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Agrometeorological strategies for reducing impacts of natural disasters in agriculture

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ABSTRACT

Over the past few decades, there is an increasing intensity and frequency of natural disasters around the world with severe socio-economic impacts, especially in the developing world. General information on natural disasters including the definitions, types, and incidence of natural disasters during 1970 to 2014 was provided. Agricultural production is highly dependent on weather, climate and water availability and is adversely affected by the weather- and climate-related disasters. Impacts of droughts, cyclones, floods, forest and bush fires on agriculture, rangeland and forestry were described with suitable examples. Failure of rains and occurrences of natural disasters could lead to crop failures, food insecurity, famine, loss of property and life, mass migration and decline in national economy. Recognizing the increasing impact of disasters and their complexity in many parts of the world, the Member Countries of the United Nations came together to enhance the global efforts to strengthen disaster risk reduction to reduce losses of lives and assets from disasters worldwide and the post-2015 environment for reducing disaster risk will be shaped by three critical United Nations-led negotiations that will conclude this year. Important aspects of the Sendai Framework for Disaster Risk Reduction (SFDRR), which was adopted at the Third World United Nations Conference on Disaster Risk Reduction (WCDRR-III) held in Sendai, Japan, in March 2015, were described. The growing concern with the possible impact of natural disasters and extreme events on agriculture and forestry has created new demands for information from, and assessment by agrometeorologists. Agrometeorological strategies for reducing the impacts of natural disasters in agriculture such as improved use of climate and weather information and forecasts, early warning systems, reorienting and recasting meteorological information, fine-tuning of climatic analysis and presentation in forms suitable for agricultural decision-making and helping marginal farmers cope with the adverse impact of natural disasters were described.

1. Introduction

Natural hazards involving weather, climate and water are a major source of death, injury and physical destruction. During the past five decades, natural disasters 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. According to the Centre for Research on the Epidemiology of Disasters (CRED, 2015), 11,938 disasters occurred during 1970 to 2014, leading to a total loss of 3.48 million lives and economic losses amounting to US$ 2.69 trillion.

Among the ten costliest storm events during 1980 to 2014, ordered by overall losses (MUNICH RE, 2015), Hurricane Katrina which occurred in August 2005 in USA ranked first with overall losses of US $ 125 billions and 1,322 fatalities followed by Hurricane Sandy which occurred in October 2012 in the Bahamas, Cuba, Dominican Republic, Haiti, Jamaica, Puerto Rico, USA, and Canada with overall losses of US $ 68.5 billions and 210 fatalities. Among the ten costliest floods during 1980 to 2014, the floods and landslides which occurred in Thailand in November 2011 ranked first with overall losses of US $ 43 billions and 813 fatalities.

A higher number of disasters that are linked to environmental hazards occur in developing countries and the impacts are greater in these countries. According to Munich Re (2013), the average percentage of direct losses per year with respect to GDP is highest in emerging economies at 2.9%, compared with developing economies (1.3%) and industrialized countries (0.8%). One of the economic sectors most affected by natural disasters is agriculture.

Agriculture is a complex system, within which changes are driven by the joint effects of economic, environmental, political and social forces (OLMSTEAD 1970; BRYANT & 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. The relationships between weather, climate and production risk are well recognised (GEORGE et al. 2005). Of the total annual crop losses in world agriculture, many are due to direct weather and climatic effects such as droughts, flash floods, untimely rains, frost, hail, and severe storms (HAY 2007). Over the course of 2014, southeastern Brazil entered one of its worst droughts in history. Over 27 million people were affected by the drought, which brought heat waves and severe losses to water-intensive crops, like sugar cane. Economic losses from the drought are estimated at $5 billion.

The risk associated with weather and climate for any region is a product of both the region's exposure to the event (i.e., probability of occurrence at various severity levels) and the vulnerability of society to the event. This aspect was elaborated by Wilhite (2007) in his excellent analysis of the drought hazard and societal vulnerability. While drought hazard is a result of the occurrence of persistent large-scale disruptions in the global circulation pattern of the atmosphere, vulnerability to drought is determined by social factors such as population changes, population shifts (regional and rural to urban), demographic characteristics, land use, environmental degradation, environmental awareness, water use trends, technology, policy, and social behavior.

2. General information on natural disasters – definitions, types, incidence during 1970 to 2014

2.1 Definitions of natural disasters

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.

2.2 Types of natural disasters

The Centre for Research on the Epidemiology of Disasters (CRED) has been maintaining an Emergency Events Database (EM-DAT) which contains essential core data on the occurrence and effects of over 18,000 mass disasters in the world from 1900 to present. The database is compiled from various sources, including UN agencies, non-governmental organisations, insurance companies, research institutes and press agencies (CRED, 2015). EM-DAT distinguishes two generic categories for disasters (natural and technological). The natural disaster category is divided into 6 sub-groups: Meteorological, Climatological, Hydrological, Geophysical, Biological and Extraterrestrial. For the purpose of this paper which focuses on agriculture, the extraterrestrial sub-group is not included. The other five sub-groups cover a total of 15 disaster types as follows: Meteorological (storms, extreme temperatures and fog); Climatological (drought, glacial lake outburst and wildfire); Hydrological (flood, landslide and wave action); Geophysical (earthquake, volcanic activitiy and mass movement) and Biological (epidemic, insect infestation and animal accident). Under these 15 disaster types, more than 30 sub-types are listed (CRED, 2015).

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

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

Meteorological drought is brought about when there is a prolonged period with below average precipitation.

Agricultural drought is brought about when there is insufficient moisture for average crop or range production. This condition can arise, even in times of average precipitation, due to soil conditions or agricultural techniques.

Hydrologic drought is brought about when the water reserves available in sources such as aquifers, lakes, and reservoirs falls below the statistical average. This condition can arise, even in times of average (or above average) precipitation, when increased usage of water diminishes the reserves.

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

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

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

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

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

2.3 Incidence of natural disasters during 1970 to 2014

Using the data available from the EM-DAT database on natural disasters from 1970 to 2014, graphics were developed on the frequency of different sub-groups of natural disasters, the percentage distribution of natural disasters amongst different sub-groups, the percentage distribution of fatalities according to different sub-groups, and the percentage distribution of total economic damage according to different sub-groups.

Figure 1 shows that the frequency of natural disasters increased steadily from 1970 with the peak frequencies in the year 2000. The percentage distribution of natural disasters amongst different sub-groups (Figure 2) shows that hydrological and meteorological disasters accounted for 70% of the natural disasters during 1970 to 2014. The percentage distribution of the fatalities according to different sub-groups (Figure 3) shows that hydrological disasters accounted for the highest percentage of mortalities followed by meteorological disasters. Maximum economic damage

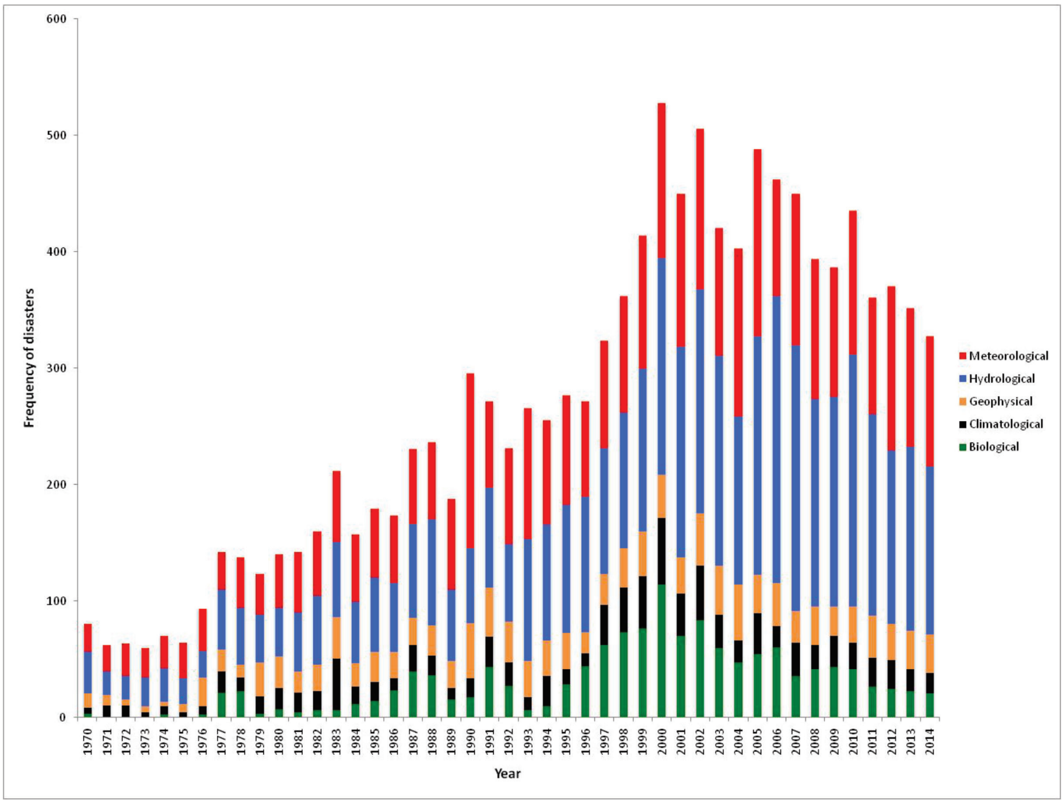

Figure 1. Frequency of natural disasters from 1970 to 2014 (Source of data: CRED, 2015)

due to the natural disasters during 1970 to 2014 (Figure 4) was caused by meteorological disasters followed by geophysical disasters.

3. 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 GDP, total employment and exports. Underdevelopment and rural poverty are two of the key factors that shape the risk to natural disasters (IFRC, 2009). The vast majority of the hungry live in the developing regions, where an estimated 780 million people were undernourished in 2014–16 (FAO, IFAD and WFP, 2015). In sub-Saharan Africa, just under one in every four people, or 23.2 percent of the population, is estimated to be undernourished in 2014–16, which is the highest prevalence of undernourishment for any region. The number of undernourished people even increased by 44 million between 1990–92 and 2014–16.

Exposure to natural hazards and disasters is a major cause of food insecurity, a problem exacerbated by climate change. Natural disasters disproportionately strike developing countries, as the lion's share of volcanic activity and El Niño-related events occur in developing countries, and the death toll is concentrated in developing countries to an even greater degree (DAYTON-JOHNSON, 2006). Be-

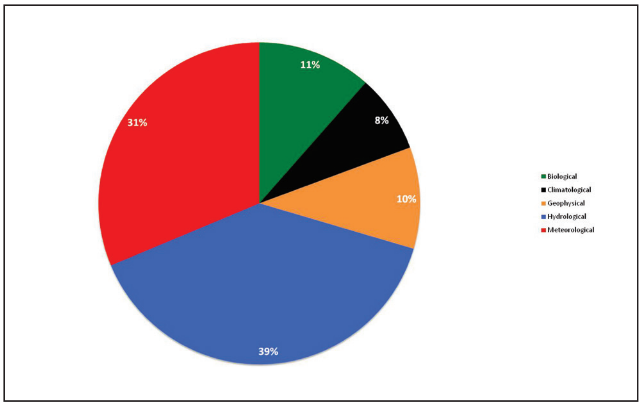

Figure 2. Percentage distribution of the natural disasters during 1970 to 2014 according to different sub-groups (Source of data: CRED, 2015).

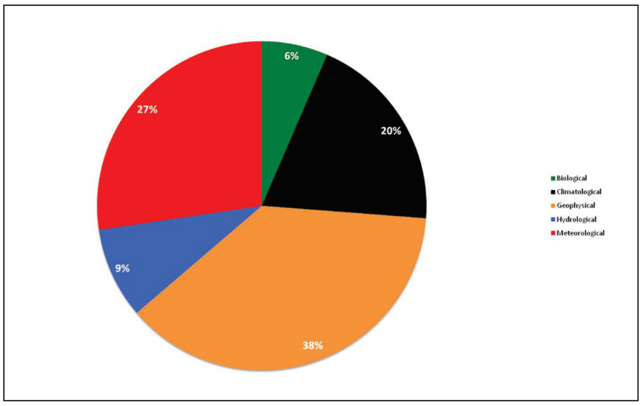

Figure 3. Percentage distribution of the fatalities due to natural disasters during 1970 to 2014 according to different sub-groups (Source of data: CRED, 2015).

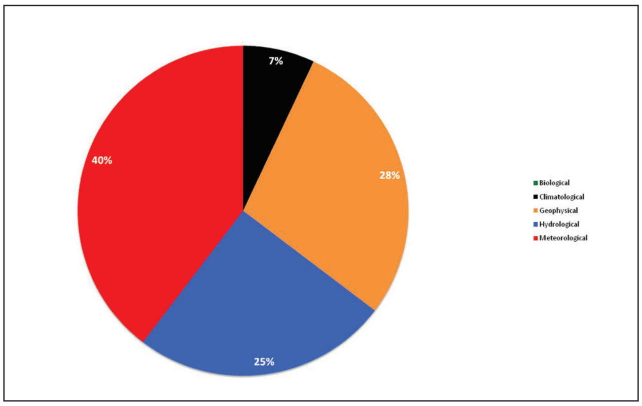

Figure 4. Percentage distribution of the total economic damage due to natural disasters during 1970 to 2014 according to different sub-groups (proportion of damage due to Biological Disasters is less than 0.01% and hence is not shown in the figure) (Source of data: CRED, 2015)

tween 2003 and 2013, natural hazards and disasters in the developing regions affected more than 1.9 billion people and resulted in nearly half a trillion US dollars in estimated damage (FAO, IFAD and WFP, 2015). When disasters strike, they have immediate repercussions on the livelihoods and food security of millions of family farmers and smallholders, pastoralists, fishers and forest-dependent communities in developing countries where agriculture employs from 30 to over 80 percent of the population. Droughts that regularly follow the onset of El Niño years are concentrated in Southern Africa and South Asia. According to UNDP (2004), while only 11 per cent of people exposed to natural hazards live in countries classified as "low-human development" countries, these same countries account for more than 53 per cent of disaster-related deaths. The World Bank estimates that Small Island Developing States (SIDS) account for two-thirds of the countries incurring the highest relative losses due to natural disasters each year. In the Pacific Islands region alone, infrastructure, buildings and cash crops with an estimated value of US$112 billion are considered to be at risk of natural disasters (WORLD BANK, 2012).

Because agriculture relies on the weather, climate, and water availability to thrive, it is easily impacted by natural events and disasters. According to FAO (2015), the agriculture sector – including crops, livestock, fisheries and forestry – absorbs approximately 22 percent of the economic impact caused by medium- and large scale natural hazards and disasters in developing countries. Agricultural impacts from natural events and disasters most commonly include: contamination of water bodies, loss of harvest or livestock, increased susceptibility to disease, and destruction of irrigation systems and other agricultural infrastructure (EPA, 2015). These impacts can have long lasting effects on agricultural production including crops, forest growth, and arable lands, which require time to mature. Learning how to prepare for and recover from natural events and disasters will decrease their long-term effects on agriculture and the environment.

Climate change multiplies the risks of natural hazards, through altered rainfall and temperature patterns as well as increased frequency and intensity of extreme events such as drought and flooding. The Fifth Assessment Report of the Intergovernmental Panel on Climate Change, released in 2014, noted that climate change is already having a negative impact on agriculture, affecting major crops, livestock production and fisheries (IPCC, 2014). These tropical areas of high exposure to climate change are also characterized by high food insecurity.

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. According to World Bank (2013), 70% of the total population in the LDCs live in the rural areas. In many countries that have failed to reach the international hunger targets, natural and human-induced disasters or political instability have resulted in protracted crises with increased vulnerability and food insecurity of large parts of the population (FAO, IFAD and WFP, 2015).

In addressing the impacts of natural disasters, the agricultural sector had not received the attention which 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 costs 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.

Currently, many developing countries are particularly exposed to natural disaster risk without the benefit of ex-ante structures to finance losses. Instead, following each major drought event or other natural disaster, those affected must appeal for financial support and are left vulnerable to the mercy of ad-hoc responses from donor governments. Livelihoods are rarely insured by international insurance or reinsurance providers, capital markets, or even government budgets in developing countries where natural disasters and agricultural price risk impede development of both formal and informal banking (HESS, 2007). Trapped into this cycle of institutional underdevelopment, poor, risk-averse farmers are locked in poverty, burdened with old technology and faced with an

Table 1. Average percentage share of damage and loss by type of hazard in different subsectors of agriculture (Source: FAO, 2015). *Forest fires cause significant damage

Subsector	Type of Hazard				
	Storms	Floods	Droughts	Tsunamis	Earthquakes
Crop	22.8	59.6	15.1	1.7	0.7
Livestock	3.2	8.4	85.8	0.2	2.3
Fisheries	16.4	9.8	3.1	70.2	0.4
Forestry*	89.1	5.0	0.0	3.2	2.7

inefficient allocation of resources.

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).

4. Impacts of natural disasters in agriculture, rangeland and forestry

When disasters strike, they have a direct impact on the livelihoods and food security of millions of small farmers, pastoralists, fishers and forest-dependent communities in developing countries. According to FAO (2015), agriculture employs over 30 percent of the labour force in countries such as Bolivia, Cambodia, Cameroon, Guatemala, India, Indonesia, Nicaragua, Niger, Philippines, Sri Lanka, and Viet Nam, and over 60 percent of people in Burkina Faso, Ethiopia, Kenya, Madagascar, Mali, Tanzania, Uganda and Zambia.

To identify trends in the economic impact of disasters on crops, livestock, fisheries and forestry, FAO reviewed 78 post-disaster needs assessments undertaken in the aftermath of medium- to large-scale disasters in 48 developing countries in Africa, Asia and Latin America decade (2003–2013) and calculated the damage and losses reported in these post-disaster needs assessments. The findings show that the 78 disasters caused a total of USD 140 billion in damage and losses on all sectors, of which USD 30 billion was on the agriculture sector. On average, agriculture absorbs 22 percent of the total economic impact caused by natural hazards (FAO, 2015). The 78 post-disaster needs assessments reviewed also indicate that, within agriculture, 42 percent of all damage and losses is on the crops subsector, followed by livestock with 36 percent. Estimates of losses were about US$13 billion for the crop sector, and US$11 billion for livestock. Data on the average percentage share of damage and loss by the different types of hazard ie., storms, floods, droughts, tsunamis and earthquakes in different subsectors of agriculture ie., crops, livestock, fisheries and forestry are shown in Table 1. In the crop sector, the damage and loss is mainly due to floods and storms while in the livestock sector, the major damage and loss is caused by droughts.

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

Disasters also cause indirect damage which refers to loss of potential production due to disturbed flow of goods and services, lost production capacities, and increased costs of production. Such indirect impacts appear progressively as a result of low incomes, decreases in production, environmental degradation and other factors related to the disaster (DAS 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 eg., anxiety or fear of future natural disasters (Oliver 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 – 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 & 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 rainfed 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, loss/GDP rates are 20% 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% of the GNP in Bangladesh was attributed to agricultural activities in Bangladesh while in Cambodia and Laos, it was 44.6 and 54.3% respectively. During the last El Niño in Ecuador, Vos et al. (1999) estimated that around 12,000 workers on banana and sugar cane plantations in the lowlands temporarily lost their jobs. In Honduras, the press reported that the rate of unemployment in the immediate aftermath of Hurricane Mitch had reached an estimated 32%, according to the firm, Asesorias Economicos.

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

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

5. Post-2015 environment for reducing disaster risk

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. Recognizing the increasing impact of disasters and their complexity in many parts of the world, the Member Countries of the United Nations came together to enhance the global efforts to strengthen disaster risk reduction to reduce losses of lives and assets from disasters worldwide.

The post-2015 environment for reducing disaster risk will be shaped by three critical United Nations-led negotiations that will conclude this year:

a) The Sendai Framework for Disaster Risk Reduction (SFDRR), which succeeded the Hyogo Framework for Action 2005–2015: Building the Resilience of Nations and Communities to Disasters (HFA), and was adopted at the Third World United Nations Conference on Disaster Risk Reduction (WCDRR-III) held in Sendai, Japan, in March 2015;

b) The Sustainable Development Goals (SDGs) are to be adopted by world leaders at the UN General Assembly in New York, in September 2015; and

c) A new agreement under the United Nations Framework Convention on Climate Change (UNFCCC) is to be adopted in Paris in December 2015.

These concurrent processes provide the international community with a unique opportunity to ensure coherence and alignment across policies, practices and partnerships in programme implementation for disaster risk reduction, sustainable development and climate change. Together they will affect how user-oriented weather, climate and water services are delivered over the coming decade and beyond to meet the evolving needs of governments, decision-makers and the public.

5.1 Sendai framework for disaster risk reduction (SFDRR)

SFDRR (UN, 2015) aims to achieve the following outcome over the next 15 years: "The substantial reduction of disaster risk and losses in lives, livelihoods and health and in the economic, physical, social, cultural and environmental assets ofpersons, businesses, communities and countries".

To attain this expected outcome, SFDRR emphasizes the following goal : "Prevent new and reduce existing disaster risk through the implementation of integrated and inclusive economic, structural, legal, social, health, cultural, educational, environmental, technological, political and institutional measures that prevent and reduce hazard exposure and vulnerability to disaster, increase preparedness for response and recovery, and thus strengthen resilience".

Taking into account the experience gained through the implementation of the HFA, and in pursuance of the expected outcome and goal, SFDRR addresses the following four priorities for action:

(a) Understanding disaster risk;

(b) Strengthening disaster risk governance to manage disaster risk;

(c) Investing in DRR for resilience; and,

(d) Enhancing disaster preparedness for effective response, and to "Build Back Better" in recovery, rehabilitation and reconstruction.

FAO (2015) emphasizes that the agriculture sectors need to be mobilized as proactive implementation partners for the delivery of the SFDRR so as to enhance local action and build resilience of the most vulnerable, which are often also the most food insecure. The applications of the agrometeorological information for reducing the impacts of natural disasters in agriculture, which are described below, address the above four priorities of action of SFDRR.

6. Agrometeorological strategies for reducing the impacts of natural disasters in agriculture

Agricultural research until the 80s was preoccupied with issues of increased productivity to feed the growing populations and the success of green revolution in many developing countries had its foundations in increased use of external inputs such as improved seed, fertilizers, water, pesticides, fungicides etc. As we moved into the 21st century, agricultural research community is faced with the challenge of balancing the continuing need for increased productivity with the new concerns regarding the growing frequency of weather and climate extremes and the impacts of natural disasters on the agriculture sector. This points to a new and important role for agrometeorologists around the world and some of the priority areas that need to be addressed are outlined below.

6.1. Improvement and strengthening of agrometeorological networks

In order to assess disaster risks, the hazard characteristics and their impacts on different agroecosystems, there is an urgent need for strengthening meteorological networks to support systematic data collection and analysis. Although agrometeorological networks have been in operation for many years now, in many developing countries and in some countries in transition, these networks are falling into disrepair due to lack of sustained funding. As more emphasis is now being placed on vulnerable regions including those in remote areas, a revaluation of the existing networks is needed to respond adequately to the needs of the priority regions and develop, periodically update and disseminate, as appropriate, location-based disaster risk information, including risk maps, to decision makers and the farming communities at risk of exposure to disasters in an appropriate format. It is also important to integrate the deployment of modern technologies, such as automatic weather stations (AWSs), for data collection and transmission in the revaluation of existing networks. The use of AWSs is becoming more and more widespread, as they provide real-time meteorological data from places in agricultural areas with very scarce stations. Data from AWSs have become essential to provide information for the assessment of risk management and for decision making.

6.2. Establishment of efficient agrometeorological databases including the acquisition and use of new sources of data for natural disaster assessement and mitigation

A basic requirement in natural disaster assessment and mitigation is an adequate agrometeorological database. This should include not only meteorological data, but also agricultural (phenological, crop management, pest and disease cycle), hydrological, land use, soil types, economic and other relevant information. Recent developments in remote sensing such as detection of soil moisture, estimation of evapotranspiration, rainfall etc., constitute new sources of data for many agrometeorological applications for disaster risk management in agriculture. These not only complement ground observations, but also offer new types of data (like those of microwave satellites), provide global coverage and can often be used to improve ground data e.g., in area averaging. It is important to take appropriate steps to promote the collection and use of these data in operational agrometeorology. With efficient agrometeorological databases, including quality controlled historical data, it is feasible to estimate the risk of extreme events in quantitative terms, which is an important information in risk assessment (GUERREIRO, 2005).

6.3. Ensuring timely dissemination of early warnings of natural hazards to the farming community and effective monitoring

Contemporary early warning systems emerged in the 1970s and 1980s, as a response to drought-induced famines in the Sahel. The 2005 World Conference on Disaster

Reduction in Kobe, Japan followed by the third early warning conference in Bonn, Germany in 2006, led to notable progress in linking early warning to early action and risk reduction. Currently systems exist to provide hazard forecasts and warnings against impending disasters induced by hydrometeorological hazards, but the hazard coverage at the country level is highly variable and reflect the countries' economic development level. The new consensus is that early warning is not only the production of technically accurate warnings but also a system that requires an understanding of risk and a link between producers and consumers of warning information, with the ultimate goal of triggering action to prevent or mitigate a disaster (IFRC, 2009). There is also a need for methodological work on the monitoring side, in particular regarding the identification of critical thresholds that should trigger early warnings. Close cooperation between agrometeorologists and their colleagues in the National Meteorological and Hydrological Services (NMHSs) can help ensure timely dissemination of early warnings of natural hazards to the farming community and effective monitoring. Agrometeorologists should promote wider utilization of existing warnings systems and disaster management information, for example by building links between climate and disaster databases.

6.4. Promotion of scientific research on disaster risk patterns, causes and effects in the agriculture sector

The analysis of data on current weather and historical climate, together with predictions and forward-looking analyses by the agrometeorologists can help monitor hazard-related trends, quantify disaster risk and the causes and effects to set priorities for coping with disaster risk in the agricultural sector. Promotion of research efforts in this area can assist in developing the capacity of farmers in understanding disaster risk and in integrating disaster risk management into their operational decision making on-farm. Such research efforts can also ensure that the development of appropriate policies and measures to mitigate disaster risk in the agriculture sector have a sound scientific basis.

6.5. Facilitating tactical planning and operational decisions by the farmers during the crop season through the provision of improved weather forecasts (both short and medium-range forecasts) and advisories

Catastrophic events like droughts, floods and cyclones, spatial and temporal changes in important weather parameters like rainfall, temperature, wind, cloud cover, humidity, etc. effect crop yields by influencing farmers' decision about selection of cultivar, use of inputs, crop management practices, etc. Short-range forecasts are normally available one day in advance, but modern agricultural practices such as sowing of weather-sensitive high yielding varieties, need-based application of fertilizer, pesticides, insecticides, efficient irrigation and planning for harvest require weather forecast with higher lead time which enable the farmers to take ameliorative measures. Thus, for agricultural sector, location-specific weather forecast in the medium range (3 to 10 days in advance) is very important. Agrometeorologists should ensure that these forecasts and advisories should be made available in a language that farmers can understand.

6.6. Promotion and use of seasonal to inter-annual climate forecasts

One of the persistent demands of farmers is the provision of reliable forecasts of seasonal climate as it would help them take appropriate decisions as to which crops/cropping systems should be chosen well ahead of the sowing rains to avoid undue risks. International cooperation in studying the science behind detecting and forecasting natural and human-made hazards has led to advances in predictive accuracy and increased lead time (Figure 2). Improvements in the ability to forecast climate variability based on the advances in our understanding of ocean-atmosphere interactions over the past two decades offers opportunities to develop applications of seasonal-to-interannual climate predictions in the agricultural sector to deal more effectively with the effects of climate variability than ever before. The first International Workshop on Climate Prediction and Agriculture (CLIMAG), held at WMO in September 1999 (Sivakumar 2000) considered a number of important issues relating to climate prediction applications in agriculture including capabilities in long-term weather forecasting for agricultural production, down-scaling, scaling-up crop models for climate prediction applications, use of weather generators in crop modeling, economic impacts of shifts in ENSO event frequency and strengths, and economic value of climate forecasts for agricultural systems. Agrometeorologists should make efforts to promote more active use of seasonal to inter-annual climate forecasts in agricultural planning and operations.

6.7. Promotion of geographical information systems and remote sensing applications and agroecological zoning for sustainable management of farming systems, forestry and livestock

Agroecological zoning offers much scope for developing strategies for efficient natural resource management and in this context, recent advances in the geographical information systems (GIS) and remote sensing have made the task of integration and mapping of a wide range of databases much easier. GIS allows the collection, management, archival, analysis, and manipulation of large volumes of spatially referenced and associated attribute data. The advantages are manifold and highly important, especially for the fast cross-sector interactions and the production of synthetic and lucid information for decision-makers. Effective use of these techniques can promote the mainstreaming of disaster risk assessment, mapping and management into rural development planning and management of, inter alia, mountains, rivers, coastal flood plain areas, drylands, wetlands and all other areas prone to droughts and flooding. This can help strengthen the sustainable use and management of agroecosystems and implement integrated environmental and natural resource management approaches that incorporate disaster risk reduction.

6.8. Use of improved methods, procedures and techniques for the dissemination of agrometeorological information

Information and communication technologies (ICTs) broadly cover the set of activities that facilitates capturing, storage, processing, transmission and display of information by electronic means. Current advances in the ICTs are changing the way farmers view information dissemination and exchange. The effectiveness of ICTs for agrometeorological information dissemination is being enhanced by linking them to other communication media which are accessible to farmers. A good example of such an activity is the Radio and Internet (RANET) project being implemented by the African Center of Meteorological Applications for Development (ACMAD) in Africa. Rapid advances made in the recent past in information technology, especially in audio-video media, need to be quickly operationalized to more effectively diffuse agrometeorological information to the user community. Here the development of a bottom-up approach of the full involvement of users is important to ensure that the methods and procedures so developed will adequately respond to the appropriate needs of the users.

6.9. Development of agrometeorological adaptation strategies to climate variability and climate change

Food and fibre production is perhaps the sector most sensitive and vulnerable to climatic fluctuations. Agricultural growth and productivity depends on food production systems that are resilient against production failure due to shocks and climate variability (FAO, 2015). This requires a strong emphasis on sector-specific disaster risk reduction measures, technologies and practices. There is a clear need identify the priority agrometeorological adaptation strategies for regions that are identified as being most vulnerable to the effects of climate variability and climate change and quickly diffuse this information to such regions. The prevailing philosophy regarding climate change mitigation, particularly in developing countries and at the subsistence farming level, has been one of "noregrets" i.e., only measures that make economic sense now should be adopted, because they reduce emissions from the agricultural sector or improve resilience of all sectors of agriculture against weather variability. All have a marked management component and could thus often be implemented at minimal cost. By systematically monitoring the impacts of natural disasters on different crops/cropping systems, agrometeorologists can help reduce the losses associated with the occurrence of natural hazards and provide input to the development of appropriate adaptation and mitigation strategies in response to changes in climate and climate variability.

6.10. Active engagement in the regional and sub-regional platforms for disaster risk reduction and in the thematic platform for agriculture sector

SFDRR calls for forging effective partnerships for disaster risk reduction. Agrometeorologists should play an active role in the regional and subregional platforms for disaster risk reduction and the thematic platform for the agricultural sector in order to forge partnerships, periodically assess progress on implementation and share the knowledge on disaster risk-informed policies and programmes and to promote the integration of disaster risk management in other relevant sectors.

6.11. Promoting weather index insurance for coping with disaster risk in the agricultural sector

According to FAO (2015), humanitarian aid and official development assistance to the agriculture sector is small when compared with the economic impact and needs in the sector. More investment is needed in disaster risk reduction to build resilient livelihoods and food production systems. In this context, the potential for the use of index insurance products in agriculture is significant (SKEES 2003). Weather Index Insurance is currently proving to be a valuable instrument in many developing countries for transferring the financial impacts of low-frequency, high-consequence systemic risks out of rural areas. Agrometeorologists can facilitate the implementation of such index instruments to cope with disaster risk in the agricultural sector by providing technical support and for monitoring and evaluation.

7. Conclusions

According to the available scientific evidence, 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. 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 a comprehensive assessment of the impacts of natural disasters on agriculture, forestry, and fisheries and strategies for mitigation of natural disasters is critical for sustainable development, especially in the developing countries. To gain a better understanding of the climate variability and climate change and to cope with the impacts of natural disasters, improved agrometeorological databases are critical to develop more appropriate levels and forms of disaster prevention, mitigation and preparedness. Programs for improving prediction methods and dissemination of warnings should be expanded and intensified. Agrometeorologists should make more efficient use of the improvements in the information and communication technologies over the past two decades to provide timely and efficient agrometeorological information and products to the farming communities to help them cope with the impacts of natural disasters and improve the agricultural productivity.

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Estratégias agrometeorológicas para reduzir os impactos de desastres naturais na agricultura

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INFORMAÇÕES

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RESUMO

Ao longo das últimas décadas, há uma crescente intensidade e frequência dos desastres naturais em todo o mundo com severos impactos socioeconômicos, especialmente nos países em desenvolvimento. Informações gerais sobre catástrofes naturais, incluindo as definições, tipos e incidência de desastres naturais de 1970 a 2014 foram fornecidas. A produção agrícola é altamente dependente das condições de tempo e clima e da disponibilidade de água e é negativamente afetada por desastres meteorológicos e climáticos. Impactos das secas, ciclones, inundações, incêndios florestais e de arbustos na agricultura, pastagens e florestas foram descritos com exemplos apropriados. Falta de chuvas e a ocorrência de desastres naturais pode levar a frustração de safras, insegurança alimentar, fome, perda de propriedades e de vidas, a migração em massa e declínio da economia nacional. Reconhecendo o crescente impacto das catástrofes e sua complexidade em muitas partes do mundo, os países membros das Nações Unidas formaram inciativas para melhorar os esforços globais de reforço à redução de risco de desastres para reduzir perdas de vidas e bens matérias em todo o mundo. E o ambiente pós-2015 para reduzir o risco de desastres irá ser moldado por três negociações críticas lideradas pelas Nações Unidas que serão concluídas neste ano. Aspectos importantes da conveção quadro de Sendai para redução de risco de desastres (SFDRR), que foi adoptada na III Conferência Mundial das Nações Unidas de redução do risco de desastres (WCDRR-III) realizada em Sendai, Japão, em março de 2015, foram descritos. A crescente preocupação com o possível impacto de desastres naturais e eventos extremos na agricultura e na silvicultura tem criado novas demandas por informações e avaliação por agrometeorologistas. Estratégias agrometeorológicas para reduzir os impactos de desastres naturais na agricultura, tais como uma melhor utilização das informações de tempo e clima e previsões, sistemas de alerta precoce, reorientação e reformulação de informações meteorológicas, ajuste fino de análise climática e apresentação em formatos adequados para a tomada de decisões agrícolas que podem ajudar os agricultores a lidar com o impacto negativo das catástrofes naturais também foram descritos.

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