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# IMPACTS OF DESERTIFICATION AND DROUGHT AND OTHER EXTREME METEOROLOGICAL EVENTS

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Report of the Working Group on the Impacts of Desertification and Drought
and of Other Extreme Meteorological Events

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## ABSTRACT

The Commission for Agricultural Meteorology (CAgM) at its 12th Session held in Accra, Ghana, 18-26 February 1999, established a Working Group on the Impacts of Desertification and Drought and of other Extreme Meteorological Events. The terms of reference for the Working Group include the following:

(a) To provide advice, within the terms of reference of the Commission, on matters relating to the implementation of the United Nations Convention to Combat Desertification and Mitigate the Effects of Drought;

(b) To survey, update and summarize existing knowledge and information on assessing those aspects of desertification, drought and other extreme meteorological events such as high temperatures, hail, floods, frosts, etc;

(c) To identify and list the actions that could be taken by the national Meteorological and Hydrological Services to increase the benefits from the implementation of the United Nations Convention to Combat Desertification and Mitigate the Effects of Drought;

(d) To develop a structure for an expert system on extreme meteorological events including the timing and duration of their long-term socio-economic effects and the meteorological information that can be provided to issue early warning and alleviate the effects of these events;

(e) To submit mid-term information on the progress of activities, and a final report to the president of the Commission not later than six months before the next session of the Commission;

This report was prepared by Working Group members: Simon Gathara from Kenya Meteorological Department who also served as the Chairman of the Working Group, Professor I. Gringof from the Russian Scientific Research Institute for Agricultural Meteorology, Engida Mersha from the agrometeorological service from the National Meteorological Agency of Ethiopia, K.C. Sinha Ray from the Department of Atmospheric Physics and Space Science from the University of Pune in India, and Petar Spasov from the Hydrometeorological Institute of Serbia.

The report starts with an overview of the desertfication and drought and then summarizes the assessment of desertification, drought And other extreme meteorological events. Next, the report gives an overview of the implementation of the United Nations Convention to Combat Desertification (UNCCD) and methods to mitigate the effects of drought. In conjuction with this chapter, the Annex provides a summary of the National Action Programme for India. Then, the report summarizes the actions to be taken by the National Meteorological and Hydrological Services (NMHS) for the UNCCD. There is a brief chapter on a proposed structure for an expert system on extreme meteorological events. The last chapter provides conclusions and recommendations of the Working Group.

# CHAPTER 1

# OVERVIEW

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## 1.1 Desertification

### 1.1 .1 General Introduction

The arid and semi-arid lands (ASAL) of many regions of the world are home to approximately 25% of the population and more than 50% of livestock, as well as hosting most of the wildlife parks and reserves. Paradoxically, these are the areas that are under the threat of desertification. The ASAL areas tend to experience a rapid population growth due to the migration from higher rainfall and agriculturally higher potential areas where population densities are high, the land fragmented and under intensive agriculture.

The problem of desertification culminates in the loss of land productivity as a result of degradation. In ASAL areas, the phenomenon manifests itself in occurrences such as the reduction in yield or crop failure in affected farmlands, reduction in perennial plant cover and biomass in rangelands with consequent depletion of pasture available to herbivores. It is also observed that as a result of reduction of available woody biomass and the consequent shortage of fuel wood or building materials, shortage of water due to the deterioration of life-support systems that often call for outside assistance or the search of livelihood elsewhere. Incidences of severe drought have been responsible for loss of livestock and wildlife and even loss of human life.

The concerns about desertification stem from its debilitating impacts on the capacity of affected populations and communities to sustain the creation of the means needed for livelihood as well as for the improvement of the environment. Under such circumstances, poverty tends to become a root cause as well as a consequence of desertification, which is often further exacerbated by the impacts of drought.

Following the United Nations Conference on Environment and Development held in Rio de Janeiro, Brazil in 1992, the UN General Assembly established an Intergovernmental Negotiating Committee on Desertification (INCD) to negotiate an international convention on desertification. The INCD, through five sessions completed a UN Convention on Desertification, which was adopted and signed in Paris in 1994.

Among the important outcomes of the convention is the particular focus on Africa's drylands. The convention does not only contain an implementation annex for Africa, but also has elaborate goals and commitments at the country level, which aim at combating desertification and mitigating the effects of drought at the national level.

Desertification is one of the major environmental issues jeopardizing the well-being and socio-economic development of thousands of people in many third world countries, particularly the African Sahel Region. A number of initiatives have been made at the global, regional, national and local levels to address the problem. The most recent global initiative is the UN Convention to Combat Desertification (UNCCD) which was adopted in June 1994 and signed on 13$^{th}$ – 14$^{th}$ October, 1994 in Paris by 85 Countries.

Until fairly recently, desertification has largely been viewed as a problem of pastoralists and nomads living in the deserts of the world, remotely connected to the complex processes of sustainable human development. Although there are divergent views regarding the causes and physical extent of desertification among scientists, (Hellden 1991; Tucker et al 1991), few dispute the fact that it is one of the most significant obstacles to sustainable human development, especially for rural populations dependent on subsistence agriculture and pastoralism for their livelihoods. Desertification is now recognized as a major global environment problem and a cause of hunger and impoverishment and large-scale population immigrations and social dislocation in the drylands of the world of the South, particularly, Sub-Saharan Africa. The adoption of the International Convention to Combat Desertification in those countries experiencing serious Drought and /or Desertification particularly in Africa, in June 1994, is perhaps the most significant milestone towards international recognition of the devastating effects of drought and desertification. It constitutes the first legal international framework for mobilizing and harnessing concerted action by governments and affected communities to comprehensively deal with the problem of desertification.

The convention is especially important to the situation of women because it lays specific guidelines for incorporating and including powerless and marginalized groups in the diagnosis of the problems and identification of measures to alleviate them.

### 1.1.2 Definition of Desertification

Desertification may be defined as “land degradation in arid and semi-arid and dry sub-humid areas resulting from various factors, including climatic variations and human activities” (CCD, 1995). It is a process, which involves all forms of degradation (natural or man-induced processes that disturb the equilibrium of soil, vegetation, air and water) of land vulnerable to severe edaphic or climate aridity, thereby leading to the reduction or destruction of biological potential of the land, deterioration of the living standard and intensification of desert like conditions.

The term desertification is sometimes also used to mean the “diminution of the biological productivity of the land leading to the spatial extension of desert-like conditions of soil and vegetation into marginal areas outside the climatic desert and intensification of such conditions over a period of time”. Emphasis is placed on arid desertification process, taking place in arid and semi-arid zones bordering the deserts under average annual rainfall less than 500 mm and “biological productivity” refers to the naturally occurring plant and animal life, as well as to the agricultural productivity of a given area.

### 1.1.3 Desertification and sustainable human development

Although scientific research has now put to rest the long popularly held image of the advancing Sahara desert, the symbolism in that image graphically depicts the formidable challenges that problems of drought and desertification pose to sustainable development, particularly to the lives of women living in regions threatened or affected by desertification. Desertification affects 25 percent of the earth’s surface and directly threatens the livelihoods of 900 million people in at least 100 countries. The issue of how to prevent the long-term consequences of desertification is increasingly becoming pertinent to developing countries, 90 of which are affected by the phenomena. According to FAO estimates, at least 40 million people suffer from malnutrition due to the affects of desertification, in Africa alone. The spectre of food insecurity, household hunger and malnutrition, recurrent famines, and mass migration threatens not only the environment and ecological balance, but also the well being of poor rural communities living in arid and semi-arid regions of the world. The challenge for policy makers, women and men living under the constraints imposed by desertification is to harness local resources, knowledge and expertise in collaborative programmes involving both national and external partners and expertise over a sustained period of time.

### 1.1.4 Population and Desertification

The relationships between people, food and desertification are complex. The most densely populated parts of the world are not usually those subject to desertification.

However, the warm semi-arid and sub-humid zones are favourable places to live: the population is commonly close to potential population supporting capacity. It may also exceed the lands' capacity, particularly where inputs for food production are too low to maintain yields. When long-term climatic fluctuations occur or when there is mining of the land, these factors can result with time in degradation by wind and water erosion, decreases in chemical fertility, physical deterioration of the soil structure, destruction of useful vegetation, and ultimately loss of productive land.

### 1.1.5 Causes of Desertification

A single environmental variable is insufficient to explain this form of degradation. It is the combination and interaction of an assortment of environmental and socio-economic factors that characterize these processes, which determine the status of desertification. Natural factors like extreme climatic fluctuations and human (anthropogenic) activities are all involved. There are four main human factors that tend to have a direct bearing on desertification:

- Overgrazing – This results when herbivore densities exceed the capacity of the vegetation to sustain their grazing pressure, resulting in devegetation, compaction and erosion of the soil. Displacement of pastoralists from marginal lands previously used for dry season grazing reserves, by farmers who occupy the high potential rangeland for subsistence agriculture, leads to overgrazing of the available pasture. Collapsed livestock marketing schemes which would previously cater for the large herds build up after wet years now account for herd sizes which grow too large to sustained by available pasture. Concentration of livestock around watering points, breakdown of traditional grazing systems and fragmentation of communal land holdings, are some of the factors that also contribute to increase in livestock herds beyond the carrying capacity of rangelands.

- Loss of Vegetation Cover – This represents a first step along the road to desertification. In dry lands where vegetation tends to be relatively sparse, plants play a vital role of stabilizing the soil, maintaining the hydrological cycle, providing shade, among others. Devegetation exposes the rangeland to the vagaries of the weather. Thus deforestation represents the most dynamic indicator of desertification as it cuts across various land uses.

- Encroachment into marginal lands – This occurs when farmland is utilized more intensely than permitted by its natural fertility. Farmers often fail to compensate for the exports of nutrients by use of artificial fertilizers or fallowing to allow for natural regeneration of fertility. Over-cultivation therefore tends to reduce soil fertility, damages soil structure and exposes it to erosion.

- Poor irrigation practices – If not properly managed, irrigated land could become degraded through soil alkalization, salinisation or water logging, rendering the land unproductive.

The four factors outlined above are related to a human element in the management of drylands, and the pursuit for socio-economic development as well as government policy tend to influence the extent to which they may affect dryland areas. Poverty, more than any other cuts across and is the most common denominator that determines the protection and proper management of natural resources. Lack of viable alternative means of livelihood by inhabitants of dryland areas often leads to methods of resource utilization that is not sustainable, ultimately leading to degradation. The following is an outline of the natural causes of desertification:

Climatic stress (interaction between climate and desertification) manifested through:

- Prolonged drought leading to vegetation destruction and loss in biological and economic productivity of the dryland.
- Wind erosion
- Water erosion: extreme drought periods in many drylands are often followed by extremely high rainfall occurrences that cause extension soil erosion.
- Climate change: permanent shift in the traditional patterns of climatic parameters.

Nature is capable of repairing loss of biological and economic productivity of dryland caused by extreme climate variability in the absence of external stress.

Thus not all-extreme climatic stresses can lead to desertification. The impact of climatic stress on desertification therefore depends on human ability to cope with such impacts in order to minimize anthropogenic impacts on the natural cycles of the drylands. Thus lack of good shock absorbers for the extreme climatic stress can lead to a reduction in food production, famine, migration, overgrazing and many land degrading activities which may indirectly lead to desertification.

### 1.1.6 Conceptual Framework Of The Desertification Processes And The Global Climate System

The global climate system is controlled by complex and highly interactive physical, biological, chemical among many other systems which involve the short and long wave radiation atmosphere, soil, land surface, freshwater bodies, oceans, flora and fauna. Presently the space-time dimensions of some of these processes are not well known. It should be noted that climate processes are driven naturally by energy from the sun. Anthropogenic processes including desertification process are adding new direction to the natural processes, which have been controlling the Global Climate System, e.g. environmental pollution, greenhouse gas warming, climate change etc.

### 1.1.7 Impacts of desertification

Like all major ecological changes, desertification may have impacts at three levels, namely on-site, off-site and global. On-site impacts relate to changes in plant growth, the reduction in standing biomass, effect of ecological succession where one plant community gets replaced by another, reduction in populations of animals, including soil fauna, loss of condition of livestock and other herbivores; changes in surface deposits, soil erosion, loss of soil organic matter, salinisation, etc. These changes often result in alteration of the micro-climate and may also add to the dust load in the atmosphere. Off-site impacts are numerous and varied, including surface deposits transported through water and wind erosion, sedimentation in water reservoirs; suspended particulate matter in the atmosphere which may effect human health and livestock; salinised and alkalized surfaces of poor deserted irrigation land may produce salt particles transportable to other productive farmland. But the effect on human life is most significant. The forced movement of peoples who have to leave their land because their life support systems have been disrupted creates environmental refugees who bring with them more pressure on their new host sites. On a global scale, the impacts of desertification on food production, biological diversity, and climate change cannot be over-emphasized.

### 1.1.8 Mitigation of the Negative Impacts of Desertification

Desertification is largely caused by human activities. Climatic stresses like prolonged drought can also cause desertification but most of these can be avoided with a proper disaster preparedness programme. Without proper disaster preparedness programmes, any extreme climatic stress will trigger off chain reaction, which often leads to desertification of the drylands. It is important to note that desertification versus climate processes are complex and highly interactive, involving various space-time dimensions. Further it should also be noted that:

- Over 70% of potentially productive drylands are currently at risk of desertification (UNEP 1992).
- Desertification problems are linked to the basic human needs, which are escalating year after year, e.g. needs for food, shelter, water, etc.
- Some desertification problems are linked to development issues.
- Desertification and climate problems have scientific, social, economical and political dimensions as recognized in Agenda 21 and the associated conventions.
- Whether preventive, convective or rehabilitation strategies are taken to minimize the desertification of the drylands.

#### 1.1.8.1 Key Scientific Issues in the Mitigation

- Assessment and Mapping; Regular assessment & Mapping
- Monitoring: current status
- Prediction; future expectation projections
- Database: crucial to any mitigation plan GTOS, GCOS, GOOS, WCOS, etc.
- Research: Understanding of the processes.
- Information exchange: Learning from successes and failures of others, sectoral exchange
- Training and education
- Transfer of Technology; e.g. Israel experience & others.
- Funding for desertification and climate research seems to be decreasing. The associated problems are increasing e.g. sound environmental management and sustainable development.
- Disaster preparedness: Direct/indirect triggers of many desertification drivers.
- Planning and management.
- Regional & international co-operation Agenda 21 and the three conventions.

## 1.2 Drought

### 1.2.1 General Introduction

Drought is an insidious hazard of nature. It originates from a deficiency of precipitation that results in a water shortage for some activities or some group.

Although the continent of Africa has suffered the most dramatic impacts from drought during the past several decades, the vulnerability of all nations to extended periods of water shortage has been underscored again and again during this same time period. In the past decade alone, droughts have occurred with considerable frequency and severity in most of the developed and developing world. Brazil, Argentina, Uruguay, Australia, the United States, Canada, India, China, and most of the countries of Southeast Asia are just a few examples of the countries ravaged by drought.

Concern by members of the scientific and policy communities about the inability of governments to respond in an effective and timely manner to drought and its associated impacts exists worldwide. There have been numerous "calls for action" for improved drought planning and management issued by national governments, professional organizations, intergovernmental organizations, non-governmental organizations, and others. However, the task of altering the perception of policy makers and scientists world-wide about drought and educating them about alternative management approaches is a formidable challenge. Governments typically treat drought as a rare and random event that is inherently unpredictable; they are unprepared to respond effectively when it occurs. Effective drought response requires long-range planning a difficult assignment for most governments.

Many scientists and policy makers now have an improved understanding of drought and its economic, social, and environmental consequences. Although impediments to drought planning exist, recent progress has created a sense of cautious optimism that society is steadily moving toward a higher level of preparedness. Also, technologies and information are available that would enable countries to more effectively mitigate the effects of drought through the development of a more proactive and systematic risk management approach.

The occurrence of severe drought worldwide during and following the extreme El Niño/Southern Oscillation (ENSO) event of 1982-83 and 1997-98 partially explains governments' increased awareness and understanding of drought and interest in planning. These droughts have focused attention on the vulnerability and lack of coping capacity of all nations. It also appears that social vulnerability to drought is increasing, largely because of population growth and society's increasing demand and competition for limited water resources. In addition, many governments now have a better appreciation of the costs associated with drought. These costs include not only the direct impacts of drought but also the indirect costs (i.e. personal hardship, relief costs, retardation of economic development, and accelerated environmental degradation). Nations can no longer afford to allocate scarce financial resources to often short-sighted response programs that do little to mitigate, and may in fact exacerbate, the effects of future drought.

In the public's mind, the subjects of drought and projected changes in climate caused by increasing concentrations of carbon dioxide and other atmospheric trace gases have become inextricably linked. For example, the 1988 drought in the United States was viewed by some scientists (and popularized by the media) as a forewarning of greenhouse warming. Others suggest that changes in climate will lead to an increased frequency and intensity of drought, although these predictions are highly speculative at present. However, we do know that droughts are a normal part of climate in virtually all regions; their recurrence is inevitable, with or without changes in climate. From an institutional point of view, learning today to deal more effectively with extreme climatic events such as drought will serve us well in preparing proper response strategies to long-term climate-related issues.

### 1.2.2 Drought Types and Definitions

Because drought affects so many economic and social sectors, scores of definitions have been developed by a variety of disciplines. In addition, because drought occurs with varying frequency in nearly all regions of the globe, in all types of economic systems, and in developed and developing countries alike, the approaches taken to define it also reflect regional differences as well as differences in ideological perspectives. Impacts also differ spatially and temporally, depending on the societal context of drought. A universal definition of drought would therefore be an unrealistic expectation.

Definitions of drought can be categorized broadly as either conceptual or operational. Conceptual definitions are of the "dictionary" type, generally defining the boundaries of the concept of drought, and thus are generic in their description of the phenomenon. For example, the American Heritage Dictionary defines drought as "a long period with no rain, especially during a planting season." Operational definitions attempt to identify the onset, severity, continuation, and termination of drought episodes. Definitions of this type are often used in an operational mode. These definitions can also be used to analyze drought frequency, severity, and duration for a given historical period. An operational definition of agricultural drought might be one that compares daily precipitation to evapotranspiration (ET) rates to determine the rate of soil water depletion and then expresses these relationships in terms of drought effects on plant behaviour at various stages of development. The effects of these meteorological conditions on plant growth would be re-evaluated continuously by agricultural specialists as the growing season progresses.

Many disciplinary perspectives of drought exist. Each discipline incorporates different physical, biological, and/or socio-economic factors in its definition of drought. Because of these many and diverse disciplinary views, considerable confusion often exists over exactly what constitutes a drought. Research has shown that the lack of a precise and objective definition in specific situations has been an obstacle to understanding drought, which has led to indecision and/or inaction on the part of managers, policy makers, and others. It must be accepted that the importance of drought lies in its impacts. Thus definitions should be region and impact or application specific in order to be used in an operational mode by decision-makers. A comprehensive review of drought definitions and indices can be found in a technical note published by the World Meteorological Organization (Hounam et al, 1975).

Drought is generally reviewed as a sustained and regionally extensive occurrence of appreciably below average natural water availability, either in the form of precipitation, river runoff or groundwater. It is a temporary feature caused by climatic fluctuations. The basic cause of drought is not only insufficient precipitation. Depending on the definition used, such as one based on available water, the arid zones of the world would be regarded as almost permanently drought-stricken, but by reference to normal rainfall, they could be classified as no more subject to drought than some heavy rainfall areas.

The many definitions lead to drought being grouped by type as follows: meteorological, hydrological, agricultural, and socio-economic. These classifications are done according to a number of criteria involving several variables, used either alone or in combination: rainfall, temperature, humidity, evaporation from free water, transpiration from plants, soil moisture, wind, river and stream flow, and plant condition.

#### 1.2.2.1 Meteorological drought

The definition based solely on precipitation is called Meteorological Drought and refers to short-period droughts or dry spells, when precipitation received is far below the expected normal. Meteorological drought is expressed solely on the basis of the degree of dryness (often in comparison to some "normal" or average amount) and the duration of the dry period. Definitions of meteorological drought must be considered as region specific since the atmospheric conditions that result in deficiencies of precipitation are highly variable from region to region. For example, some definitions differentiate meteorological drought on the basis of the number of days with precipitation less than some specified threshold. Extended periods without rainfall are common for many regions; such a definition is unrealistic these instances. Other definitions may include actual precipitation departures to average amounts on monthly, seasonal, year, or annual time-scales. Definitions derived for application to one region usually are not transferable to another since meteorological characteristics differ. Human perceptions of these conditions are equally variable. Both of these points must be taken into account in order to identify the characteristics of drought and make comparisons between regions.

### 1.2.2.2 Agricultural drought

This is related to physiological drought, which is determined from conditions of natural vegetation, crops, livestock, pastures and other agricultural systems. It is defined by measure of the availability of soil water to plants or animals. In this case, radiation (heat), drying wind and evaporation become important factors. It is usually measured by the effects of water deficit in terms of economic losses to agriculturists. The economical loss terms can include factors like drop in crop production, livestock deaths, industrial losses, plants not planted or replanted, changes in land use, emergency relief expenses, as well as losses incurred after the agricultural drought (e.g. losses through wind and water erosion). Agricultural losses from economic terms may be very difficult to assess or compare with some previous episodes since similar patterns of drought may have a different economic impact at various stages of development to the agriculturist. For example a drought episode may cause a drop in agricultural production similar to some earlier ones, but a sharp rise in the market prices of the products during the drought period may result into higher profits to the agriculturist.

Thus agricultural drought links characteristics of meteorological and hydrological droughts to agricultural impacts, focusing on precipitation shortages, differences between actual and potential evapotranspiration, soil water deficits, and so forth. A plant's demand for water is dependent on prevailing weather conditions, biological characteristics of the specific plant, its stage of growth, and the physical and biological properties of the soil. An operational definition of agricultural drought should account for the variable susceptibility of crops at different stages of crop development.

### 1.2.2.3 Hydrological drought

Hydrological drought is the deficit of runoff into rivers and other surface water resources and in groundwater resources. It involves the description of availability of water, in the form of precipitation runoff, evaporation, infiltration, river systems, and other surface/ groundwater inflow/outflow systems, which may be included in the hydrological water balance equation as follows:

$$W = G - L$$

Where: W = available water for the system use
G = total incoming water of the system (precipitation, Infiltration, storage, etc.)
L = total water loss (evaporation runoff, etc.)

Thus hydrological droughts are related more with the effects of periods of precipitation shortfall on surface or subsurface water supply (i.e. stream flow, reservoir and lake levels) rather than precipitation shortfalls. Hydrological droughts are usually out of phase or lag the occurrence of meteorological and agricultural droughts. Meteorological droughts result from precipitation deficiencies; agricultural droughts are largely the result of soil moisture deficiencies. More time elapses before precipitation deficiencies show up in components of the hydrological system (e.g. reservoirs, groundwater). As a result, impacts are out of phase with those in other economic sectors. Also, water in hydrological storage systems is often used for multiple and competing purposes (e.g. power generation, flood control, irrigation, recreation) further complicating the sequence and quantification of impacts. Competition for water in these storage systems escalates during drought, and conflicts between water users increased significantly.

#### 1.2.2.4 Socio-economic drought

This type of drought associates the supply and demand of some economic good or service with elements of meteorological, hydrological, and agricultural drought. Some scientists suggest that the time and space processes of supply and demand are the two basic processes that should be included in an objective definition of drought. For example, the supply of some economic goods (e.g. water, hay, and electric power) is weather dependent. In most instances, the demand for such goods increases as a result of increasing population and/or per capita consumption. Therefore, drought could be defined as occurring when the demand exceeds supply as result of a weather-related supply shortfall. This concept of drought supports the strong symbiosis that exists between drought and human activities. Thus, the incidence of drought could increase because of a change in the frequency of the physical event, a change in societal vulnerability to water shortages or both. For example, poor land use practices such as overgrazing can decrease animal carrying capacity and increase soil erosion, which exacerbates the impacts of and vulnerability to future droughts. This example is especially relevant in semiarid regions and in areas of hilly or sloping terrain.

### 1.2.3 Drought Characteristics and Severity

Droughts differ from one another in three essential characteristics; intensity, duration, and spatial coverage. Intensity refers to the degree of the precipitation shortfall and/or the severity of impacts associated with the shortfall. It is generally measured by the departure of some climatic index from normal and is closely linked to duration in the determination of impact. The simplest index in widespread use is the percent of normal precipitation. With this index, actual precipitation is compared to "normal" or average precipitation for time periods ranging from one to twelve or more months. Actual precipitation departures are normally compared to expected or average amounts on a monthly, seasonal or annual time period. One of the principal difficulties with this (or any) index is the choice of the threshold below which the deficiency or precipitation must fall (e.g., 75 percent of normal) to define the onset of drought. Thresholds are usually chosen arbitrarily. In reality, they should be linked to impact. Many indices of drought are in widespread use today, such as the decile approach, the Palmer Drought Severity Index, Crop Moisture Index and the Yield Moisture Index.

Another distinguishing feature of drought is its duration. Droughts usually require a minimum of two to three months to become established but then can continue for several consecutive years. The magnitude of drought impacts is closely related to the timing of the onset of the precipitation shortage, its intensity, and the duration of the event.

Droughts also differ in terms of their spatial characteristics. The areas affected by severe drought evolve gradually, and regions of maximum intensity shift from season to season. In larger countries, such as Brazil, China, India, the United States, or Australia, drought would rarely, if ever, affect the entire country. On the other hand, it is indeed rare for drought not to exist in a portion of these countries in every year. Thus, the governments of these larger countries are more accustomed to dealing with water shortages and have established an infrastructure to respond. For smaller countries, it is more likely that the entire country may be affected since droughts are usually regional phenomenon - they result from large-scale anomalies in atmospheric circulation patterns that become established and persist for periods of months, seasons, or longer.

From a planning perspective, the spatial characteristics of drought have serious implications. A large-scale regional drought may significantly influence a nation's ability to import food, a potential impact mitigation strategy, from neighbouring countries that may be affected equally. Likewise, the occurrence of drought worldwide or in the principal grain exporting nations, such as during the ENSO event of 1982-83, may alter significantly a developing country's access to food from donor governments (Glantz, 1994).

## 1.3 Conclusion

Planning for a more prosperous future must take into account the relationship between population growth, the potential for increasing food supplies and the danger of exceeding what the land can sustain. Population planning, in all its forms, can help to reduce pressure on the most vulnerable land. Integrated land use planning can help governments, technical staff and farmers to make wise decisions for the best use of limited land and water resources. Desertification can be diminished by adopting an integrated balance sheet approach to agricultural productions, and by encouraging participation of the farmers and other land users in developing and managing sustainable land use systems which protect and at the same time make good use of all the land resources from the desert to humid areas.

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## Further Reading

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## CHAPTER 2

## ASSESSMENT OF DESERTIFICATION, DROUGHT AND OTHER EXTREME METEOROLOGICAL EVENTS

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The United Nations Convention to Combat Desertification in those Countries Experiencing Serious Drought and/or Desertification, particularly in Africa recognized that drought and desertification are global problems affecting all regions of the world and called for joint action by the international community. The Convention noted that the "strategies to combat desertification and mitigate the effects of drought will be most effective if they are based on sound systematic observation and rigorous scientific knowledge and if they are continuously re-evaluated" (CCD, 1995). The Governments of over 150 countries have signed this Convention and ratified it with the aim of uniting their forces to combat this (and other) harmful natural phenomena and processes.

Over the last few years the Russian Scientific Research Institute for Agricultural Meteorology (VNIISKhM) has developed the concept and methodology for the creation and operation of a Drought Monitoring Centre (DMC) in Russia and in the national Meteorological and Hydrological Services (NMHSs) of the Commonwealth of Independent States (CIS). The preparatory material, in particular the Centre's Regulations, is a description of its functions and comprehensive drought indicators, including the methodology for recording such indicators, were drawn up by VNIISKhM and were subsequently adopted by the NMHSs of the CIS. The operational experiments carried out in the Russian Federation by VNIISKhM over the last two years have demonstrated the practical value of a DMC issuing operational 10-day notices on the onset and development of droughts.

In October 2001, in Obninsk, Russian Federation, the thirteenth session of the CIS Intergovernmental Council for Hydrometeorology examined, approved and recommended that Roshydromet create a CIS Drought Monitoring Centre within VNIISKhM, with coverage extending to Armenia, Azerbaijan, Belarus, Georgia, Kazakhstan, Kyrgystan, the Russian Federation, Tajikistan and Uzbekistan. DMC practical work is scheduled to begin in these States in spring 2002.

This paper examines information on extreme and dangerous hydrometeorological phenomena (including desertification and drought). It addresses their particularities and means of assessing and mapping such phenomena, and gives general information on measures introduced to mitigate their negative effects on agricultural production and to reduce the damage they cause.

When natural events have characteristics that exceed or fail to meet certain parameters in daily, 10-daily, monthly, seasonal or yearly periods, they are known as *extreme hydrometeorological and agrometeorological (or other) natural events*. Generally, such events produce severe conditions for the survival of plants and animals, i.e. conditions that are at the organisms' tolerance limit. Tolerance (from the latin *tolerantia* – patience) is the capacity of organisms to endure environmental factors that are not optimal for them. Different species have different tolerance levels. As a rule, tolerant species form stable biocenoses and become climax species. For example, xerophytes are better able to tolerate long periods of drought than mesophytes.

In Russia the hydrometeorological events that are considered to be *particularly dangerous are those that, by their intensity, duration, extent or time of onset* (e.g. during the critical period of plant growth) *could cause or do cause significant damage to agricultural crops or animals.* The extent of the danger is determined by the extent of the damage: national, regional, oblast[1] or raion[2] level etc.

The amount of natural resources exploited for the requirements of human society increases each year, destroying nature's characteristic self-regulation processes and balances. The emergence of desertification in the Aral Basin, the Caspian Sea and Lake Balkhash is a vivid example of ecological disasters in the 20th Century.

## 2.1 Desertification and drought

Desertification is actively developing in many regions of the world. It affects all natural zones, and is becoming increasingly aggressive in the temperate zone, including the high mountain areas of the continents. However, the development of desertification is particularly intense in the arid and semi-arid regions of the world, as these have ecosystems that are the most vulnerable to extreme conditions and the increased pressure of human activity.

In the Russian Federation, this desertification which had previously been considered a local phenomenon limited to the degradation of pastureland, has led to the loss of large expanses of farmland and has reduced biomass productivity and biodiversity, mainly in the south. Different forms of desertification have been observed (as per the situation in the year 2000) in 35 constituent parts of the Russian Federation, areas in which approximately half the country's population resides and where over 70 % of agricultural products are produced. According to various evaluations, approximately 100 million hectares of farmland have been affected by desertification or face a potential threat from it.

Desertification is intense in the Republics of Kalmykia and Dagestan and in the Astrakhan and Rostov oblasts. In the Black Lands of the Republic of Kalmykia, from 1954-1994 average, severe, very severe and total desertification were observed, causing maximum instability in the mid-1970s and maximum damage in the mid-1980s. Desertification has affected 82% of the Republic of Kalmykia. In 1913 the Republic of Kalmykia had up to one million head of cattle at pasture, and the area of pastureland undergoing degradation was just 5%; in 1985 there were 5.2 million head of cattle and the area of pastureland undergoing degradation because of desertification was almost 95 % (B. V. Vinogradov, 1993).

Because of overgrazing, in the lowland areas and foothills of Dagestan the degradation of grazing land has intensified. In one form or another, desertification has affected over 2.5 million hectares of farmland and forest.

Krasnodarsky kray, Stavropolsky kray and Volgograd oblast have also been subjected to desertification. Desertification also threatens lands in the southern part of the steppes of many of the chernozem-rich (black soil) central oblasts of Russia, western Siberia, Krasnoyarsky kray and Altaisky kray, and the Republics of Bashkortostan, Khakassia, Buryatia, Tyva and Ingushetia.

The degradation of deer pastures due to the overgrazing of domestic and wild deer is a northern variant of desertification, as is the destruction of soil and plant cover due to the uncontrolled off-road use of land rovers and cars associated with the exploitation and geological prospecting of mineral deposits. More than 68% of all deer pasture, or over 230 million hectares, has undergone degradation.

[1] An "oblast" is an administrative sub-area of a region. (Translator)
[2] A "raion" is an administrative sub-area of an oblast. (Translator)

Arid and dry areas cover more than 4.6 million square kilometres of the territory of the former Soviet Union, with a population of over 70 million. This assessment was carried out using the criterion of the ratio of total annual precipitation to potential evapotranspiration, which was assumed to be approximately 0.65. More intense desertification can be observed in the independent States of Central Asia, which have a population of over 55 million people. Over 59% of the territory of Uzbekistan, approximately 60% of Kazakhstan and 66.5% of Turkmenistan has been subjected to human-induced desertification. The main type of desertification, that of degrading plant cover, affects 37% of the total area of these countries (Glazovsky and Orlovsky, 1996).

As a result of the degradation of pastureland, productivity has decreased by 30-40% in the highland areas of Kyrgyzstan, and by 40-60% in Tajikistan. Almost all of Kazakhstan's arable land has lost up to 20-30% of its humus; approximately 30% of the pastureland vegetation (65 million hectares) has degraded (Sobolev, 1996).

Specialists have suggested various approaches for assessing land degradation. A distinction can be made between *arid climates* and *drought* when we look at the climatic factors that cause desertification. In our understanding, *drought* is a natural event of nature, caused by atmospheric circulation processes, entailing a prolonged absence of precipitation (or its significant reduction relative to the average norms over several years) in combination with increased air, soil and wind temperatures, leading to a sudden reduction in the corresponding humidity, the exhaustion of soil moisture reserves and disruption of the water balances of plants and animals. Droughts can reduce agricultural production and, in extreme circumstances, can lead to the total destruction of all harvests, livestock and even people. An *arid climate* is the climate of an arid area in which, for climatic reasons, the probability of drought is more than 50%, as opposed to the situation in dry areas, where the humidity of atmospheric precipitation is never sufficient for dry-land farming.

There are numerous empirical relationships, which express the aridity coefficient of various arid regions in the scientific literature. Because of the diversity of the natural historical conditions prevailing in the world's arid zones, a number of methodological approaches using various meteorological parameters are required. Extremely detailed reviews of methods for assessing dry and arid conditions and drought are well known in scientific circles, as they have been published in the national and international scientific literature.

The various empirical expressions of drying coefficients can be organized into the following groups:

1. Formulas that reflect the relationship between total atmospheric precipitation and total temperature for the year, or for various periods of the warm season;

2. Formulas that reflect the relationship between total atmospheric precipitation and evaporation for a predetermined period of time;

3. The relationships between total precipitation, temperature and relative humidity for a predetermined period of time;

4. Formulas using the water deficit and evaporation deficit values;

5. Aridity indices representing the relationship between moisture reserves in the soil layer within reach of the roots of plants and sum of air temperatures for a predetermined period.

The criteria for drought currently found in international literature is extremely varied, both in terms of their input parameters and in terms of their quantitative values. This diversity is related to the wide physical and geographical distribution of arid and semi-arid territories on the planet, and is also related to the specific characteristics of certain ecological conditions, including soil and plant cover, relief, distance from a water supply, etc. Let us look at some examples of drought assessment methods.

In general terms, drought is defined by a group of experts in terms of harvest levels. Therefore, for example, a drought may be assessed if there is a reduction of cereal crop harvest by 20-25 % of its average value for steppes and forested steppe regions. This is an agronomic drought indicator.

Meteorological indicators give the characteristics of meteorological elements, describing the physical conditions of drought, such as the number of days without rain or the length of the period with below-normal precipitation. Hounam et al (1975) list the following drought criteria: less than 0.10 inch (0.25 cm) of precipitation over 48 hours; weekly precipitation equal to or less than half the normal; 10 days with less than 1.5 inches of precipitation; 15 days without rain; 21 and more days with less than 30 % of the normal precipitation, etc. The same parameters are applied to such indicators as daily evaporation and the number of days with a hot dry wind, high air and soil temperatures, etc.

Complex indicators give more comprehensive characteristics. In Russia, the relative (non-dimensional) indicator known as G. T. Selyaninov's hydrothermal coefficient (HTC) has been widely used (Selyaninov, 1930):

$$\mathbf{HTC = R / 0.1 \, \Sigma \, T,}$$

Where:

R is the total precipitation for the period having an average air temperature of greater than 10°C; and

ΣT is the sum of average daily air temperatures for the same period, which is divided by 10, giving a figure that characterizes evaporation quite well.

Thus the HTC indicates an arid area from 0.4 to 1.3, an extremely arid area from 0.4 to 0.7 and a slightly arid area from 1.0 to 1.3, and a moist area at when the coefficient is higher than 1.3.

Budyko (Hounam et al, 1970) proposed a moisture indicator (MI):

$$\mathbf{MI = R / 0.18 \, \Sigma \, T,}$$

where:

R is the total rainfall for the year (in millimetres); and

0.18 Σ T is evaporation, equivalent to the sum of the temperatures for the period when the temperature was over 10°C, reduced to 0.18 times that value.

Professor N. V. Bova (1941) considered drought to be a combination of wind and soil phenomena, giving rise to a disparity between plant water requirements and actual soil moisture content:

$$\mathbf{K = W + R / 0.1 \, \Sigma T,}$$

where:

W is the value for the spring soil moisture reserves at a depth of 1 meter;

R is the total precipitation for spring and summer;

and $\Sigma T$ is the sum of positive air temperatures since the spring temperature exceeded 0 °C.

A more detailed assessment of drought can be obtained by the index ($S_i$), proposed by Ped (1975):

$$S_{i\ (\tau)} = \Delta T/\sigma_T - \Delta R/\sigma_R - \Delta W/\sigma_W,$$

where:

*i* is a point;

the other indicators are;

T, the temperature anomaly;

R, rainfall; and

W, soil water, relative to the norms for a given period (10 days, month or season).

This equation represents atmospheric and soil drought, which is the most dangerous type of drought for agricultural production.

N. N. Ivanov (1948) proposed an empirical formula for calculating evaporation:

$$E = 0.0018\ (25 + T)^2\ (100 - a),$$

where:

E is the monthly evaporation in millimetres;

T is the mean monthly air temperature; and

a is the mean relative humidity for the month.

Shashko (1967) uses the relationship between total precipitation (P) and the total mean daily value for water vapour pressure deficiency (E – e) as a moisture indicator:

$$Md = \Sigma P\ /\ \Sigma\ (E\text{-}e).$$

Agrometeorological indicators are established by studying two parallel series together, one characterizing biological phenomena and the other characterizing physical phenomena. Consequently, Ulanova (1975) proposed the use of a moisture coefficient ($C_y$) to assess general (atmospheric and soil) droughts:

$$C_y = W_B + \Sigma\ R_{y\text{-}y1}\ /\ 0.01\ \Sigma\ T_{y\text{-}y1},$$

where:

$W_B$ is the usable soil moisture reserves at a depth of 1 m when the average daily spring air temperatures exceed 5 °C, in millimetres;

$\Sigma$ R is the sum of precipitation for May and June, in millimetres;

and $\Sigma$ T is the sum of mean daily air temperatures for May and June.

The value of $C_y$ corresponds to:

very severe drought when $C_y < 15$

severe drought when $15 \leq C_y < 20$

average drought when $20 \leq C_y < 25$

In the United States, India and other countries the Palmer method is often used (Palmer, 1965). It calculates precipitation according to the equation:

$$\mathbf{P = ET + R + RO - L,}$$

where:

P is precipitation, and the other values are respectively total evaporation, soil waterlogging, drainage and water losses in the soil. This criterion makes it possible to determine the onset, end and intensity of a drought.

Table 1 presents data from V.A. Zhukov and O.A. Svyatkina (2000) and shows the probability of drought conditions in the vegetation period and the average losses of spring grain crops for various regions of the Russian Federation.

**Table 1. Probability of drought conditions and average losses of spring gram crops of the Russian Federation**

| Characteristics | Drought conditions during: | | | | | |
|---|---|---|---|---|---|---|
| | sowing-tillering | tillering-ear formation | ear formation-ripening | sowing-ear formation | tillering-ripening | sowing-ripening |
| **The Volga Region** | | | | | | |
| Probability, % | 0.09 | 0.07 | 0.12 | 0.11 | 0.07 | 0.11 |
| Average losses (% of max. harvest) | 30 | 40 | 25 | 70 | 60 | 85 |
| **The Central Blacklands** | | | | | | |
| Probability, % | 0.11 | 0.12 | 0.13 | 0.09 | 0.07 | 0.08 |
| Average losses (% of max. harvest) | 35 | 35 | 20 | 60 | 50 | 50 |
| **The Northern Caucasus** | | | | | | |
| Probability % | 0.10 | 0.12 | 0.06 | 0.15 | 0.08 | 0.10 |
| Average losses (% of max. harvest) | 20 | 35 | 30 | 40 | 50 | 60 |

A comprehensive review of drought indices and drought probability can be found in publications by H.E. Landsberg (1975) and L.J. Ogallo (1989).

*Desertification* is a multilevel, pulsating, dynamic process and can therefore only be monitored, assessed and mapped by studying the dynamics of its individual components and of the complex effects of this process. Assessment and monitoring is carried out at worldwide, regional and local levels. This involves the use and interpretation of satellite imagery of various scales, aerial photographs and surface monitoring methods. A method for diagnosing desertification has been proposed which is based on a landscape-ecology method (using ecological profiles) and observation programmes at comprehensive point sources and in select areas, in comparison with protected lands.

According to the FAO, the following should be considered when assessing desertification:

- The actual state of the area;
- The rate of desertification (relative to the temporal dynamics of that state);
- The threat of desertification (the likelihood of it occurring) due to bioclimatic stress, the inherent vulnerability of the ecosystem and human pressure on the ecosystem from different forms of land use.

The rate (or danger) of desertification can be assessed using radiation aridity index I (Budyko, 1958):

$$\mathbf{I = R / LP,}$$

where:

R is the radiation balance (for the year);

L is the latent evaporation heat (for the year); and

P is the precipitation (for the year).

It has been established that this index has approximately the following scale:

- More than 10: desert;
- 7 – 10 : desert limits (semidesert);
- 2 – 6: semi-arid area;
- Less than 2: subhumid to humid climate.

In general, the effects of desertification can be seen when I = 2 – 7 which, in the majority of cases, is caused by overgrazing and irrational soil cultivation in conjunction with the clearing of large expanses of trees and bushes for fuel. Together, these factors culminate in an increase in the reflective capacities of the soil (increased albedo). The increased land area with low productivity results in the ecosystem losing some or all of its capacity to absorb $CO_2$, the most important "greenhouse gas", which in turn aggravates global climate change by facilitating global warming. The increase of dust erosion from bare soil (soil not protected by plant cover) changes the diffusion and absorption in the atmosphere of solar radiation. A number of research projects have used dynamic modelling to prove that an increase in albedo over large areas leads to a further reduction in precipitation. This must be considered as a potentially catastrophic, positive form of feedback - a vivid example of the impact of desertification on climate. Consequently, the results of overgrazing, irrational land use and fires are:

- Increased albedo and reduced absorption of solar radiation;
- Increased soil temperature and the creation of stressful conditions for living organisms;
- Erosion of the mineral and organic parts of the soil;
- Decreased soil water-retention capacity;
- Development of wind and water erosion.

All these inter-related processes bring about negative changes in ecosystem micro- and mesoclimates and degradation of soil and plant cover. Even the energy balance in the lower levels of the atmosphere changes above degraded land which has been deprived of large expanses of its natural plant cover, due to the change in solar radiation absorption, reflection and radiation (albedo). Changes in evaporation and precipitation values also affect the water balance of the area, reinforcing desertification. An idea of the complex inter-relationship of drought, human economic activities and desertification is given by the graphic model proposed by Middleton (1987).

*Strong winds, dust storms and wind erosion of the soil* are processes in which the wind destroys the upper, more fertile, layers of the soil and the underlying rock (wind erosion), with the consequent displacement and re-deposition of erosion products. *Strong winds* (more than 25 m/s) damage plants, crops, orchards and forests. They knock down stands and cause ripe fruit and seeds to fall; they increase plant transpiration and soil surface evaporation that, in insufficient water conditions, cause plants to wilt and even dry up completely. Strong winds make it difficult to carry out work in the fields such as sowing, spring fertilization and harvesting, etc. Hurricane force winds cause considerable damage in fields and orchards, breaking stalks and tree trunks, particularly those laden with fruit, removing the upper layer of the soil which is not protected by plant cover and, in the winter, blowing snow from open areas of the field and uncovering the roots of winter crops, etc.

*Dust storms* are harmful meteorological phenomena (average wind speed of no less than 15 m/s, visibility of less than 500 meters, duration of not less than 12 hours) during which a large quantity of dust, sand and topsoil is displaced. These particles are carried by the wind sometimes thousands of kilometres from the source and settle over large expanses of land in volumes amounting to millions of tonnes. Factors such as the drying out of topsoil, the partial or total lack of plant cover in fields and the correspondingly low humidity (less than 50%) increase the probability of dust storms. They are caused by natural and man-made factors, often including agriculture that is not suited to the climate of the region. Dust storms were repeatedly observed in the former Soviet Union. For example, as a result of the natural disaster of spring 1960 in the Northern Caucasus, the lower Don, eastern Ukraine and the lower Volga, 50% of winter crops were destroyed and had to be re-sown. After this dust storm, it was noted in Rostov oblast that forested swathes protecting fields retained from 5 to 30 $m^3$ of fine soil for every linear meter of forest. The height at which deposition occurred varied from 0.5 to 3.0 meters, depending on the density of the trees and the swath's "wind permeability". According to calculations by Svisyuk (1986), for every centimetre of topsoil removed per hectare, approximately 30 kg of nitrogen, 20 kg of phosphorous, 300 kg of potassium and 2-3 tonnes of humus were lost. Dust storms cause damage that cannot be easily rectified. The renewal of a 1 cm depth of topsoil under natural conditions would take 250-300 years.

The recurrence of dust storms varies from region to region. In western Siberia, the average over many years comes to 15-20 days per year; in Kazakhstan, this value varies from 10 (in the north) to 40 (in the south); and in the Central Asian deserts, it may reach 30-50 days per year or more.

It is known that the removal of particles from the soil starts at different wind speeds depending on the texture of the soil (Table 2).

**Table 2. Wind speed at which wind erosion starts, for soils with various textures.**

| Soil | Wind speed (m/s) 15 cm above the surface of the ground |
|---|---|
| Sandy | 2-3 |
| Sandy with loam | 3-4 |
| Slightly loamy | 4-6 |
| Very loamy | 5-7 |
| Loam | 7-9 |

Dust storms are essentially a form of soil erosion, namely *wind erosion.*

Local farming systems should be developed for each soil-climate zone, and should include soil protection measures that take into account the particularities of the climate, microclimate, and local relief and soil types, the types of crops and varieties being cultivated and soil working techniques. Implementation of this set of measures helps to preserve the extremely valuable national wealth found in the land and in soil fertility, to give prior warning of the possible development of soil erosion and to mitigate the destructive effects of existing soil erosion.

*Torrential rain. Water erosion.* Atmospheric precipitation is the main source of water (necessary for plant development and productivity) for non-irrigated plants. This is extremely important not only in its quantity but also in its seasonal and monthly distribution regime, intensity and duration. Intensity is the amount of precipitation that falls per unit of time, usually measured in mm/min. It is well known that short downpours have the greatest intensity. The world record for torrential rain was set in Iowa (United States) in July 1955, when a rainfall occurred with an intensity of 17.5 mm/min. Daily precipitation maximums have reached: 350 mm in Europe, 245-260 mm in Armenia and on the Black Sea coast in the Caucasus, 210 mm in south-western Ukraine and 120 mm in central Russia. The greatest daily rainfall maximum, at more than 1000 mm, was recorded in the tropical regions (India and the Philippines). It should be noted that one mm of rain is equivalent to 10 tonnes of water being poured over one hectare of land.

Torrential rain in the European part of Russia often causes lodging in large expanses of grain crops (up to 20-30% and more). It also leeches nutrients from the upper layers of the soil into the deeper layers that are rarely within the reach of plant roots. Leeching of potassium salts, for example, weakens the process of starch formation in potatoes. Waterlogged soils also severely inhibit mechanical crop harvesting.

*Water erosion* is a process in which the upper, most fertile layer of the soil is removed by rainwater and snowmelt, with the water displacing the erosion products and re-depositing them elsewhere. During the heaviest downpours water cannot be absorbed into the soil. Consequently most of it flows downhill, washing away the topsoil, exposing the root systems of grain crops, leeching nutrients and sometimes completely uprooting plants. Water erosion forms gullies that are practically useless for agriculture. The following factors affect the intensity of erosion: the uniformity of the field, intensity and duration of rainfall or thaw, local relief, the steepness of the mountain slopes, the amount they are forested or ploughed, and the excessive use of hill pastures for livestock grazing (overgrazing), etc.

Preventive agrotechnical measures and costly engineering works are carried out to combat water erosion. For example, perennial grasses with strong root systems are sown in erosion-prone fields to anchor the topsoil. Hills and mountain slopes are ploughed perpendicular to the flow of water. Bushes and trees are planted on the slopes of gullies and hills, and livestock grazing is limited in order to reinforce the soil with natural plant cover.

In nature, both wind and water erosion are usually seen together. Furthermore, they tend to add to and augment one another's negative environmental impact. Erosion is a form of soil degradation, and a factor of desertification. In Russia, more than 50 million hectares of farmland, including 35 million hectares of pastureland, is affected by water and wind erosion, and the area of eroded land increases every year by 4-5 thousand km$^2$. Specialists have estimated that the yearly loss of fertile soil into the atmosphere by wind erosion is 0.37 t/ha (Glazovsky and Orlovsky, 1996).

In Kazakhstan more than 17.5 million hectares of ploughed fields and approximately 30 million hectares of pastureland is affected by wind and water erosion. Water erosion alone has affected more than 85 thousand km$^2$ of agricultural land in Georgia and approximately 7 thousand km$^2$ in Moldova. Wind and water erosion in Ukraine have affected an area of more than 310 thousand km$^2$.

Both forms of erosion are manifestations of desertification.

Chepil and Woodruff (1963) proposed empirical models for calculating wind aggressivity, or the wind index:

$$\mathbf{C = V^{3} / 2.9\ (PE)^{2},}$$

where:

C is wind aggressivity;

V is wind speed;

P is precipitation;

ETR is evapotranspiration; and

PE – ETR = E, which is precipitation efficiency.

Water erosion is measured by loss of soil per unit area, per unit of time. This value is a function of total precipitation, the empirical coefficient of proneness to soil erosion, slope gradient (the basis of erosion), agrotechnical coefficients and other parameters.

Contemporary methods for assessing and mapping desertification have been developed by FAO and UNEP, and have been put into practice in a number of subsequent publications (Kharin et al, 1999; Borlikov, et. al, 2000). According to the FAO/UNEP concept, desertification is divided into type, category and aspect (FAO/UNEP, 1983). Types of desertification include types of land degradation, i.e. water erosion, wind erosion, soil salination, crust formation and soil compression, the reduction of organic elements in the soil, the presence of toxic substances in the soil and plant cover degradation. It is recommended that these types of land degradation be assessed using four categories of desertification: slight, average, severe and very severe. The aspects of desertification include: the present state (PS); rate or speed of desertification (RD); internal threat of desertification (ITD), including landscape characteristics, that describe stability during degradation; the effect of livestock on the surrounding environment (LE), determined by the number of cattle grazing per unit of land; and the population density (PD), determined by the number of residents per $km^2$. The total threat of desertification (TTD) encompasses all these aspects:

$$\mathbf{TTD = PS + RD + ITD + LE + PD}$$

It is recommended that the following table be used to determine TTD, since it shows the degree of influence of each aspect, empirically determined and expressed in points.

| **Category of desertification** | **Number of marks** | | | | | **Total Index** | |
|---|---|---|---|---|---|---|---|
| | PS | RD | ITD | LE | PD | Σ points | Average value |
| Slight | 3 | 3 | 3 | 4 | 2 | ≤ 30 | ≤ 6.0 |
| Average | 6 | 6 | 6 | 8 | 4 | 31 - 45 | 6.1 |
| Severe | 12 | 12 | 12 | 15 | 8 | 46 - 60 | 9.1 – 12.0 |
| Very severe | 18 | 18 | 18 | 25 | 12 | > 60 | > 12.0 |

It should be noted that the desertification criteria are of a regional character, and can include various characteristics. As an example, let us look at the criteria applied for assessing desertification in the Caspian region of Russia (Borlikov, et al., 2000):

1. Plant cover degradation (the plant society): reduction in the projected amount of plants covering the soil (%), reduction of pastureland feed reserves (%);

2. Wind erosion: presence of malicious wind erosion (%), soil turf cover (%), projected soil cover by bushes and shrubs (%);

3. Water erosion: type of erosion washing away the topsoil (cm), area covered by pools and gullies (%), reduction of projected soil cover by plants (%);

4. Human-induced desertification: uprooting of trees and shrubs (% of total area), turf destruction (%), area of human-induced damage (%);

5. Salination of irrigated land: degree of salination (solid residues (%)), total toxic salts (%), chemical composition of salination during irrigation; area over which salt levels have increased (%), reduction of crop productivity (%).

The World Atlas of Desertification (UNEP, 1992) determines arid areas using an indicator representing the relationship between the average yearly level of total precipitation (P mm) and potential evapotranspiration (PET mm), which ranges from 0.05 to 0.65.

A map of the arid zones of the world was published using this classification, with the following criteria for the zones:

- very arid ($P/PET < 0.05$)
- arid ($0.05 \leq P/PET < 0.20$)
- semi-arid ($0.20 \leq P/PET < 0.50$)
- dry sub-tropic ($0.50 \leq P/PET$).

A drawback of this classification is that it distorts the natural borders of soil-climate zones. Practice has shown that it would be more accurate to create a map of zones using landscape indicators, taking into consideration annual precipitation (Kharin, et. al., 1993):

1. Semi-arid territories are low and high plains with precipitation of 400 - 250 mm, with semi-desert types of soil and flora;

2. Arid territories are low and high plains with precipitation of 250 - 50 mm, with desert types of soil and flora;

3. Very arid territories are low and high plains with precipitation of less than 50 mm, with fragmented, primitive soils and rare desert flora.

While the climatic component of the desertification process should be considered in assessments of the degradation of arid lands, a distinction must be made among the following:

1. Desiccation, which is a long dehydration process that can extend into tens, hundreds or even thousands of years;

2. Drought, which is a short-term natural phenomenon;

3. Desertification, which is a process involving anthropogenic degradation of the land.

Remote methods are widely used for the assessment and mapping of desertification processes. Large-scale high and low resolution aerial and satellite photographs provide data. The latter may be used to assess desertification at the global and regional levels and for retrospective monitoring of global processes. The photographs, or more precisely the space images, are used as a so-called "vegetation index", commonly called a Normalized Difference Vegetation Index (NDVI). It is calculated according to the following formula:

$$\mathbf{NDVI=(NIR-RED)\ /\ (NIR+RED)}$$

where:

NIR is the spectral radiance in AVHRR channel 2 (0.72-1.1 micrometer);
RED is the spectral radiance in AVHRR channel 1 (0.55-0.68 micrometer).

This kind of satellite photo information, with resolutions of 8 km and 1 km and which describe the NDVI, is processed by the United States Geological Survey and can be accessed over the Internet. The spectral radiance of soil and plant cover recorded in these areas characterizes various desertification processes. The NDVI is an indirect indicator of the plant cover density and productivity. The signal recorded by the remote sensor is influenced not only by the plant cover density, but also by the phenology of the plants, soil moisture and anthropogenic processes.

Many research projects have established a correlation between the NDVI and the monthly amount of precipitation for sandy and stony deserts. Higher correlation coefficients have been found between mean monthly vegetation indices and precipitation for the current month and two previous months. It has been established that vegetating annual grasses have a major influence, as the abundance of such flora varies from year to year and is in clear correlation with the NDVI.

For example, Kharin, et al., (1998) established that the correlation dependency between the NDVI and the amount of precipitation in the Kyzylkum desert is greater in the April - May period, when there is the maximum productivity of pasture vegetation (r=0.68-0.73). These correlations were established for 1982, a dry year, and for 1992, which was a wet year. According to the data for these years for the territory of the Central Asian plain, several changes occurred in land composition. For example, oasis surface area increased by 0.7%, the surface of degraded forest and brush vegetation increased by 0.6% and that of degraded semi-savannah increased by 0.3%; the surface of shifting sands decreased by 0.5%. The use of the NDVI to assess land degradation makes it possible to study its dynamics, so as to select the most representative season. For example, for the territory of the Republic of Kalmykia, the most representative season for the study of desertification is May, during the period of maximum development of the plant cover, when the greatest NDVI contrasts can be observed among the various natural phenomena in the arid lands. The coloured NDVI mosaic registered 11 classes during this period, ranging from 0.6 to 0.06. For various Russian regions undergoing desertification, the optimum period for satellite photography was found to be between the first ten days of April and the last ten days of May.

The NDVI is thus a universal means of assessing the status and productivity of vegetation cover, especially in arid regions, as it is influenced by: the types of predominant vegetation, the vegetation's density per unit area and stage of development, as well as soil texture, soil surface humidity and relief. A degradation of the plant cover leads to a reduction in the protective soil cover with vegetation, a decrease in biodiversity and a drop in productivity. Human activity influences the status of the underlying surface. With the use of the NDVI, it is possible to assess various types of desertification and erosion processes. Data on annual NDVI changes may be used for the retrospective monitoring of the status of natural ecosystems.

The NDVI can be used in a number of situations to identify soil types and to assess damage to the plant cover from fires, floods and animal-induced desertification. To assess and map desertification, an NDVI with various resolutions should be used: globally, with a resolution of 8 kilometres; nationally, with a resolution of 1 kilometre; and regionally with a resolution of 200 meters or less.

In this field of research, we should mention a very useful work (Kogan, 2000) in which the author described the recent development by NOAA/NESDIS of a numerical method of drought detection using NOAA operational satellites. The author stated that this was the first globally universal technique to deal with such a complex phenomenon as drought. The method has been approved by NOAA and has been successfully put to use in 25 countries.

Using this technique, droughts can be detected four to six weeks earlier than previously, and can be delineated more accurately on maps. This makes it possible to diagnose the impact of the drought on grain production with more lead time, which is the most vital need for global food security and trade.

A new method for the early detection and monitoring of droughts and of their impact on crop productivity is based on assessments of the vegetation stress experienced by plants in arid conditions. Plant stress is determined by NOAA-AVHRR satellites through general monitoring of plant status, moisture, and temperature conditions in the regions of the world. When a hub of arid phenomena is detected, regular, more precise satellite photos are taken and numeric information is processed in greater detail.

Unlike conventional methods which use two NDVI channels, the new numeric method recommends the use of three channels: visible (VIS, channel 1); near infrared (NIR, channel 2) and infrared (IR, 10.3 to 11.3 micrometers, channel 4). The new method is based on the use of the three fundamental laws of the environment: the law of minimum, which postulates that primary production is proportional to the amount of the most limiting growth resource and is lowest when one of the factors, such as soil moisture, is at the extreme minimum; the law of tolerance, i.e., the ability of organisms to adapt to variations from their optimum environment; and the "principal of carrying capacity" (p.77). For more detailed information, interested readers should refer to this publication (Kogan, 2000).

## 2.2 Other types of hazardous hydrometeorological phenomena

The concept of hazardous natural hydrometeorological phenomena includes meteorological, agrometeorological, hydrological and marine phenomena which can lead to fatalities or cause significant economic losses. Hydrometeorological phenomena are considered as hazardous when they reach critical parameters or meet certain hydrometeorological levels or criteria. WMO Members each set "their own" criteria based on specific natural conditions. For example, for the conditions in the Russian Federation the following characteristics have been established for dangerous natural hydrometeorological phenomena:

### Meteorological phenomena

| Type of dangerous phenomenon | Characteristics and criteria |
|---|---|
| Strong wind (including squalls) | Wind speed (including gusts) not less than 25 meters per second |
| Tornado, waterspout | A strong whirlwind as a column or funnel directed from a cloud to the land or water surface |
| Very heavy rain (wet snow, rain with snow) | Precipitation of no less than 50 mm in 12 hours |
| Rainstorm (very strong shower) | Precipitation of no less than 30 mm in 12 hours |
| Very heavy snow | Precipitation of no less than 20 mm in 12 |

| Type of dangerous phenomenon | Characteristics and criteria |
|---|---|
| | hours |
| Prolonged heavy rains | Precipitation of no less than 100 mm in a period of over 12 and under 48 hours |
| Large hail | Hail diameter of no less than 20 mm |
| Heavy snowstorm | General snowstorm or blowing snow with a mean wind speed of no less than 15 meters per second, visibility of under 500 meters and a duration of at least 12 hours |
| Heavy dust storm or sandstorm | Dust storm or sandstorm with a mean wind speed of no less than 15 meters per second, visibility of under 500 meters and a duration of at least 12 hours |
| Heavy glaze-ice and rime deposit on wires | Diameter of the deposit on the wires of no less than 20 mm for glaze-ice, or no less than 35 mm for compound deposits or wet snow, and no less than 50 mm for crystallized or granular rime |
| Thick fog | Visibility of less than 50 meters |
| Hard frost | From November to March, the anticipated minimum temperature meets criteria set by the Hydrometeorological Service |
| Extreme heat | From May to August, the anticipated maximum temperature meets criteria set by the Hydrometeorological Service |
| Exceptional fire hazard | A class 5 fire hazard index (10,000° according to Nesterov's formula) |
| Avalanche | Major avalanche causing significant damage to economic structures of threatening populated areas |

## Agrometeorological phenomena

| | |
|---|---|
| Frost | A fall in air or soil surface temperature to under 0°C, with a background of positive mean daily temperature during an active crop vegetation period (over 10°C), causing plant damage |
| Waterlogging of soil | During a vegetation period, soil at a depth of 10-12 cm is visually sticky and runny for at least 20 consecutive days. On certain days (no more than 25% of the period in question) the soil may be slightly wet. |
| Dry, hot wind | A period of at least three consecutive days when at least one observation for each day reports relative air humidity of 30% or less with a wind of at least 7 meters per second and temperature over 25°C during a florescence, ripening or maturing period for cereal crops |
| Atmospheric drought | During a vegetation period, a lack of effective precipitation (over 5 mm in a 24-hour period) for a period of no less than 30 consecutive days, with a maximum air temperature of over 25°C (or 30°C in southern regions). On certain days (no more than 25% of the period in question) the maximum temperature may be lower than these limits. |

| | |
|---|---|
| Soil drought | During the vegetation period, for a period of no less than 30 consecutive days the usable moisture reserves in the 0 to 20 cm soil layer is not over 10 mm, or for a period of no less than 20 days if at the beginning of the drought period usable moisture reserves in the 0 to 100 cm soil layer amount to not more than 50 mm |

**Various hydrological phenomena**

| | |
|---|---|
| Freshet | Annual increase in river water level caused by melting of snow and ice to within 10% of the high-water marks |
| Flood | Rapid increase in water level occurring irregularly from heavy rains and short-term snow melt, to within 10% of the high-water marks |
| Mudflow | Flood in a mountain river with a very high content of mineral particles and mountain rock fragments |
| Low water | Decrease in water level to under the designed marks of water intake facilities and navigation levels for navigable rivers at specific locations for no less than 10 days |

*Frost.* This is a short-term decrease in air or soil-surface (herbage) temperature to 0°C or less, observed during the vegetation period (usually at night), with a background of positive mean daily air temperatures. In temperate zones, frosts are especially dangerous in late spring and early autumn, which corresponds to the active vegetation period of plants, as they limit the use of agroclimatic resources for the territory in question.

Frosts and associated weather conditions can be distinguished into three different types, depending on the processes that produce them: *advection frost*, *radiation frost* and *(combined) advection-radiation frost*. *Advection frost* occurs as a result of the incursion of cold air masses, usually because of a transformation in seasonal atmospheric circulation. *Radiation frost* occurs on quiet, cloudless nights when the mean daily air temperature is relatively low, as a result of intensive radiation from the Earth's surface and cooling of the surface and the neighbouring air layer to negative temperatures. *Combined advection radiation frost* occurs as a result of the incursion of cold air masses over a given territory combined with subsequent night cooling of the atmospheric surface layer to negative temperatures because of radiation from the underlying surface.

Frosts can also be distinguished by their length, intensity and recurrence rate, and the degree of threat they pose to various crops (which have differing extents of frost-resistance).

Plant resistance to frost and the extent of damage depend on many factors, including the time, intensity and duration of the frost, the type, variety and development stage of the plants, growing conditions and the rate at which the damaged plant tissue thaws. For example, shoots of spring wheat are damaged by frost at -9°C to -10°C, but during florescence a temperature of -1°C to -2°C is considered a severe frost; for the cotton plant, at any stage of development, a temperature of -0.5°C to -1.0°C is considered a severe frost.

There have been cases when springtime incursions of cold arctic air masses into cotton-growing regions of Uzbekistan led to advection frosts that wiped out cotton shoots in extensive areas (hundreds of thousands of hectares).

In fruit crops, the flowers and buds, seed buds, tree buds and bush buds are the most vulnerable to frost damage. In central Russia, where the recurrence rate of late spring frosts is high, there are significant losses to the fruit and berry harvests.

Various measures have been developed to combat the effects of frosts in regions with a high recurrence rate of spring and autumn frosts. A series of local farming techniques are employed for crops, orchards and vineyards with the aim of reducing heat loss in plants through their own radiation and by means of artificially increasing the temperature of the atmospheric surface layer. These include abundant watering or irrigation prior to the onset of the frosts, the use of smoke and various film or tissue covers, and any other means at hand.

Correct placement of crops, orchards and vineyards in areas less vulnerable to radiation and advection-radiation frost is of the utmost importance, especially in areas with pronounced relief.

Selection of frost-resistant crops and varieties, the choice of the sowing period and the planting of wooded frost barriers can significantly reduce the possibility of frost damage.

There are various active frost protection methods. For instance, vineyards can be protected by special stationary fans that pump warm air to the plants at a given time and environmentally harmless heat-producing substances can be added to the soil surface, including calcium hydride salts, which react with water vapour in the air to produce heat for a few hours. Experiments conducted in Russia (at the Russian Scientific Research Institute for Agricultural Meteorology, VNIISKhM, and at the Typhoon scientific production enterprise) have shown that spreading 200 grams per square meter raised the surface temperature by 2.5°C to 3.0°C.

### 2.3 Hail, hail damage and hail suppression

*Hail* is a type of precipitation, which falls during warm times of the year from large cumulonimbus clouds in the form of solid ice particles of various sizes. Hail can sometimes be very large; it can damage or destroy crops, and is capable of killing various agricultural animals and even people. The destruction of crops, orchards and vineyards by hail is called *hail damage*.

In order to avert hail damage or partially reduce the intensity of hailstorms, technical measures are used to prevent the formation and precipitation of hail in clouds. Weather radar locates hail formation zones in large cumulonimbus clouds, and special chemical reagents (such as dry ice, silver iodide and lead iodide) are seeded in the clouds from aircraft using aerosol generators or special rockets. As a result, in the cloud the number of condensation points - for the formation of the future hail - increases sharply, and the colloidal stability of the supercooled cloud is disturbed. Small hailstones fall from the cloud, go through the warm layers of air located under the zero isotherm and melt, producing rain, which is not as dangerous for crops.

Hail suppression is a type of weather modification, which acts on clouds. It is most successful in large basins located between mountains. There, the formation of clouds, which present hail hazards can be reliably forecast, as the air circulation patterns are well known.

There have been cases in which hail damage has completely destroyed hundreds of thousands of hectares of crops in the northern Caucasus, Moldova, Ukraine, Georgia, the Ferganskaya valley in Uzbekistan, the Gissarskaya valley in Tajikistan, the Crimea, the Carpathian region and in other areas of the former Soviet Union. The loss to plantations and crops depends not only on the size of the hailstones, but also on their density per unit area and the duration of the hailstorm.

In the countries of the former Soviet Union, experience has in recent years shown that protecting such high-value crops as grapes, cotton, tobacco, corn and fruit from hail damage is economically justified.

At Roshydromet's Russian Scientific Research Institute for Agricultural Meteorology (VNIISKhM), Prof. O. D. Sirotenko and others are carrying out large-scale research into the impact of possible climate changes (using the different scenarios put forward by the IPCC WMO/UNEP Working Group) on agricultural production, regional agroclimatic conditions and countries' food security.

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## CHAPTER 3

# IMPLEMENTATION OF THE UNITED NATIONS CONVENTION TO COMBAT DESERTIFICATION AND MITIGATE THE EFFECTS OF DROUGHT

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### 3.1 Introduction

Around the world's deserts there is a wide extent of arid, semi-arid and dry sub-humid land supporting a large human population. The total areas of arid, semi-arid and dry sub-humid regions cover 40% of the earth's land surface. Vast areas of these dry lands, somewhere between 1 and 3.6 billion ha are thought to be suffering from some degree of degradation. The areas affected encompass over 100 countries and some 900 million people, who may be suffering from adverse social and economic impacts of dry land degradation (Sivakumar et al. 2000). These zones in many places suffer from acute distress and even of tragic famine. Particularly in Africa, where the climate has recently been hostile, immense problems have arisen. Western China, Australia, northeastern Brazil and northwestern parts of India have also experienced stress in recent years. Desertification affects about one sixth of world's population. The spread of deserts is due to two main causes. First of all, human populations of the arid zone have grown enormously in recent decades and the need for food, fiber and resources has grown accordingly. In many areas the demands made on soils, vegetation and climate now greatly exceed their capacity to yield. The second cause are climatic fluctuations can produce changes in spatial and temporal distribution of rainfall. These two factors together appear responsible for the spread of desertification.

Desertification has been defined by United Nations Convention to Combat Desertification as land degradation in arid, semi-arid and dry sub-humid areas resulting from various factors including climatic variations and human activities. Desertification occurs because dry land ecosystems are extremely vulnerable to over exploitation and inappropriate land use.

Drought is a phenomena associated with scarcity of water. It is broadly classified into three categories. Meteorological drought is said to occur when there is a prolonged absence or marked deficiency or poor distribution of precipitation compared to normal rainfall in a given region. Hydrological drought indicates the scarcity of water in surface and underground resources. Agricultural drought occurs when the rainfall and soil moisture are inadequate to meet the water requirement of crops. It is a temporary feature caused by climate variations, and occurs in virtually all climate regimes but with a higher frequency and probability in semi-arid and sub-humid regions. Meteorological drought should be seen as a major cause of desertification, especially if drought conditions occur during several consecutive years, leading to a drastic impact on human activity.

There is a growing recognition of the importance of meteorology, climatology, and hydrology in understanding process of desertification and also combat the same. Accordingly, the following responsibilities may be carried out by NMHSs to combat desertification: monitoring of meteorological and hydrological parameters in order to evaluate desertification processes; studying the meteorological and hydrological factors needed to determine proper land-use and management practices; preparing various climatic and drought – probability maps, providing meteorological and hydrological input to anti-desertification technology; research efforts have to be geared up to make a reliable assessment on the likely impact of drought. A public awareness program can be arranged to educate masses on various mechanism that are available to cope up with drought situation.

Proper coordination of activities of various agencies in implementation of drought management plan may be made.

## 3.2 Background

### 3.2.1 Genesis of UNCCD

The desertification began to emerge as a major environmental issue in the early 1970s. In 1973, United Nations established its office to combat desertification and drought in the Sahel, Africa. In Aug-Sep 1977, a United Nations conference on Desertification (UNCOD) was convened in Nairobi, Kenya to produce an effective, comprehensive and coordinated programme for addressing the problem of land degradation. UNCOD was an outcome of extensive studies and consultations undertaken at the global, regional and local level involving scientists, policy and decision makers and experts from R&D institutions and other organizations from all over the world. The UNCOD recommended the United Nations Plan of Action to Combat Desertification (PACD). A subsequent UN General Assembly resolution adopted the recommendation of the conference in December 1977. However, the implementation of PACD was severely hampered by limited resources. Assessments were made in 1984, 1987 and 1989 by UNEP that indicated that desertification continued to spread. The UN commission for Sustainable Development Report in 1988, observed that desertification had become one of the most serious environmental and socio-economic problems of the world. The various assessments by UNEP continued to point out that desertification results from complex interactions among physical, chemical, biological, socio-economic and political problems that were local, national and global in nature. A new strategy for WMO activities in support to combat desertification was adopted in 1990 by the 42$^{nd}$ session of the executive council. In 1992, UNEP produced a World Atlas of Desertification (UNEP 1992). The studies indicated that over the preceding 20 years, the problem of land degradation had continued to worsen. In the past, dry lands recovered easily following long droughts and dry periods. Under modern conditions, however, they tend to lose their biological and economic productivity quickly unless they are managed in a sustainable manner.

The UN Conference on Environment and Development (UNCED) (also known as the Earth Summit) held in Rio de Janeiro, Brazil in June 1992 provided a platform for addressing a number of major global environmental concerns such as climate change, biodiversity, and deforestation. The Rio Summit also highlighted the problem of desertification and recommended that the United Nations General Assembly establish an Inter-governmental Negotiating Committee (INCD) to prepare a Convention to Combat Desertification in those countries experiencing serious drought and/or desertification, particularly in Africa. The Committee was established in early 1993. It held five preparatory sessions before adopting the Convention on 17th June 1994 in Paris.

### 3.2.2 Activities of WMO in the field of drought and desertification prior to UNCED

The following activities have been under taken in the following areas related to the subject of drought and desertification:

- Training seminars and workshops to train national personnel on the application of meteorological and hydrological data and information to avoid or combat desertification and to alleviate the effects of drought including remote-sensing technique in the arid, semi-arid and sub-humid areas.

- Training courses in operational application of agrometeorology and hydrology in agriculture including crop protection in semi-arid areas.

- Roving seminars on application of meteorological and hydrological information to assess soil loss by water and wind erosion, dust and sand dune transport and stabilization, potential primary production of natural pastures and for effective planning and management of water for sustainable irrigated crop production.

- Symposia on meteorological and hydrological aspects of droughts and desertification.

A large number of publications have been published on the use of meteorology and hydrology in desertification, drought, soil and land degradation, land use and range land management and crop production and protection. WMO has also provided assistance to the members affected by desertification and drought to prepare projects to ameliorate these problems.

### 3.2.3 UNCED Agenda 21

The United Nations Conference on Environment and Development (UNCED) that took place in Rio del Janeiro in June 1992 was a milestone event and it embraces all areas of sustainable development. Agenda 21 of UNCED deals with how to make development socially, economically and environmentally sustainable. Chapter 12 of Agenda 21 deals with drought and desertification. The following six programme areas have been included in Chapter 12.

1) Strengthening the knowledge base and developing information and monitoring system for regions prone to desertification and drought including the economic and social aspects of these ecosystem;

2) Combating land degradation through, inter alia, intensified soil conservation afforestation and reforestation activities.

3) Developing and strengthening integrated development programmes for the eradication of poverty and promotion of alternative livelihood systems in areas prone to desertification;

4) Developing comprehensive anti-desertification programmes and integrating them into national environmental planning;

5) Developing comprehensive drought preparedness and drought relief schemes including self help arrangements, for drought-prone areas and designing programmes to cope up with environmental refugees;

6) Encouraging and promoting popular participation and environmental education, focusing on desertification control and management of the effect of drought.

### 3.2.4 WMO activities in support to combat drought and desertification during post UNCED period

The United Nations Convention on drought and desertification was opened for signature on 14-15 October 1994. The Convention entered into force on 26th December 1996, 90 days after 50 countries had ratified it. As on 10th December 2000, 172 countries have acceded/ratified the Convention (Annex.1: Status of Ratification of the UNCCD). India was an active member of the INCD process and became a signatory on 14th October 1994 (the day it was opened for signature). India ratified the Convention on 17th December 1996 and it came into force in that country from 17th March 1997 (90 days after the date of ratification)

A number of articles in the UNCCD address issues are directed at, or are relevant to, implementation of the convention (CCD 1995). In particular, articles 10, 11 and 16 to 19.

These topics include:

- National Action Programme
- Sub-regional and regional Action programme
- Information collection Analysis and Exchange
- Research and Development
- Transfer, acquisition, Adaptation and Development of Technology
- Capacity Building Education and Public awareness

Annex I, II, III, and IV of UNCCD indicate regional implementation for Africa, Asia, Latin America and the Caribbean and for the Northern Mediterranean respectively.

The Conference of Parties (COP) oversees the implementation of the convention. It is established by the convention as the supreme decision making body and it comprises all ratifying governments. The last session of the COP (COP 5) was held in Geneva, Switzerland in October 2001, which reviewed and elaborated several technical points related to early warning system. COP 5 also noted improvements in data collection using remote sensing and Geographical Information System (GIS) in addition to conventional methods. It emphasized capacity building through technical assistance and training.

Many of the activities contained in Agenda 21 form part and parcel of the WMO normal activities and these are organized through its various scientific and technical programmes such as World Weather Watch Programme, the Agricultural Meteorology Programme, the World Climate Programme, the Hydrology and Water Resource Programme, the Atmospheric Research and Environment Programme, and various WMO technical commissions. WMO will continue these programmes which are reviewed every four years by congress.

Several Roving Seminars have been organized by WMO in collaboration with other national and international agencies on the use of meteorological, climatological and hydrological data for effective planning and management of water for sustainable irrigated crop production and thereby, minimize land degradation by water logging and salinisation. These joint activities should be continued.

## 3.3 Drought And Desertification

### 3.3.1 Causes of drought

The occurrence of persistent drought is primarily linked to displacements or variations in strength on time scales of a month to several years in the normally observed large-scale features of the atmospheric general circulation. These circulation variations affect the development of the local rain-producing disturbances. The causes of such circulation variations are not well understood but it's links with sea-surface temperature and snow cover have been established. However, such knowledge does not yet constitute an adequate basis for reliable drought prediction.

A number of regional interactions between the atmosphere and the underlying surface are thought to play in maintaining drought. Such feedback could result from a large increase in surface albedo and its effect on the radiation balance, which occurs in drought conditions and from diminished water storage and hence reduced evaporation over continued areas. WMO and its members should continue research into the above circulation variations and the interactions between the atmosphere and land. Improved knowledge will help the prediction of weather and climate in drought prone areas.

### 3.3.2 Causes of desertification

Two major factors are certainly involved in desertification, namely the periodic stress of climate on the one hand and human use and abuse of sensitive and vulnerable dryland ecosystems. Climatic fluctuations, with changes in the temporal and spatial distribution of rainfall, may result in lengthening of aridity phases, higher temperatures and winds of greater intensity. Similarly, increasing human pressure on the ecosystem may result in the extension of the cultivated area beyond the borders where the man-environment equilibrium can be maintained properly. Such human pressure normally includes the extension of irrigated areas, improper land use practices in semi-arid and sub-humid areas, resulting in land degradation through water and wind erosion, over grazing by livestock, deforestation for firewood and building and bush and forest fires, salinisation, alkalinisation and water logging. In addition, several processes may operate simultaneously, feeding back into the system, thus intensifying the degradation of the land resources base and the decline of the biological productivity. These are normally referred to as feedback mechanisms.

### 3.3.3 Prediction of droughts

As drought is a phenomena associated with water scarcity, the period during which water scarcity is likely to be experienced and the extent of water scarcity, the areas/regions that are likely to be affected by drought have to be known in advance. Such information can be utilized to make an assessment of the impact of drought and identify suitable measures for mitigation of droughts.

Precipitation is the major source of water supply particularly in the dry farming environments and there is need for the prediction of precipitation well in advance assumes special significance. Most countries of the world issue seasonal forecasts of precipitation.

The prediction of the occurrence of drought over smaller regions/areas may not be feasible in the near future. Therefore, the following information is needed:

i) Probability estimates of droughts of various durations and intensity based on long term climate records; and

ii) The cut-off dates up to which either the failure of rainfall or severe deficits in rainfall are likely to have adverse effect on productivity of predominant crops grown in the region will be useful.

The information on probable occurrence of droughts of various intensities can be used for evolving land use systems and appropriate management practices that can minimize the impact of drought, in the event of its occurrence. Information on the critical dates beyond which sowing of the traditional crops/varieties is likely to adversely affect the crop yields can facilitate in evolving contingency crop plans under rain-fed conditions. Finding adequate fodder for the cattle during the years of drought is a serious problem and mobilization of fodder from elsewhere involves an enormous cost of transportation. Therefore, fodder security has to be on the top of agenda in drought prone areas. Generation of raw material as input for agro-based rural industries will provide additional employment opportunities for the people living in drought prone areas.

### 3.3.4 Monitoring and early warning system for drought and desertification

Drought prediction is still heavily reliant on monitoring of observed pattern of monthly and seasonal rainfall, stream flow, ground water levels, snow pack and other parameters. Developing predictive skill for large geographic regions on a monthly and seasonal timescale offers promise for increasingly useful forecasts of the onset severity and duration of drought. The UNCCD emphasizes the importance of providing effective early warning systems that enable rural communities to take early and timely action to reduce the damage caused to life and property. Article 10 on National Action Programmes calls on the affected country parties to enhance national climatological, meteorological, and hydrological capabilities. Article 16 on the information collection, analysis and exchange also calls on parties to integrate and coordinate the collection, analysis and exchange of relevant short-term and long term data and information, as it would help accomplish inter alia, early warning and advance planning for periods of adverse climatic variation.

Early warning systems for desertification encompass the systems developed for forecasting and analyzing droughts, floods, wind erosion and other climatic phenomenon that contribute to the degradation of land (WMO, 1999).

The expert group meeting on Early Warning Systems for Drought Preparedness and Drought Management, which was organized by WMO from 5-7 September 2000 in Lisbon, Portugal, reviewed the status of drought early warning systems and assessed the need to meet the increasing demand for drought mitigation and planning efforts (Wilhite et al. 2000). The expert group made some important recommendations. Some of them are given below:

- Identify information needs of users at the local level.

- An early warning system must be part of national drought policy

- The drought preparedness and mitigation systems should be comprehensive and proactive, and should encompass drought monitoring, drought impact assessment, and institutional arrangements. All these components must be underpinned by a vigorous research and development programme.

- Priority should be given to improve existing meteorological, agronomic and hydrological observation networks and associated analytical and predictive tools and models.

- It is important that governments develop and adopt national drought policies that move them from a reactionary or crisis driven approach towards a strategy to mitigate the impacts of drought.

### 3.3.5 Impacts of drought

The impact of drought on agriculture, land use and degradation and water resource management is especially visible in semi-arid and sub-humid areas.

In many semi-arid and sub-humid areas, the occurrence of drought has been a phenomenon observed periodically for hundreds or thousands of years. Basically, the local plant, animal and human life had adapted itself to the occurrence of drought. In a “balanced” system, the exploitation of micro-climatic opportunities maintains or even enhances their existence. There is a certain “elasticity” to accommodate a temporary change in one of the components in the supply/demand balance, be it a seasonal or annual drought or a sudden temporary increase in precipitation. Ecosystems are not able to cope, without major modifications in their characteristics and appearance, with permanent changes in these components, such as those caused by climatic changes as opposed to climatic variability or by a permanent increase in the animal or human population. If these changes occur the interaction between each component of an ecosystem will need to be reassessed.

### 3.3.6 Drought impact assessment

Development of drought management plans have to be realistic and should be based on sound scientific data based on the impact of drought on society and environment as well as both on short-term and a long-term basis not only for averting the crisis but also in reducing the risk. The impact assessment approaches may not be common and cannot be universally applicable. For example, some of the developed countries may not experience food shortages for their internal consumption but may not be able to meet the demand for export in the event of drought whereas developed and developing countries are likely to be affected by drought in their own state as well as due to occurrence of drought from the states where it can import. Therefore, the impact assessments have to be addressed at:

- Micro level
- Regional level
- National level and
- International level

Simultaneously, there is also a need for evolving models to predict the impact of drought in various sectors as a function of drought management strategies depending upon the time of occurrence of drought and its intensity. It is also necessary to assess the impact of droughts during the event as well during the recovery period. Lack of high quality data is the major constraint to impact assessment. Investment to improve data quantity, documentation quality and communication will benefit the data users and researchers.

### 3.3.7 Drought Management

Scientific research assumes significant importance in developing long-term strategies for drought management based on drought assessment and response system. The interrelated issues that need attention are:

- Drought prediction
- Detection, monitoring and early warning
- Impact assessment
- Adaptation and
- Response

Lack of information necessary to provide basis for evolving drought management plan is one of the major limitations. The information includes meteorological, agronomic, demographic and socio-economic data. The problem is confounded by insufficient historical databases and the lack of systematic efforts to compile existing information into forms that can be comparable with other data, readily analyzed and updated and summarized for policy makers. Even if the information exists, it is not effectively transformed by the scientific community for the use of appropriate policy makers. Databases are also required for impact studies, development of socio-economic models to assess policy alternatives and enhanced models to predict physical and biological processes.

### 3.3.8 Management of Natural Resources

Some of the strategies believed to alleviate drought conditions include

- Ground water exploitation
- Soil and water conservation
- Intercropping
- Introduction of alternate crops/varieties
- Afforestation
- Creation of storage facilities for food and fodder

### 3.3.9 Drought Mitigation

Drought is a recurring phenomena and its occurrence cannot be avoided. However, its impact can be minimized through application of science and technology in developing drought management plans. In a country like India, there will always be some areas, which are not affected by drought while some other areas may be highly impacted from drought. Therefore, there is a need to develop infrastructure for drought mitigation. The major issues need to be addressed are:

- An early warning/monitoring system needs to be developed to generate information on the onset, duration, intensity and termination of drought conditions for use by the decision makers at all levels.

- Research efforts have to be geared up to make a reliable assessment on the likely impact of drought.

- Availability of resources such as credit, fertilizers, pesticides and power for increasing the production.

- Organization of buffer stocks of food grains and fodder to cope up with the likely/anticipated shortages.

- Co-ordination of the activities of various agencies in implementation of drought management plans.

- Education of the general public on various mechanisms those are available to cope up with the drought situation.

- Creation of better avenues for employment to reduce the percentage of population depending upon agriculture in drought prone areas.

- Providing economic relief through creation of durable assets rather than through subsidies.

**3.3.10 Combat Desertification**

Measures to combat complex problems of desertification should include the following additional integrated measures.

- Awareness may be created among the local population regarding the danger of indiscriminating felling of trees and overgrazing.

- The natural resources of soil, water, forests and pastures should be judiciously utilized and conserved.

- Population growth should be controlled in order to reduce overexploitation of land.

- Livestock grazing pressure should be reduced and specialized fodder-growing farms to be created. In the rangeland areas, proper rotation grazing should be practiced.

- Energy efficiency in desert areas should be improved to reduce the undue collection of fuel wood.

- Creation of protective forest belts by using local species well adapted to the desert condition to provide an effective measure against desertification.

- Creation of protective forest belts to fight wind and sand erosion near oases to help protect field crops, arrest sand movement and give food and shelter to wild life.

- Greater regional and international cooperation in scientific, technical and social sectors concerning desertification should be encouraged.

Sinha Ray (2000) has discussed the various categories of drought affecting crop production in the dryland, namely, early-season drought, mid-season drought, late season or terminal drought, apparent drought, and permanent drought. He also gave an overview of the early warning systems in India, viz. long range seasonal forecast of the India Meteorological Department, services rendered by Agricultural Meteorology Division including Agromet Advisory Services and Farmers' Weather Bulletin and feedback from user agencies. He has also discussed regarding the drought research unit, crop yield forecast unit and rainfall climatology for agricultural planning unit of India Meteorological Department. He has also explained the function of National Center of Medium Range Weather Forecast (NCMRWF), Central Research Institute for Dryland Agriculture (CRIDA), National Remote Sensing Agency (NRSA) towards drought monitoring and early warning system. He also enlisted various drought management procedures. Kogan (2000) discussed the contribution of remote sensing in a drought early warning system.

## 3.4 Terms Of Reference (a)

To provide advice within the terms of reference of the commission on matters relating to the implementation of the United Nations Convention to combat desertification and mitigate the effects of drought.

The most important objective of the Convention is to combat desertification occurring in the dryland regions of the world and to mitigate the effects of drought.

The percentage of dry land area of the world is given below:

**Table 3.1 Classification of the Regions on the basis of aridity index**

| Climate Zone | P/PE ratio covered | % of world |
|---|---|---|
| Arid | 0.05-0.20 | 12.5 |
| Semi-arid | 0.21-0.50 | 17.5 |
| Dry sub-humid | 0.51-0.65 | 9.9 |

Where P is mean annual precipitation and PE is mean annual potential evapotranspiration.

*Source: Williams and Balling (1996): WMO-UNEP Report on Interactions of Desertification and Climate*

"Combating desertification" includes activities, which are part of the integrated development of land in arid, semi-arid, and dry sub-humid areas for sustainable development which are aimed at:

(i) Prevention and/or reduction of land degradation;

(ii) Rehabilitation of partly degraded land; and

(iii) Reclamation of desertified land.

Under the Convention, the most important obligation of the affected developing country Parties is to prepare a National Action Programme to combat desertification and mitigate the effects of drought.

### 3.4.1 National Action Programme

National Action Programmes (NAP) is one of the key instruments in the implementation of the convention. They are strengthened by Action Programmes on sub regional (SRAP) and regional (RAP) level. National Action Programmes are developed in the framework of a parcipative approach involving the local communities and they spell out the practical steps and measures to be taken to combat desertification in specific ecosystems.

#### 3.4.1.1 Action Programmes to Combat Desertification in Africa

The following countries of Africa have already submitted their National Action programme to the CCD secretariat: Benin, Burkina Faso, Cape Verde, Djibouti, Ethiopia, Gambia, Lesotho, Madagascar, Malawi, Mali, Niger, Nigeria, Senegal, Swaziland, Tanzania, Tunisia, Uganda, and Zimbabwe. The National Action Programmes of a few Nations in the following sections are given as examples.

**National Action plan to combat desertification in Ethiopia**

I. Improving knowledge on drought and desertification.

Research and development - a research and development system which shall be demand driven shall be put in place.

II. Improving the socio-economic environment

(i) Policy on environment - policy provision for the conservation and sustainable utilization of land and other natural resources in arid, semi-arid and dry sub-humid areas shall be adequately integrated other sustainable development policies.

(ii) Security of tenure and access to natural resources: the government shall insure that land and other natural resources administrative measures adhere to the requirements of provisions in the federal and regional state constitutions as well as legislation and regulations designed to guarantee security of tenure to land and access to natural resources.

(iii) Creation and development of Markets - increased effort to facilitate the development of markets which will enable farmers and pastoralists to sell their products as well as to buy necessities, particularly inputs required for production.

III. Improving Basic infrastructure.

Social and infrastructural investment: all efforts shall be made to provide the basic infrastructure (e.g. roads, water supply, health care) in order to improve the health and living conditions of the farmers and pastoralists as well as to simulate economic growth.

IV. Programs which promote alternative livelihoods

Alternative livelihoods / source of income: a conducive environment for the creation of diversified forms of alternative livelihood and income generating activities for the farmers and pastoralists shall be promoted inside as well as outside arid, semiarid and dry sub humid areas in order to alleviate poverty, increase income and reduce pressure on land and natural resources.

V. Rural credit programmes, including the establishment of a fund to combat desertification and the effects of drought.

Rural credit institutions: Rural credit institutions shall be facilitated and actively promoted, particularly in those areas where poverty is prevalent and the pressure on land and natural resources in high.

VI. Programmes for the intensification and diversification of agriculture.

A strong and vigorous diversification program both as a complement and alternative to the traditional pastoral system of production and land use need be put in place.

VII. Awareness building and access to information.

Awareness programs tailored to the needs of farmers and pastoralists in the arid, semi arid and dry sub humid areas as well as to the needs of policy and decision makers at all levels shall be promoted; appropriate desertification and drought information systems shall be established at community, district, province and national levels.

VIII. Measures to enhance institutional organization and capacity

The institutions and organizations that are required for the better conservation and sustainable utilization of the land and natural resources in these areas, particularly the institutions and organizations at the local level, shall be strengthened and where lacking their free and voluntary development nurtured.

IX. Program for empowerment of women

Every effort should be made to ensure the participation of women in all activities designed to combat desertification and mitigate the effects of drought.

**Djibouti**

In its National Action Plans (NAPs) to combat desertification, the government of Djibouti has charged its ministry of water with the task of conducting activities that sensitive the public on the mechanisms of the UN Convention to Combat Desertification. These include media campaigns, seminars and workshops to sensitize the relevant authorities so that the people at the grassroots are eventually consulted.

**Eritrea**

The Government of Eritrea has designated its Agency for Environment to be its focal point in the NAP process. The preparation of NAP has been going on since October 1994. The process pulls together relevant bodies. There are national projects on soil conservation in place and over 49,000 students involved in tree planting. Thus there are key projects designed to combat desertification including the installation of micro-dams and a framework to address desertification.

**Kenya**

Article 6 of the Regional Implementation Annex for Africa states that National Action Programmes shall be a central integral part of a broader process of formulating national policies for the sustainable development of affected African country parties. This provision fits very well with Kenya's on-going efforts aimed at achieving sustainable development as is illustrated by the prevailing policies and institutional framework.

With regard to policy, the 1985 decentralizations of planning from the national to the district level perhaps provide the best example of the Government's commitment to achieving sustainable development. The enactment of the Development Policy for the Arid and Semi-Arid Lands (ASAL) in 1992 provides yet another example of this commitment. Recent policy shifts towards the same direction are illustrated by the Social Dimensions approach to poverty alleviation as well as the implementation of the National Environment Action Plan Process (NEAP).

The existing institutional network exhibits the same enabling environment for the implementation of the NAP. In place are government ministries and departments, universities, non-governmental organisations as well as community-based organisations. Indeed, there exists a wide range of actors dealing with issues on desertification and drought, and whose activities are sectoral in nature. In order to set in place an integrated approach to desertification control as required by the convention, there is need for a specific body charged with the co-ordination of the on-going activities. In this respect, the National Environment Secretariat (NES) has been identified as the body appropriately placed to co-ordinate the implementation of the convention.

As Kenya’s premier environmental agency, the NES convenes the Inter-Ministerial Committee on Environment (IMCE). This is the “vehicle” through which the Ministry of Environment and Natural Resources co-ordinates the environmental matters in the country. To address issues pertaining to the convention, the NES has set up an IMCE sub-committee on Desertification and Drought which intends to ultimately encourage participation by all the major stake-holders. Towards the implementation of the provisions of the convention, the sub-committee has incorporated the following elements of the NAP as evolved by the National Environment Action Plan (NEAP) process:

(a) Assessment and Mapping of Desertification

(b) Drought Monitoring and Preparedness

(c) Addressing socio-economic characteristics as well as population management through education programmes, development of human resources, creation of effective and suitable employment opportunities, appropriate land tenure systems and migration.

(d) Ensuring popular participation as a key component in the preparation of NAP.

(e) Education and Public awareness

(f) Promotion of trade through development of infrastructure for marketing of output from the ASALs and promotion of industrial and trade skills to enable creation of wealth in the affected areas and,

(g) Initiation of Research and Development Programmes in the ASALs under sectors such as agriculture, Livestock and Forestry as well as introduction of suitable and appropriate technologies.

The evolution of the NAP would be incomplete if the major stakeholders were left out of the process. In appreciation of this fact, the National Coordinating Body actively encourages the involvement of NGOs. In this respect, the National NGO Coordinating Committee is well represented in the IMCE Sub-committee on Desertification and Drought.

**Uganda**

The tone of the NAP was set in Uganda through an awareness workshop, which also recommended areas of priority. Actions to combat poverty, insecurity, water scarcity and secure land tenure, soil and agricultural production, and actions to eliminate inadequate policies were identified by Drought and Desertification Secretariat as key areas that need to be addressed if there is to be any success in improving livelihoods and combating desertification and drought. The National Co-ordinating Committee formed four task forces on NAP charged with awareness, and legal aspects, planning and finance, information and research and the fourth one, charged with social and policy aspects of the convention.

**Sudan**

The Sudan National Drought and Desertification control Co-ordination and Monitoring Unit (NDDU) prepared the background work for NAP and organized a workshop of information awareness and Sudan five year programme for INCD in July 1995. The participants included all relevant government institutions, decision-makers, NGO's, UN and other relevant bodies. Awareness campaigns have conducted throughout the country. NGOs are also involved in the exercise of trying to involve local populations so as to come up with a practical NAP. NDDU utilized the GIS system and produced maps of Sudan identifying desert prone zones.

#### 3.4.1.2 Action programmes to Combat Desertification in Asia

Following countries of Asia have submitted their National Action Programme: China, India, Kyrgyzstan, Laos, Mongolia, Tajikistan, Turkmenistan, Uzbekistan, and Yemen.

The resolutions adopted during the first Regional Conference on the implementation of the United Nations Convention to Combat Desertification were held in New Delhi, in August, 1996 that prepared the ground for the preparation of the Convention's Regional Action Program for Asia. Guided by the principles and provisions of the Convention, especially those in its Annex (ii), the Regional Implementation Annex for Asia, Asian country Parties with continued assistance from the UNCCD Secretariat, have taken initiatives aimed at achieving the objectives of the Convention. As a follow-up to the New Delhi meeting, two other meetings were held: The Ministerial Conference on Regional Cooperation to implement the United Nations Convention to Combat Desertification in Asia, held in Beijing in 1997, and the international Expert Group Meeting on the Preparation of the Regional Action Programme for Combating Desertification and Mitigating the Effects of Drought in Asia, held at Bangkok in 1998.Those meetings carried the Asian region through a process of mobilizing political commitment to regional and sub regional collaboration. They also paved the way for the formulation of a framework for the Regional Action Programme (RAP) and development of National Action Programmes (NAPs). Furthermore, the meetings established Thematic Programme Networks (TPNs) that provides structural support to RAP and NAPs that essentially, are at the core of action for combating desertification in the region.

China assumes the responsibilities of the TPN1, Desertification Monitoring and Assessment, India assumes that of TPN2, Agro forestry and Soil Conservation in Arid, semi-arid and Dry Sub-humid areas. Similarly, Iran assumes the responsibility of TPN3, Rangeland management in arid areas including the fixation of sand dunes, and Syria to that of TPN4, water resources management for agriculture in arid, semi-arid and dry sub-humid areas. Mongolia and Pakistan are entrusted with the responsibility of TPN5 and TPN6, to strengthening capabilities for drought impact mitigating and desertification combating and Assistance for the implementation of integrated Local Area Development Programmes (LAPDS) initiatives respectively.

**CCD implementation at the sub-regional level**

**(i) Central Asia**

Sub-regional collaboration has been promoted to tackle land degradation and foster sustainable management of natural resources. Within the frame of the Sub-Regional Action Programme to Combat Desertification in Aral Sea Basin, the five priority areas of cooperation have been identified and the process of pilot projects development has started. A working group of the CCD focal points that was established as a sub-regional coordinating body should enhance coordination of related activities at the sub-regional level.

**(ii) West Asia**

As part of the Sub-regional Action Programme for Combating Desertification for West Asia, two ACSAD concerning the implementation of TPNs and TNs in the concerned countries. The sepro posals are now with the GM for mobilizing resources. The implementation of TNs should be facilitated in a manner to create synergies with Asian TPNs and to catalyze further actions at the national level.

**(iii) Pacific Islands**

The two consecutive workshops that were held in Apia, Samoa from 21 to 25 May 2001 set out a useful basis for promoting sub-regional collaboration. Concrete actions should be taken to develop initiatives on agro forestry and water harvesting as well as early warning systems Pacific islands.

**(iv) South East Asia**

South East Asian countries find a great deal of merit in addressing land degradation issues and promoting mutual learning process for facilitating the CCD implementation at the sub-regional level. It is suggested to convene a sub-regional workshop in Indonesia to be facilitated by the CCD Secretariat to facilitate this process.

**(v) North East Asia**

As increasing attention has been given to sand particles such as dust storms and yellow sand issues in North East Asia or even the Northern Pacific region, it is suggested to organize an international workshop with interested parties and international organizations and make use of TPN1 and TPN3.6 activities to review the status of yellow sand/dust storms and their impacts and explore effective measures for arresting such phenomena through enhancing national, sub-regional, regional and international efforts to combat desertification.

**(vi) South Asia**

South Asia is comprised of large deserted areas and is the most densely populated region in the world with some of the world's poorest people. The South Asian Association for Regional Cooperation (SAARC) and the South Asian Cooperative Environment Programme (SACEP) do serve the purpose of regional cooperation in general environmental issues but do not cover desertification specifically. It would be appropriate to consider the possibility of constituting a mechanism in South Asia to deliberate on issues to combat desertification.

**CCD implementation at the global level**

Awareness raising in conformity with the recommendation 2.13 of the Third Asia-Africa Forum regarding the selection of a specific theme to bring greater focus on the commemoration of the World Day on Combating Desertification, the Chairman of the Asia Group was invited to submit for consideration at the COP5 a proposal for adopting a recommendation and selecting a theme such as "sand storms and mankind" or "land degradation in mountains" as a specific theme for the commemoration of the World Day on Combating Desertification on 17$^{th}$ June 2002.

**Asia – Africa collaboration**

The participants endorsed the Chairman's Summary of the Third Asia-Africa Forum and reiterated their wish that the Summary shall be brought to the attention of wide-ranging policy makers and stakeholders so as to pursue the effective measures for materializing recommendations proposed at the Third Asia-Africa Forum.

### Highlight of the national level activities in Asia

**Bangladesh**

In promoting public awareness and an integrated ecosystem management, consideration is currently given to establishing coordination and steering bodies for the CCD implementation. The monitoring and assessment of aridity in countries is needed. Technical and financial assistance is required. The CCD Secretariat should be empowered to better assist the affected CCD member countries.

**Cambodia**

Ministries promote coordination in the areas of combating desertification and land degradation. It is proposed to convene a national workshop on combating land degradation and mitigating the effects of drought aimed at facilitating the formulation of the NAP that is postponed from June to late summer this year. It is hoped that the CCD Secretariat and the Global Mechanism could provide Cambodia with catalytic assistance.

**China**

Two key field projects of combating desertification were initiated, including the Desertification Control Programme around the Beijing Area, and the Fourth Phase of the Three-North Shelterbelts Project. The drafted State Law of Controlling and Combating Desertification has been submitted to the National People's Congress. Hopefully it will be ratified in the near future. It carried out activities to commemorate $7^{th}$ World Day on Combating Desertification that is17 June with a wide range of media coverage. A publication was recently released on modalities, science and technologies on combating desertification. The Coordination Meeting was hosted by the China State Forestry Administration in Beijing from 6-7 June 2001 with co-sponsorship with the GM, the CCD, the UNDP and the Asian Development Bank focusing on resource mobilization, partnership building and linkages between combating desertification and ameliorating the people's livelihood. China suggests that further support shall be provided to promote the amending and implementing of the NAP. The CCD Secretariat and the GM should continue to promote coordination to implement the actions recommended by the Coordination Meeting. North East Asia collaboration has been becoming important in order to take actions to study trans-boundary phenomena of sand storms/dust storms. It is suggested that the TPN1 should undertake the task. Proper recognition should be also paid to the important role that the CCD Regional Coordination Unit has done for Asia based in Bangkok.

**Mongolia**

The outcome of the Mongolia National Forum on Combating Desertification and Promoting Synergistic Implementation of Multilateral Inter-linked Convention held from 18 – 20 June in Ulan Bator was presented at the Third Asia-Africa Forum. Twenty laws and national programmes were formulated and place in implementation that are expected to strengthen the efforts to facilitate the implementation of the National Plan of Action to Combat Desertification in Mongolia. It is important to promote the activities to combat desertification together with the proper pasture and livestock management. Capacity building in a variety of areas remains essential.

**India**

Land degradation is a primary concern for India. India assumes the responsibilities of the TPN2 host country and remains active in other TPNs such as TPN1. The national coordinating committee was set up and is composed of ministry representatives that have been promoting the formulation of the national action programme to combat desertification.

The committee doesn't have its autonomous budget, but it can oversee the finalization and implementation of the NAP.

India has prepared their National Action Programme in a very systematic manner involving various ministries, government departments and NGOs. They formed a steering committee, which constituted four working groups and separate work was allotted to each group for implementation of United Nations Convention to Combat Desertification. India UNCCD has taken lot of initiatives by way of establishing a monitoring mechanism for desertification, integrated water shed programmes, conservation and eco-restoration activities, integrated water resource development plan, land use planning, management of natural resources of the country etc. A large number of policies and strategies for environmental conservation, a large number of programmes like social sector and community development, health and literacy, income generating scheme for poverty eradication, credit assistance for agro based activities, capacity building and strengthening the role of various stake holders, Desert Development Programme (DDP), Drought Prone Areas Programme (DPAP), etc. Technologies have been developed to control land degradation in various bio-climatic regions and reclamation of degraded land. As an almost ideal National Action Programme, we may look at the NAP of India in some more detail. (Annex I)

**Indonesia**

Indonesia has been promoting the implementation of relevant national policies to address land degradation and drought. Indonesia has been facilitating the preparation of the national action programme. Catalytic assistance is requested in this regard. Indonesia also finds a great deal of merit in organizing a sub-regional workshop on the formulation of NAPs in Indonesia to enhance the harmonized approach in the formulation and implementation of the NAPs and to strengthen collaboration in the sub-region. CCD reporting help guides could be improved taking into account the formats required for other related environmental conventions.

**Islamic Republic of Iran**

Iran promotes activities to combat desertification. Awareness raising activities at all levels including political and community levels are part of the important activities. The DESCONAP Office, a regional network on combating desertification in Asia launched by ESCAP in 1980's has been playing a leading role in promoting desertification control activities. In Yazd, the Yazd International Center for Sustainable Development of Desert Communities is expected to promote sustainability in a dry land livelihood. Iran also supports the development of TPN3 activities. NGOs have been playing an important role in the desertification control activities. Iran should be able to contribute to training programme including those relate to inter-regional collaboration.

**Japan**

As a non-affected developed country, Japan has been supporting the activities to combat desertification through official development assistance, voluntary contributions to the CCD Secretariat and scientific cooperation. Japan recently hosted the Ad Hoc Panel Meeting on Early Warning Systems. Japan continues to support the national and regional activities to facilitate the CCD implementation.

**Jordan**

Jordan has been promoting the implementation of the CCD and other related environmental conventions such as the Convention on Biological Diversity. Jordan identified the priority activities for combating desertification. The Biodiversity Action Plan and the Economic Development Plan articulate their linkages with combating desertification. The

NAP shall be implemented with the support of the GEF, UNDP, UNDP/UNSO Office in Beirut after signing project documents in this year.

**Kazakhstan**

Kazakhstan has come to the final stage of preparing the NAP. It has been actively in Aral Sea Basin. It expects to facilitate the NAP implementation and at the same time promote its involvement in the SRAP for Central Asia and TPNs for Asia.

**Kyrgyzstan**

The NAP was prepared including 35 pilot project proposals submitted by various preparers. The year 2002 has been designated as the Year of Mountains on initiatives of the President of Kyrgyzstan. It is proposed that the focal point of Kyrgyzstan shall be a contact person in the preparatory stage of the International Conference on Mountains' Problems to be held in Bishkek, Kyrgyzstan in 2002.

**Lebanon**

NAP implementation is under way with the assistance of the GTZ and the GM. The NAP preparation and adoption is currently of utmost importance. It intends to further develop partnerships to facilitate the activities to combat desertification, tackle land degradation and promote sustainable use of land based resources.

**Myanmar**

Land degradation has been exacerbating due to a variety of causes that include human induced causes such as inappropriate agriculture practices. Since 1954, the Government has been promoting reforestation programmes including dry zones. The Green Dry Zone. Department has been playing an important role in this respect. During 1997-98, intensive efforts have been made to promote nature reserves and water resource management. Myanmar intends to facilitate the NAP formulation that would include the concrete provisions for the Myanmar's participation in the TPNs.

**Nepal**

Nepal promotes a participatory approach in the activities to combat desertification. Nepal plans to facilitate the formulation of the NAP by undertaking required assessment on land degradation and land use. Nepal conducts an assessment study on technical and financial gap. Further attention shall be given to rehabilitating degraded land areas. Nepal requests the CCD Secretariat and the GM to give due consideration to the Nepal's need for catalytic assistance in facilitating the NAP and promoting capacity building activities.

**Pakistan**

About 75% of the entire population has been affected by desertification and the affected population groups are often at an economically disadvantageous position. Pakistan pursues the implementation of the CCD for the benefit of the local population that is vulnerable to desertification. Salinization and drought also adversely affect the rural communities. Sustainable natural resource management remains a significant challenge for Pakistan. Pakistan completed the formulation of the NAP and the Environment Minister approved it. The Pakistan Environment Protection Council is expected to approve it. The preparation of TPN6 has been delayed due to the other pressing requirements. Pakistan requests the CCD Secretariat to assist Pakistan in preparing the TPN6.

**Papua New Guinea**

Papua New Guinea has a diversified culture with many local languages and tribes. Copper, gold and oil mining are major sources of revenues. PNG does not have a desert, but faces severe land degradation due to mining and logging. PNG plans to form a national coordination committee for the CCD implementation that will also consider the formulation of the NAP the Environmental Conservation Agency is responsible for the CCD implementation. PNG hopes to organize a national awareness seminar on the CCD and to receive assistance from the CCD Secretariat for this purpose.

**Republic of Korea**

Republic of Korea does not have a desert or severe land degradation problems. The Republic of Korea however, is affected by yellow sand and dust storms from neighboring countries. The Republic of Korea provides China and Mongolia with some assistance to promote reforestation and the activities to arrest sand dune movement.

**Sri Lanka**

The National Committee of Experts on Land Degradation was established to examine the land use policies in Sri Lanka. Consideration is being given to the proposal of formulating a national policy for combating land degradation. Agro forestry, sustainable management of domesticated animals and water conservation are some of the key components that are deemed as essential for facilitating the national policy implementation to combat land degradation and promote sustainable land use. Awareness campaigns and study tours are organized. Financial and technical assistance is required in particular for the NAP preparation. Regional collaboration also remains important.

**Syria**

Under the activities of the projects of the National Action Plan to collaborate on combat desertification in Syria, awareness campaigns are undertaken. A draft national action plan that was formulated based on the inputs from experts is ready for review at the national level forum. Syria also regards the TPN4 as an important activity to contribute in the regional efforts to combat desertification.

**Turkmenistan**

The great magnitude of the population has been affected by desertification in the country. Turkmenistan has been moving forward to implement pilot projects to achieve concrete results in combating desertification.

**Uzbekistan**

Uzbekistan is severely affected by desertification. It prepared its NAP for combating desertification and land degradation. Uzbekistan facilitates the implementation of the NAP with the improvement of water resource management. The projects have been financed by the government and have been successful. However, it requires further financial resources for this purpose.

**Viet Nam, Socialist Republic of**

The Ministry of Agriculture and Rural Development formulated the first draft of the NAP in June this year. With the support of Japan, Socialist Republic of Viet Nam intends to promote the implementation of the project to foster reforestation to arrest sand dune movement and biomass production. The Ministry of Agriculture also promotes partnership building within the country to support reforestation activities in the country.

**Netherlands**

Netherlands provides developing countries with assistance at the level of 0.8% of its GDP of which a significant part is spent to improve environmental protection. Efforts will be made to mainstream the activities to combat desertification in the development assistance programmes in a decentralized manner. Networks will also have to be developed among institutes, scientists and stakeholders within the Netherlands as well as between the Office of Foreign Affairs and the Netherlands embassies in affected countries. Netherlands intends to conclude agreements with the secretariats of CCD, UNFCCC and CBD to promote their synergistic implementation. Netherlands also works with the UNDP/UNSO in the areas of combating desertification.

**NGO (EPF of Japan**)

Limited public awareness on desertification and its impacts remains to be an obstacle in promoting activities to combat desertification. Environmental education and awareness raising campaigns are part of the responses that EPF contemplates to promote. EPF promotes personnel exchanges such as group leaders and teachers between Japan and the countries affected by desertification.

**Global Mechanism (GM)**

The GM has been supporting activities at national, sub-regional and regional levels, particularly with the relation to partnership building and resource mobilization. The GM is committed to working with all country Parties to the Convention, and as such is willing to continue its work with affected country Parties of the Asia region in facilitating the implementation of the Convention.

**3.4.1.3 Action programme to Combat Desertification in Latin America and Caribbean**

Ecuador has submitted its National action programme.

**3.4.1.4 Action Programme to Combat Desertification in Northern Mediterranean.**

Greece, Italy and Portugal have already submitted their National Action programme to the CCD secretariat.

**National Action Programmes (Naps) Of the Group of Northern Mediterranean Annex IV Countries of the UNCCD**

National Programmes to combat drought and desertification have already been presented by the five Parties of the Northern Mediterranean annex countries, namely: Portugal, Italy, Spain, Greece and Turkey.

The progress made in drawing up and implementing National Action Programmes in countries in the group is as follows:

**Greece**

The Greek National Committee for Combating Desertification was established by the ministerial decisions of the Ministry of Agriculture. Its members include officials of the Ministers of Agriculture, Environment, Public Works, Development, Economy and Foreign Affairs, and delegates from universities, research institutes and NGOs. The Committee has prepared a Provisional National Action Plan on the basis of documents and suggestions submitted by four working groups of experts. The Plan was distributed to concerned public and private organisations and the media. It also has been presented at municipal meetings. The main components of the NAP are follows: desertification processes in Greece; general measures on desertification prevention and mitigation; measures concerning the agricultural sector; measures related to the forest sector; measures concerning fauna; measures concerning the stock-raising sector; measures concerning the water resources sector; and measures concerning the socio-economic sector.

The Committee has published a report on drought and its mitigation in Greece. The National Report on the implementation of the Convention has been prepared and submitted to the UNCCD. The basic conclusions which was set up by preliminary work can be summarised as follows: Desertification is a real threat and areas under various degree of desertification threat occupy approximately 1/3 of the country; Mitigation efforts so far have been insufficient: There is an urgent need for serious legal and institutional changes; There are serious knowledge gaps concerning factors, processes and mitigation of desertification.

**Italy**

The Italian President of the Council has instituted the National Committee to combat drought and desertification in 1997. Its most important activity has been the involvement of different institutions and the organisations to co-ordinate initiatives to combat drought and land degradation taking in account the social, economic, energetic, environmental and cultural aspects.

The National Action Programme to combat drought and desertification in Italy was approved in 1999, and it refers to: soil protection; sustainable management of water resource; impact reduction of the productive activities; territorial re-balance; information, training and research.

The information training and research programme to combat drought and desertification is deeply involved with the National Research Plan for the protection of climate. The Italian regions play a fundamental role in the implementation of the NAP due to administrative decentralisation, i.e. planning and actions are performed locally and not centrally.

The cooperation on objectives with developing countries is an integral part of the Italian NAP, and actions to combat desertification will be one of the priorities of Italian cooperation, which is aimed at working with the countries affected, in conjunction with other donor countries, to provide the technical and financial support required to implement the NAP.

**Portugal**

A National Coordination Group was created in 1996 to elaborate the NAP. The Group prepared a synthesis document on the causes and consequences of desertification in Portugal to give the public a scientific and technical background for discussion. Scientific Council was also created to support the National Coordination Group, so its covering areas such as Climate, soil, water, rural development, economy and sociology.

The national Action Programme to Combat Desertification was approved in 1998 as a result of a widespread participation of governmental and non-governmental institutions, institutions of the civil service from affected regions, media, universities, environmental NGOs, and others. In support of the NAP implementation, a National Desertification Observatory was created, which will work closely with the National Committee, making possible the monitoring and the assessment of the programme's implementation.

**Spain**

A Working Group for the NAP draft preparation was constituted under the co-ordination of the Ministry of Environment. NAP draft has been already elaborated and submitted to the Spanish society for a general process of discussion. As a previous step to the discussion, amendment and approval of the draft NAP, a document of Guidelines of the National Action Programme against Desertification was prepared and approved in 2000. The consultative process is structured based in the organisation of a set of sector working groups. The representative of the administration and the civil society will form these groups of discussion. After the consultative process in these groups, the definitive document will be submitted to the Government for its approval.

The Draft NAP presents the assessment of the status of the desertification in the country and the proposals for a national policy against desertification. These proposals are the determination and delimitation of the areas for action, the coordination of related sector policies and the identification and development of set of specific actions against desertification.

**Turkey**

Immediately after becoming Party to the Convention, a National Awareness Seminar was organised in 1988 with participation from governmental and nongovernmental organisations and scientists from universities and research institutions. In recent years, Turkey have put intensive efforts to develop a National Action Programme with inclusion of information taken from the relevant governmental and non-governmental organisations, institutions and universities.

Besides the contributions from various governments, agencies and organisations, another input for the preparation and the implementation of the NAP is an UNDP umbrella project. This project aims to provide institutional framework and coordination with the Government of Turkey for the integration of environmental concerns in development policies/programmes/plans in two cross-sectoral areas: sustainable energy and atmospheric protection and combating desertification. The project will supply support for the preparation of the NAP and pilot projects for the application of the NAP.

**The Former Yugoslav Republic of Macedonia**

The most significant initiatives currently undertaken in the country are related to the preparation for ratification of the United Nations Convention to Combat Desertification. In recent years, Yugoslavia has put intensive efforts to raise awareness, create new initiatives and disseminate information about drought and desertification issues. The International Symposium "Drought and Plant Production" held in 1996, considered the various aspects of drought which is one the most frequent and the most wide spread climatic factor that limits plant production in the country, as well as in the Balkan region on the whole. In 1988, a Balkan Drought Workshop was held and discussions included the establishment of a Balkan Drought Regional Centre that would involve drought mitigation strategy and regional cooperation initiatives. Some initial steps were taken such as creating a database for meteorological, hydrological and agricultural drought research.

## 3.5 Recommendations Regarding Implementation Of Unccd And Mitigating Drought

### 3.5.1 Monitoring and assessments of drought and desertification

Realistic monitoring of drought and desertification requires homogeneous, systematic and timely observations of meteorological, climatological and hydrological parameters, in arid, semi-arid and dry sub-humid areas. WMO proposes to ensure the availability, through the WWW Global Observing System (GOS) and Global Telecommunication System (GTS), of regular and prompt assessment statements so that they can be of optimal use in drought preparedness and response actions and anti-desertification programmes.

NMHSs should strengthen many aspects of drought monitoring including: maintaining networks of meteorological, agrometeorological and hydrological stations; data collection and analysis in a timely and systematic manner; preparation of proper drought climatology for all districts of the country; dissemination of basic information; and researching the effect of agrometeorological and hydrological factors on land degradation and desertification processes. There is also a need for a global database on the frequency, intensity and duration of meteorological and hydrological drought.

### 3.5.2 Forecasting of drought

The forecasting of meteorological drought is not yet operationally possible. However, most countries issue seasonal precipitation forecasts. It is possible to minimize the adverse effects of drought by providing and using advanced information on the probable occurrence of drought and on the likely effects of drought. WMO and NMHSs should continue to search for methods for forecasting of drought and thus help in reducing human impact on the land and its resources.

### 3.5.3 Alleviating the effects of drought and combat against desertification

Meteorological, climatological and hydrological information can be used to alleviate the effects of drought as well as its effects on microclimatic conditions, desertification and land degradation. One prime requirement is the enlistment of the co-operation of the users and potential beneficiaries of meteorological, climatological and hydrological information such as engineers, agriculturalists, land use planners and managers.

Meteorological data are used to calculate the actual daily water requirements in irrigated agriculture, thus ensuring that crops receive the right amount of water needed for optimal growth without wasting water resources, and reducing the chances of desertification, land degradation, water logging and salinization through over-irrigation.

Overgrazing is one of the principal causes of land degradation in natural pastures. WMO should continue to organize roving seminars to train staff of national meteorological and livestock husbandry services in the analysis of the results of the models that exist and how to provide the technical information on the carrying capacity of pastureland based on agrometeorological data.

Land degradation through water erosion is another process contributing to desertification. One important factor affecting soil erosion is the “aggressivity” of rainfall, a combined result of certain rates of rainfall, its amount, intensity and duration. WMO should continue to organize roving seminars to train staff of NMHSs and soil-conservation services including engineering in the analysis of rainfall observations to provide the information on rainfall aggressivity, which helps them to take erosion-control measures.

### 3.5.4 Implementation of application techniques

The techniques to use meteorological and hydrological information are implemented by NMHSs jointly with the national user services concerned. For example in some countries, a small-scale pilot project should be carried out as a first step with technical assistance provided by WMO in which the effectiveness of the techniques, information and dissemination methods to ultimate users can be examined.

### 3.5.5 Research

Under the framework of the WMO Tropical Meteorology Research Programme and the Agricultural Meteorology Programme, member countries of WMO have undertaken research activities concerning the causes of desertification and drought. Possible causes of large-scale variations of the global atmospheric circulation have also been studied within the

WMO/ICSU World Climate Research Programme (WCRP). These activities should be continued and will help to understand drought and desertification under projected climate change scenarios.

### 3.5.6 Education and training activities

In addition to the activities in education and training in meteorology, hydrology, and agrometeorology, WMO should continue to organize specific training jointly with FAO and other international or regional organizations. This training should be provided through regional workshops, roving seminars and national follow-up activities (missions by consultants or seconded experts).

WMO has prepared, and should continue to prepare, training material, practical manuals, technical publications and other guidance material, including posters, for distribution to Members.

### 3.5.7 Public awareness and communication

During the coming years, WMO in collaboration with NMHSs should give increased attention to create public awareness and to communicate with a view to bridge the gap between scientific knowledge in the areas of desertification and drought and the users of meteorological, climatological and hydrological information, thereby improving environmental awareness and increased project impact. Efforts should be made to include these aspects in WMO training programmes, information and communication techniques in order to improve the dissemination of information to appropriate decision-making authorities particularly on early warnings and forecasts that affect the populations concerned. Public awareness programmes for farmers and pastoralists on improved management of land and water resources on dry land should be arranged.

### 3.5.8 Capacity building

WMO actively promotes the establishment of national agrometeorological services, which should collaborate closely with the user services, often through a formal or informal multi-disciplinary working groups and national climate committees. Its long-standing commitment to encourage collaboration between Hydrological, Meteorological and Agricultural Services also contributes to this objective. Land degradation and desertification and sustainable use of land resources also receive consideration in the work of these committees.

### 3.5.9 Combating land degradation

Proper criteria for declaring drought emergencies and triggering various mitigation and response activities should be improved. Use of agrometeorological data for effective water management to avoid salinization and water logging should also be promoted.

### 3.5.10 Develop strategies for implementation of meteorological and hydrological aspect of monitoring desertification, national development plans and environmental action plans

An organizational structure and a delivery system that assures information flow between NMHSs and other government agencies involved in the drought monitoring and mitigation should be developed. The duties and responsibilities of all agencies should be properly defined.

### 3.5.11 Comprehensive drought preparedness and drought relief scheme and drought mitigation

NMHSs should undertake research to understand the causes of drought and desertification, and develop methods for forecasting drought and provide inputs into drought preparedness and response plans, and provide early warning to decision makers, land and water users. Remote sensing data in addition to conventional data should improve the inputs. Crop specific models should be developed using GIS and (RS) data/technology. The outputs are to be used operationally for farmers' strategy planning for improving the quality and quantity of agricultural products. Food security systems, including storage and marketing facilities, should be established and strengthened.

### 3.5.12 Programmes for alternative livelihood

A conducive environment for the creation of diversified forms of alternative livelihood and income generating activities for the farmers and pastoralists should be promoted in order to alleviate poverty, increase income and reduce pressure on land and natural resources.

### 3.5.13 Integrated Approach

UNCCD programme implementation and mitigation of drought should be integrated with the national drought policy for preparedness and mitigation.

### 3.5.14 Development of an Expert System

There is the need to develop an user friendly Expert System on drought and other extreme events, which should be in a position to issue early warnings to alleviate the adverse effects of these events and also be in a position to give advisories during various crop growth stages.

## 3.6 Conclusions

- The extent to which one can cope with the effects of drought and combat desertification depends mainly on a rapid and unequivocal assessment of the past and real-time meteorological and hydrological conditions and on the issue of reliable forecasts. This can only be done when the meteorological, climatological and hydrological data and information are available and hence emphasizes the need for an efficient and reliable data gathering and monitoring network.

- WMO has been actively involved in the field of drought and desertification for more than two decades. However, the recent UNCED and its Agenda 21, Chapter 12 has given WMO and the NMHSs added responsibilities in these areas. National implementation is urgently called for in drought and desertification. WMO should also take the lead role.

- WMO should continue to promote the judicious use of the meteorological and hydrological data and information in the planning and management of agricultural and other land-use programmes, in order to minimize land degradation and desertification and provide guidance material on the application of the data to technical and socio-economic development projects.

- Under the leadership of WMO, most of the countries affected by desertification have either implemented their National Action Programme or are in the process of implementing the same. However, some of the countries have expressed their views to seek support from the international community for funding a major part of the investments required for the formulation and implementation of specific activities envisaged under the programme.

- It is expected that both WMO and the NMHSs will strive their best in implementing the drought and desertification programme.

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## CHAPTER 4

# ACTIONS TO BE TAKEN BY THE NATIONAL METEOROLOGICAL AND HYDROLOGICAL SERVICES FOR THE UNITED NATIONS CONVENTION TO COMBAT DESERTIFICATION

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## 4.1 General

The World Meteorological Organization (WMO) and the National Meteorological and Hydrological Services (NMHSs) have been involved for many years with the question of desertification and the linkages between climate change/variability and drought. Over time this has resulted in activities under the various WMO programmes, particularly under Agricultural Meteorology programme and the Hydrology and Water Resources programme. The United Nations Convention to Combat Drought and Desertification (UNCCD) has demonstrated the importance of this issue to many countries, identifying the role which the NMHSs and WMO can play in the efforts to achieve the convention's ultimate objective. In this regard therefore, several articles and topics mentioned in the UNCCD, in particular articles 10 and 16 to 19 are directed to WMO and the NMHSs.

These topics include:

i) The promotion of systematic observation, collection, analysis and exchange of meteorological, climatological and hydrological data and information;

ii) Drought planning, preparedness and management;

iii) Research into causes and effects of drought and climate variations as well as the possibility of long-term climate prediction with a view to providing early warning of drought;

iv) Strengthening of hydrological and meteorological services;

v) Transfer of knowledge and technology;

vi) Capacity building in the relevant fields of drought and climate, education and public awareness;

## 4.2 Some Activities At The International, Regional And National Levels

Article 16 of the UNCCD states, " The Parties agree, according to their respective capabilities, to integrate and coordinate the collection, analysis and exchange of relevant short/long term data and information, in order to ensure systematic observation of land degradation in affected areas and to better understand and assess the processes and effects of drought and desertification". This would help to accomplish, inter alia, early warning and advance planning for periods of adverse climatic variations in a form suited for practical applications by users at all levels, including local populations. The UNCCD Conference of Parties at the Fifth session (COP-5) held in Geneva from 2-4 October 2001, reviewed and elaborated the following technical topics related to Early Warning Systems (EWSs):

1) Critical analysis of the performance of early warning and monitoring and assessment systems, linking traditional knowledge and early warning systems, especially in the

areas of the collection of data, dissemination of information and measuring for drought preparedness.

2) Methods for and approaches to the prediction of drought and monitoring of desertification, particularly the method of analyzing vulnerability to drought and desertification, especially at the local, sub-national and national levels, with special regard to new technological developments

3) Mechanisms to facilitate an exchange of information between scientific and technological institutions, in particular focusing on national and sub-regional networks on the prediction of drought and monitoring of desertification,

4) More detailed measures for drought and desertification preparedness, in cooperation with the approaches, from hazard protection to risk management, adopted by the International Strategy for Disaster Reduction (ISDR), which replaced the IDNDR in 1999.

Recognizing the importance of building on existing operational early warning systems for drought and food security, which have been operational for over 20 years, COP-5 noted several positive developments. These include improvements in data collection and analysis using remote sensing and Geographic Information Systems (GIS), in addition to conventional methods. COP-5 also pointed out that major problems continue to retard the effectiveness of some of these systems. These include the following among others:

a) Weak institutional arrangements: weakness in EWSs information dissemination and use;

b) Lack of proper co-ordination among stakeholders;

c) Untimely release of Early Warning results;

d) Lack of trained personnel;

e) Insufficient use of information on drought and desertification in the national planning processes.

The UNCCD further agreed that the existing early warning and monitoring and assessment systems should converge into a complementary framework in the future, thereby using the same institutional arrangements. Similar databases and indicators stress the importance of these conceptual and operational issues of EWSs for improving their performance and cost-effectiveness.

The main point to be noted is the UNCCD's goal of moving from short-term disaster protection approaches in areas of drought and desertification, to risk management strategies, which focus on disaster prevention in the long-term and sustainable development. This approach emphasizes the importance of involving the risk management, communication and exchange of information, methods of raising awareness, planning, and participatory monitoring and evaluation. In accordance with these principles, the EWSs should not be based entirely on scientific and technical information, but should include risk management as well.

The UNCCD also promotes sustainable development and encourages the inclusion of National Action Programmes (NAPs) in National Development Framework. The purpose of the NAPs is to identify the factors contributing to desertification and also the practical measures necessary to combat desertification and mitigate the effects of drought. Consequently, national action programmes constitute the fundamental framework for desertification preparedness. In this context the UNCCD/COP-5 made a number of new recommendations that are important for the WMO and NMHSs activities. These include:

- Improving drought early warning systems by integrating land degradation information;

- Building up desertification monitoring systems on existing drought early warning systems as much as possible;

- Capitalizing on the experience of operational drought early-warning systems in using remote sensing techniques to monitor indicators, which are also used to assess desertification such as rainfall, vegetation, and land, use;

- Capitalizing on remote sensing and GIS experiences and assessing desertification through a wide range of physical, biological, social, and economic indicators;

- Improving the understandability and accessibility of remote sensing products for decision-making and land use;

- Enhancing the capacities through technical assistance and training.

### 4.3 Other Activities

It is very important to note that prediction and response to drought conditions and desertification are increasingly being considered as important adaptation measures to climate variability and change, under the RIO Conference on Environment, and by the United Nations Framework Convention on Climate Change, Inter-Governmental Panel On Climate Change, World Meteorological Organization, UNEP and FAO.

On the regional level, in accordance with UNCCD regional annexes, Africa, Asia, Latin America and Caribbean, the Northern Mediterranean and Eastern and Central Europe, have been developing the regional Thematic Programme Networks (TPNs) on specific topics. The TPNs offer useful frameworks for promoting information exchange between scientific and technological institutions, in particular focusing on national and sub-regional networks, for the prediction of drought and the monitoring of desertification.

At the national level, some member countries have established NAPs, which have been set up under the UNCCD. Some of these countries have also developed drought monitoring systems as well as systems for collecting and analyzing data including developing data and information delivery systems, and training on how to use or apply products in routine decision-making.

### 4.4 Recommendations

From a long-term perspective, appropriate action-oriented NMHSs programmes should be developed to address the priority issues identified in International Conventions and be linked to existing networks and NAPs of the UNCCD. In addition to adequate participation in the preparation of integrated NAPs to combat drought and desertification in vulnerable areas, NMHSs should, with the support of WMO, ensure implementation of those programmes. The programmes include the following:

- Monitoring and strengthening the observing networks and developing early warning systems, especially in the context of enabling EWS to provide information on spatial extent of drought, duration of drought, time of occurrence of drought in relation to the crop calendar, and severity of drought. Many networks exist that monitor key meteorological elements or elements of the hydrologic system. Other physical indicators must be linked on a national basis. This is critical to ensuring comprehensive monitoring of climate and water systems. Helpful technology includes automated weather stations, soil moisture sensors and satellite data;

- Assessment of the probable frequency and severity of droughts and desertification, with provision of information adapted to users' needs;

- Providing government agencies and farm communities with appropriate meteorological and hydrological forecasts and data, and dissemination of agrometeorological data, forest and fire weather indices for use in monitoring and responding to droughts, desertification and land degradation;

- Ensuring widespread distribution of seasonal predictions, which are available through World and Regional WMO Centers;

- Improving the understanding of the physical mechanisms, especially the causes of extreme climate events as well as seasonal to inter-annual climate variations. In addition, the improvement of predictions and conversion of forecasts to management decisions that would optimize the application of meteorological and hydrological data and information to ensure preparedness, management, response and remedial actions against adverse effects of drought and desertification, and other extreme events;

- Building databases for assessing water shortages and potential impacts (e.g., precipitation, evapotranspiration, seasonal weather forecasts, soil moisture, ground water, reservoir and lake levels, etc.;

- Drawing up impact assessment methodologies;

- Establishing various medium and long-term research programs aimed at studying the weather and climate of arid, semi-arid and sub-humid and other desert-prone areas with a view to the prediction of long term trends in the general circulation, different rain-producing atmospheric disturbances, and meteorological drought, using statistical and dynamical methods.

- Promoting regional research in weather, climate and hydrology, especially on the causes and prediction of drought and on means of reducing impacts on socio-economic development, according to UNCCD National and Regional Action Programmes;

- Ensuring the necessary education and training of staff in agrometeorology and hydrology, particularly on specific techniques to predict (including different remote sensing technologies), assessing and minimizing the effects of desertification and drought;

- Increasing efforts to improve public awareness and understanding in other government agencies and economic sectors, with a view to interpreting scientific studies and predictions of drought periods and desertification, to ensuring their use to reduce adverse impacts; and

- Establishing special agrometeorological, forestry and hydrological forecasting services as required.

These activities need to be targeted towards sustainable socio-economic development objectives (in accordance with UNCCD principles). The results obtained by the NMHSs' specific programmes would make it possible to identify the best practices to combat drought and desertification in the affected areas and to improve protection and sustainable management of soil, water and forest resources.

## CHAPTER 5

# A STRUCTURE FOR AN EXPERT SYSTEM ON EXTREME METEOROLOGICAL EVENTS

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## 5.1 Introduction

Extreme meteorological events like drought, flood, heavy rains, severe thunderstorms, hailstorms, tornados, squalls, high temperature, frost, dust storms, sandstorms, etc., have adverse impact on agricultural production and livestock. They also have great socio-economic impact. National Meteorological and Hydrological and Agrometeorological services issue adverse weather bulletins and agrometeorological advisories for these extreme events. These advisories are based on meteorological, hydrological and agricultural data. Remote sensing data are also used for finalizing the advisories. These advisories are sent to the various competent authorities for activating proper warning system at various levels.

There is a need for proper expert system that should include all types of data for a particular extreme event. The Expert System should be in a position to provide information that should be user friendly A computer-based data management system and application of multi-process models in agricultural meteorology along with Geographical Information System (GIS) and remote sensing data in addition to conventional data will be useful to achieve this goal.

The Terms of Reference (d) for this section is as follows: To develop a structure for an expert system on extreme meteorological events including the timing and duration of their long term socio-economic effects and the meteorological information that can be provided to issue early warning and alleviate the effects of these events.

## 5.2 Structure of an Expert System

There have been many discussions that in order to make information on extreme meteorological events more useful, a user friendly and versatile expert system is needed. The system should provide information regarding early-warning systems. This includes efficient techniques for the management of ground-based and radar-derived agrometeorological and agronomic data and development of techniques and methods to manage remotely-sensed agrometeorological and agronomic data. GIS allows one to quickly and easy access the large volume of information associated with environmental issues, and provide a comprehensive view on advisories and bulletin by using an integrated set of data. This could help in preparation of agrometeorological information through the production of simple and easily understandable products in the agrometeorological bulletins. Provision of agrometeorological information to the user community needs a paradigm shift from data and information to advisories.

Effective agrometeorological data management strategies and tools are very useful in responding to the growing concerns of agricultural productivity, sustainability and food security. New technology on electronic communication and networks offers greater opportunity for improving data base management technologies the new technological innovations and tools should be responsive to the user needs. A clear linkage of standardized formats in a modular conceptual structure of data base management programmes is needed and that the development of techniques and services should be enhanced to make weather data and products accessible on the internet in near real time. There is a need for a greater integration of remotely-sensed data in the management of agricultural weather information. It is important to encourage the use of standardized phenological scales for various crops to establish history and pattern recognition of the carefully structured data with respect to climate variations and climate change scenarios.

The use of improved tools such as GIS and remote sensing could help in preparation of agrometeorological information through the production of simple and easily understandable products in the agrometeorological advisories. Early warning of extreme agrometeorological events is of great value for the user community and it is recommended that agrometeorological bulletins and advisories include a section to highlight such events for the users. The GIS would integrate and analyze diverse data such as climatic zones, soil types, cropping patterns, and remote sensing data like vegetation cover, land degradation, soil moisture. The system would then synthesize these data and useful information could be extracted to be able to issue suitable warnings or advisories in an user friendly manner with the help of the expert system.

Drought will be used as an example of an extreme meteorological event in order to explain further the structure and functioning of the expert system. A similar procedure can be followed for each of other extreme events.

### 5.2.1 Extreme Meteorological Events and their socio-economic effects

Drought is universally acknowledged as a phenomenon associated with scarcity of water. Although droughts are still unpredictable, they are a recurring feature of the climate. Drought varies with regards to the time of occurrence, duration, intensity, and the extent of area affected from year to year

### 5.2.2 Socio-economic Effects of Drought

Agricultural drought occurs when the rainfall and soil moisture are inadequate to meet the water requirements of crops. In dryland areas where irrigation facilities are almost non-existent, rainfall is the main source of water for various crops. The major challenge in dryland agriculture is to establish ways to minimize reductions in agricultural production through efficient soil, water, and crop management practices during the drought years. The drought conditions may lead to:

- Shortage of food production due to failure of crops;
- Shortage of fodder and drinking water for cattle, migration of livestock population, and even a decrease in the animal population;
- Shortage of resources for agricultural operations during the subsequent year as a result of decrease in animal population; and deforestation to meet the fuel shortage for cooking in rural areas because of non availability of agricultural wastes and crop residues.
- The other socio-economic implications of drought include increase in prices of essential commodities, import of food grains, distress sells of cattle, rural unemployment, malnutrition, health hazards, and depletion of assets at the farmers' level. Human and social factors aggravate the effect of drought as it takes several years for small and marginal farmers' in dryland areas to recoup the losses.

### 5.2.3 Meteorological Information to be provided to issue early warning and to alleviate the effects of drought

- Mitigation
- Preparedness
- Response

- Recovery

These have already been covered in detail in Chapter 3 of the report.

### 5.2.4 Decision making for the Expert system

There should be sufficient number of observational points in the network that should be functional and meet the need of the critical regions. The data should include rainfall, soil moisture, potential evapotranspiration, crop, weather relation, remote sensing data and information regarding type and stage of the crop various drought indices and up-to-date research findings may be included for decision making. This will be helpful for analysis and preparation of advisories and timely dissemination.

### 5.2.5 Working principle of expert system

The expert system should be interactive. It would work as per the following algorithm:

| | |
|---|---|
| **Step 1** | It will ask the user for the choice of the extreme event from the names that will be displayed on the monitor. |
| **Step 2** | After getting the response the expert system will ask to select the type of crop and its stage. |
| **Step 3** | After getting the above information will ask for the place for which advisory is sought. |
| **Step 4** | The system will find out the agriculture zoning of the place from the overlaid map of GIS. It will also check the vegetation index from the remote sensing data overlaid in the system and also calculate various indices from the climate/weather data available in the database. |
| **Step 5** | After proper analysis and using an integrated approach, the expert system will be in a position to give a proper advisory. |
| **Step 6** | Issue warnings or advisories. |
| **Step 7** | Go back to Step 1. |

Similar procedure can be used for each extreme event.

### 5.2.6 Flood and Heavy rainfall and other extreme events

The detailed information regarding extreme meteorological events have already been included in Chapter 3 of this report. The CAgM Working Group on Agrometeorological Related Extreme Events produced a technical report giving exhaustive information regarding extreme events (WMO Technical Note No. 201, 2001). For each extreme event, the database should include location, time and details about severity of the phenomenon. For example, if we consider flood, its definition varies depending upon the user’s interest (hydrological, climatological, agricultural, etc.) and also complex phenomena and are viewed in different perspectives. They occur due to a variety of causes and are subject to a variety of influences. Their incidence also varies in space and time from local to regional spatial scale, and from a few hours to several days.

A flood is broadly defined as, the condition that occur when water overflows the natural or artificial confines of a stream or other body of water, or accumulates by drainage over low-lying areas. An agriculturist's definition of a flood is not precise but is related to extensive agricultural lands being submerged under water for a length of time that results in damage to standing crops. The type of flood that occurs depends not only on the type and amount of precipitation, but also upon the antecedent conditions of the soil and the geomorphology and physiography of the region. The main types of flood are snowmelt floods, flash floods or cloudbursts, flood associated with tropical storm surge, floods due to dam failure, etc.

Data on the frequencies and duration of water levels and discharges exceeding certain thresholds are very important for design and planning. Generally the regular observational network does provide information on storm-rainfall distribution or on flood peak discharges of tributary streams. A tropical cyclone constitutes one of the most destructive natural disasters that affect many countries around the globe, causing tremendous loss of life, property, agriculture etc. The impact of tropical cyclone is greatest over coastal areas where strong winds and flooding from rainfall at the time of landfall can cause a disaster. The movement of cyclone causes a storm surge across coastal areas. Storm surge is the most devastating feature associated with a tropical cyclone. The tropical cyclone causes irreparable damage to the agriculture, ranches and forests and can cause great loss of life, especially in developing countries.

The effects of strong winds in coastal areas are seen on the trees in the coastal areas. Winds, which blow from coastal seas, spray a lot of salt on the coastal areas, making it impossible to grow crops sensitive to excessive salt. Wind effects agriculture significantly. The degree of its effect on crops depends on speed, time of occurrence and duration.

Hail causes a significant damage to agriculture, damaging agricultural crops, vineyards and fruit trees over large areas. Hail is the most detrimental to agriculture during the second half of the vegetative period of crops. Significant injury of winter cereals takes place in the maturation period.

Dust storms have exceptionally strong, sometimes disastrous effects on farmlands. The damage to crops by dust storms is recognized over West Africa, Kazakhstan, central states of North America and Canada.

For crops affected by pest and diseases, information is needed on the state and stage of plant, the availability and the release of spores, incidence and spread of infection etc. Information is also required on the hatching of various insects. Various locust species are spread among several of the world's semi-arid zones, namely Australia, Brazil, China and Africa. Desert locusts are found in the Sahel. Once a population has reached a sufficient size, they begin to move under the influence of winds until they reach an area where conditions are favorable for reproduction (moist soils and vegetation). This migration is largely controlled by agrometeorological, climatological and synoptic conditions.

Agriculture depends on the climate of a particular region. Each plant has its own climatic requirements for growth and development and any large deviation from it exerts negative influence. Extreme temperature values, which are very low below the threshold value, or very high above the threshold value are hazardous to plant development and growth.

Fires over large areas, which are very common in arid regions of the world, often result in considerable loss of human lives, vegetation, crops, livestock and man made structures. Fires are sometimes a cause of desertification in arid and semi-arid areas. Intensive wood fires may destroy the soil cover by burning the debris layer and organic matter in the upper horizon, resulting in the elimination of soil fauna and subsequently in water and wind erosion. Any change in the vegetative cover due to fire may also lead to changes in the microclimatic conditions of the ecosystem, which in turn has an effect on the intensity of water and wind erosion, thus causing great damage to the fertile layer.

The database in extreme events should contain the name of the event, type of the event, location of the event, timing of event, links to other events, etc. The basic components of the databases should have descriptions of the long term effects including recovery, description of the extreme factor, impact assessment, production loss, environmental loses etc. Thus each extreme event has adverse impact on agricultural production. The expert system would help provide risk assessments of potential crop damage, warnings, and advisories and provide user-friendly bulletins for the users.

## 5.3 Conclusions

1) All information utilized for issuing warning and advisories should be included and suitable integrated software can be developed for the expert system for each extreme event. The database should include location, time, and severity of the phenomenon and the quantitative estimate of damage or injury.

*2)* The first and the most basic requirement in agrometeorological hazard assessment for extreme events is an adequate database. If sufficient quality data are available, it may be feasible to estimate the risk in the extreme events in quantitative terms. An overall assessment will include information not only on meteorological and hydrological aspects, but also on social, economic, geographical and other factors.

*3)* The emotional shock of disaster, the death or injury of family members, the separation of families, changes in living accommodation, the burden of hardship from material loses, physical handicap resulting from injury and the loss of income or employment all may create socio-economic problems and affect the ability of an individual or family to recover. The agencies concerned must be conscious of the need to deal with such problems.

## 5.4 References

WMO. 2001. CAgM working group on Agrometeorology related to extreme events. WMO – Tech note No. 201, World Meteorological Organization, Geneva Switzerland.

# CHAPTER 6

# CONCLUSIONS AND RECOMMENDATIONS

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## 6.1 Conclusions

WMO's role in the implementation of the UNCCD continues to be of paramount importance in view of the fact that realistic monitoring of drought, desertification and other extreme events requires homogeneous systematic and timely observations of meteorological, climatological and hydrological parameters, in the arid, semi-arid and dry sub-humid areas.

There is increased scientific knowledge and information on ways of assessing the different aspects of desertification and drought and other extreme events. Enhancing capabilities in adapting and applying the methods available and in improving the understandability and accessibility to modern technology such as remote sensing would contribute significantly to the combat against drought and desertification.

Given that forecasting of drought is not yet operationally possible, it is vital that WMO and its Members continue the search for methods for forecasting of drought and thus help in reducing human impact on land and its resource.

Significant developments have been noted regarding existing operational Early Warning Systems for drought and food security. However major setbacks including weak institutional arrangements, lack of coordination among stakeholders, untimely release of early warnings and advisories continue to hinder the effectiveness of these systems.

Though drought is not a consecutive phenomenon, the frequency of drought occurrences and the extent of desertification have increased considerably in recent years especially in the arid and semi-arid areas of the world. This is mainly due to global climate change and anthropogenic factors. To deal with the latter, concentrated efforts should be made to further promote public awareness and information exchange at the level of the users, participatory mitigation measures such as afforestation programmes should be practiced by the countries affected and finally, appropriate land use policies should be developed in countries where there are no such policies to minimize the impacts of drought and desertification.

## 6.2 Recommendations

The following are the recommendations of the working group:

- In the light of the definition of desertification in the UNCCD as land degradation resulting from various factors, including climatic variations, there is a need for creating a global database on the frequency, intensity and duration of meteorological droughts, at least for the past 50 years. Such a global database would help to understand the role of climatic factors in land degradation at national, regional and international levels. It is recommended that CAgM appoint a group of experts to discuss the structure of such a global database and develop and distribute appropriate software for creation of national databases by agrometeorological Services of Members and subsequently create a global database.

- In order to enhance the value of the database on meteorological droughts described above it is important that a similar database on hydrological droughts and a database on the impacts of meteorological and hydrological droughts on agriculture, livestock and forestry be developed. It is recommended that the Commission on Hydrology (CHy) examines the issue of database on hydrological droughts and that FAO and other appropriate international organizations examine the creation of the database on the impacts of droughts on agriculture, livestock and forestry.

- National Meteorological and Hydrological Services and regional centres such as ACMAD and DMCs should provide timely information on the onset, spread and intensity of extreme events while ensuring that the collection, analysis and exchange of information addresses the needs of local communities and those of decision makers, with a view to resolving specific problems, and that local communities are involved in these activities.

- In the provision of information on the incidence of extreme events, it will be useful to also provide guidance on the likely yield losses of different crops and forestry and livestock losses.

- In order to enhance the implementation of the United Nations Convention to Combat Desertification (UNCCD), agrometeorological services should take an active role in strengthening drought preparedness and management strategies, including drought contingency plans at the local, national, sub-regional and regional levels, which take into consideration seasonal to interannual climate predictions.

- It is recommended that agrometeorological services of Members participate actively in drought preparedness and drought management plans at the national level by:

  (a) Preparing a well-formulated list of hazardous extreme events;

  (b) Providing accurate definitions of each of these extreme events;

  (c) Using agroclimatological zoning approaches;

  (d) Defining critical phases of crop growth that are sensitive to drought and their durations for different crops that are likely to be affected by droughts;

  (e) Developing an appropriate system of information communication ie. from observation point to data centres and then to national centres where data are processed;

  (f) Clearly stating the action that is needed to reduce damage during the times when extreme events occur and clearly differentiating it from routine information weather;

  (g) Developing a document that sets out clearly the order of different actions to be taken by NMHSs should an extreme occur and clearly outlines the responsibilities of individual units;

  (h) Promoting the use of long-range climate forecasts in agriculture, forestry and livestock.

- NMHSs and regional centres should carry out studies on the climatology of various extreme events, which affect agriculture and their impacts.

- It is recommended that scientific studies be broadened at the national and regional levels (WMO Regions) regarding the development of methods, techniques and forecasts (in particular on the medium and long-range) related to hazardous hydrometeorological events such as: drought, hot and dry winds, flows, storms, etc., as well as desertification, degradation of biodiversity, etc.

- In order to obtain an objective assessment of the consequences of severe hydrometeorological events it is recommended that multidisciplinary committees comprising NMHSs, agricultural agencies and insurance companies be organized at the national level.

- It is vital that an expert system on extreme meteorological events and meteorological information (that is needed to issue early warning and alleviate the effects of these events) be created as soon as possible for use by NMHSs. It is recommended that CAgM at the next intersessional period take appropriate measures to develop and distribute widely such an expert system.

- WMO, in collaboration with other national, regional and international organizations promotes the judicious use of the meteorological and hydrological data and information in the planning and management of agricultural and other land-use programmes, in order to minimize land degradation and desertification and provide guidance material on the application of the data to technical and socio-economic development projects.

- WMO continues to promote research in climate variability and the occurrence of drought, including large-scale global atmospheric circulation with a view to a better understanding of the climate.

- WMO promotes education and training programmes and capacity building that will create public awareness about drought and desertification issues and preparedness and response through remedial actions, in collaboration with other regional and international organizations as appropriate.

- WMO should encourage Member States who are threatened by drought and desertification and who have not yet ratified UNCCD to do so as soon as possible.

## ANNEX

### National Action Programme Of India

India became a signatory to the UNCCD on 14th October 1994 and it came into effect on 17th March 1997. One of the obligations of all developing country Parties to the Convention, including India, is to prepare the National Action Programme to Combat Desertification and to mitigate the effects of drought. The Ministry of Environment and Forests, as the National Focal Point for the implementation of the Convention, initiated the process of preparation of National Action Programme through the setting up of a High-Level National Steering Committee (NSC) in July 1999. The NSC decided to constitute four Working Groups (WG) on various issues relevant to desertification. These are:

- WG#1- Desertification Monitoring and Assessment,
- WG#2- Sustainable Land Use Practices for Combating Desertification,
- WG# 3 - Local Area Development Programme, and
- WG# 4 - Policy and Institutional Issues.

The National Action Programme was formulated through a wide cross-sectoral consultative process involving a large number of Ministries, Departments and organizations at the Central and State levels. NGOs and grass roots level organizations were also consulted for their views and specific suggestions at various stages of the programme formulation.

The National Action Programme seeks the support from the international community for funding a major part of the investment required for the formulation and implementation of specific activities envisaged under the Programme.

In India, from a total surface area of 328 mha, nearly 173.6 mha is classified as degraded land. The total population is 1012 million, as per 2000-2001 census of India. India has a diverse agro-climate, topography and soil types on the basis of which it has been categorized into various regions. A major part of the country is rainfed. Rainfall, therefore, constitutes an important parameter in the classification of the country into various regions for the purpose of planning.

### Dryland (Arid, Semi-Arid, Dry Sub-Humid) Regions Of India

The arid, semi-arid and dry sub-humid regions constituting the 'drylands' cover about 228.3 mha (69.6%) of the total land area (328 mha) of the country. A large number of States fall within the drylands. However, almost the entire North-Eastern Region covering the States of Assam, Meghalaya, Nagaland, Tripura, Manipur, Mizoram, Sikkim and Arunachal Pradesh, and the State of Uttaranchal in North India do not fall within the dryland region. In addition, parts of Jammu & Kashmir, parts of Himachal Pradesh, coastal areas of Karnataka, Maharashtra, Goa, and major parts of the States of Kerala, Orissa, West Bengal and the Islands of Andaman & Nicobar and Lakshwadeep and Minicoy, which are predominantly humid/per humid also do not fall within the dryland regions. It is however important to note that land degradation is a serious problem even in the humid/sub-humid regions of the country, particularly in the hilly regions, where the main process of land degradation is water erosion resulting in high losses of topsoil and fertility. Major parts of the dryland regions in the country are rainfed, while some are irrigated. The country's programmes are therefore, not targeted to addressing land degradation in the drylands alone, although special emphasis is given to rainfed regions.

### (I) Arid - The Great Indian Thar Desert

The Great Indian Desert also known as the Thar Desert, lies in Western Rajasthan and comprises of an area of 196,150 sq. km. In addition, an area of about 15.2 mha of cold desert is located in Jammu and Kashmir and the Lahul-Spiti region in Himachal Pradesh.

**Table 1. General Information on Thar Desert**

| Population engaged in (in million) | 1980 | 1990 |
|---|---|---|
| Agriculture | 13.48 | 17.50 |
| Animal Husbandry | 2.84 | 3.20 |
| Household Industries | 0.13 | 0.15 |

Population engaged in (in million) 1980 1990
Agriculture 13.48 17.50
Animal Husbandry 2.84 3.20
Household Industries 0.13 0.15

**Table 2. Land use in the 'Thar' Desert**

| **Area in km$^2$** | **1980** | **1990** | **1993** |
|---|---|---|---|
| Desert Area of no or minimal value | - | - | 4270 |
| Area in danger of desertification | - | - | 134300 |
| Cultivated area | 128300 | 131670 | 123378 |
| Pastureland | 59760 | 53800 | 52284 |
| Others | 2840 | 3880 | 4285 |

Source: Report of Ministry of External Affairs (MEA) submitted to the Commission of Sustainable Development (CSD) in 1995.

### (II) Semi-Arid

About 123.4 mha (37.6%) of the country's geographical area consists of the semi-arid region. The semiarid tropical areas (SAT) can be further classified into dry and wet. In the SAT, the crops and cropping systems are quite diverse depending on the soil type and the length of growing season. Sorghum, cotton, soybean, groundnut and pulses are the major crops grown in this zone.

### (III) Dry Sub-Humid

About 54.1 mha (16.5%) of the country's geographical area falls within the dry sub-humid region. The dry sub-humid region receives fairly high rainfall providing ample opportunities for water harvesting. This can be effectively integrated with the safe disposal of excess runoff to overcome water congestion of soils for crops (other than rice). Rainfed rice is the predominant crop followed by pulses, oilseeds and to some extent, vegetables. Fruit crops particularly in Orissa are also an important component of the production system.

A close study of the present land-use pattern and the trends during recent years will help to suggest the scope for planned shifts in the pattern.

## Need for Soil and Land Degradation Information

The natural resources of a country are of primary importance for the sustainability of ecosystems, conservation of natural resources and for optimal productivity of the land. Soils are highly vulnerable to degradation and nature takes a long time (300-1000 years) to form an inch of the topsoil mainly due to combined effects of climate, vegetation, organisms, topography, and parent materials. Soils perform many functions such as biomass production, habitat for organisms, and as one of the functional units for ecosystems. Sustaining and supporting life on land depends primarily on the health and purity of soils to produce biomass and to absorb and decompose toxins. The impairment in any soil function reduces their quality, value and capacity to provide the basic necessities to support ecosystems. Hence, comprehensive information on soil resources in terms of soil types, their spatial distribution, and for addressing the processes of degradation and various issues relating to soil conservation such as rainfed farming, soil conservation in catchment areas, and watershed management (MOA 1999). Therefore, the management of soil resources is essential for both continued agricultural productivity and protection for the environment. Lack of adequate information on soil resources and improper land use planning has resulted in many of the present problems of land degradation and desertification.

## Use of Remote Sensing in Desertification Monitoring & Assessment

For taking suitable remedial measures such as reclamation of degraded land, and proper utilization of wastelands for productive purposes, it is necessary to obtain timely and accurate information regarding the location and extent of wastelands. In 1985, the National Wastelands Development Board (NWDB) commissioned the National Remote Sensing Agency (NRSA) to prepare a wasteland map of the country as well as for each State. The National Wastelands Identification Project was started in 1986 in technical collaboration with the Department of Space and Survey of India. A total of 146 districts were showing more than 15% of their area as wastelands.

Remote sensing techniques being used in Natural Resource Management by the National Remote Sensing Agency (NRSA), India are listed below:

## Use of Remote Sensing in Natural Resource Management (NRM)

- Sustainable Land Management.
- Desertification Monitoring & Assessment.
- Watershed Management.
- Natural Disaster Management.
- Drought Early Warning, Preparedness and Management.
- Monitoring and Mapping of Degraded Lands.
- Land use/Land cover Changes.
- Management of Water Resources.

*Source: NRSA, 1999*

## Drought and Drought Monitoring

**Drought:** Drought is understood as a period of extreme dryness due to lack of sufficient water. India has been divided into 35 meteorological sub-divisions. A meteorological sub-division is considered to be affected by drought if it receives total southwest monsoon rainfall, less than 75% of the normal seasonal rainfall. Further, it is classified as moderate and severe if the seasonal rainfall deficiency is between 26 to 50% and more than 50% of the normal respectively. A year is considered to be a drought year in case the area affected by one of the above two criteria for drought either individually or collectively is more than 20% of the total area of the country. Based on the data collected using the above criteria, it has been noticed that there were 26 drought years since 1875.

1918 was one of the worst drought years when more than 70% of the country was facing drought (Sinha Ray and Shewale, 2000). During 1965-66 also, a widespread failure of the summer monsoon rainfall led to prolong and severe drought conditions over considerable part of the country. As a result of severe crop failure, the Planning Commission recommended the study of droughts in India and to develop methods for forecasting crop-yield. This resulted in the establishment of a Drought Research Unit at the India Meteorological Department (IMD), Pune in June 1967 for undertaking agro-climatic study of droughts, and the formulation of monthly forecasts of overall food production based on meteorological data. In India, drought occurs more frequently in the arid and semi-arid regions, where the coefficient of variation of annual rainfall is high. In the arid areas with mean annual rainfall generally less than 400 mm, drought is a very frequent phenomenon. In semi-arid regions, where the mean annual rainfall varies from 400 to 1000 mm, droughts occur in 40 to 60% of the years either due to deficit in seasonal rainfall during the main cropping season or due to inadequate soil-moisture availability during the period of prolonged dry spells between two successive spells of rainfall. The regions of the country can also be categorized as drought prone based on the frequency of drought by the region. For example, western parts of West Rajasthan and Kutch are chronically drought affected. Other areas under dry farming can come under drought areas.

## Drought Early Warning

Early warning systems (EWS) related to drought and crop/vegetation assessment in the country have been in operation at national as well as at the state level through state departments and agencies. Early warnings on drought are systematically issued by the IMD and the Department of Agriculture, Ministry of Agriculture, Government of India. Many of the state governments have their own EWS. For example, Gujarat has a system called “Weather Watch Group”, which draws experts and information from different departments/agencies and provides early warning.

Rainfall is the best indicator of drought over an area. IMD has a large amount of rainfall data since 1875. Based on these data, drought intensities and drought prone areas have been identified on all meteorological sub-divisions across the country. It is difficult to predict drought well in advance to help the affected regions for implementation of appropriate drought mitigation measures. As the occurrence of drought depends principally on the amount of rainfall, the aim should be to forecast the deficient monsoon season rainfall and its distribution. The India meteorological Department (IMD) is the principal organization, which gives seasonal forecasts of rainfall. To monitor and assess agricultural drought, a Drought Research Unit (DRU) working under the IMD has developed aridity indices based on rainfall, potential and actual evapotranspiration, taking into account soil moisture and using water budgeting method. The DRU of IMD prepares Aridity Anomaly Maps for forecasting drought, which provides a useful indicator of dry conditions/ onset of drought during the rainy season.

## Agriculture and Meteorology

A division of Agricultural Meteorology has been functioning in the IMD since 1932 with the main objective to apply meteorological knowledge to agricultural activities. By analyzing the 70 years of rainfall records of about 2000 stations, the periods and amounts of ‘assured rainfall’ have been computed for various regions over India. This information is helpful in selecting appropriate crops for various regions, determining the favorable growing seasons for rain fed crops and selecting drought - tolerant crop. Indian agriculture is strongly dependent on the monsoon activity, with about 80% of the country being rainfed. Dry tract farming is an area where the annual rainfall is between 400 to 1000 mm and with practically no irrigation facility and the importance of weather to agriculture is therefore of utmost importance in deciding its success or failure. The use of weather information for agriculture led to the development of agrometerological concepts relating weather conditions and events to plant growth, crop microclimate, and production selection of crop species.

IMD provides the following services on weather to farmers:

**Agro-meteorological Advisory Service (AAS) of IMD (Farmers Weather Bulletin)**

Farmers can make immediate and tactical decisions in their day-to-day fieldwork if they get forecasts 7 to 10 days in advance. The issue of operational Farmers' Bulletins commenced in 1945 from its various regional and state meteorological centers. Weather services to farmers are one of the important operational services rendered by IMD which started in 1945. In order have a more effective and purposeful service to the farmers, the Agro-meteorological Advisory Service (AAS) was started by IMD in 1975, in co-ordination with State Agricultural Departments. Under the AAS, forecast bulletins are issued once a week from 11 Meteorological Centers (MCs) and twice a week from Regional Centers (RCs) in the country. The National Commission for Agriculture recommended in 1976 that weather bulletins for farmers should include advice on agricultural operations and should be prepared after joint discussions between weather forecasting officer and agricultural officer from the local office of agricultural department to make them purposeful. At present agricultural advisories based on prevailing and expected weather conditions are being provided through 17 AAS units of IMD functioning at Ahmedabad, Bangalore, Bhopal, Bhubaneshwar, Kolkata, Chandigarh, Chennai, New Delhi, Gangtok, Guwahati, Hyderabad, Jaipur, Lucknow, Patna, Pune, Srinagar, and Trivandrum. In addition to these services, IMD also provides crop weather outlooks, and crop yield forecast for planners. These bulletins indicate the onset of rains, probable rainfall intensity and duration, weak or break monsoon conditions, occurrence of frost, hail, squall etc. These also contain daily district-wise forecasts of weather including heavy rainfall warnings and low temperature, which are injurious to plants. The advisory bulletins take into consideration the state and stage of crops, agricultural operations in progress, prevalence of pests and diseases, soil moisture studies in conjunction with the prevailing weather and weather expected in the next 24 hours. Routine weekly/bi-weekly discussions are arranged between the Agricultural Meteorologists of the Department and Agricultural officers of the concerned State Departments for preparation of these bulletins. The bulletins contain specific advice for the farmers to protect their field crop from adverse weather or to make best use of prevailing favorable weather to increase production. These bulletins are issued twice daily for broadcast in different regional languages through All India Radio Stations (Sinha Ray, 2000).

**Flood Control**

The IMD, with the purpose of reducing soil erosion, has also established ten Flood Meteorological Offices at Lucknow, Agra, Asansol, Hyderabad, Patna, Guwahati, Bubaneshwar, New Delhi, Jalpiguri, and Ahmedabad. The floods often cause erosion of fertile soil and lead to land degradation. The purpose of these offices is to give flood warnings and forecast.

**National Centre for Medium Range Weather Forecasting (NCMRWF)**

The Government of India approved a project of National Centre for Medium Range Weather Forecasting (NCMRWF) in 1989 with the prime objectives of developing operational capability of medium-range (3 to 10 days in advance) weather forecasting capability and providing agrometeorological advisory services for each of 127 agroclimatic zones of the country. The Department of Science & Technology is implementing the Project mainly in collaboration with IMD, ICAR and the state agricultural universities. The agrometeorological advisory component is being implemented through agricultural research and extension stations established in different agroclimatic zones and are functioning under ICAR and the State Agricultural Universities (SAUs). In order to evolve a more viable structure, establishment of experimental AAS units was begun in 1993 has now been extended to 82 agroclimatic zones of the country. NCMRWF disseminates weather forecasts (currently 4 days) to these units for their respective zones (through VSAT, fax or phone) and agricultural scientists of the concerned stations prepare advisories for the farmers which are then disseminated to the users through mass media (local newspapers radio, and TV), personal contact, and extension personnel. These bulletins are issued twice a week at most of these stations. AAS units also provide local agrometerological data and farmers feedback on the advisories.

**Use of Remote Sensing Applications**

The Department of Space of the Government of India uses remote sensing data for early warning under NADAMS. IRS-WiFS data and NOAA-AVHRR data are being used for issuing early warnings in the country. Two band data is used to generate Normalized Difference Vegetation Index (NDVI). These NDVI images are composited over every fortnight to provide early warnings on the crop condition and general agricultural drought through bulletins. At present, eleven states of the country- Andhra Pradesh, Bihar, Gujarat, Haryana, Karnataka, Madhya Pradesh, Maharashtra, Orissa, Rajasthan, Tamil Nadu, and Uttar Pradesh are covered under the programme of early warnings and bulletins giving the district-wise status are issued from August to October. These bulletins are sent to the concerned state government (Agricultural Department and Relief Commissioner).

**Factors, Processes and Impacts of Desertification in India**

Desertification is land degradation in the drylands due to a number of factors including climatic variations and human activities. Man-made causes include, expansion of agriculture and unsustainable agricultural practices such as over cultivation, overuse of nutrient inputs, poor irrigation practices, deforestation and overgrazing. Population pressures, social conflicts and disruption of social systems, inappropriate government policies and poverty often induce such unsustainable resource management practices. People affected by desertification often need to draw on their limited assets in order to survive, which accentuates their poverty. This constitutes a vicious cycle linking deteriorating natural resources to deteriorating livelihoods as people need to encroach further on fragile soils, sparse vegetation and limited water resources to meet their basic needs for food, shelter and livelihood. Many of the complex causal relationships are not fully under-stood. It is often very difficult to separate the causes from the effects.

**Unsustainable Agricultural Practices**

Unsustainable agricultural practices include excessive use of fertilizers, pesticides, frequent cropping patterns, inappropriate technologies, or choice of crops/ plants. Non-point sources of pollution are a problem in areas with wide application of fertilizers.

**Unsustainable Water Management Practices**

Poor and inefficient irrigation practices, such as the over extraction of ground water, particularly in the coastal regions resulting in saline intrusion into aquifers are some of major unsustainable water management practices which has led to problems of desertification in such regions. Over extraction of groundwater without compensatory recharge has led to the depletion of groundwater table.

**Land Use changes**

Diversion of land from forestry and agriculture to other land uses has been one of the principal causes of land degradation. Diversion of forest lands for non-forestry purposes was curtailed with the enactment of Forest (Conservation) Act in 1980 with the objective of arresting the diversion of forest land for non-forestry purposes. Wherever diversion of forest land is unavoidable, for instance for developmental projects (energy, infrastructure, transportation, etc.) compensatory afforestation on non-forest land is mandatory. However, loss of prime forests could have an impact in the long-term stability of the forests. The other land use change is due to encroachment, through violation of forest boundaries and illegal farming in forests. Due to their illegal status, they are unable to receive extension services and improve their farming systems, further accelerating land degradation. The encroachment of forest land, and the socio-economic pressure to regularize them, continues to be the most pernicious problem of forest protection.

**Deforestation**

It is difficult to separate the causes from the effects of deforestation and forest degradation. Some direct causes of deforestation are land clearances for agriculture (including shifting cultivation), other land use changes including unplanned urbanization, land transfers, different forms of encroachments, over-grazing, uncontrolled and wasteful logging, illegal felling, and excessive fuel wood collection.

**Shifting Cultivation**

Shifting cultivation refers to a farming system in which a short but variable cultivation phase (on slash-and-burn land) alternates with a long and equally variable fallow period. With increasing pressure on forest lands, and shortening on the fallow period, this practice of farming which was once in balance with nature has become disorderly causing considerable damage to the regeneration of forests cleared in this manner. Deleterious effects include deforestation, spread of sterile grassland, soil erosion, and loss of productivity of forest and agricultural land.

**Collection of Fuel wood**

Consumption of timber and fuel wood in India is considerably (4 to 5 times higher) than what can sustainably be removed from the forests. Much of the rural energy for cooking comes from collection of fuel wood from forests. In 1990, the estimated removal of fuel wood was about 250 million cu. cm, which has been estimated to increase to 310 million cu.cm by 2000 (MOEF, 1999). This contributes to the overall deterioration of the quality, stocking condition and productivity of the forest ultimately leading to deforestation and degradation.

**Grazing in Forest Land**

Forest lands are an important source of grazing and fodder in the absence of adequate pastureland and a viable policy of fodder development. It is estimated that that over 270 million livestock consisting of over 50% of India's livestock graze in the forests (NFAP, 1999). These include traditional ethnic sedentary village livestock and migratory animals herded by ethnic grazers. Additionally grazers collect an estimated 175 to 200 million tonnes of green fodder annually. This results in overgrazing and over-extraction of green fodder, leading to forest degradation through damages to regeneration and compaction of soil. A sample survey of Forest Survey of India (FSI) estimates that impact of grazing affects 78% of the country's forests, of which 18% suffers high incidence and 31% medium incidence. Grazing occurs even in protected areas. In another survey, 67% of the national parks and 83% of the wildlife sanctuaries surveyed reported grazing incidences.

**Forest fires**

Forest fires annually affect about 35 mha of forest area. The environmental impacts of these depend on forest type and the nature and severity of damage depend on the type of forest, availability of fuel and climatic factors.

**Industrial Activities**

Industrial effluents and mining are also gradually emerging as important agents of desertification. In most cases the root of the problem is the mismanagement by land users and poor implementation of pollution control regulations. Industrial effluents and their discharge into inland waters and irrigation with poor quality water in many parts of the country are degrading stretches of land in some of the states. Industrial effluents from textile, printing and dyeing industry and their discharge into streams and rivers, which are non-perennial with no flow during the dry season severely contaminates them. Use of such waters for irrigation has affected agricultural land as well. Besides productivity decline or complete loss, progressive degeneration of bio-diversity is yet another major consequence of land degradation. In many areas the groundwater has been polluted. Some of the most affected areas are found in Pali, Jodhpur and Balotra in Rajasthan due to the dyeing industry. Bicchri is also affected in Rajasthan due to the discharge of highly toxic effluents. Large tracts of land have been rendered unfit in industrial estates such as Vapi, Ankleshwar in Gujarat and Pattancheru and Bollaram in Andhra Pradesh which houses a large number of chemical manufacturing units. Vaniyambadi in Tamil Nadu is affected due to effluents from leather processing industrial units.

**Mining Activities**

Mining is another major industry, which is a factor of desertification in the country. This is especially with unplanned open cast mining and dumping of mine refuse in the vicinity of agricultural lands. Despite guidelines and regulations for undertaking adequate environmental measures, mining operations and open cast mining of sandstone, limestone, marble, gypsum, and clay are practiced by small-scale entrepreneurs who do not undertake post-mining operations. Consequently, such areas are gradually turned into wastelands. China clay, Fuller's earth, calcite and gypsum generate fine particles that are washed down the slopes with runoff and get deposited in the adjoining cultivated fields. This eventually leads to problems of water logging and salinity.

**Disposal of Solid & Toxic Wastes onto Land**

In many parts of the country such as Vapi, Ankleshwar, in Gujarat; Pattancheru and Bollaram in Andhra Pradesh, Pali and Balotra in Jodhpur, large tracts of land have been rendered useless due to the disposal of toxic industrial wastes. In some areas, this has led to ground water contamination as well. The costs for reclamation of such land, if carried out as per requirements, would be enormous.

**Demographic pressures**

Population pressures are a significant factor for land degradation. The decennial growth rate of population during the decade 1981-91 in the desert region was 29% compared to 23% for the country (MOEF, 1996). The livestock population also increased from 9.4 million in 1951 to 14.4 million in 1961 (53% increase) and to 15.52 million in 1971 (8% increase). The density of livestock on grazing lands has consequently increased. The increase of cattle, buffaloes and camels has been very high in this region. As population increases, the demand on natural resources is further magnified. This has led to further intensive use of land and other natural resources in drier regions. The consequence is an imbalance between the human and animal population on the one hand and plants, water, and land resources on the other. As the demand by humans persists and increases, the resources tend to become depleted and, as depletion proceeds, the stress upon them becomes even greater. Thus, a process of progressive degradation of resources is set into operation, which intensifies with drought. If not checked in time, it would lead to loss of vegetation, leading to loss of biodiversity. The barrenness of the land affects the hydrological cycle that can affect the rainfall pattern for the region. In the semi-arid, sub-humid regions of the country, there are some areas such as the Gangetic Plains, where the population density is one of the highest in the world.

### Drought and Land Degradation

Drought is generally a naturally occurring phenomenon due to deficit of rainfall in a region. However, drought impacts can be exacerbated due to absence of vegetative cover impacting the hydrological regime. Drought could thus be another causative factor for land degradation. Arid and semi-arid regions in the country encounter moderate to severe droughts frequently leading to crop failures and famines. While droughts of transient nature may not cause significant adverse impacts on the crop and livestock production, severe droughts of recurring nature lead to lower biomass production, poor grain yields and scarcity of fodder. In areas with restricted growing season and soils of poor water holding capacity, droughts have a significant impact on the total biomass yield. Such situations result in minimal inputs of organic carbon into the soils. Even the biomass recycling through leaf litter from perennials is reduced. Further more, scarcity during drought years leads to enhanced grazing pressure by the livestock which accentuates the problem of loss of vegetative cover. The process is aggravated if the following year also is a drought year. Therefore, recurrent droughts can lead to land degradation mainly through decline in biomass production and depletion of organic carbon (humus) in the soils. It is, therefore, not surprising that some of the most severely degraded land are found in the chronically drought prone areas having shallow and light textured soils.

### Processes of Desertification

The different processes involved in land degradation include:

(i) Wind erosion
(ii) Water erosion
(iii) Salinity-Alkalinity
(iv) Water logging

### Soil Erosion

Soil erosion by water and wind account for 87% of the area affected by soil degradation. It has been estimated that between 1977 and 1997, the area critically affected by erosion has almost doubled.

### Wind Erosion

Wind erosion is the major process of land degradation in the hot arid regions of the country affecting 10.46 mha. These include the states of Rajasthan, Haryana, Gujarat, and Punjab, covering an area of 28,600 sq. km of which sand dunes and sandy plains cover 68%. Wind erosion is also prevalent in the coastal area where sandy plains dominate and in the cold desert regions of Leh in Jammu & Kashmir.

### Water Erosion

Water or run-off induced soil erosion is the most serious process of land degradation and desertification in the country affecting about 107.1 mha of the country's geographical area. In the Indian context, it results in loss of topsoil and terrain deformation (ravines, gullies, etc.). Soil erosion through accelerated sheet wash and rill/gully development occurs mainly in the Saurashtra and Kutch uplands and along the eastern margin of the Thar Desert in Rajasthan, where the average rainfall varies from 350 mm to 500 mm. The major reasons are increased cultivation of marginal land with high slopes and shallow soils, destruction of natural vegetation for fuel and fodder, overgrazing and other environmentally destructive uses. In the Aravalli hill ranges along the eastern margin of the Thar, the hill slopes are being regularly denuded of natural vegetation cover for fuel wood, and fodder. Consequently the soils are being washed out by sheet rill and gully erosion, so much so that in many areas there is hardly any soil left to start replantation programmes. In Kutch region, the problem is partly related to a slow natural uplifting of the terrain over the centuries, leading to a change of base level and increased erosion.

**Soil Salinity- Alkalinity**

Vast areas in the otherwise productive Indo-Gangetic plain cutting across the states of Haryana, Punjab, Uttar Pradesh and some coastal regions of Gujarat have lost their productivity due to soil salinity–alkalinity. Excess soluble salts characterize these soils with sodium carbonate in substantial quantity. Consequently, the soils accumulate sodium on the exchange complex thus resulting in poor physical properties including low infiltration rates. In many areas a layer of calcium carbonate concretion, which is normally found at a depth of 1 m, acts as a barrier for root penetration into the soil. The high soil pH adversely affects germination, plant growth, and nutrient availability to plants. The process of salinisation develops due to irrigation with ground water containing excess of carbonate and bicarbonate ions (secondary salinisation), runoff from adjoining undrained basins, and a rise in ground water table as a consequence of mismanagement of irrigation command. This is a man-made problem. In addition, there is natural salinity in depressions in landscaping of lower elevations.

**Water Logging**

Water logging is estimated to affect about 8.52 mha of the land surface. The problem is severe in the Indira Gandhi Canal Command Area in Rajasthan, where excess irrigation in the soils having gypsum-rich barriers at shallow depth and poor drainage planning are the major causes for degradation in these canal command areas, leading to saline-sodic water and salt-rich hard pans. Some areas of Uttar Pradesh, Haryana and Punjab under agriculture also have this problem. According to a World Bank study, India loses 1.2-2.0 million tonnes of food grain production every year due to water logging (ICAR, 1999).

**Impacts of Desertification**

**Impact of Human Population Pressures on Forest Resources:**

Population pressures per unit area of forest are one of the highest in the world. In 1991, the national average density of population per sq. km of forest land was 1320 and ranged from 2860 in the northwestern states to 191 in the northeastern region. Consumption of wood (timber and fuel wood) in India is considerably (4 to 5 times) higher than what can sustainably be removed from the forests. In 1990, the excess removal of fuel wood was estimated to be about 250 million cu. m with an expected increase to 310 million cu. m by 2000 (NFAP, MOEF, 1999). These are steadily adding to forest degradation and deforestation.

**Impact on Biodiversity**

Due to degradation of forests and natural habitats for expansion of agriculture, river valley projects and industrial and urban developments, the biodiversity of the country is under threat. Some adverse Impacts of Deforestation are the following:

**Environmental Impacts**

- Loss of ecological stability;
- Loss of biodiversity;
- Reduction in carbon sink capability and their effects on climate;
- Floods, drought and related losses;
- Damages to watershed;
- Soil erosion;
- Silting up of reservoirs;

- Desertification and Drought;
- Changes in hydrological regime.

**Social and Economic Impacts**

- Loss of employment;
- Food and Livelihood security.

**Impact of Livestock Population Pressures on Grazing & Forest Land Resources**

The high livestock population of India is increasing further and has low productivity. With the steady rise in animal populations, pastures and grazing lands have been subjected to overuse. This has resulted in loss of vegetation and affected their regeneration potential leading to slow degradation of grazing land, which eventually would become barren. A substantial percentage of pasture and grazing lands has been encroached upon for agricultural and other purposes. The reduction in the extent of availability of land for grazing has led to more and more forests being used as grazing grounds.

**Table 3. Livestock grazing on forestland (in millions) -** *(Source: MOEF, 1999)*

| Year | Livestock grazing |
|---|---|
| 1957-58 | 35 |
| 1973-74 | 60 |
| 1995 (estimate) | 90 |

Livestock production in India is to a large extent dependent on crop residues and crop by-products. The total supply of feed and fodder in 1993 was of which 398 million tons was straw, 573.50 million tons of green fodder, and 41.98 million tons of concentrates (MOEF 1993). It is estimated that during 1993, the country faced a deficit of 570 million tonnes of green fodder and 276 million of dry fodder. The 1995 combined availability of green fodder from permanent pastures, other grazing lands, agricultural lands and forests was estimated at 434 million tonnes, whereas the minimum requirement was estimated to be 882 million tonnes. The big gap has resulted in unlimited and unrestricted grazing in forest lands. Forests have been an important source of grazing land and for fodder in the absence of adequate pasture land. It is estimated that about 270 million livestock graze in forests. Additionally, grazers collect an estimated 175 to 200 million tonnes of green fodder annually. This further results in overgrazing and over extraction of green fodder leading to forest degradation through their deleterious effects on soil compaction and poor regeneration of forests (MOEF, 1999).

The numbers of livestock is increasing at a rate of 2% per annum mounting a tremendous pressure on the limited land resources (ICAR. 1999). There has been a steady decline in the area and quality and quantity of CPRS, as a result of increase in population and livestock pressures. About a third of the total feed intake of the ruminants in India, large and small, is by grazing on common property resources (CPRs). Overgrazing by herds far larger than what the land can sustain, year after year, has progressively rendered them into marginal or wastelands, grossly eroded and changing plant association, making them unsuitable for bovines and fit only for sheep and goats. It is clearly understood that the cause and effect of all these retrogressive changes in the common property resources (CPRs) and more generally on the ecosystem, emanates from the enormous increase in human population followed by increases in animal populations, which far beyond the land's ability to sustain.

**Impacts of Depletion of Vegetative Cover**

One of the impacts is the gradual change of ecosystem through loss/replacement of one species with another. In many parts of Rajasthan, there has been a gradual change in the natural vegetation found in the region and plant density. For example, in the sandy areas of little rainfall (less than 200 mm annual rainfall), grass species such as *Lasirus sindicus-Elesine compressa* are being slowly replaced by *Aristida funiculata - Dactyloctenium sindicum*, with a concomitant decline in basal cover and plant density. Similarly, the permanent pastures and fallows in the high rainfall zones that once supported a good stand of trees and shrubs now present a stunted landscape. At many places poor quality shrubs and grasses like *Crotalaria burhia*, and *A. funiculata* are replacing the original species. The common grazing lands around villages have now turned as some of the severely degraded sites, due to over exploitation and gross neglect. Encroachment of these village commons for crop production and other non-farm activities has also led to conversion of these pasturelands to other uses. On average, the area with good grass species in the < 300 mm average annual rainfall areas has declined by about 7% while in the >300 mm average annual rainfall zone the decline has been far greater from 8 % to 12%. This has a significant effect on the potential fodder production from these lands.

**Impacts of Soil Erosion**

Sand dunes and other sandy landforms in the Thar Desert are most vulnerable to wind erosion/deposition. Sandy landforms in the western part of the desert (Agro-ecological Sub-Region (ASER): 2.1, 2.3) are more unstable and vulnerable than those in the east. This is especially due to the decreasing rainfall and increasing gradient in the wind velocity from east to west direction. The threshold velocity for initiating wind erosion has been estimated to be around 10 km/hr (Prasad & Biswas, 1999). However, wind velocities of as much as 30 km/hr are common, leading to loss of topsoil and terrain deformation in the affected regions. In other parts of the Thar and in western parts of Haryana, large-scale introduction of tractor ploughing in the sandy terrain, including the dune slopes, is increasing the sand load manifold for Aeolian processes, and is threatening more areas through new sand dune formation and advancement of old dunes. The destruction of natural plant cover in the sandy terrain for fuel and fodder, extending the areas of cultivation to less suitable sandy tracts and higher slopes of sand dunes, and land leveling in the Indira Gandhi Canal Command area, are also accelerating the Aeolian process.

**Impacts of Water Erosion**

The national average of rate of soil erosion, based on existing soil loss data, has been estimated as 16.35 t/ha/yr, yielding a total soil loss of 5.3 billion tonnes annually in the country. About 64% of the eroded soil comes from the Shivaliks, the Western Ghats and the northeastern states. Of the eroded soil, nearly 29% of the total eroded soil are permanently lost to the sea, 10% end up in reservoirs and about 61% transferred from one place to another. The transfer of eroded soil into reservoirs results in the reduction of the storage capacity by 1-2 % annually. The data on river valley projects on 17 medium and small reservoirs in India have shown that the rate of inflow of sediment is about 3 times (9.17 ha-m/100 $km^2$/annum) compared with the design rate of (2.93 ha-m/100 $km^2$/annum), rendering their life expectancy and the hydroelectric power generation to one-third the planned capacity. The annual water erosion rate has been estimated to range from less than 5 t/ha/yr (for dense forests, snow clad mountains and arid desert regions) to more than 80 t/ha/yr in the Shivalik Hills. The annual erosion rate in the northeastern region (which practice shifting cultivation) showed topsoil losses exceeding 40 t/ha/yr. The annual erosion rate in the Western Ghats and the coastal regions varied from 20 to 30 t/ha/yr and can be as high as 60 to 70% if they are under shifting cultivation. This results in formation of ravines which affect a land area of approximately 3.97 mha and occur along the banks of the rivers Yamuna, Chambal, Mahi, Tapti, and Krishna, and regions with shifting cultivation regions affecting about 4.91 mha in the north-eastern regions.

### Impacts of Erosion on Soil Fertility

Soil erosion is directly linked to deterioration of soil health, which in turn affects crop productivity and sustainability (Prasad and Biswas, 1999). Erosion also takes away with it every year 14 million tonnes of such major nutrients as nitrogen, phosphorus, and potassium form the country's soils. Red and lateritic soils are particularly prone to this problem. Intensive cropping has further hastened the process of nutrient removal. The eastern part of Jammu and Kashmir (AESR 1.1) is the worst affected with respect to loss of soil organic matter (SOM) besides parts of Rajasthan and Gujarat. SOM is one of the key resources supporting crop productivity. However, it is a dynamic resource responding to the changing land uses and input-output ratios. It has a significant bearing on soil properties related to productivity as also erosivity. Under intensive cropping and imbalanced fertilizer application systems (relying largely on N fertilizers), SOM content declined irrespective of the cropping systems and soil types. The Government of India has not estimated the economic losses due to impacts of all the factors and processes of land degradation. According to the Tata Energy Research Institute (TERI), New Delhi, the economic losses caused by lower crop yields, and reduced reservoir capacity has been estimated to be in the range of 89-232 billion rupees, as a result of loss of 11-26% of agricultural output (Pachauri and Sridharan 1998).

### Impacts of Inefficient Water Management

Inefficient water management is observed at all levels (city, province, and village) leading to drought-like situations. In places of acute water scarcity, long hours are spent for water collection, which affects the quality of life and is a direct loss to the economy. The availability of renewable freshwater resources per capita in India has fallen from 6000 cubic meters in 1947 to about 2300 cubic meters in 1997 (Pachauri and Sridharan 1998). The adverse impacts of temporary / long-term fall of water logging are reflected in overall effect on the ecology, reduced agricultural output, limited choice of crops, and impacts on the socioeconomic conditions of the affected region. According to a World Bank study, India loses 1.2-6.0 million tonnes of food grain production every year due to water logging (Prasad and Biswas, 1999).

### Impacts of over abstraction of Ground Water

The excessive pumping of groundwater for irrigation purposes in intensively cultivated areas of Punjab, Haryana, and Western Uttar Pradesh has caused the lowering of ground water table in certain pockets. The states that currently overexploit groundwater the most are also the country's agriculturally important states, each with a net irrigated area of over 0.3 million hectares, and groundwater is the predominant source of irrigation in eight states (Pachauri and Sridharan 1998). During the past decade, ground water table has dropped at a rate of 0.5-0.8 meter per year in Haryana and 0.2-1.0 m per year in Punjab. Major metro areas such as New Delhi and Chennai have over exploited their ground water and the levels have dropped drastically. The overexploitation of groundwater in some areas has made its extraction increasingly expensive and not viable. The effect of such high costs is likely to be particularly severe on small and marginal farmers. A falling water table requires greater expenditure on extraction, which the small and marginal farmers can ill afford. In the Kutch region of Gujarat, the over extraction of ground water has led to saline water intrusion into coastal aquifers resulting in deterioration of water quality. Reclamation of saline ground water is one of the most difficult problems of reclamation of degraded lands.

The quality of life of rural communities is determined by food security, water security, sustained availability of fuel and fodder and adequate income generation. The responsibility of collection of fuel wood, fodder and water requirements of the family in many rural areas rests with the women. The quality of life of women particularly in the severely affected regions of the country, especially belonging to the backward communities, is extremely hard. Many of them spend a life of drudgery spending a large amount of their daily time for collection of fuel wood, food, fodder and water needs of the family. An increase in collection time indicates a progressive degradation of the land and a corresponding decline in quality of life of people in such regions. In many areas, the men have migrated to cities and the women are the de-facto heads of families looking not only after children but also responsible for all aspects of running the household and their livelihood. The contribution and importance of women in the development of the family unit as well as to the local community and to the economy has not been given the attention that it deserves.

**Impacts of Desertification on Migration from Rural Areas and Urbanization**

Whereas the urbanization in the industrialized countries resulted from industrial development, today the urbanization in developing countries is the result, in most cases, of pressures from declining quality of life in rural areas. From the 1991 census, 26% of the country's population (217 million) live in urban areas. This is expected to be about 300 million in 2001 and is expected to rise to 590 million by 2025 (MOE, 1994). Twenty-three metropolitan cities account for 32.5% of the urban population in the country. Desertification, per se, is not the only reason for migration to cities and nor is migration the only source of urban growth. In fact with the advent and expansion of the electronic media, the hopes and aspirations of people have increased enormously, which is also one of the contributing factors to migration to cities. The changing role of media also has profound implications on the changing consumption patterns, which have direct and indirect impacts on the natural resources. There is a well-established correlation between desertification and migration from rural areas. Forced migration to urban areas due to desertification leads to an inability to adjust to exigencies of urban living and hence creation of slums and the associated social stress. In India, migration throws most urban Plan Programmes out-of gear and leads to an inability to provide basic civic services and facilities such as housing, water supply, energy, transportation, etc. leading to creation of unauthorized colonies and slum clusters in towns and cities, increased pollution and environmental degradation and the consequent decline in the quality of life.

**Impact of Desertification on Climate**

The extent of impact of desertification on climate is a very complex phenomenon not fully understood. The changes in vegetative cover due to various human-induced changes can influence the solar radiation and thus the energy balance of both the surface and atmosphere of the earth (Williams and Balling, 1996). For example, any change in the surface albedo (reflection of sunlight) due to vegetative loss will affect the amount of solar radiation absorbed by the surface. Similarly, changes in soil moisture levels will determine the portion of energy that is used in evaporation and transpiration processes, which in turn affects the microclimate. Other factors such as wind speeds, surface temperatures influence the evapotranspiration rates.

**Action taken by India**

As a measure to Combat Desertification and Mitigate the Effects of Drought, the following Policy, Strategy and Legislative Frameworks have been developed:

- **Policy**
  - National Water Policy 1987
  - National Land Use Policy Outline 1988
  - National Forest Policy 1988
  - National Policy on Education, 1986 as amended in 1992
  - Policy on Abatement of Pollution, 1992
  - National Livestock Policy Perspective, 1996
  - National Agricultural Policy, 2000
  - National Population Policy, 2000
  - National Land Reforms Policy Grazing and Livestock Management Policy.
  - Policy on Drought

- **Strategies for Environmental Conservation**
    - Conservation Strategy and Policy Statement on Environment and Development, 1992
    - National Policy and Macro-Level Action Strategy on Biodiversity, 2000

- **Legislative Framework**
    - Forest (Conservation) Act, 1980
    - Environment (Protection) Act, 1986
    - Water (Prevention & Control of Pollution) Act, 1974 as amended in 1988
    - Wildlife (Protection) Act 1972 as amended in 1988
    - Constitutional Amendments (73 rd and 74 th ) of 1992
    - Biodiversity Bill

The following Institutional Framework was established:

- **Institutional Framework**
    - Institutional Structure at the Central Level
        - Ministry of Environment & Forests
        - Ministry of Rural Development
        - Ministry of Agriculture
        - Ministry of Water Resources
        - Ministry of Human Resource Development
        - Other Ministries and Departments
    - Institutional Structure at the Local Level
    - Institutional Framework for R&D

The following Programmes for combating Desertification were implemented:

- **Social Sector & Community Development Programmes**
    - Schemes for Women & Child Development
- Balika Samridhi Yojana
- Swayam-Siddha (Indira Mahila Yojana)
- Swa-Shakti
    - Programmes on Health & Literacy
- Reproductive & Child Health Programmes (RCH)
- Integrated Child Development Services (ICDS)
- Literacy Programmes
- Scheme for Welfare & Development of Socially Backward Communities
    - Local Community Development Programme
- Jawahar Gram Samridhi Yojana (JGSY)
- Rural Drinking Water Supply & Sanitation
    - Income Generating Schemes for Poverty Eradication
    - Credit Assistance for Rural and Agro-Based Activities and Schemes
- Micro-Credits for Rural Development
- National Bank for Agriculture and Rural Development (NABARD)
- Apex Finance & Development Corporation
- Micro credit Assistance to women.
    - Capacity Building and Strengthening the Roles of Various Stakeholders in the Degraded Regions of the Country
- Capacity Building under Watershed Programmes for Wastelands
- Integrated Child Development Services (ICDS) Training Programme
- Support to Training and Employment Programme for Women (STEP)
- Employment & Income Generating Training -cum-Employment-cum-Production Units for Women
    - Meeting Energy Needs of the Rural Sector
    - Conservation of Land Resources and Eco-restoration of Degraded Lands

- Land Development and Conservation Programmes
- National Watershed Development Project for Rain fed Areas
- Soil Conservation in the Catchment of River Valley Projects
- All India Coordinated Research Project for Dryland Agriculture
- Watershed Projects
- Programmes for Natural Resource Conservation
- Programmes for Ecorestoration of Degraded Lands

- Integrated Afforestation and Eco-development Project Scheme
- Integrated Wastelands Development Programme
- Eco-Task Forces
- Scheme for Reclamation of Alkali Soils
  - Programmes Specifically for Addressing Desert & Drought Prone Regions
- Desert Development Programme (DDP)
- Drought Prone Areas Programme (DPAP)
- Indira Gandhi Nagar Project

Technologies for conservation of soil, water and vegetation are developed by:

- Technologies for Combating Desertification
  - Technologies for Conservation of Soil, Water & Vegetation
    - Integrated Soil Fertility Management
    - Integrated Nutrient Management
    - Soil Quality Monitoring
    - Use of Modeling for Assessment of Resources Status
    - Permanent Vegetative Cover through Alternate Land use Systems
    - Alternate Land use Systems for Different Agro-Ecological Regions
    - Technologies for Soil & Water Conservation
      (i) Soil and Rainwater Conservation
      (ii) Inter-Terrace Land Treatments
      (iii) Water Harvesting and Recycling
      (iv) Tillage
      (v) Mulching
      (vi) Increase in Water Storage

  - Technologies Specifically to Control Land Degradation in different Bio-Climatic Regions
    - Arid Region
      (i) Control of Wind Erosion
      (ii) Stabilization of Sand Dunes
      (iii) Shelter belt /Wind break Plantations
      (iv) Management of Pasture & Rangeland
    - Semi-Arid and Dry Sub-Humid Region

  - Technologies for Management & Reclamation of Degraded Land
    - Management of Soil & Water Erosion
    - Rehabilitation of Mine Spoils
    - Management and Utilization of Industrial Effluents
    - Management of Salt-affected Soils and Waterlogged Areas
    - Reclamation of Waterlogged Saline Soils
    - Alternate Land Uses for Salt Affected Soils
    - Agro forestry for Moderately Alkaline Soils/Reclaimed Soils

  - Traditional/ Indigenous Technologies for Combating Desertification
    - Agriculture
    - Water Harvesting
    - Conservation of Forage Resources
    - Combined Production System

- Protection of Vegetative Cover -Sacred Groves
    - Water Utilization Practices
    - Energy
    - Storage of Grains/Tubers

- Technologies for Drought Mitigation
    - Measures to Combat Land Degradation Caused Due to Drought
    - Use of Early Warning Systems
    - Agriculture Based Technologies

- Crop Weather Modeling
- Contingent Crop Planning
- Mid-Season Correction

Initiatives have been undertaken by:

- Integrated Watershed Programmes
- Common Approach for Watershed Development
- Establishment of Watershed Development Fund (WDF)
- Vision 2025 for Integrated Watershed Programme
- Use of Indicators for Evaluation of Watershed Programmes
- Working Group set up by Planning Commission
- People's Participation in Conservation and Eco-restoration Activities
- Joint Forest Management
- Eco-development Scheme
- NGO's has been involved to combat desertification and participation in various committees and task forces setup by government of India.
- Environmental issues have been integrated for the process of economic reforms and sustainable development as stipulated in Agenda 21 and the countries environmental action plan

The following Institutes are also involved for land degradation, national forestry and water resource management:

- National Mission for Assessment of Land Degradation
- National Forestry Action Programme (NFAP)
- National Commission for Integrated Water Resources Development Plan

The following New Policies & Programmes have been undertaken:

- National Policies on Agriculture, Population and Biodiversity
- Establishment of Departments of Land Resources and Drinking
- Implementation of Gender Related Issues.
- New initiatives in Information Dissemination & Awareness Raising.
- Role of Information Technology (IT) Sector in Combating desertification
- Externally Aided Projects

The Contingency Plan for Drought Management consists of:

- Relief Measures for Drought Mitigation
- Drought Monitoring by Centre and States
- Interlinking National Efforts with Regional, Sub-Regional, Inter-Regional and Global Activities in Combating Desertification
- Use of Benchmarks & Indicators
- Use of Traditional Knowledge
- Desertification Monitoring & Assessment and Use of EWS

- Principal Constraints to Integration of NAP into UNCCD Programmes and Activities at the Regional, Sub-Regional, Inter-Regional and Global Activities in Combating Desertification
- Issues & Recommendations
- Land Use Planning
  - National Land Use Policy
  - Land Degradation Monitoring & Assessment
  - Programmes & Schemes for Addressing Land Degradation
- Management of Natural Resources of the Country
  - Land
  - Water Resources
    - Meeting Water Requirements of the Country
    - Use of Cost-Effective Water Harvesting Systems
  - Environmental Issues
  - Unsustainable Agricultural Practices
- Meeting Food-Fuel-Fodder-Energy Requirements of the Country
  - Food Security
  - Fuel-Fodder Security
  - Meeting Rural Energy Needs
- Participatory Approach to LADPs
  - Decentralized Governance
  - Institutional Framework at the Local Level
  - Role of NGOs.
- Social Sector and Community Based Programmes
  - Issues on Human Development
  - Gender Empowerment
- Other Issues pertaining to Community & Social Sector

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