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DEFINITIONS, CHARACTERISTICS AND WORLD DISTRIBUTION OF ARID AND SEMI-ARID LANDS

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INTRODUCTION

For over two decades, the international community has been actively concerned with problems of arid and semi-arid zones. From 1951 to 1962, a world-wide programme of arid zone studies was carried out by UNESCO, to promote and stimulate research in various scientific disciplines bearing upon the problems of arid regions. This programme resulted in the publication of some 28 volumes of Arid Zone Research, covering hydrology, plant ecology, human and animal ecology, climatology, energy resources, etc., and the setting up of some 200 research units in 40 countries. In addition, during the past ten years, UNESCO has been involved in the preparation of several thematic maps presenting up-to-date scientific knowledge on the natural resources of arid areas.

The current UNESCO programmes most directly related to the problems of arid and semi-arid zones are the Man and the Biosphere Programme (MAB) and the International Hydrological Programme (IHP). Two of the 14 major project areas under the MAB Programme are directly concerned with these problems. Project 3 deals with the impact of human activities and land use practices on grazing lands, including those in arid and semi-arid areas, while Project 4 concerns the impact of human activities on the dynamics of arid and semi-arid zone ecosystems, with particular attention to the effects of irrigation.

Recently, widespread droughts and famine in the Sahelian zone of Western Africa drew worldwide attention to the problem of the management of arid and semi-arid areas. Two resolutions put forth by the United Nations in 1974 requested specific action.

Resolution 3337 (XXIX) assigned high priority to developing concerted international action to combat desertification, and requested the Secretary General of the United Nations to convene a UN Conference on Desertification. The United Nations Environment Programme (UNEP) was given the responsibility to execute this resolution and is convening a Conference on Desertification in August/September 1977.

Resolution 1898 (LVII) of the Economic and Social Council requested the Secretary General of the United Nations to convene an ad hoc interagency task force on arid zones, which would work to identify the obstacles not yet overcome by science and technology that are encountered by the developing countries; and the social, economic and institutional obstacles preventing the application of available technology.

An interagency working group which met in October 1974 decided that UNESCO, in view of its long experience in the field of arid zone research, should convene the task force to prepare a report on the obstacles to the development of arid and semi-arid zones. This report was completed in early 1975 and was submitted to an intergovernmental working group of the UN Committee on Science and Technology for Development, in order that the task force could make its own recommendations to the Committee on Science and Technology for Development. The comments of this working group, and those of several organizations which are members of the ad hoc task force, were included in the original report.

The original document was expanded to include a more detailed consideration of the physical aspects of arid and semi-arid zones, irrigation problems; urban, industrial and tourism development, and obstacles to the transfer of technology. A world aridity map was also prepared, together with an accompanying brochure explaining the methodology adopted for the preparation of the map.

CHARACTERISTICS AND WORLD DISTRIBUTION OF ARID AND SEMI-ARID LANDS

The map, while serving as a general background document for the UN Conference on Desertification, also aims to update the climatic map by Meigs (1953) which was based on the knowledge of the arid zones at that time, essentially Thornthwaite's data and index (1941, 1948). Since then, the climatological data have increased in number and in quality, so that the limits and boundaries of the arid and semi-arid climates and zones could be improved and made closer to the field observations.

The UNESCO map shows the geographical distribution of the arid and semi-arid zones of the world, including the desert zones, and also the subhumid ones which were not represented in Meigs' map.

The scale is 1/25 000 000. At this scale some generalizations had to be made, and the detailed and peculiar properties of some regions could not be stressed, although these regions do not cover large surfaces. The geographic frame of 1/25 million was a reduction of the 1/5 000 000 map edited by the National Geographic Society of New York.

The basic source of information was the evaluation of the degrees of aridity on a bioclimatic basis, considering the relative importance of precipitation, and evaporation and transpiration from soil and plants. This was done for 1600 stations by the World Meteorological Organization (WMO) and the Meteorological Institute in Bonn (Federal Republic of Germany, Drs. Flohn and Hemming). Whilst Meigs' map on the world distribution of arid and semi-arid homoclimates was based on the humidity index of Thornthwaite (1948), calculated from the values of evapotranspiration from the mean monthly temperatures, the values used for the UNESCO map are those of the ratio P/Etp, where P represents mean annual precipitation and Etp potential evapotranspiration, calculated according to Penman's formula. This formula takes into account the radiation balance and the aerodynamic aspects to evaluate the evaporating power of the atmosphere. The same ratio has been adopted by Rosetti and Riquier at FAO, to design a map on the desertification risks for

northern Africa and the Middle East at a scale of 1/5,000,000, and a 1/25,000,000 map of the world on the same topic. The calculations of the P/Etp ratio were made for all the 1,600 stations. However, the boundary lines between zones of differing degrees of aridity (including the subhumid zone), were drawn by also taking into consideration local topography, soils and vegetation, based on the most recent publications and personal expertise.

Four classes or degrees of aridity have been distinguished and they allow for the identification of the main geographical zones usually recognized. These are the hyperarid, the arid, the semi-arid and the subhumid.

The hyperarid zone corresponds to the true desert areas, for which P/Etp is less than 0.03, with a very low and erratic rainfall occuring in any season. These regions have almost no perennial vegetation, but ephemerophytes could develop during some favourable years. Neither agriculture nor livestock husbandry are possible, except in the oases, although some nomadic grazing is possible.

The arid zone, where P/Etp is between 0.03 and 0.20, supports steppe or shrubland vegetation. It is sparse and depending upon the regions consists of shrubs and bushes, succulent or thorny plants or even leafless plants. Extensive nomadic grazing is the usual form of land use, and no rainfed agriculture is practised. The mean annual rainfall for this zone varies from 100-150mm to 300-350 mm.

The semi-arid zone where P/Etp is between 0.20 and 0.50, and contains steppes and shrublands, some savannas and tropical thickets. These are often good livestock husbandry regions, where rainfed agriculture shows great risks due to the high annual and interannual variations in rainfall. Annual rainfall varies from 300 to 600 and even 800 mm in regions with maximum summer rainfall, and between 400 and 600 mm in areas with winter maximum rainfall such as the Mediterranean and subtropical regions.

The transition to the subhumid zone is difficult to delineate as it is extremely fluctuating. One could indeed consider the whole semi-arid zones as a transition between the dry regions and the humid ones, as, depending on the years, they could be arid or, on the contrary, clearly humid. It really depends on the duration of the dry season beyond seven to eight months.

The subhumid zone, where P/Etp is between 0.50 and 0.75, mainly has an indicative value in showing the boundaries of the semi-arid zone. However, it includes all the regions which are submitted to a progressive aridification, mostly under human influence. Vegetation types vary: tropical savannas, Mediterranean maquis, or thickets, North American chapparal, chernozem steppes of the USSR, etc. Agriculture is the predominant land use pattern.

In order to avoid repetition and redundancies, these four zones are not detailed in the brochure of the map; the presentation is rather of large regions, characterized by a series of common features, such as the European Mediterranean countries, the Near and Middle East region, Central Asia, the Indian subcontinent, Australia, the Saharan, Sahelian and Sudanian regions, North America, and South America. Such a subdivision mainly refers to geographical regions, which are presented with reference to the map; for each, the climate features are shown and illustrated as diagrams, especially for those climates or areas which could not be mapped (due to the scale). The natural vegetation of each region, including the most characteristic species and the most used among them are also given. This information is completed by data on the main soil types and the main patterns of land use.

Within each of the four classes or degrees of aridity, the temperature regimes are defined by mean temperature (in °C) of the coldest (winter) and the warmest (summer) month of the year. These temperature regimes are the same as those distinguished by Meigs, and the consideration of winter and summer temperatures expresses the annual thermal range, which depends on latitude and continentality.

Instead of being indicated by letters and numbers, as in Meigs' map, the temperature regimes in the UNESCO map are shown as colours:

warm winter (20 to 30°C minimum monthly temperature) -- light purple and deep orange;
mild winter (10 to 20°C) -- deep orange to deep yellow;
cool winter (0 to 10°C) -- deep to light yellow;
cold winter (less than 0°C) -- deep green to light green.

These classes are subdivided according to the maximum monthly summer temperature, i.e., very warm summer (> 30°C)
warm summer (20-30°C)
mild summer (10-20°C).

Besides this zonal aspect, the map also shows the length of the drought periods or seasons and the precipitation regime for approximately one thousand representative stations, which are indicated by colored circles.

The number of dry months, i.e. with less than 30 mm rainfall, is indicated by the diameter of the circle, from 1, 2, 3 months for the lowest diameter, to 12 months for the highest diameter; a triangle means less than 1 dry month. It is to be stressed that in those low rainfall climates, the number of dry months does not differ very much from the result which may be obtained by applying the definition of a dry month, used by Gaussen and Bagnouls (1957) and by Walter and Lieth, as P<2t.

A blue circle indicates a dominant summer drought and winter precipitation regimes, sometimes shifted towards spring; a green circle also indicates a dominant summer drought, although there is a shorter and less pronounced winter drought; there are two wet seasons, one towards the end of autumn, the other at the beginning of spring.

Red and orange circles indicate a dominant winter drought, with, in the former case, summer precipitation regimes, and in the latter two wet seasons -- one towards the end of spring, the other at the beginning of autumn.

Purple and grey circles indicate transition regimes: the former, with two wet seasons, one in summer, the other in winter; distinct drought periods, in spring and autumn; the latter, irregular regimes, rains either occasional and unpredictable or, in wetter zones, distributed throughout the year without well-defined maxima, or with unpredictable maxima.

It is to be stressed once more that the scale of the map imposed a high degree of generalization. Although the boundaries of the aridity zones were drawn to reflect the value of the P/Etp ratio for every station, there still is some arbitrary decision with regard to these boundaries, especially in the regions where there are information gaps. Phenomena vary in the field continuously and progressively (except in clear-cut situations, e.g., steep slopes or relief, coastal lines, etc.) and it is rather difficult to assign a clear-cut limit to the mapped phenomena. This is a shortcoming of all climatic mapping undertakings. Therefore the subhumid boundary was not indicated.

That is why, whenever possible, information on soils, vegetation, and topography was taken into consideration, e.g., in the western African coast. The map was established according to the available data which usually are means over a large number of years (25 to 30 years for example). But the calculation of means overshadows the actual phenomena, which may be important for the natural vegetation, livestock rearing, or agriculture. Thus, two stations considered in the same rainfall category may have, during the same year, two very different total amounts of rainfall. For the same station, the total annual rainfall, the number of days of rainfall, and of dry months can vary from one year to the next. Such a variation increases according to the degree of aridity and of the length of the dry season. Such a variation could lead in subtropical or mediterranean regions to an interannual variability which gives, one year, a tropical regime to the station (summer rainfall), and another year a mediterranean regime (winter rainfall, i.e., during the short-day season).

So the extreme variability of precipitation, in time and space, does appear as one of the essential characteristics and common features of the arid and semi-arid regions. However, it is worthwhile to recall the main factors of their diversity.

MAIN FACTORS OF DIVERSITY

Climatic Conditions

The diversity of climatic conditions gives rise to very different situations. Beyond a simple classification into arid and semi-arid regions, it is important to consider the duration of the sparse rainfall, and the duration and timing of the dry season. It is obvious, for example, that the problems of irrigation, "dry farming" and livestock movements will be dealt with differently on the northern fringes of the Sahara, where the rain falls in winter, and on the southern fringes, where the rain falls in summer. In the case of rainfed cultivation, dry farming techniques are well suited to zones with winter rainfall, for evaporation is relatively low and part of the water can be stored in the ground and used by the plants the following year. On the other hand, they are not very effective in zones of summer rainfall, because evaporation is so high at this time of year. The climatic originality of a given semi-arid zone thus appears for a large part to be a function of the general characteristics of the adjacent subhumid zone, and that is another important factor of diversity.

Moreover the precipitations registered by rain gauges cannot always be considered reliable indicators; one of the original features of arid and semi-arid coastal or sub-coastal regions is the presence of hidden precipitations (for example dew), resulting from a greater humidity of the atmosphere (Chili, Morocco, Mauritania, Tunisia, etc.).

Finally, thermic conditions vary widely from one arid or semi-arid region to another: the hot deserts lying in the tropics (Sahara and deserts of Arabia) and the deserts of the temperate zone, characterized by cold winters and greater annual thermic ranges because of their continental location, have often been opposed. Generally, as we cross the tropics towards higher latitudes, the annual range of temperatures becomes greater than the diurnal range. In the hot deserts, the annual range is between 15 and 25°C (24, 4°C at Timimoun in the Algerian Sahara). It is markedly higher in the continental deserts of the temperate zone (37, 7°C at Turgai in Central Asia) where the range of extremes is rather exceptional (sometimes over 90°C). As a consequence, the harshness of winter temperature in the steppes of Central Asia creates conditions altogether different from the relatively mild ones prevailing on the fringes of the Mediterranean world, where the constraints on man are not as great.

Likewise the exceptional heat of certain deserts (in absolute value as well as duration) imposes various types of adaptation to animal life and exercises physiological and neurophysiological constraints on man which limit his activity.

Allogenic Rivers

The presence of allogenic rivers, rising in non-arid regions (Colorado in the United States, Amu Daria and Syr Daria in Soviet Central Asia, Indus in Pakistan, Nile in Egypt, the wadis which flow down from the Atlas in North Africa, etc.) may radically modify the development of a region. These rivers have often made it possible to extend the irrigated areas considerably, but in other cases their utilization remains very incomplete (Niger, Logone-Chari, Senegal, etc.) or might be oriented differently.

The nature of the flow of these rivers introduces considerable variation: for example, the flow of the Nile, governed mainly by tropical precipitations, is very different from that of the mountain rivers of higher latitudes, which are subject to phenomena of snow retention, combined in places with karst retention. Further, the conditions for using surface and underground water resources vary according to topography and a number of geological features, thus are contrasted the Sahara and the Arabian peninsula on the one hand, and Central Asia and the Andean countries on the other.

In the particular case of ground-waters, essential to the development of agriculture and the settlement of populations, a distinction must be established between regions where the geological substratum is made up of generally resistant and impermeable crystalline rocks and those where it is made up of sedimentary rocks with varied facies. In ancient crystalline terrains (shields), the importance of groundwater remains local and its reserves limited. Furthermore, it is usually difficult to assess its extension and force precisely. Most interesting then is the ground water with underground flow (inferoflux) found in alluvium produced by the mechanical disintegration of the crystalline substratum.

In sedimentary terrains, on the contrary, the extension of ground water is considerable and may be found at a number of different levels (water tables of the continental intercalary zone and of the terminal continental zone in the Sahara separated by terrains not suited to the storage of water).

In order to exploit these resources, it is essential to distinguish between ground water, which is being constantly replenished, although often irregularly, and fossil ground water (not being actually replinished). The advantages of sedimentary basins over crystalline shields are obvious, and the geological structure of arid and semi-arid regions, thus constitutes a non-negligible factor of differentiation as regards its repercussions on water resources.

Soil Conditions

Soil conditions vary greatly according to the distribution of the parent rocks, climatic conditions and topography. In many instances there is no real soil and the original substratum is often apparent. When a soil does exist, sandy soils seem best suited to the storage of water. In irrigated zones, silty soils may appear in certain respects more propitious than sandy soils, but present severe risks of soil degradation, especially in regions where natural drainage is poor (Nile delta, plains of the lower Euphrates, etc.).

The accumulation of various salts (NaCl, Co_3Na_2, SO_4Na_2, SO_4Ca, etc.) is generally important because of the intensity of evaporation. Concentration of salts is at its worse at the bottom of depressions where, for climatic and topographic reasons, the flow of rivers to the sea is impossible. Haloplytic plants alone are able to develop in these conditions (playas of North America, takyrs of Central Asia, sebkhas of North Africa).

Finally, all soils of the arid and semi-arid zones remain to varying degrees vulnerable to erosion, hence the overriding importance of all operations of soil fixation, conservation and restoration. The urgency of these operations will appear even more clearly when we consider that in certain cases we are dealing with fossil soils. These soils were created under climatic conditions altogether different from those which now prevail, and therefore once destroyed, would not reconstitute.

Continental Localization

The continental situation of many arid and semi-arid zones has a great influence on development possibilities, insofar as modern development depends heavily on contacts with the outside world. Thus, coastal regions have a definite advantage over regions located thousands of miles from the sea. The ease and frequency of relations with technologically advanced countries with a high standard of living, or even with the vital centers of a nation, are usually decisive factors in the development of these zones. This is illustrated by the contrasting conditions of development in the Chad Basin and in Northern Mexico, respectively.

The position occupied by the arid and semi-arid regions in the countries concerned (marginal, important, essential, or even vital) obviously affects the attention governments pay to them, and, in particular, the investments, public or private, available for their development. These investments consequently are rarely attracted by areas where the immediate return on investment is less certain than anywhere else.

Population Density

Population density constitutes an essential element of differentiation. In some semi-arid regions development may be hindered by shortage of labor. In other regions, the poverty of the inhabitants is due to their great numbers relative to the possibilities of the environment in a given technical, economic and social context. Large sized human, as well as animal populations can lead to dangerous overexploitation and cause serious damage to the environment. The maps of livestock and population distribution established in 1976 for the nations of the Sahel, emphasize some important contrasts and enable one to locate the most endangered zones.

However, similar population densities, subjected to comparable natural conditions, will be faced with vastly different development problems, depending on a certain number of factors. The particular cultural setting (North American, South American, Muslim, Australian) makes for a specific perception of the environment and of its problems.

Lastly, as the social and psychological problems of adaptation to new ways of life are far greater than the technical ones, the approach to development will differ according to the part played by nomads, semi-nomads and sedentary peoples, within a given region.

All this brings us to ask the fundamental question for the future of arid and semi-arid regions: when a choice is possible, should surplus population be maintained in its original environment, or on the contrary, relocated in more favourable areas?

Mineral and Power Resources

The availability of mineral or power resources, as well as the conditions of their exploitation, greatly influence the rate of development. The relative isolation of certain sites and the extraction problems play an important part. However, the evolution of prices on the world market may render profitable the mining of once abandoned deposits, and in many of these nations, highly increase the value of mineral fuels or raw materials. Processing possibilities obviously have a direct bearing on economic and social development. The intermediary stages of the processing of industrial products are poorly represented in the arid and semi-arid zones. On the one hand we have regions where mining industries, or basic processing industries (concentration of an ore for example) predominate, on the other, oases with light industries of a high technical level (electronics for example), as in the United States. Finally, the recent development of tourism has definitely privileged certain areas. This development is governed by a number of factors (presence of beaches or archeological sites, ease of communications with the countries which "supply" tourists), which combine to create a great variety of situations.

Consequently, this great diversity renders extremely difficult the elaboration of development models which do not account for regional characteristics. However, in the presence of common constraints, limited mainly to the irregularity of the water resources leading to extremely hazardous utilization conditions, the most severe problems arise not in the arid, but in the semi-arid zones. There are specific solutions for the use of arid zones, based on division of arid areas into specialized land use units. In semi-arid zones there is conflict between various methods of development (agriculture or animal husbandry) and the choice becomes even more difficult with increasing population densities. Moreover, the threat of desertification by human intervention is obvious in these ecosystems; it is characterized by the spread of desert conditions beyond desert margins, or the intensification of desert conditions within arid regions, which usually manifests itself as a trend towards diminished productivity: lowered carrying capacity for stock, diminishing crop yields, a progressive reduction in real incomes or in social well-being, and/or a reduction in the number of people supported.

ECOLOGY AND ENVIRONMENTAL CONCERNS IN ARID LANDS

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The title of this conference, as has been announced, is: "Alternative strategies for desert development and management." The reason for any pressure to develop on the desert is primarily the result of the ever-growing human population. This results in more and more pressure on planet earth for food and other resources required as necessities or luxuries of life. Any strategy based on the single solution of the reduction in the total number of humans in the world is not acceptable. Such a suggestion must be considered to be only a minor part of the total proposed solution.

During the several days of this conference, a number of papers were devoted to attempts at identifying critical constraints on desert development and management. Time and again we have heard direct or implied statements made that only water is needed to make gardens of all of the deserts of the world! These and certain other statements made at this conference make it evident that many persons striving to help improve the quality of life for humans everywhere - and especially in the arid and semi-arid zones - are quite unaware of some of the controlling factors and basic rate parameters controlling the worlds ecosystem.

Unfortunately ecologists do not yet have enough knowledge to provide precise values for rates nor even for total values. However many have long understood and their importance to humans has been repeatedly underscored by many workers in the past several decades. None of the following material is new. It is based on a whole series of studies that have been summarized in papers such as those of Dregne (1970), Talbot (1972), and Sherbrooke and Paylore (1973). Essentially it is a rewrite of material presented by me (Cockrum, 1976) in Proceedings of the West Africa Conference held at the University of Arizona, Tucson, in April, 1976.

As far as the human population (of the world or any sized subpart thereof) is concerned, the statement is often made - and appears to be a basic premise of the United Nations - that all areas should be developed. However only a few megalomanical individuals have ever thought that he or she personally knew what was "best" for everyone! Within the United Nations, the definition of "developed" appears to mean "an improvement in the quality of life." Almost every sapient member of Homo sapiens recognizes that (a) improved "quality of life" should be compatible with the real desires of the majority of the local residents and not