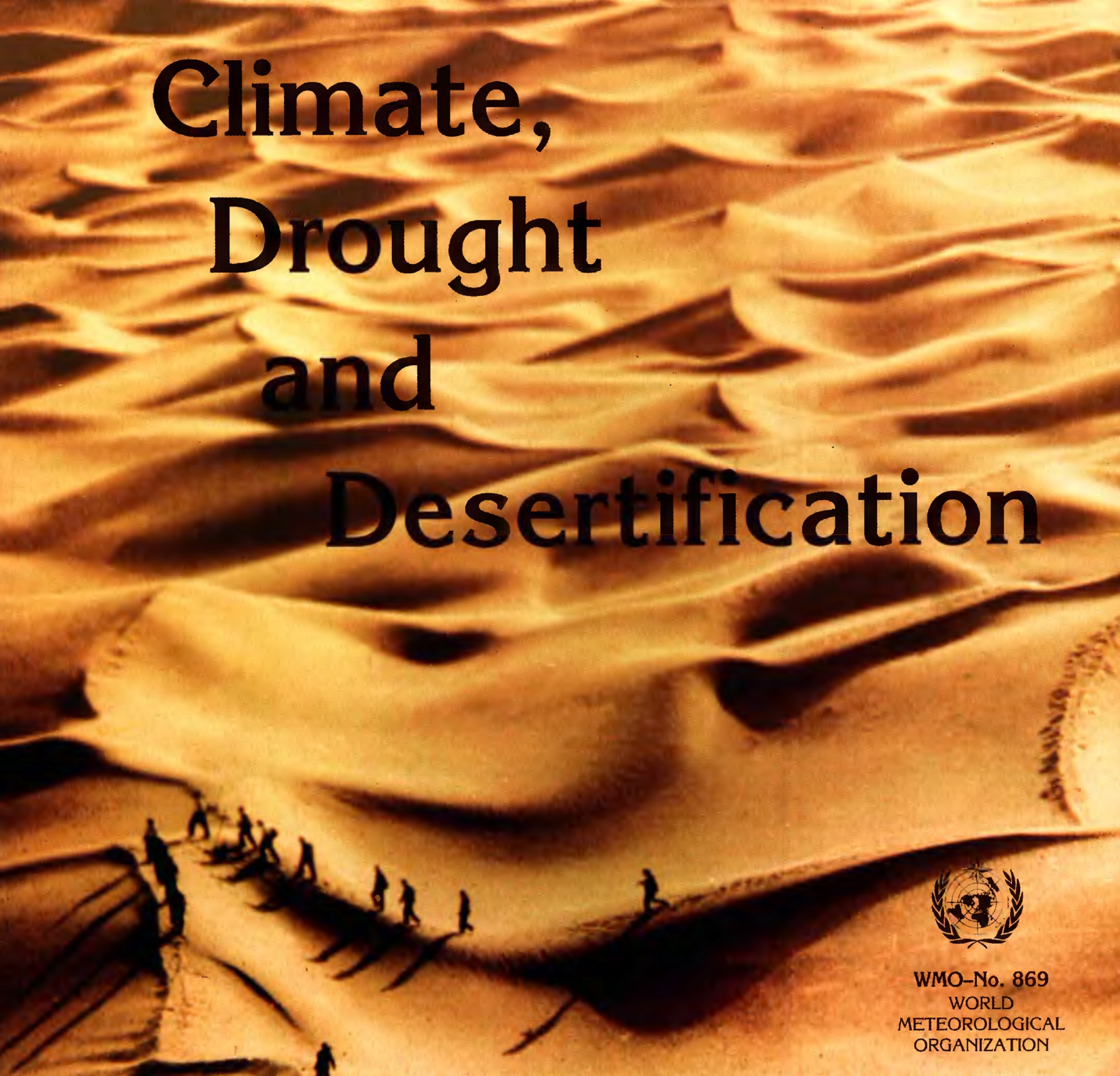
Climate, Drought and Desertification



WMO-No. 869
WORLD METEOROLOGICAL ORGANIZATION

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Geneva, Switzerland

Cover: View of the Gobi desert, People's Republic of China. The Talimu basin is the largest inland basin in the world, most of which is covered by the Gobi desert and swampy grassland (FAO/H. Zhang)

WMO – No. 869

ISBN 92-63-10869-2

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Switzerland
1997

FOREWORD

The United Nations Convention to Combat Desertification (CCD) is a major outcome of the Earth Summit held in Rio de Janeiro in June 1992. Following the signing of the Convention in Paris in October 1994, this innovative document came into force on 26 December 1996. The ratification of the Convention by 112 countries, some of which are not directly affected by desertification, signifies the importance accorded by the international community to this global problem.

Today some 250 million people from over 100 countries are directly concerned by desertification with another billion at risk. The projected increase in the world's population to 10 billion by the year 2050 will further stretch the carrying capacity of the Earth. In addition to increasing pressure from humans and animals, climatic events in particular recurrent droughts exacerbate land degradation processes. By combating desertification, the world would at the same time be combating poverty, minimizing environmental refugees, protecting the environment, reducing the risk of civil strife and regional conflicts and thus contributing to world peace and security.

For these reasons, it is imperative that all nations of the world and the relevant international and regional organizations should work together to address this global scourge. Within the context of its plan of action to combat drought and desertification, WMO will continue to encourage the increased involvement of the national Meteorological and Hydrological Services (NMHSs) and regional and subregional meteorological and hydrological centres in addressing the issues of relevance to the CCD, especially those stipulated in Articles 10, and 16 to 19, of the Convention.

In this respect, WMO will promote systematic observation, collection, analysis and exchange of meteorological, climatological and hydrological data and information; drought planning preparedness and management; research into the causes and effects of climate variations and long-term climate predictions with a view to providing early warning; capacity-building and the transfer of knowledge and technology. WMO's Programmes, in particular the Agricultural Meteorology Programme and the Hydrology and Water Resources Programme, will continue to support these efforts.

On the occasion of the First session of the Conference of the Parties to the CCD, which marks an important milestone in humanity's collective struggle against drought and desertification, WMO has prepared this booklet which explains the interaction between climate, drought and desertification, and WMO's contribution in addressing these scourges. We hope that it will be a positive contribution to enhance the understanding of decision-makers, the media and the public to some of the issues involved so that they could be addressed knowledgeably. The global commitment to the Convention is an investment into sustainable development and in the future of humanity.

(G. O. P. Obasi)
Secretary-General

Drought and desertification — twin problems of drylands

Desertification is currently perceived as the degradation of drylands, which occurs as a subtle and continuous process. The arid, semi-arid and sub-humid drylands, defined according to their "aridity index" (the ratio of annual precipitation to potential evaporation), cover some 40 per cent of the Earth's land surface. They are home to a large human population and unique species of plants and animals.

Drylands offer many challenges to humanity, many of which have for several centuries been successfully answered using the lessons and survival techniques of previous generations. Yet today in many dryland areas there are scenes of much distress and even of tragic famine. Vast areas of drylands, perhaps as much as 3.6 billion hectares, suffer from some degree of degradation. Inappropriate management of agro-ecosystems, compounded by severe climatic events such as recurrent droughts, have tended to make the drylands increasingly vulnerable and prone to rapid degradation and hence desertification. More than 100 countries and as many as 900 million people may be suffering from the adverse social and economic impacts of dryland degradation, which makes desertification a global problem.

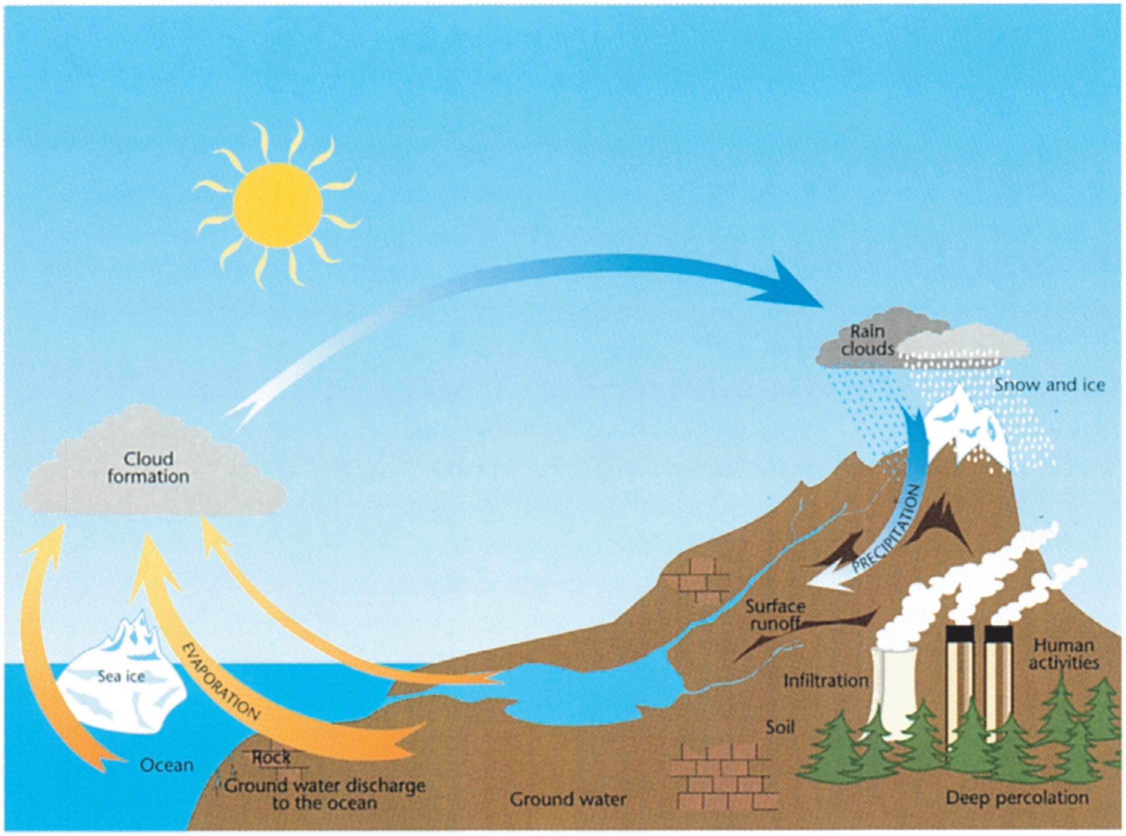
Desertification is caused by two major factors often acting in unison — namely, natural forces, through periodic stresses of extreme and persistent climatic events such as drought; and human use and abuse of sensitive and vulnerable dryland ecosystems. The feedback processes between the natural and human-induced causes, however, are not fully understood.

Of the many climatic events that influence the Earth's environmental fabric, drought is perhaps the one that is most linked with desertification. Drought is a natural hazard originating from a deficiency of precipitation that results in a water shortage for some activities or some groups. It differs from aridity in that the latter is restricted to low rainfall regions and is a permanent feature of the climate. Drought occurrences are common in virtually all climatic regimes.

Drought is the consequence of a natural reduction in the amount of precipitation over an extended period of time, usually a season or more in length, often associated with other climatic factors (such as high temperatures, high winds and low relative humidity) that can aggravate the severity of the event. Because drought affects so many economic and social sectors, scores of definitions have been developed by a variety of disciplines; these can be grouped mainly as meteorological, hydrological, agricultural and socio-economic droughts.

We are all well aware of the widespread misery caused by the recurrent droughts in the 1970s and 1980s in the Sahel and in the

Chronic droughts threaten the productivity of drylands (H. Fromm)



The GEWEX water cycle

eastern and southern parts of Africa. Severe drought in southern and southeastern Ethiopia has prompted the Ethiopian Government to launch an appeal this year for international assistance for an estimated one million affected pastoralists.

Desertification and drought are not the problems of Africa alone. Extensive droughts recur in Asia, especially in parts of China, India and the Middle East and in Australia. In North America during the summer of 1996, precipitation was below 50 per cent of normal in parts of the southern United States and northeastern Mexico. In early 1997, exceptionally dry weather persisted in southwestern Europe and fewer than 10 mm of precipitation were received between 26 January and 23 March 1997 in much of the central and eastern Iberian Peninsula, France, much of northern Italy, and portions of Corsica, Sardinia, and the Balearic Islands.

Wind erosion poses problems for soil management in some dryland ecosystems such as the Sahel (WMO/M.V.K. Sivakumar)

Interactions of climate and desertification

Climate has a major impact on dryland soils, vegetation, water resources and human land use. Dryland flora and fauna suffer from the constraints of large diurnal and seasonal variations in temperature and even greater yearly vagaries in rainfall and soil moisture. Dryland plants and animals have developed a complex array of behavioural adaptations that allow them a high degree of resilience to climate variability. However, in the end, ecosystem complexity is a function of climatic elements, including precipitation, temperature, evapotranspiration, hours of sunshine and total solar radiation.

There is a strong correlation between plant biomass and rainfall, since rainfall influences vegetation production, which in turn controls the spatial and temporal occurrence of grazing. Both field observations and remote sensing data have confirmed very large spatial variations in dryland plant density and biomass, as well as equally important temporal fluctuations in biomass in response to seasonal and interannual fluctuations in rainfall. Regeneration of grazed vegetation and the ability to regraze an area are also controlled by rainfall. Following an extended period of drought, vegetation regeneration may be quite difficult.

On the other hand, two of the worst threats for generally vulnerable dryland soils come from erosion due to wind and rain. The sparser the plant cover, the more severe are the impacts of these events. Wind erosion is especially damaging if strong winds prevail during the dry season. Rain splash erosion can be more destructive when a depleted canopy cover offers a weak resistance to the mechanical effect of raindrops.

From the hydrological point of view extreme rainfall variability forces a corresponding flow variability in dryland rivers, and consequently in runoff and soil moisture. The latter, of critical importance to crop productivity, is affected not only by the amount and seasonal incidence of rainfall, but also by the ability of soils to absorb and store water and by moisture losses through evapotranspiration.

WMO has been in the forefront of research on desertification from its beginnings in the mid-1970s, when it was suggested that human activities in drylands could alter surface features that would lead to an intensification of desertification processes and trends. The "expanding Sahara" hypothesis paved the way to the Charney* description of a biogeophysical feedback mechanism, proven later by using the numerical climate model of the Goddard Institute for Space Studies.

Human-induced changes in dryland surface conditions and atmospheric composition can certainly have an impact on local and regional climate conditions in that they directly affect the energy budget of the surface and the overlying atmospheric column. These changes to the energy balance have been simulated in many numerical modelling studies covering almost all dryland areas of the world. The outcome of these studies underscored the need to improve our knowledge of the climate/desertification relationship and, at the same time, called for improvements in the quantity and quality of the data available for further simulations. Accordingly, the WMO World Climate Research Programme launched the Global Energy and Water Cycle Experiment (GEWEX) to study the atmospheric and thermodynamic processes that determine the global hydrological cycle and energy budget, and their adjustments to global changes such as an increase of greenhouse gases. Many of the fundamental issues associated with interactions of desertification and climate are receiving attention in the GEWEX objectives.

Empirical studies that had begun with the analysis of historical records received a considerable thrust from improvements on remote sensing observation and measurement technologies. The International Satellite Land Surface Climatology Project (ISLSCP) has substantially improved the amount and quality of data available for use in empirical and numerical modelling studies.

*Charney, J.G., P.H. Stone and W.J. Quirk. 1975: Drought in the Sahara: A biogeophysical feedback mechanism. *Science* 187: pp. 434-35.

What can be done in the future about the interactions between climate and desertification?

Based on our knowledge of the interactions of desertification and climate, the joint WMO/UNEP study by Williams and Balling on the Interactions of Desertification and Climate, published in 1996, has offered the following recommendations to improve our understanding of the interactions between climate and desertification:

- Adoption of uniform criteria and methods to assess desertification;
- Establishment of regional training centres to monitor dryland degradation;
- Identification of sources and sinks of carbon;
- Identification of sources and sinks of aerosols and trace gases;
- Evaluation of dryland rehabilitation projects;
- Enhancement of regional climate monitoring networks;
- Coupling of numerical modelling studies with empirical field measurements;
- Assessment of biogeophysical models of Sahelian drought;
- Application of seasonal climate forecasting in dryland management;
- Provision of natural resources information to local communities.

Global climate change and dryland climate

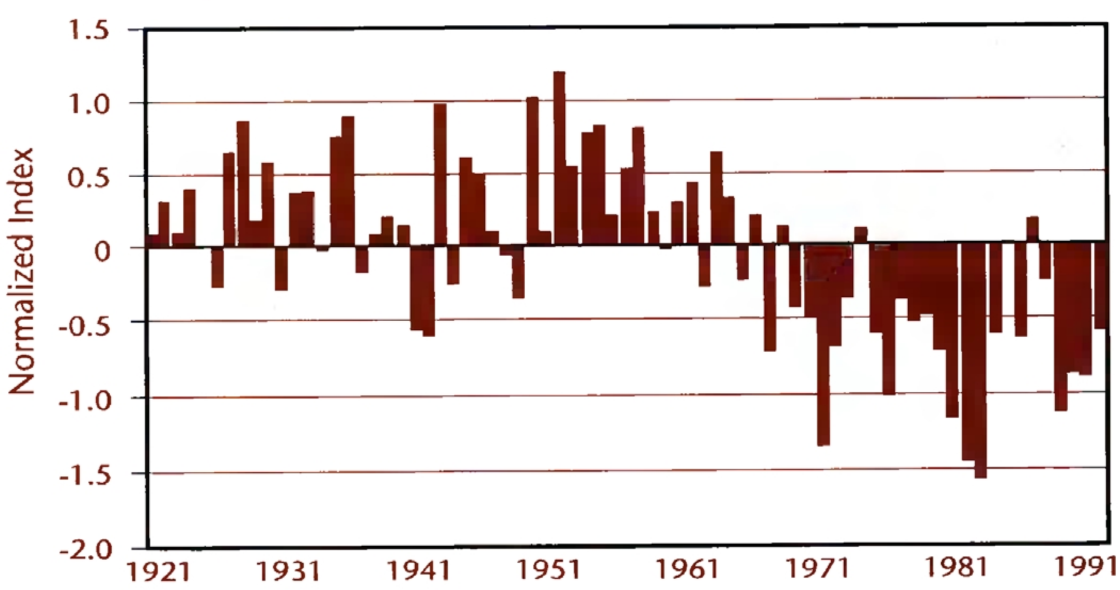
The inherently large year-to-year variations in dryland precipitation levels are interrelated with natural and external variations occurring within the entire global-scale climate system. By far the most pronounced change in precipitation levels in recent times of any of the dryland areas has occurred in the Sahelian region. Here, precipitation levels have dropped sharply since the mid-1950s and the decrease in precipitation has contributed to enormous human and economic losses in the region. Interrelated changes in sea-surface temperatures (including linkages to El Niño/Southern Oscillation events), land-surface conditions, general atmospheric circulation pattern and atmospheric concentrations of various greenhouse gases have all been proposed to explain at least some of the variance in the observed regional precipitation levels.

Many scientists and policymakers believe that climate changes in drylands over the next century will be driven, in some part, by the continued build-up of anthropogenic greenhouse gases. The increases in the global atmospheric concentration of carbon dioxide, methane, nitrous oxides, various halocarbons and other greenhouse gases are well documented, and the upward trends for many of these trace gas concentrations are expected to continue well into the next century. According to the Second Assessment Report of the WMO/UNEP Intergovernmental Panel on Climate Change (IPCC), models project an increase in global mean surface air temperature relative to 1990 of about 2°C by 2100.

The numerical models also suggest that drylands will also warm substantially over the next century, particularly in the higher latitudes. Although the regional estimates of temperature rise are considered even less certain than estimates for the entire planet, estimates of dryland temperature increases are generally greater than the global change in temperature. Precipitation predictions for these arid and semi-arid regions are far less certain.

The predicted increase in temperature would most probably have the effect of increasing potential evapotranspiration rates in the drylands, and in the absence of any large increases in precipitation, many drylands are accordingly predicted to become even more arid in the next century. Desertification is more likely to become irreversible if the environment becomes drier and the soil becomes further degraded through erosion and compaction.

Precipitation index for the western sub-Saharan Sahel (June-September) 1921-1993 (from NOAA/NWS/NMC/CAC, Washington, DC)



Climatic feedback: Do human activities worsen drought?

Since the impacts of drought have been so widespread in the past two to three decades, it is natural to ask the questions: Do human activities worsen drought? Does desertification create feedback that exacerbates the climatic stresses? Can altered ways of using land and water set matters right?

Direct anthropogenic pressures, such as overgrazing, over-cultivation and deforestation will cause a decrease in vegetation cover, exposing vulnerable soils to erosion. The low moisture content, low levels of organic matter and weak structural stability of the soil will lead to a loss of nutrients and water-holding capacity, thereby reducing plant growth. Dryland soils are known to be particularly sensitive to erosion, and several studies have shown that most cultivated land in sub-Saharan Africa loses more nutrients than it gains, causing large decreases in crop yields. As yields decrease, there is even further pressure on land when fallow periods are reduced or abandoned. Removal of deep-rooted trees and shrubs may also affect processes associated with rainfall recycling.

Loss of vegetation can propagate further land degradation via land surface-atmosphere feedback. This occurs when a decrease in the vegetation reduces evaporation and increases the radiation reflected back to the atmosphere (albedo). The consequent reduction in cloud formation and rainfall causes a feedback, which further reduces vegetation. Large-scale experiments, in which numerical models of the general circulation have been run with artificially high albedos over the desert areas, have suggested that large increases in the albedo of subtropical areas should reduce rainfall, but the quantitative effects in actual situations have not yet been firmly established. Some of the models also suggest changes in rainfall in other areas. Another feedback mechanism that has been investigated concerns the surface roughness. It has been suggested that the elimination of tall trees and shrubs in the desertification process reduces surface roughness. Numerical modelling indicates that such a change towards a smoother surface should diminish rainfall in some areas, and increase it elsewhere. The processes are complex, but the effects may be large.

The above examples demonstrate qualitatively that changes being wrought by human land use may actually contribute to the worsening of climate. But some climatologists believe that the suggested changes are no different from the natural, internal variability of the climate system and that normal or even humid conditions would return in due course to the drought-stricken areas as the atmospheric circulation rights itself or shifts into another pattern.

Underlying assumptions, testable conclusions and model results in various biogeophysical feedback models of the Sahel drought

- Overgrazing reduces vegetation cover;
- Reduced plant cover increases albedo;
- Increased albedo decreases net radiation;
- Decreased surface net radiation results in surface cooling;
- Surface cooling promotes subsidence of air aloft;
- Subsidence decreases convection and cloud formation;
- Reduced convectional instability leads to less precipitation;
- Additional drying in the Sahel region leads to regional climatic desertification which positively feeds back to overgrazing;
- Atmospheric general circulation models show that an albedo increase from 14 per cent to 35 per cent north of the Intertropical Convergence Zone (ITCZ) results in a southward shift of a few degrees in the ITCZ;
- Rainfall in the Sahel region is thus decreased in the model by 40 per cent during the rainy season.

Charney et al. (1975)

WMO's activities in support of the combat against drought and desertification

Several articles and topics mentioned in the United Nations Convention to Combat Drought and Desertification, in particular Articles 16 to 19, are directed to WMO and the national Meteorological and Hydrological Services (NMHSs). These topics, which are within the mandate of WMO, include:

- The promotion of systematic observation, collection, analysis and exchange of meteorological, climatological and hydrological data and information;
- Drought planning, preparedness and management;
- Research into causes and effects of drought and climate variations as well as into the possibility of long-term climate prediction

with a view to providing early warning of drought;

- Capacity building in the relevant fields of drought and climate, including transfer of knowledge and technology.

Given the importance of the interactions between climate and desertification, WMO has accorded a major priority to this area. Its action plan to combat desertification was first adopted in 1978 at the thirtieth session of the Executive Council of WMO and has gone through several revisions. The Agricultural Meteorology Programme under the World Climate Programme (WCP) and the Hydrology and Water Resources Programme of WMO, through their Commissions for Agricultural Meteorology (CAgM) and Hydrology (CHy), respectively, have launched a number of activities in support of the combat against drought and desertification. A brief summary of WMO's strategy and its activities are as follows:

Mauritania — Dune fixation with windbreak fences made from branches of Balanites (FAO/R. Faidutti)

Monitoring and assessment of drought and desertification

WMO will continue to assist the NMHSs to establish, operate and maintain an effective and efficient observation network, strengthen the collection, communication, analysis and dissemination systems with appropriate data management, and provide information adapted to the needs of user communities.

WMO will continue to assist Members in the evaluation and use of meteorological, climatological and hydrological data and information and in the development of relevant techniques for the assessment of and combat against the effects of drought and desertification.

WMO will continue to support the drought-monitoring centres located in Nairobi for eastern Africa and in Harare for southern Africa, and the Regional Training Centre for Agrometeorology and Operational Hydrology and their Applications (AGRHYMET) for the Inter-State Committee on Drought Control in the Sahel (CILSS) countries.

Application of meteorological and hydrological data

WMO will continue to assist Members in, and prepare guidance material for, the application of meteorology and hydrology to technical, scientific and socio-economic development programmes, especially in agriculture and land-use projects, assessment of water resources, and in instituting preparedness, management, response and remedial action against adverse effects of drought and desertification.

In the implementation of this objective, WMO is cooperating with a number of relevant organisations, including the Food and Agriculture Organization of the United Nations (FAO) and the Consultative Group on International Agricultural Research (CGIAR). WMO, in cooperation with the Office to Combat Desertification and Drought (UNSO)-United Nations Development Programme (UNDP), organized a Workshop on Drought Preparedness and Management for Western African countries in Banjul, The Gambia in September 1995. WMO also organized a Workshop in June 1996 on Drought Preparedness and Management for Northern African Countries in Morocco.

Wind erosion is among the major processes contributing to land degradation, especially in West and North Africa and West Asia. WMO co-sponsored, along with the International Center for Agricultural Research in the Dry Areas (ICARDA), the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) and UNEP, an Expert Group Meeting in April 1997 on the Problems and Control Strategies for Wind Erosion in Africa.

WMO organized an International Workshop on Drought and Desertification from 26-30 May 1997 in Bet Dagan, Israel, in co-operation with the Regional Meteorological Training Centre of Israel. WMO will continue to support the African Centre of Meteorological Applications for Development (ACMAD) located in Niamey, Niger.

Research

WMO is strengthening and intensifying the research on the interactions between climate and desertification. The urgent need to predict interannual climate variations is impelled by the socio-economic upheavals that have occurred, especially in Africa, over the past few decades. Statistical forecasts of seasonal rainfall up to three months in advance are currently being made, but through a coordinated research effort significant improvements in reliability and lead-time could be expected. Equipped with an improved understanding of the physical mechanisms that govern the climate and with more reliable predictive models, countries would be in a far better position to predict the onset of drought and hence mitigate the devastating consequences. Strategic plans could then be developed for capitalizing on the extended predictive capabilities and for converting the forecasts to management decisions that will optimize the use of existing resources. CLIVAR, a research

Drought preparedness and management

Drought severity is dependent not only on the duration, intensity, and geographical extent of precipitation deficiency, but also on the demands made by human activities and vegetation on a region's water supplies. Two insidious characteristics of drought make it different from other natural hazards. First, as the effects of drought often accumulate slowly over a considerable period of time and may linger for years after the termination of the event, the onset and ending of drought are difficult to determine. Second, the impacts of drought are less obvious and are spread over a larger geographical area than the damages that result from other natural hazards.

The economic impacts of drought range from direct losses in agriculture-related sectors, including forestry and fishing, to losses in recreation, transportation, banking and energy. Environmental losses are the result of damages to plant and animal species, wildlife habitat, forest and range fires, air and water quality degradation, and soil erosion. Finally, social impacts involve mainly public safety, heath, conflicts between water users, inequities in the distribution of impacts, loss of life, rural migration and reduced quality of life.

From a planning perspective an appropriate management of drought situations may significantly improve a nation's mitigation strategy by improving the:

- Ability to import and/or store food;
- Targeting of drought assistance to vulnerable population groups;
- Allocation of scarce financial and human resources;
- Effectiveness of post-impact recuperation programmes.

In order to build the national capacities to develop strategies for drought preparedness and management, WMO organizes workshops/training seminars on this topic. The main components of these capacity-building activities are:

- Monitoring/developing early warning systems;
- Building databases for assessing water shortages and potential impacts;
- Drawing up impact assessment methodologies.

Wind erosion in Africa and West Asia — problems and control strategies

Wind erosion, the removal of soil by the wind, is one of the most damaging effects of wind in many parts of the world. It is a major problem in regions with a strongly marked annual dry season and hence is a potential hazard in all dry environments. The occurrence of wind erosion at any place is a function of weather events interacting with soil and land management through its effects on soil structure, tilth and vegetative cover. As with water erosion, the most severe form of wind-erosion damage comes from relatively rare, severe events.

The challenge of wind erosion is multiple: to identify where wind erosion is most threatening to sustainable agricultural productivity, to devise practicable and farmer-friendly measures to contain it, and to determine how to transfer these measures, for instance through extension services.

Despite the growing realization of the problems of wind erosion in West and Central Africa (WCA), and West Asia and North Africa (WANA), there is little qualitative and quantitative information on their seriousness and the location of problem areas. In order to discuss the long-term strategic plans to counter wind erosion and reduce the resulting damage, ICARDA, ICRISAT, UNEP and WMO organized an Expert Group Meeting in Cairo, Egypt from 22-25 April 1997 to:

- Review the occurrence and forms of wind erosion in the dry areas of WCA and WANA;
- Discuss available control measures, both indigenous and improved, and assess the extent and potential of application in different regions; and
- Identify appropriate methodologies for identifying hot spots (at different scales), quantifying erosion and risk of erosion, and developing simple control measures.

The Expert Group identified the following priority areas: the need to understand the major processes involved; improved models of wind erosion; a better understanding of farmer perceptions; and a survey of local practices and socio-economic constraints to the adoption of wind-erosion control techniques.

To enhance global, regional and national awareness of wind-erosion problems and to develop appropriate control strategies, the Group recommended that:

- Design of wind-erosion strategies should be approached at different spatial and temporal scales;
- For improving the quality of life, emphasis should be placed on the development of policies that encourage judicious and adequate land use and resource conservation;
- Priority should be given to developing methodologies of land degradation assessment as it is related to wind erosion and associated risk evaluation;
- Emphasis should be placed on inter-disciplinary and participatory approaches to research and technology adoption;
- International cooperation in wind-erosion research and control programmes should be encouraged;
- An action-oriented research proposal should be developed to address the priority issues identified in International Conventions and be linked to existing networks and National Action Programmes of the United Nations Convention to Combat Desertification.

programme on the climate variability and prediction for the 21st Century, of the World Climate Research Programme emphasizes the following research themes:

- Establishing the limits of predictability taking a regional approach and giving special attention to global ENSO (El Niño/ Southern Oscillation) response areas and monsoon circulation systems;
- Assessing the results of GCM (Global Circulation Model) coupled model runs to assess their ability to reproduce the patterns of spatial and temporal variability of rainfall;
- Studying drought and flood inducing processes;
- Investigating the predictive capability of Sea Surface Temperature (SST) and ocean-atmosphere coupling processes in

the tropical Atlantic and Indian Oceans using the proposed observational arrays;

- Improving the understanding of tropical mid-latitude interactions and their impacts on predictability for northern and southern Africa;
- Investigating land-sea-air interaction processes using remote and *in situ* observations, and conducting numerical modelling experiments to establish feedback processes; and
- Establishing the development of innovative, low-cost solutions to land-based observational and communication needs, and to the construction of data bases, identifying centres of existing expertise and developing assistance programmes and projects to ensure the potential for a local base of ongoing research.

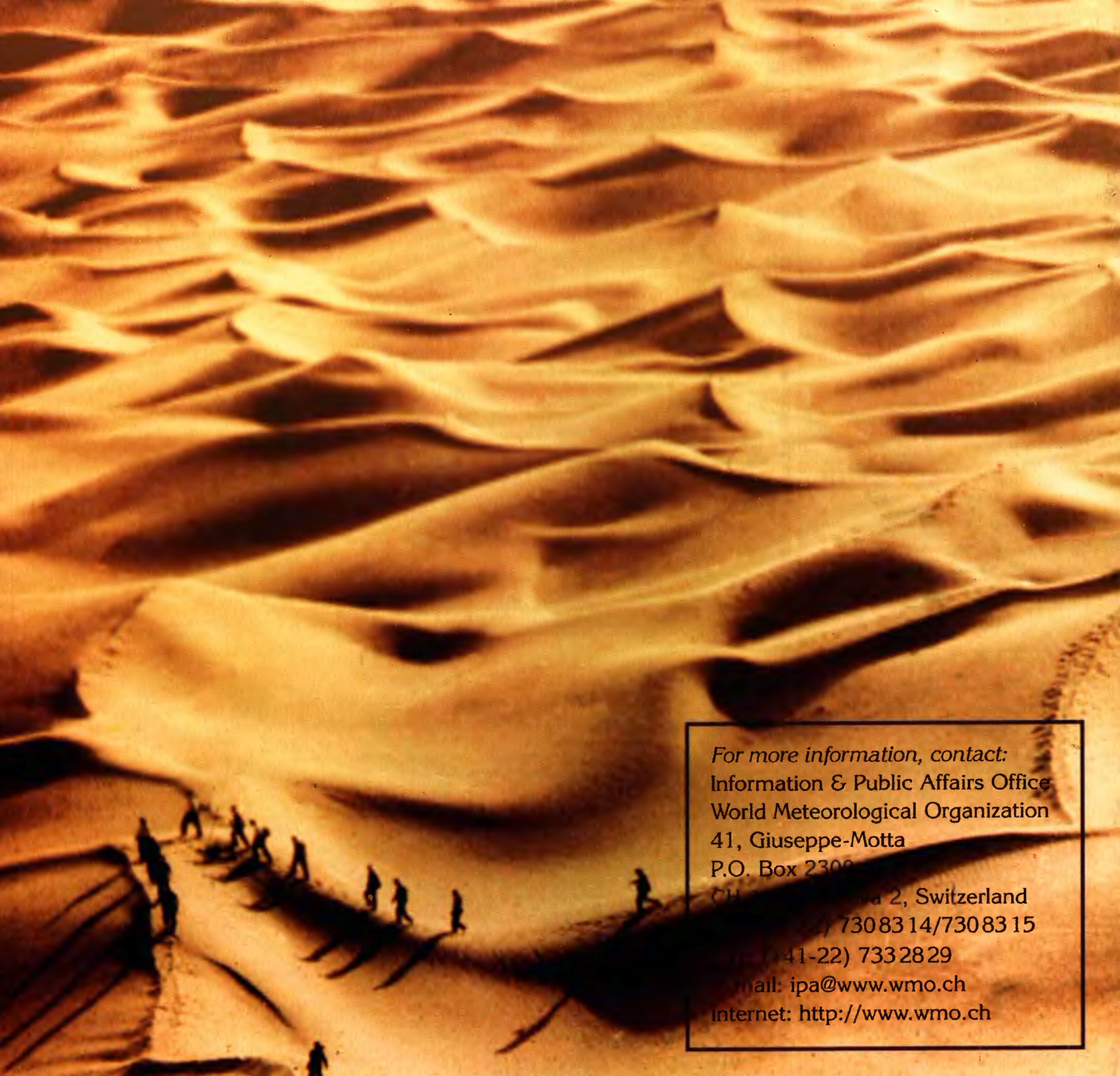
Various research programmes are being undertaken for the study of the weather and climate of arid, semi-arid and sub-humid and other desert-prone areas with a view to the prediction of long-term trends in the general circulation, different rain-producing atmospheric disturbances, and meteorological drought, using statistical and dynamical methods.

Education and training including public awareness

WMO will give top priority to training and education. Through short- and medium-term expert missions, roving and training seminars, training courses and symposia, WMO arranges on-the-job training in operational agrometeorology, and training in specific techniques to assess and minimize the effects of desertification and drought, especially in arid, semi-arid, sub-humid and other desert-prone areas.

WMO organizes roving seminars on the application of meteorological data and information in cooperation with FAO and training in drought preparedness and management in Africa, Asia and Latin America.

WMO will give increased attention to creating public awareness and to communication with a view to bridging the gap between research and applications.



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