters. Since the major impact of natural disasters is on poor farmers with limited means in developing countries, community-wide awareness and education programs on natural disasters should be a priority. Programs for improving prediction methods and dissemination of warnings should be expanded and intensified. Efforts are also needed to determine the impact of disasters on natural resources.

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