CHAPTER 1

Agrometeorology in Extreme Events and Natural Disasters – An Overview

1.1 Introduction

Extreme events due to both atmospheric and non-atmospheric factors have been causing a heavy toll of death and suffering throughout the world. The continuous onslaught of nature's fury has not only led to the loss of lives but has also led to the economic losses including loss of agricultural production. Nearly 90 percent of the natural disasters and 95 percent of the total disaster-related deaths worldwide, occur in the developing countries. The economic cost associated with all natural disasters has increased 14 fold since the 1950's (World Disasters Report, 2001). These losses are growing largely because of the increasing concentration of population and investments in vulnerable locations coupled with inadequate investments in measure to reduce risks. Worldwide, annual economic costs related to natural disasters have been estimated at about 50 to 100 billion dollars. By the year 2050 it is predicted that globally 100,000 lives will be lost each year to natural disasters and the global cost could top 300 billion dollar annually (SEI, IUCN, IISD, 2001).

Natural disasters and extreme events were believed to be an inseparable part of nature and a series of undesirable fluctuations in climate could endanger food security. Disasters induced by natural extreme events may deeply affect the social structure of the area struck and cause severe consequences for human and environment, agriculture, forestry, rangeland and fisheries (Das, 2005). Many studies on droughts, landslides, floods, cyclones, land erosion, etc. conducted in the developing countries reveal that disaster-prone communities are living at virtually subsistence levels and very limited livelihood options and opportunities are available to the at-risk communities in these countries. Most of the disaster-prone population still depends on agriculture as a major source of earning. Agriculture includes farming and also animal husbandry, pastoral activities, fishing and harvesting the forests.

In spite of recent technological developments which have helped to increase agricultural production in many countries, growth of plants and animals continue to depend to a large extent on the weather conditions. Aspects of crop and livestock production, as well as agriculture's natural resource base, that are influenced by weather and climate conditions include air and water pollution; soil erosion from wind or water; the incidence and effects of drought; crop growth; animal production; the incidence and extent of pests and diseases; the incidence, frequency, and extent of frost; the dangers of forest and bush fires; losses during storage and transport; and the safety and effectiveness of on-farm operations (Mavi and Tupper, 2004).

Each plant has its own climatic requirements for growth and development and any large scale deviation from it exerts negative influence. The adverse effects of floods and droughts often entail far-reaching socio-economic and environmental implications and may include loss of life and agricultural productivity; mass migration of people and animals; environmental degradation; and shortage of food, energy, water and other basic needs. The degree of vulnerability to such natural hazards is high in developing countries where necessity tends to force the poor to occupy the most vulnerable areas. Inappropriate management of agro-ecosystems, compounded by severe climatic events such as recurring droughts in many parts of the world, have tended to make the dry lands increasingly vulnerable and prone to rapid degradation and hence desertification (Nunez, 2005). Even in the high rainfall areas, increased probability of extreme events can cause increased nutrient losses due to excessive runoff and water-logging. Growth of plants is most sensitive to temperature just above a threshold value and near the maximum value, where growth normally stops. Therefore, periods of extreme temperature i.e., low temperatures below the threshold value and high temperatures above the maxima are hazardous to plant development and growth. Extreme temperature conditions during cold spells cause stress and frost; high temperatures lead to heat stress, and both affect agricultural production. Snow and ice storms in late spring or early autumn are very hazardous to many temperate crops.

Similarly extremes of moisture conditions namely dry desiccating winds, drought episodes and low moisture conditions as well as very humid atmospheric conditions including wet spells tend to affect agriculture. High soil moisture in situations of water logging and flooding associated with heavy rainfall and tropical storms have adverse effect on plant growth and development since they influence the rate of transpiration, leaf area expansion and ultimately plant productivity. Drastic changes in rainfall variability can have very significant impact, particularly in climatically marginal zones such as arid, semi-arid and sub-humid areas where incidence of widespread drought is frequent. Dry desiccating and strong winds reduce agricultural production as a result of very high evapotranspiration rates. It also causes mechanical damage to plants with weak stems by logging such as the sugarcane and the banana (Das, 2005). Climate extremes also affect the plants indirectly through its effects on development of crop insects, pests and diseases; though locusts cannot thrive under severe cold conditions and extremely wet situations.

1.2 Natural Disasters – Definitions and Types

According to Sivakumar (2005), 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. For some disasters like drought, lack of appropriate definition of natural disaster itself is a problem. Definitions of natural disasters are based on the need to respond to development and a humanitarian agenda. Different disasters can be classified as different types by different databases. For example, a flood which was a consequence of severe wind storm may be recorded as one or the other. Flood (as related to rains) and drought may be long lasting (Gommes and Negre, 1992), but in Asia their short durations are more common. 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”. 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.

A disaster, according to Susman et al. (1983), is the interface between an extreme physical event and a vulnerable human population. In the same way an extreme agrometeorological event is the interaction between a vulnerable agricultural system and extreme weather conditions. However, the definition of extreme agrometeorological event is broader, as it includes weather conditions conducive to the development of agents like pests and diseases that adversely affect all aspects of agriculture including livestock, pasture, forests and fisheries.

In themselves weather extremes are not necessarily hazardous, although they may become so if they prevail for prolonged periods of time. This accumulation effect of weather extremes is evident in the cases of droughts, heat waves and floods. Atmospheric factor may fulfill a variety of roles in the development of the hazard situation. A broad distinction can be made between phenomena such as thunderstorms, tropical cyclones, tornadoes, squall lines and hailstorms which involve the sudden impact of very large amount of energy discharged in an extremely short time, and those features which become hazards only if they exceed tolerable magnitudes within or beyond certain time limits. In the latter category can be included wind hazards associated with extra tropical low pressure systems, snow, heavy rain, frosts and droughts. Earthquake, volcanic eruptions and landslides, although they belong to geological events, are likely to result in losses to forestry or agricultural operations. Tsunami, a series of waves caused by an underwater earthquake or volcanic eruption, is capable of creating massive devastation when it hits land. The waves travel very quickly in deep ocean waters, reaching speeds as fast as a jet plane. As the tsunami approaches the coastline and shallow water, it slows in speed but builds in height. As the tsunami comes ashore, it brings with it a tremendous amount of energy and waves that can reach heights of over 100 feet. As the massive wall of water crashes onshore, it can cause severe coastal erosion, which wears away of coastal land or beaches.

Chapman (1994) classified natural hazards into three main groups:

(a) Hazards originating primarily from the atmosphere and hydrosphere such as tropical cyclones, tornadoes, thunderstorms, floods, droughts, storm surges, sand storms and dust storms.

(b) Those originating primarily from the lithosphere such as earth-quakes, volcanic explosions, mass earth movements (e.g., mudslides, land- slides) and avalanches, and

(c) Those originating primarily from the biosphere such as wildfire, bacteria, viruses, diseases causing agents.

The most important of these extreme climatic events from agriculture and livestock point of view are:

1. Tropical storms (cyclones, hurricanes, typhoons, etc.) associated with high winds, flooding and storm surges.
2. Floods (other than those related to tropical storms), heavy rains due to monsoons, water logging and landslides.
3. Severe thunderstorms, hail storms, tornadoes and squalls.
4. Drought and heat waves.
5. Cold spells, low temperature, frost, snow and ice-storms.
6. Dust storms and sand storms.
7. Weather related fires (the lightening).
8. Pests and diseases of crops and livestock.

1.3 The Role of Meteorological Data and Information

The weather parameters which cause loss or damage to plants and animals are usually snow, ice, heavy rains, air pollution, excessive heat or cold, drought, local severe storms, hail, sand storms, strong winds and floods and sea salt damage in maritime areas. The secondary effects of weather which adversely affect agricultural production include frost, forest and bush fires, locust invasion and the incidence of pests and diseases. When user-focussed weather and climate information are readily available, and used widely by farmers and others in the agricultural sector, losses resulting from adverse weather and climatic conditions can be minimized, thereby improving the yield and quality of agricultural products.

The first and the most basic requirement in agrometeorological hazard assessment for extreme events is an adequate database. While measures to optimize an extreme event data base should be vigorously persuaded, it must be recognized that basic data collection, processing and storage remains the corner stone of any research and operational aspects of extreme events. For each extreme event the database should include location, time and details about severity of the phenomenon. The extent of damage or injury, caused by each phenomenon must also be recorded preferably quantitatively.

Accurate information on extreme meteorological parameters has a great potential for increasing output to the farmers. The information is also useful for modification of crop environment, protection from frost, strong winds and also for irrigation scheduling leading to efficient water management and drought preparedness.

The extension of cultivation into less suitable climates increases the risk of damage due to climate, particularly the meteorological extremes. A successful development of agricultural economy of a country is, therefore, to a large extent, dependent on the use of climatic information and in particular the agrometeorological adverse factors. For examining effect of agroclimatic extreme events, all aspects of climatology of the locality must be considered. It should include physical properties of the atmosphere and upper soil layers. In particular, radiation climate is of fundamental importance. Systems of observation must also be devised in anticipation of damage for remedial measures after the extreme weather has occurred. The nature of the observation for each such extreme agrometeorological event must vary with the type of hazard.

A country prone to tropical cyclone should install additional observational facilities to supplement the basic meteorological network required for its normal forecasting and climatological purposes. The data collected in such cases should also include losses of human/cattle lives, the number of people injured, areas inundated and damage, crop losses, the number of dwellings destroyed/damaged, etc. Environmental baseline data from 2004 tsunami waves, including assessments of the local environment, risks from hazardous/toxic materials was also lacking. Local governments in the affected countries, for example, pointed to a need to build local capacity to collate and manage such data.

The real time monitoring and assessment of drought need collection of rainfall and other related drought data. It is necessary to supplement the synoptic data with information on evaporation, radiation, soil moisture, under-ground water table, etc. Accumulated precipitation amount is one of the most essential elements in a real time drought surveillance service and must supplement data on temperature, humidity, cloudiness and wind. In relation to weather hazard, data are also required of the state of crops and whether they are in such a stage of development to be particularly liable to weather hazards.

Data including frequencies and duration of water levels and discharges exceeding various values and those concerning severe storms and floods are very important for design and planning. Generally regular observational network do provide information on storm-rainfall distribution or on flood peak discharges of tributary streams. Also during severe floods, permanent stream gauge installations are often washed away and records lost. For these reasons valuable information can be obtained by a flood survey conducted in the storm/flood area following a severe occurrence. High water marks along rivers are useful in delineating flooded area and assess damage. These marks could also be used with other data to compute peak discharge of stream by indirect methods.

Extent, depth and water equivalent of snow cover together with daily and accumulated number of degree days above or below a certain base and melting degree days are useful for forecasting snow-melt run-off. A particularly important case is that of frost which can be very damaging to plants and so special forecasts are needed for frost. Soil moisture data at weekly/monthly intervals when presented in graphical form are useful in scheduling application of irrigation and also in river forecasting.

For crops affected by pest and diseases information is needed of the state and stage of plant, the availability and the release of spores, incidence and spread of infection etc. Information is also required of the hatching of various insects, the buildup of insect population or their invasion from the other territories.

Microclimatic observations inside or close to the borders of forests are needed for understanding many forest processes. Many pathological conditions depend on the occurrence of high relative humidity for development whereas it is low relative humidity which is of concern in forest fire control. Since there is a direct relationship between weather and fire-danger, and between weather and fire behaviour, a knowledge of past, present and future weather is desirable. This should include information on temperature, relative humidity, wind, precipitation and thunderstorm. Information is also required of the state of forest litter and its liability to fire. The use of periodic seasonal data of certain specific forest areas prone to forest fires could be used by the forest managers to enable them taking certain fire prevention measures in advance to mitigate possible damages (Das, 2010).

The ability of cattle in the open air to withstand low temperature is fairly high. However, the secondary effect of weather often accompanying a cold wave causes widespread losses of such animals. Snow covers forage and the cold freezes drinking water supplies; so a number of cattle caught in a winter storm tend to starve rather than die directly from the cold wave. Cattle, pig, poultry and other livestock are adversely affected by high temperature together with high relative humidity. Meteorological data on these aspects are highly useful to forecast these extreme episodes and minimize the loss.

Without doubt, the most spectacular observing tool in the last few decades is the meteorological satellite. Some of these satellites provide data on “wetness” of vegetated surface and “surface wetness”. These data, though not directly forming part of the agrometeorological extremes do provide sufficient information when a meteorological extreme like tropical storms, excessive rains, drought or attack by pests may occur and are thus highly useful.

1.4 Socio-economic Impact of Extreme Events

Agrometeorological disasters affect all walks of society and the impact is widespread because it also reflects the interaction between development and the environment on the one hand and between social and economic aims on the other. However complexities and variety of technical aspects get involved when consideration has to be given to social, economic and even psychological factors (Das, 2003a; Ray et al., 2019).

In many respects the human response to the danger from extreme events is the very core of disaster prevention and preparedness. Ultimately, the success or failure of the systems depends upon people. Every agrometeorological disaster brings forth in its wake stories demonstrating endless diversity of human reaction to the extreme weather episodes. Age, health, education, family situation, experience from previous disasters and many other socio-economic factors play a key role, but they are so complex that no clear-cut pattern of human behaviour could be evolved for general application to future disaster situations.

Determination of the factors influencing the human response to danger related particularly to the national culture, has a very real role to play in reducing loss of life and injuries from typical cyclones. Loss of life when storm warnings are disregarded is a consequence of the attitudes and emotions of the people. Undoubtedly, this is a problem deserving close attention.

It is, however, the negative or adverse impacts of extreme events referred to as damages or losses which are more pronounced and do affect human society significantly (Joy, 1991; Mitchell and Griffiths, 1993; Sofield, 1993; De et al., 2005). Impacts of extreme events can be direct or indirect. Direct impacts arise from direct physical contact of the events with people, their animals and property. For example, when bush fires come into contact with crops and farm buildings or when drought conditions directly reduce crop yields and lead to the deaths of livestock and people. Indirect impacts of extreme agrometeorological events are those induced by the events. Indirect impacts often occur away from the scene of the extreme event or after the occurrence of the event. Indirect impacts include evacuation of people in the event of cyclone landfall, disruption to household and leisure activities, stress induced sickness and apprehension and anxiety of future extreme events like floods or bush fires (Handmer and Smith, 1992; Anaman, 1996).

Indirect impact is normally termed secondary economic impact, in economic jargon. The secondary economic impact of an extreme weather event results from its impact on the local and regional economy due to an extreme event initially affecting one or a number of sectors of the economy. For example, prolonged drought may lead to direct losses in the form of reduced yields or deaths of farm animals but may also lead to various indirect effects on incomes of suppliers of inputs to farmers. Impacts of extreme events can also be classified as tangible or intangible. Tangible impacts are those which can be easily measured in monetary terms. For example, the increased rainfall from severe weather events, the amount of which can be measured by meteorologists. Tangible losses or adverse impacts are easily quantifiable, losses such as damages to farm buildings from bush fires or floods for which the losses can be sometimes replaced if the properties are insured. Intangible impacts are often difficult to be measured in monetary terms and hence direct market value does not exist. Intangible losses or adverse impacts are sometimes referred to as non-economic or "social costs" (Togola, 1994). Intangible losses include anxiety and fear of future severe events (Oliver, 1989), inconvenience and disruption to farm work and stress-induced ill- health and human fatalities. Intangible benefits or positive impacts of severe events include improved preparedness by the society for future severe events.

A proposal to locate industry in a disaster-prone area should be examined in relation to the probability of damage (vulnerability) and to such economic factors as access to water, energy, transport, labour, raw materials etc. The environmental impact of disaster prevention measures should also be considered. For example, flood-control measures and proper flood-plain management sometimes yield valuable benefits by reducing risk of silting, soil erosion and landslide (Johnson, 2003). These illustrations are superficially but fairly straight forward and self-evident.

People who experience the tropical cyclones are usually ready to pay particular attention to any warning that is issued and to follow the given advice, including evacuation to safe areas. It is necessary to ensure that all people have an awareness of the dangers posed by tropical cyclones. Indeed, since memories are apt to fade the awareness must be kept alive and up to date among those whose experience of tropical cyclone is not very recent.

The emotional shock of disaster, the death or injury of the family members, the separation of families, changes in living accommodation, the burden of hardship from material losses, physical handicaps resulting from injury and the loss of income and employment etc. all create problems and affect the ability of an individual or family to recover quickly after the event has occurred. There is need to deal with such problems at the level of understanding of the persons concerned. Some situation may require only counseling and advice but there are often many cases which can be relieved only by material help and the constant support from the society.

The factors discussed above i.e., damages from wind, rain, flood, storm surge etc. may be regarded as representing the direct impact of tropical cyclones upon a country. The losses and damages attributed to these factors can be assessed in terms of deaths and injuries to the population, buildings and installations destroyed or in need of repair, destruction of crops and livestock etc. However, there are additional, indirect consequences which cause losses to individuals, industry, community or the nation. The magnitude of these effects can be very large and they should not be ignored in a survey of disaster damage. For example, a tropical cyclone can lead to disruptions of the work force and to other activities resulting in substantial losses in productivity. Factories and warehouses may be out of commission for varying periods.

Loss of personal belongings, due to extreme climatic events can be an especially severe blow to families whose financial reserves are low. In the domestic area, breakdowns in public utilities can also lead to significant losses. For example, an electricity failure which puts refrigerators out of action might result in the loss of perishable food. All these losses, great in some homes, small in others, when aggregated can amount to a substantial financial loss to a whole community.

1.5 Positive Impact on Agriculture of Extreme Events

While it is easier to contemplate negative impact of extreme events such as droughts, tropical cyclones and floods, there are several positive impacts or benefits of extreme events. Increased rainfall in coastal areas from tropical cyclones (Ryan, 1993), fixing of atmospheric nitrogen by thunderstorms, the germination of many native plant species resulting from bushfires and the maintenance of the fertility of the basin soils due to river flooding are some of the positive impacts of extreme meteorological events (Blong, 1992). There are some advantages of drought at certain times in the development of some crops such as the sugarcane where a brief dry spell is essential during the pre-harvest stage that helps increase the sucrose content of the cane. Also there is often a lower incidence of pests and diseases in periods of drought. Transport firms involved in shifting fodder and livestock and tourist organizations do derive benefit from drought.

1.6 Negative Impact on Agriculture of Extreme Events

In order to assess the impact of weather disaster on agriculture, one must link two fundamental aspects, – first, the disaster proper, i.e., the destructive power of the event and secondly, the characteristics of the agricultural system which has been hit. This is illustrated below in the example of Bangladesh, based on FAO statistics and Rahman (1985). Good examples are also provided by Xiang and Griffith (1988) for China. Between 1970 and 1984, three major weather disasters struck Bangladesh. In mid-November 1970, one of the worst cyclones in history; in 1978-1979 a severe drought befell the country, followed in 1984 by extended heavy floods lashing from May to September. Each of these disasters resulted in a sharp decrease of the rice production, the staple food of the country (Gommes, 1995). Weather disaster interactions with agriculture are complex and that they are likely to involve non-agricultural factors as well.

Thresholds and qualitative effects characterize a number of plants and animals with regard to their response to weather factors. Very well-known examples are the effect of temperatures on rice sterility and the breaking of the stems and branches of certain rubber cultivars by wind. Windstorms, tropical storms (hurricanes and typhoons) with very high winds can destroy fields of cereals within minutes and will reduce the yield. The plantation crops suffer more direct and apparent damage than natural forests, to such that the latter constitute efficient protective barriers. Of course, root and tuber crops and creeping plants suffer very little from hurricanes/tropical storms, while tree crops and cereals may be badly hit. Similarly floating rice varieties are characterized by very fast stem elongations which can keep pace with rapidly rising water during floods.

A table showing some weather factors which may negatively affect agriculture (Gommes, 1995) is given below.

Table 1.1

Weather factor	Negative effects on agriculture of extreme values (both direct and indirect)
Rainfall	Direct damage to fragile plant organs, like flowers; soil erosion; water logging; drought and floods; landslides; impeded drying of produce; conditions favourable to crop and livestock pest development; negative effect on pollination and pollinators.
Wind	Physical damage to plant organs or whole plants (e.g. defoliation, particularly of shrubs and trees); soil erosion; excessive evaporation. Wind is an aggravating factor in the event of bush or forest fires.
Air moisture	High values create conditions favourable to pest development; low values associated with high evaporation and often one of the most determinant factors in fire outbreaks.

Table 1.1 ***Contd….***

High temperatures	Increased evapotranspiration; induced sterility in certain crops; poor vernalization; survival of pests during winter. High temperatures at night are associated with increased respiration loss. "Heatwaves", lengthy spells of abnormally high temperatures are particularly harmful.
Low temperatures	Destruction of cell structure (frost); desiccation; slow growth, particularly during cold waves; cold dews.
High cloudiness	Increased incidence of diseases; poor growth.
Hail	Hail impact is usually rather localized, but the damage to crops – particularly at critical phenological stages - and infrastructure may be significant. Even light hail tends to be followed by pest and disease attacks.
Lightning	Lightning causes damage to buildings and the loss of farm animals. It is also one of the causes of wildfire.
Snow	Heavy snowfall damages woody plants. Un-seasonable occurrence particularly affects reproductive organs of plants.
Volcanic eruptions, avalanches and earthquakes	The events listed may disrupt infrastructure and cause the loss of crops and farmland, sometimes permanently. A recent example of carbon dioxide and hydrogen sulphide emissions from a volcanic lake in Cameroon caused significant loss of human life and farm animals.
Air and water pollution	Air pollutants affect life in the immediate surrounding of point sources. Some pollutants, like ozone, are however known to have significant effects on crop yields over wide areas. In combination with fog, some pollutants have a more marked effect on plants and animals. Occurrences of irrigation water pollution have been reported.

Direct effects include loss of the property and the decrease in income of the people and the damage of the machineries in enterprises and the public sector. Indirect effects on agriculture appear progressively as a result of decrease of production, environmental degradation and other factors related to the disaster (Das, 2005). In agriculture there can be large losses in primary production on account of delays in the recovery of arable land that has been inundated. For an annual crop, the office of the United Nations Disaster Relief Co-ordinator estimated a global loss (direct and indirect) at 1.5 to 2 times the direct loss (the lost harvest value). For a perennial crop, the global loss was evaluated at 5 to 7 times the value of the lost harvest.

For most developing countries, loss to life, property and the crop represents a bigger part of the damage caused by a climatic disaster (Das, 2005). A perennial crop needs a number of years before it is restored to its normal situation. In monetary terms, the losses incurred by livestock rearing, forestry and fisheries mostly remain below those suffered by agriculture. In Madagascar, for instance, according to FAO a cyclone in 1983-84, caused crop losses of 85% of the total damage to the agricultural sector, where as the damage to the infrastructure and equipment (drainage, irrigation channel etc.) barely reach 15%. The traditional small scale fisheries were also hit by the cyclone. Livestock losses were negligible.

It was worth mentioning that the losses affecting cash crops, which constitute a major source of export earnings in a number of developing countries is rather high. In Nicaragua, for example, it is reported that direct losses of export crops due to Hurricane "Juana" ("Joan") in 1988 amounted to 21% of the total losses in the agricultural sector (Midinra, 1988). Coffee and bananas suffered a direct loss of their fruits and mechanical damage to their plants. Nonetheless, food crop losses were estimated to be higher (35%), while the livestock sector was less affected (8%, of which one fifth was poultry). The conditions which trigger pest and disease development after the cyclone hits the area are rarely directly harmful per se. They are usually a combination of moisture or temperature conditions which do not directly affect crops and hence are regarded as indirect effects.

In December 26, 2004, a massive earthquake of magnitude 9.0 followed by a number of aftershocks triggered tsunamis that affected Indonesia and neighbouring countries in Asia and the east coasts of Africa, causing serious damage to the coastal areas and small islands (Lay et al., 2005). The power of tsunami wave washed away vegetation in coastal areas making it hard to regrow. In Indonesia, it was estimated that 20% of sea grass beds, 30% of coral reefs, and 25-35% of wetlands, and 50% of sandy beaches of the west coast, have been damaged. In some local areas, 90% damage was reported to mangroves and coastal forests. In Thailand, 15 to 20% of the coral reefs were affected by the tsunami primarily due to siltation and sand infiltration. In the Nicobar Islands 51-100% of mangrove systems, 41-100% of coral reefs, and 6.5-27% of forest ecosystems were damaged. Mangrove systems near river mouths and channels appear particularly susceptible to loss due to heightened flow concentrated at river mouths and inundation of mangrove forests through river channels (UNAO, 2005; UNEP, 2006).

The impact assessment from natural hazards should be based on sound economic principles. The evaluation of adverse impacts of extreme events on agriculture and rural society requires delineating the impacts on society in general from those on individuals, households or businesses. The distinction is necessary to determine financial losses applicable to individuals and societal economic losses attributed to society as a whole. A single economic unit such as a farm is dealt with via analysis in changes in net income when financial losses are considered. Market prices are often used to approximate changes in income imposed by extreme events on individuals (Anaman, 2003). For societal economic analysis, the analysis is done for all members of a defined society affected by the extreme events. The society can be a town, a region or a nation. Market values are sometimes adjusted to reflect economic scarcity of resources and inherent market imperfections. Regardless of whether an individual economic unit or the whole society is being considered, impacts are always measured as the difference between the occurrence and non-occurrence of an extreme event (Anaman, 2003).

1.7 Impact of Natural Disasters on Rangeland and Forestry

The primary use of rangelands which include unimproved grasslands, shrublands, savannahs, and hot and cold deserts, has been and is for grazing by domestic livestock and wildlife. In rangelands, the amount and timing of precipitation are the major determinants of community structure and function. Other driving forces that determine plant community composition, distribution, and productivity include temperature, fire, soil type and herbivory. These driving forces prevent species senescence and allow for periodic rejuvenation by eliminating biomass and organic debris above the ground and thereby liberating nutrients (Das, 2003b). Due to the impact of natural disasters on rangelands, it was estimated that hundreds of thousands of people died and nearly half of the entire livestock herds and two millions of wild animals were killed due to the severe droughts and land desertification at the southern edge of the Sahara desert. Droughts cause inappropriate herding practices, forcing liquidation of livestock at depressed prices. Cyclones and floods also cause destruction of vegetation and livestock in rangelands (Sivakumar, 2005). Some regions in the rangelands particularly the desert areas are widely recognized as sources for crustal-derived aerosols (dust) that are transported by strong wind in the atmosphere. Linkage of the impact of atmospheric dust on the surface to the atmospheric energy balance is complex, and is related to its size distribution, source strength, deposition rate, extinction, scattering, absorption, single scattering albedo, symmetry factor and optical depth of the dust (d'Almeida, 1989). Savannah burning contributes significantly to global emission of soot, as well as nitrogen, carbon and ozone. Given that total biomass burning from Savannah contributes about 40% of gross emission from all sources (Crutzen and Andreae, 1990), the contribution from dryland burning is conservatively estimated to be around 10%.

The short-term weather fluctuations creating disturbances such as high temperature, heat waves, frosts, etc. affect forests on spatial scales ranging from leaves to the canopy. Each disturbance affects forests differently.

Some cause large-scale tree mortality, whereas others affect community structure and organization without causing massive mortality (e.g., ground fires). Forest disturbances influence carbon storage in trees or dead wood. Climatic warming and associated lower humidity and increase in the frequency and severity of droughts would increase the incidence and severity of wildfires, especially in the boreal region. Changes in fire and storm frequencies are likely to have major impacts on the cover, composition, age-distribution and biomass of forests (Das, 2003b). The response of forest ecosystems to climate change, risks, and uncertainties can be expressed in terms of boundaries shift, changes in productivity, and risk of damages (e.g., forest fires). During 1982/83 and 1994/95 El Nino events, South East Asia experienced severe smoke and haze episodes associated with forest and bush fires due to reduced rainfall and drought conditions (Motha and Murthy, 2007). Forest fires are another natural disaster that causes large-scale damage to plants, animals, and human lives and property. Forest fires seriously affect human health, economy, and environment. Biomass burning which is common practice in the tropical and sub-tropical forest areas and dry land fires are significant sources of atmospheric aerosols and track gas emissions.

1.8 Impact of Natural Disasters on Fisheries and Aquaculture

The types of disasters that affect the fisheries and aquaculture sector include natural disasters such as storms, cyclones/hurricanes with associated flooding and tidal surges, tsunamis, earthquakes, droughts, floods and landslides. Disasters of human origin affecting the sector have included oil and chemical spills and nuclear/radiological material. Food and nutrition security, post-conflict and protracted crises, HIV/AIDS and sector-specific hazards (e.g. aquatic animal diseases and pest outbreaks) can also have significant impacts on aquaculture production and fisheries (FAO, 2012). In addition to the tragic loss of life, the effects of disasters on the sector can include the loss of livelihood assets such as boats, gear, cages, aquaculture ponds and broodstock, postharvest and processing facilities, and landing sites.

Climate change may result more extreme events such as cyclones, storm surges and inland flooding that may have impact on fisheries and aquaculture through loss of fish stocks, damage to fish boat and other farm structures. While there is not much evidence for an increase in cyclone frequency (IPCC, 2001), there is often speculation that this may happen along with a general increase in climate variability. A combination of low atmospheric pressure and strong winds can create storm surges that inundate low lying coastal areas causing damage to agriculture, aqua-farms and off shore fisheries. High winds and waves may damage marine structure used for the cultivation of shellfish and finfish such as cages and platforms resulting in loss of stock and damage or loss of facilities. Inundation of coastal areas is likely to be greatest over flat low lying land which is also of the type suited to the culture of brackish water species such as shrimps (Handisyde et al., 2005).

The impact of storms and cyclones on aquaculture may be severe in financial terms as marine and brackish water species likely to be affected are often of high value. The impacts of flood will be manifested in physical damage to infrastructure, causing stock to escape, reduction in salinity, occurrence of fish disease and abrupt loss of capital. Drought conditions may induce risk of reduced water availability, erosion of water quality leading to fish diseases and reduction in production. The overall potential outcome of natural disasters on fisheries and aquaculture will be decrease in value of coastal and inland fisheries with reduced production, decline in economic returns from fishing operations, higher insurance costs for aquaculture, conflict with water users and increased per unit production cost (FAO, 2018).

In the longer term, the impact of the effects of disasters can be considerably mitigated by the effectiveness of response activities. However, damage caused by disasters can have social and economic impacts throughout and well beyond the sector (such as in terms of reduced employment and food availability). Other longer-term disasters such as fish disease outbreaks can build up over time and significantly affect production (Barrange et al., 2018).

1.9 Impact of Natural Disasters on Environment

Droughts, floods, heat waves, frost, forest fire, and other extreme events periodically wreak havoc on crops, pastures, livestock, and contribute to pollution both downstream and off-farm. Environmental degradation is the direct manifestation of the vulnerability of ecosystem to natural disasters and extreme events. Erosion and re-sedimentation are physical effects caused by running water during heavy rains and floods, while water logging and root asphyxiation affect crop physiology. But floods may have positive effects as well like silt deposition, water reserves repletion and soil desalinization. Of particular notice in this context are river-bed changes and major land-slides which may completely modify the agricultural landscape. Unprecedented rates of deforestation and biomass burning in tropical dry forests in addition to forest fires are dramatically influencing biogeochemical cycles, resulting in resource depletion, declines in biodiversity, and atmospheric pollution. Deforestation, land clearing, weed invasion, and loss of wetlands could lead to ecosystem alteration, including change to vegetation cover and composition and the incidence of diseases and pests on plants and animals. Water erosion, wind erosion, saltation and sedimentation, and coastal erosion could result in transport of soil and deposition elsewhere. Soil salinity, degradation of soil structure, soil fertility decline, soil acidification, water logging, and soil pollution could lead to soil degradation, involving the alteration of soil properties in situ. Clearing of vegetation, rapid abandonment of exhausted cropland, and expansion of cropping into new and marginal land all set up a vicious pollution cycle that is hard to break (Motha and Murthy, 2007). In some areas, desertification seems to lead to atmospheric cooling while in other areas, desertification leads to atmospheric warming and increased potential evapotranspiration. Linkage to rainfall changes is even more complex.

A number of observations on the impact of the tsunami on the environment were recorded in the affected countries. Solid waste and disaster debris remain the most critical environmental problem faced by the countries. Disposing these wastes in an environmentally appropriate manner was a huge challenge. Combined with the issue of waste is that of hazardous materials and toxic substances that have been inadvertently mixed up with ordinary debris. These include asbestos, oil fuel, and other industrial raw materials and chemicals. Rapid clean-up of affected areas has also resulted in inappropriate disposal methods, including air burning and open dumping, leading to secondary impacts on the environment. UNEP reported extensive damage to natural ecosystems in the affected countries. These include coral reefs, mangroves, sea grass beds, coastal areas, wetlands, agricultural fields and forests, and aquaculture areas.

1.10 Extreme Events and Risk Management in Agriculture

Extreme weather events and climate anomalies have major impacts on agriculture. Degrading environmental conditions, when compounded by severe climatic events such as recurrent droughts, will make the drylands increasingly vulnerable to desertification causing more serious negative effects on agriculture and animal husbandry. In coping with risks systematically, especially when main risks are compounded with other factors, a reliable risk management system is essential to prevent or mitigate potential risks and uncertainties through appropriate preparedness and response strategies. Risk management in agricultural meteorology can comprise of early warning systems provided by government authorities and agricultural management systems operated at farmer’s site. The former will be mainly responsible for issuing warnings and advisories from authorities, while the latter for preparedness and response measures being made by farmers. It also needs proper communication mechanisms between two systems to share information in timely manner. In both the developing and developed worlds risk characterization and management are important aspects of farming. To cope with agrometeorological risks and uncertainties effectively, they should be observed, detected, monitored, assessed, forecasted, warned by relevant authorities at national or local levels and then diverted to a farmer's site in a timely manner and with certain level of reliability. It should be based on systematic framework provided by government's risk management authorities including National Meteorological and Hydrological Service (NMHS) of each country for better risk management. Risk management involves choosing among strategies that reduce the social and financial consequences of the variations in production and income. High preparedness, prior knowledge of the timing and magnitude of weather and climate and effective recovery plans will do much to reduce the impacts of the extreme events. When user-focused weather and climate information are readily available, and used wisely by farmers and others in the agriculture sector, losses resulting from adverse weather and climatic conditions can be minimized, thereby improving the yield and quality of agricultural products. To make an appropriate decision on a timely basis, farmers should have a wide range of timely information and knowledge on both risk sources and vulnerability of farming system to impending risks. Unfortunately certain agricultural risks are very difficult to detect by farmers themselves, especially those risks with very short-led time like torrential rain, violent hailstorms, tornado, etc. They have to rely on local or national meteorological services for warnings and advisories on these short-range risks. Even with these kinds of early warnings, farmers should take account of uncertainties existing intrinsically within early warnings at farmer's site.

In keeping with the impact of natural disasters, disaster insurance could be a critical instrument of development in the field of crop production, providing financial support to the farmers in the event of crop failure. Proper insurance systems can help farmers to cope with the increasing volatility of their losses due to extreme climate events and have a great potential to help raise awareness among decision-makers of the problems associated with climate hazards and natural disasters (Das, 2005; Hoppe, 2007). Crop insurance can also streamline loss assessment procedures and help in building up huge and accurate statistical base for crop production. Weather-based index insurance is slowly gaining recognition as one of the methodologies that can be used to sustain livelihoods and reduce poverty as part of the Millennium Development Goals (MDGs). At the farm level, weather-based index insurance allows for more stable income streams and could thus be a way to protect peoples' livelihood and improve their access to finance (Mukhala and Chavula, 2007).

Based on Clarkson et al. (2006), there are six requirements that must be met if farmers are to manage risks related to climate extremes, variability and change. These include:

- Awareness that weather and climate extremes, variability and change will impact on farm operations;
- Understanding of weather and climate processes, including the causes of climate variability and change;
- Historical knowledge of weather extremes and climate variability for the location of the farm operations;
- Analytical tools to describe the weather extremes and climate variability;
- Forecasting tools or access to early warning and forecast conditions, to give advance notice of likely extreme events and seasonal anomalies, and
- Ability to apply the warnings and forecasts in decision making.

Since the willingness and ability to bear risks differ from farm to farm, there is usually variation in the risk management strategies used by producers. Also farmers have many options for managing the risks they face and most use a combination of strategies and tools. Some strategies deal with only one kind of risk, while others address multiple risks. Most producers use a mix of tools and strategies to manage risks. Some of the more widely used strategies include (USDA, 2006):

- **Enterprise diversification:** this is based on the assumption that incomes from different crops and livestock activities are not perfectly correlated, meaning that when some activities produce low incomes other activities will likely offset this decreased earning by producing higher income;
- **Financial leverage:** this refers to the use of loans to help finance farm operations; higher level of debt, relative to net worth, are generally considered riskier; the optimal amount of leveraging depends on several factors, including farm profitability, the cost of credit, tolerance for risk, and the degree of uncertainty in income;
- **Vertical integration:** this can decrease risk associated with the quantity and quality of inputs or outputs since a vertically integrated

firm retains ownership or control of a commodity across two or more phases of production and/or marketing, thereby spreading risk;

- **Contracting:** this can reduce risk by way of granted prices, market outlets or other terms of exchange which are settled in advance; contracts that set price, quality, and amount of product to be delivered (marketing contracts); contracts that prescribe production processes to be used and/or specify who provides inputs (production contracts);
- **Hedging:** this uses futures, or options, contracts to reduce the risk of adverse price changes prior to an anticipated cash sale or purchase of a commodity;
- **Liquidity:** this refers to the farmer's ability to generate cash quickly and efficiently in order to meet financial obligations; liquidity can be enhanced by holding cash, stored commodities, or other assets that can be converted to cash on short notice without incurring a major loss;
- **Crop yield insurance:** this pays indemnities to producers when yields fall below the producer's insured yield level; coverage may be provided through such instruments as private insurance or government subsidized multiple peril crop insurance;
- **Crop revenue insurance:** this pays indemnities to farmers based on gross revenue shortfalls instead of just yield or price shortfalls; and
- **Household off-farm employment:** this can provide a more certain income stream to the farm household to supplement income from the farming operation.

Specific risk management measures that can be used include irrigation and water allocation strategies; shelter from wind or cold; shade from excessive heat; anti-frost and anti-erosion measures; soil cover and mulching; plant cover using glass or plastic materials; animal housing and management; climate control in storage and transport; and efficient use of herbicides, insecticides, and fertilizers (Hay, 2007).

1.11 Early Warning Systems for Extreme Events

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 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 (Sivakumar, 2008). In that process action can be taken to considerably reduce the resulting loss of life and socio-economic damages. Early warning helps to reduce economic losses by allowing farmers to better protect their assets and livelihoods. It can guide farmers in selling livestock or selecting appropriate crops for probable drought conditions. It aims at reducing not only the immediate impact of a disaster but also the knock-on effects on assets that can reduce economic wellbeing and increase poverty. Early warning information allows farmers to make decisions that contribute to their own economic self-sufficiency and their sustainability. If well integrated into a systematic framework of risk reduction, early warning systems can provide many development benefits to farmers.

There is a growing global awareness of the importance of early warning systems. In the context of the Indian Ocean Tsunami in 2005, the UN's office for the Coordination of Humanitarian Affairs (OCHA, 2005) stated that the objective of the early warning include the following: the rapid boosting of the capacities for action and planning by public authorities; and linking the available technical capacities on natural disasters with humanitarian and emergency management capacities. Also the activities of early warning were to quickly assess the warning capacities of the region, establish interim networks, conduct regional meetings for both training and coordination, develop interim information materials, and provide necessary coordination and support. The expected impacts are the improved public confidence and security, provision of authoritative information products to the humanitarian community, and sound foundations for coordination and informed implementation of early warning systems.

Early warning systems of climate extremes allow sufficient times for individuals and communities to act to reduce loss of life, personal injury and damage to property and fragile environments. An assessment of risks provides the basis for an effective warning system by identifying potential threats from hazards and establishing the degree of local vulnerability and resilience to hazardous climate conditions (WMO, 2006). 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 improvement in early warning and evacuation system (Obasi, 1997).

National Meteorological and hydrological Services (NMHSs) contribute to all four phases of an early warning system: prevention, preparedness, response and recovery. The application of climatological and hydrological knowledge to assess risk contributes to disaster mitigation. Providing forecasts and warnings of severe weather, extreme temperatures and droughts or flood in a timely manner contributes to preparedness. Updated warnings, forecasts, observations and consultation with emergency and relief agencies contribute to the response phase. Finally, specially tailored and targeted forecasts, as well as other advices, assist recovery operations.

Use of improved climate and weather information and forecasts along with efficient early warning systems would contribute to the preparedness for extreme weather events. When user-focused weather and climate information are readily available, and used wisely by farmers and others in the agriculture sector, losses resulting from adverse weather and climatic conditions can be minimized, thereby improving the yield and quality of agricultural products.

New technologies have brought about an accelerated increase in our knowledge of the climate system. Today the accuracy of forecasts of large-scale weather patterns for seven days in advance is the same as those for two days in advance only 30 years ago. The accuracy of tropical cyclone track forecasts and the timeliness of warnings have been steadily improving in the past few years (Obasi, 1998; Sivakumar, 2005). The current state of the art of the weather forecasts allows the short-term prediction of rare and dangerous local events such as rainstorms, frost with reliability and accuracy and very high spatial resolution, as well as the accurate medium range prediction (Soderman et al., 2003). Having information on the future trend of precipitation three months or more in advance could be of extreme importance in many fields of large economic, social, environmental and strategic relevance: agriculture and forestry, land and landscape management (to forecast droughts or heat waves for example), international cooperation and catastrophy management (Maracchi et al., 2007). When properly communicated and absorbed, early warning may empower farmers and communities threatened by natural hazards to prepare themselves in sufficient time and in an appropriate manner so as to minimize the risk of the impending hazard. Technologically oriented early warning, integrated with field data on crop and livestock conditions, price movement, human welfare etc. is crucial for tracking drought, its onset, its impact and farmers' response to it (Rathore and Stigter, 2007). A definition of warning stages (e.g., normal, alert, alarm, emergency as is prevalent for cyclones in India) should be generated by the early warning system to trigger government and other responses. The effective warning system should have meteorological/agricultural information, production estimates, price trends of food and feed, availability of drinking water and household vulnerabilities, so that a variety of indices related to production, exchange and consumption could be addressed. The challenge is that information on the spatial extent and duration of risk events, time of occurrence with reference to crop calendar and severity of the events could operationally help in the preparations of coping strategies.

To study certain impacts of meteorological hazards on agriculture and forestry and improve our understanding of certain preparedness issues, use of remote sensing data is a precious tool in obtaining spatial information on areas of interest where ground measurements are difficult. Moreover, additional information on the land may be essential in establishing its sensitivity to water excess or deficit, water and wind erosion, and the risks of soil degradation. In recent years, many investigations have demonstrated the capacity of satellite-borne sensors to provide information on various crop indicators, which help to monitor and identify crop stress more effectively. For example during drought conditions, physiological changes within vegetation may become apparent. The National Remote Sensing Agency (NRSA) in India is using a vegetation index to determine vigour of vegetation (Das, 2000).

Not surprisingly the major concerns in forecasting severe weather include modelling the possibility of occurrence (precise onset of the event) and intensity and determining the specific locations to be affected by the event (Nyakwada, 2004). The timeliness of issuing the forecast to provide adequate response to users is also a major concern. In areas where severe weather forecasting is well developed, the various elements associated with the occurrence are defined, such as the specific parameters and threshold for occurrence, the evolution of meteorological parameters and patterns associated with the occurrence and the climatology, which include the potential areas of occurrence. Thus, a forecast must be phrased as a probabilistic outlook statement (Das et al., 2010). Forecasts cover a time continuum ranging from less than one hour to short- and medium-term (hours to days) to seasonal, annual and decadal time-scales (WMO, 2006). Whatever the time period, early warning systems can calculate risk, using forecasts stated in terms of probability. However, the low level of predictability of extreme events acting at meso- or microscale (frost, thunderstorms, hails, tornadoes, and so forth) is an important limitation to the usefulness of forecasts for agriculture.

1.12 Remote Sensing Techniques for Disaster Risk Management

The natural disasters such as droughts, floods, cyclones, hailstorms, earthquakes, volcanic eruptions, pests, forest fire and landslides seriously disrupt the functioning of a community or a region causing wide spread human, material or environmental losses. The phenomena and the effects differ greatly from one type of disaster to another. One disaster can give rise to several different adverse effects. The time-scale of disasters differs from very short duration of few seconds for earthquakes to, few minutes for volcano, few hours for cyclone, few days for flood and months or even years for drought. While natural disasters occur on all continents, the susceptibility to these disasters differs from one area to another. Earth observation satellites have established their unique capability to continuously monitor land and atmospheric parameters for providing advance warning of major hazards. While the geo-stationary satellites provide continuous, synoptic observations over large areas (like continuous weather watch, including cyclone monitoring capabilities), lower earth orbiting satellites have the advantage of providing much higher resolution imageries, even though at lower temporal frequency. Satellite (fixed or mobile) communication facilities are vital in large number of disaster management situations, especially in data collection, distress alerting, position location and coordinating actual relief operations in the field. In addition, search and rescue satellites provide capabilities such as position determination facilities onboard, which could be useful in a variety of land, sea and air distress situations.

Remote sensing data at spatial resolutions ranging from 10 m to 100 m available at varied temporal resolutions have been successfully utilized to produce land use and land cover maps at a desired accuracy of at least 85% (Arora, 2003). The remotely sensed derived land use and land cover maps are frequently used as input, to a Geographical Information System (GIS) for several disaster related studies, for example landslide hazard zonation, evaluation of fire risk and flood risk management (Sivakumar and Hinsman, 2004).

The weather satellites (geo-stationary) such as INSAT and GOES provide almost continuous data on day to day basis beneficial for providing information for issuing early warning and specifying the geographical location of hazards such as severe thunderstorms and tornadoes, thereby assisting the emergency response teams for timely evacuation of the people in the hazard-prone areas. The visual interpretation of SPOT images before and after the cyclone also demonstrated the potential of the remote sensing data sets to identify the large scale changes in coastal and shallow marine areas produced by the cyclones (Loubersac et al., 1991). The large scale damage due to cyclone visible in SPOT images was helpful in planning emergency aid and reconstruction. During drought, physiognomic changes of vegetation may become visible. Satellite sensors are capable of discerning many such changes through spectral radiance measures and manipulation of such measures into vegetation indices that are sensible to the rate of plant growth as well as to the amount of growth (Curran, 1990). The visible and near infrared bands on the satellite multi-spectral sensors allow monitoring of the greenness of vegetation. This property is used in the case of monitoring drought, as the stressed vegetation and other bare ground, water, etc. reflect differently. Remote sensing and GIS tools can be used in flood analysis to determine and delineate the floodplains. Further, these may also assist in mapping and monitoring flood inundated areas, assessing damages due to floods and in flood hazard zoning. Advanced Very High Resolution Radiometer (AVHRR) images obtained before and after the flood can be classified to generate the flood maps of the region. These maps can be compared to assess the damage due to floods. Forest fires are another natural disaster where remote sensing and GIS can be employed successfully. The detection and monitoring of fires in the quickest possible time helps the emergency management agencies to prevent large-scale damage to life and property.

1.13 Prevention of and Preparedness for Extreme Events

In recent decades people throughout the world have become increasingly alarmed by natural disasters which are becoming more frequent and more destructive. The forces of nature cannot yet be controlled. Humans cannot prevent the formation of a tropical cyclone, an earthquake or the eruption of a volcano. However, we are able to contain rivers stem tides and build structures that give considerable, if not total, resistance to the forces of nature. Since natural phenomena will continue to occur, the problems they present must be faced, and due priority to policies for disaster planning, preparedness and prevention must be given.

Disaster prevention measures are complex because of their wide scope and their technical nature. They relate not only to the disasters themselves but also reflect the interaction between development and the environment on the one hand and between social and economic interests on the other. Except where social considerations are not overriding priority, decisions on disaster prevention should be based on cost-benefit and associated criteria. For example, a proposal to locate an industry in a disaster-prone area should be examined in relation to the probability of damage (vulnerability) and economic factors such as access to water, energy, transport, labour, raw material, etc. The environmental impact of disaster prevention measures should also be considered. Flood control measures and flood measurement may yield valuable benefits by reducing risks of silting, soil erosion and landslide. When considering the social, economic, and even physiological factors at national, regional and local levels, the complexities of disaster prevention and range of technical options to employ are great.

Disaster preparedness is the plan of action or emergency measures which come into force when an extreme agrometeorological event is about to occur. These measures remain in force until sometime after the adverse conditions have abated, because action is required not only when an event is approaching but also when it is actually present and in its aftermath. While most emphasis should be placed on preparedness and timely management interventions, there will always be a need for the capacity to recover quickly and minimize the residual damages of adverse events and conditions (Stigter et al., 2003).

In an integrated disaster plan, there are two categories of measures. The first concerns those of a permanent nature, referred to as prevention measures. These include structural components like levees, dams, reservoirs, etc., and non-structural components like land use and zoning, building codes, etc. The second category points to preparedness measures consisting of emergency measures, though these must also be planned well in advance. Both categories are essential and should not be viewed as separate undertakings but as essential parts of the overall system for protecting life and property.

Stigter et al. (2003) opined that lessons learned from the analysis of wide ranging cases of coping strategies fitted in three preparedness categories: (i) livelihood focus support, (ii) participation perspectives, and (iii) community perspectives. As to the first category, beyond contingency and response planning there needs to be basic contemplation whether there are alternatives for the present livelihood situation. These could include changing place, changing subsistence activities, changing income generating activities for the individual/family etc. Insurances may be a way out. Governments may offer such possibilities, families/individuals have to respond; conditions may force people to leave or to accept worsening conditions. For the second category, Stigter et al. (2007) observed that participation issues depend on education, income, occupation, and information channels. It was observed that the more the participation, the better are the chances of solving problems or living with problems. By applying participatory techniques, people are engaged in a process of the analysis of the situation and the risks they face. Finally it was shown that where a community was able to organize itself, the third preparedness category, with the active involvement of local people for common goal, offers increased chances for a better livelihood and more secure future.

1.14 Rehabilitation

If, as a result of the material damage suffered in a locality a large-scale programme of rehabilitation is required, the aim might be to improve rather than merely restore existing living standards and social conditions. Morale is a key factor in rehabilitation. It is possible for people to emerge from a disaster feeling hopeless and apathetic. If the attitude is allowed to persist, people will become over-dependent on welfare services and be a permanent burden to the nation. High morale can be fostered by helping people but at the same time promoting self-reliance (Das, 2003a).

Rehabilitation should be carried out via a two-prolonged programme covering both the victims of the disaster and the public services and amenities. For the victims, assistance may include the repair of the homes; the provision of basic home needs such as furniture and kitchen utensils, the provision of food and clothing and resettlement. In the agricultural sector, all possible help should be directed at the recovery of land, resowing, desalination, replacement of crops and livestock, repair of irrigation facilities, etc. The costs of restoring these facilities can be very heavy and this consideration should be compared with area's vulnerability and other factors.

1.15 Conclusions

With increasing incidence of extreme events and natural disasters around the world, a comprehensive assessment of their impacts on agriculture, forestry, and fisheries and strategies for their mitigation is critical for sustainable development, especially in the developing countries. For many disaster-prone countries, agricultural losses due to exceptional weather events are a real constrain on their global economy. Indirect effects may continue to affect agriculture negatively long after the extreme event took place. The time needed to recover from some agrometeorological events range from months to decades. A comprehensive assessment of impacts of natural disasters on agriculture requires a multi-sectoral and integral approach involving key organizations. National disaster reduction measures are in place in a significant number of the countries surveyed and ongoing research and development to improve and expand these measures is also a feature of many national strategies to minimize adverse effects of extreme events on agriculture. Since major impacts of the 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.

By taking anti-disaster preparedness measures in advance and thereafter by undertaking systematic post-disaster correctional measures, the effect of most of the dreadful natural calamities can be considerably mitigated. Long-term disaster reduction efforts should aim at promoting appropriate land-use in the disaster-prone areas, by harmonizing land suitability with agricultural development strategies. The measure to promote proper land-use should include both legislative and economic inducements and creation of public awareness of proper land practices.

Current natural disaster management is largely crisis driven. There is an urgent need for a more risk-based management approach to natural disaster planning in agriculture and other related sectors. An effective risk management approach would include a timely and user-oriented early warning system with rapid dissemination of information to users. Agricultural risk zoning is an essential component of natural disaster mitigation and preparedness strategies. Given the complex nature of databases, GIS and remote sensing should be employed to facilitate strategic and tactical applications at the farm and policy levels.

On account of vast similarity of situation arising out of geographical factors, social and economic conditions, it will be advantageous to undertake specific case studies of work done for prevention and mitigation of extreme events in metropolitan centers in different countries of Asian and Pacific region in particular, which are more prone to frequent disasters as compared to other continents. This will bring out typical features common to many countries, which can be considered by the countries concerned in mitigation and prevention of extreme events.

Disaster prevention policies should encourage the incorporation of disaster prevention as one of the variables in the normal process of social, economic and physical planning. The harmonizing of disaster prevention policies and measures between different sections of national development should be achieved in much the same way that national planning authorities harmonize economic and social goals across different sections. There is a long road to cover between policy and technical implementation.

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