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# World Climates and Food Supply Variations

## Climate has great variation including drought but improved use of favorable areas could increase food supply.

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In this article we outline the major variations in the world's climates and suggest how these variations should be taken into consideration in any plans that are made to improve world food production and supply. Much has been written in recent years about climate and climatic change, particularly as it relates to agricultural production and world food supplies (*1*). Climate, the average expression of all weather events over many years, is often the least understood branch of meteorology. Yet, the abstract statistics, resulting from the ups and downs of daily weather events, relate how most of the arable land areas of the world are used for human food production.

A. H. Boerma, the director general of the Food and Agricultural Organization, stated in February 1973 (*1*), in regard to the world food situation, that ". . . there remains one vast incalculable—nature itself. One thing that has been harshly, even humiliatingly, made clear in the last 2 years is that, despite all our technological progress, despite all the buoyant hopes invested not long ago in the so-called Green Revolution, harvests are still far too often at the mercy of the weather. In this respect, at least, man has so far failed to master his natural environment." He continued, ". . . in the name of reason, can this world of the 1970's, with all its scientific prowess and its slowly growing sense of common purpose, go on enduring a situation in which the chances of enough decent food for millions of human beings may simply depend on the whims of one year's weather? Is this a tolerable human condition? Emphatically not!" He then suggested that developing countries should give much higher priority to their agriculture and that "all countries which are in a position to do so—including developing countries—should participate in concerted policies for actively building up food reserves." To date, the concept of establishing large central food reserves has met with defeat. In view of the fact that some areas of the world are known to have climates that are less favorable for food production than others, it would seem to be a more realistic goal to establish decentralized stores of food (primarily grain) in locations close to where they might be needed. In many instances, this would also be a more acceptable goal politically.

That sizable deviations in climate and weather events do affect agricultural production cannot be debated. But the extent to which such climatic deviations affect world food supplies as well as what can be done, plus the difficulty of improving the situation, have too often been treated only as forecasts of tragedies by those not experienced in the agricultural sciences and technologies.

When addressing the question of world population and food supplies, one must realize that an energy equivalent of 13 to 15 billion in food that could be consumed by human beings is currently diverted through animal agriculture. Proper concern should be given for feeding livestock primarily feed stuffs not useful directly to man.

For example, this should include perennial and annual forage crops with much fiber content, plus plant residues such as sugar cane bagasse, citrus pulp, straw, corncobs, leaves, and stems of various grain crops. The function of the ruminant animal with its four stomachs can be greatly extended in using crop residues and other organic substances to grow food for man from fibrous material that he cannot eat directly. In too much of the world these valuable ruminants are not fed, but simply forced to forage on wasteland. Animals as well as grain represent storage mechanisms for food. Further improved feeding practices in favorable times for them could result in more effective "storage" for seasons and years of stress, instead of extreme loss of weight and even death of the animals during such periods. The local on-farm storage of roughage and other feed for animals as feed reserves to be used during stress periods can be a key to further improvement of the use of animals as a human food storage mechanism.

Another important consideration has to do with the climatic requirements of staple crop production. Much of the world's staple food grains are produced in regions having alternately wet and dry seasons. Such climates, in which periods of highest solar radiation, temperatures, and seasonal precipitation are in phase, fulfill the seasonal production cycle requirements of (monoculture) annual staple grain and protein–oil seed crops (see Fig. 1). These

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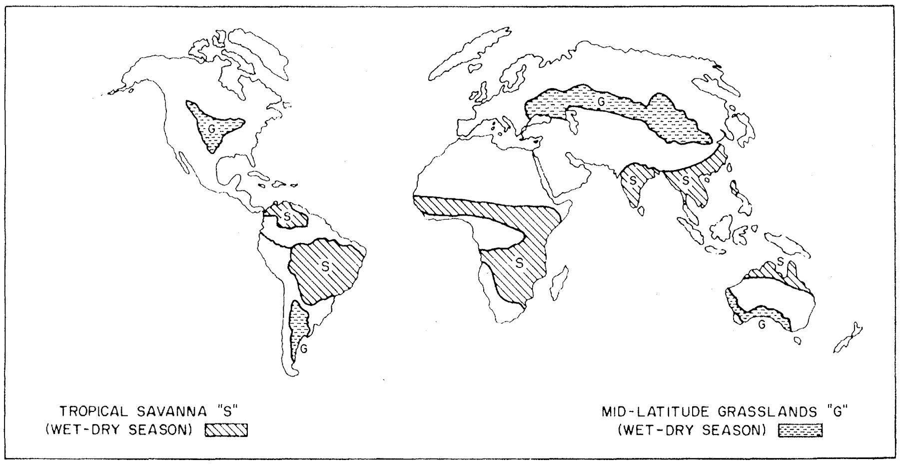


Fig. 1. A map of the world showing areas where solar radiation, temperature, and precipitation are at a maximum during the normal growing season. [Data from (*10*)]

areas in the world have a good combination of light energy for photosynthesis plus heat and moisture for the large-scale growth of a single crop.

The major wheat-producing areas of the world are confined to the grasslands of North America, South America, eastern Europe, Asia, and Australia. Corn is grown mostly in the warmer and wetter portions of these same regions. The great rice areas of India, southeastern China, and other regions of southeast Asia are largely confined to the tropical and subtropical monsoonal climates (*2*). All of these wet and dry climates of the world have a transitional gradient across them, from humid forest climates on one side to arid deserts on the other. Therefore, it is not surprising that such areas, particularly those bordering on or degrading into deserts, are often subject to drought. In many such areas little research on food crop production has been conducted in these transition zones. The rather new international research centers set up in Nigeria, Colombia, and India, in addition to the older ones in the Philippines and Mexico, are directed toward fulfilling this need. These will provide invaluable starting points, with information and experimental materials for new and expanded national food crop research programs in these countries.

## World Climates and Agricultural Production

For a climate to be considered truly tropical, it must be free from freezing temperatures. Such conditions are mostly confined to 20° to 25° north and south of the meteorological equator; the meteorological equator is about 5° north of the geographic equator in most parts of the world.

The true tropical rain forest climates saddle the meteorological equator by about plus or minus 5° latitude. These climates feature a diurnal temperature change larger than the annual temperature change. There are two periods of maximum rainfall, usually just after each equinox period, and there is a surplus of water in all seasons. Solar radiation exhibits very little change during the year. The soils are impoverished because of intense leaching. There is no extensive cultivation of any one staple crop in these climates. Thus, it has been difficult to select the best crops for improvement. New research can help select the best investment potentials among the food crops available. But such research efforts are generally only in the planning stages at this time.

To each side of the tropical rain forest climates, and at higher latitudes in both hemispheres, lie the tropical monsoonal regions. They feature rainfall during the season of high sun—that is, when the sun's position shifts into the respective hemispheres directly overhead on its annual swing between the Tropic of Cancer and the Tropic of Capricorn. The tropical wet and dry climates are ideal for rice production and other staple grain and oil-seed crops because solar radiation, temperature, and rainfall are at a maximum during the same season. But they are also subject to drought in the savanna regions bordering the great deserts.

At higher latitudes north and south of the tropical wet-dry climates, beginning between 20° and 25° in each hemisphere, lie the great subtropical desert climates. These areas occupy nearly 25 percent of the land areas of the world. They are subtropical because freezing temperatures can occur, and do, in most areas during the winter season of each year. These desert regions lie between 20° and 35° latitude north and south of the meteorological equator. Successful agricultural production in the heart of these climates requires irrigation. Crop production that depends only on natural rainfall occurrence is often attempted on the borders of these areas. Such crop production attempts often include short season millets and drought resistant sorghums. In times of food shortage and consequent high grain prices, wheat production, for example, is greatly expanded into marginal areas. Russia's recently announced plan to increase grain-producing lands by 30 percent will, no doubt, require the cultivation of some marginal areas that are subject to unfavorable variations in climate, including both drought and extremely short growing seasons (*3*).

North and south of these great deserts at about 30° to 35° latitude in each hemisphere lie the so-called subtropical Mediterranean climates, where there are frequent frosts as well as maximum rainfall in the winter season, while the periods of maximum solar radiation and temperature occur in the summer. Mediterranean climates are thus not ideal for extensive crop production, but many specially adapted crops are grown successfully in these regions. Winter wheat, winter rye, and the cool season grasses are good examples of crops well adapted to the Mediterranean-type climate.

Between latitudes 35° and 55° in the Northern Hemisphere, and between 30° and 45° in the Southern Hemisphere, lie the belts of temperate climates. They exhibit large seasonal variations in precipitation, temperatures, and solar energy. In the temperate forest climates precipitation occurs the year round, similar to the tropical forest climates. Also, within these varied temperate regions lie the grassland or steppe climates. These climates exhibit wet and dry seasons, with high solar radiation, temperature, and precipitation occurring in phase in the late spring and summer—a situation similar to that in the tropical regions that have wet and dry seasons.

These midlatitude grassland climates produce a unique soil formation with a

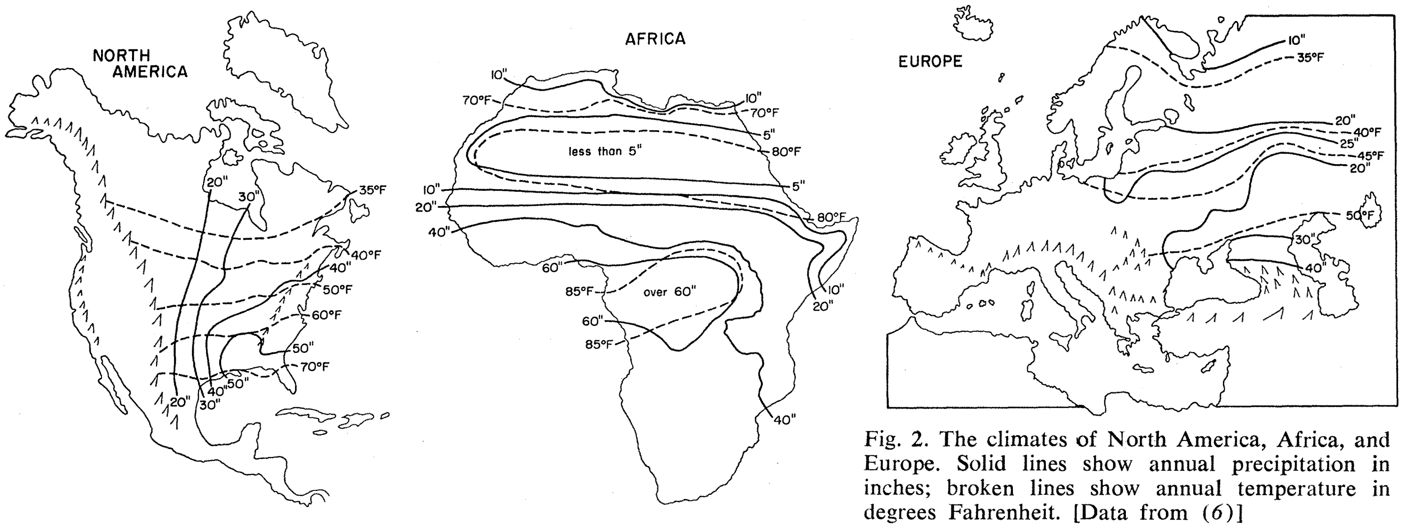


Fig. 2. The climates of North America, Africa, and Europe. Solid lines show annual precipitation in inches; broken lines show annual temperature in degrees Fahrenheit. [Data from (6)]

thick surface layer rich in plant nutrients and with topographic features well suited to extensive cultivation. This soil is a product of the natural climax vegetation produced by a unique balance between precipitation and temperature. Regions having these climates and soils are extensive in North America, eastern Europe, and Siberian Asia, and, to a much lesser extent, in the other continents. They have been described as boundless and treeless—as seas of grass. They are subhumid to semiarid, lying between midlatitude humid forest climates and the arid, cold desert climates. Normally there is enough seasonal rainfall in these regions for the cultivation of plant species that can complete their life cycle in one growing season. But drought is too frequent for perennial species that require a continuous water supply. Again, the great asset of these midlatitude grassland climates is that the periods of maximum solar radiation, temperature, and precipitation occur in phase during the normal growing season. These regions are readily adaptable to extensive staple grain production the world over. They are particularly suited to the production of wheat—"the bread of life" (*4*).

## Some Reasons for the Variations in World Food Supplies

The increase in the world's human population requires that, in addition to all the land now under cultivation, additional arable land be utilized. In most instances this means that land that may be marginal in every way must be considered for food production. Among the climatic risks of crop production in these areas, drought normally heads the list because often these new lands lie in the drier areas of both the tropical and the temperate high latitudes, and wet and dry climates. As far as agriculture is concerned, a transitional zone between a climate that has wet and dry seasons and a desert climate is an area of high drought risk in all parts of the world, whether it is a midlatitude grassland, a tropical monsoonal area, or a savanna.

Further, if world climate is changing, as often postulated in recent months (*5*), then it follows that these transitional lands should usually lie where shifts in climatic factors are likely to be observable first. Such tension zones or ecotones lie at the edge of wet and dry climatic areas. This could be a plausible explanation of the changes that are being observed in the Sahel area on the south side of the Sahara Desert today.

## Differences in Climatic Risks among Continents

Transitional zones in some parts of the world are more risky than others. One possible explanation for this situation is that annual isotherms (temperatures) and annual isohyets (rainfall) run parallel to each other in some parts of the world but not in others. For example, in Africa annual isotherms and isohyets run parallel from the equator north to the Sahara Desert (Fig. 2). This area probably has the steepest gradient from humid to arid conditions across a transitional zone, on a continental scale, in the world. A similar type of pattern exists in mid- and high-latitudes of eastern Europe (Fig. 2), where the annual isotherms and isohyets run more or less parallel to each other across Europe and Siberian Asia. But in the North American continent east of the Rocky Mountains the annual isotherms and isohyets run at approximately 90° to each other, particularly in the midcontinental grassland regions (Fig. 2). South America is similar to North America in this respect (*6*).

The contributing physical cause of the continental differences relates to the orientation of the major mountain ranges of the New World and the Old World continents. In the former they are oriented in a north-south direction, while on the Eurasian continent the major ranges run mainly in an east-west direction.

The earth's wind systems, because they flow primarily from west to east (the variable westerlies), or from east to west in the case of the trade winds, are influenced by the orientations of the major mountain ranges in each continent. In North America, the Rocky Mountains range causes an increased variability in the prevailing westerly flow, pushing it downward over the eastern portions of North America. This increases the north-south flow of wind and transports moist tropical air masses deep into the midcontinental regions of the North American grasslands; it also pushes polar air masses southward. This accounts for much of the observed mean isotherm-isohyet patterns in midcontinental North America. In comparison, the east-west orientation of the major mountain ranges on the Eurasian continent parallels the direction of the prevailing westerlies, allowing the mean flow of these winds to remain much more stratified. This, in turn, allows the mean annual isotherms and isohyets to remain more parallel over the vast interior of the Eurasian continent, and results in climatic transitional gradients that are much steeper in the north-south direction (*7*).

In terms of agricultural production, these climatic features give an advantage to the New World continents. The mean annual isotherms and isohyets, because they are not parallel in the vast grassland climatic areas of the Americas, allow a favorable water balance to be extended over very broad areas in the north-south direction. Also, they allow for agricultural production areas to be less stratified in a north-south direction than they are in the Eurasian continent, and ensure against a slight mean seasonal shift in the prevailing westerly flow; thus, they reduce climatic risk. This fact was stated in another way by Glenn T. Trewartha when he evaluated U.S. agricultural climatic risk (*4*): "No other region on the Earth of equal size is so well endowed physically—in surface configuration, soil, and climate for agricultural use."

## Climatic Changes and the Views of Climatologists

Among climatologists there are two general schools of thought concerning the application of weather statistics to contemporary problems. According to one school, weather events from one year to the next are independent of each other and occur at random; according to the other school, such events relate to cyclic patterns or to causes not fully understood. The important differences between these two schools is that those who adhere to the former see weather events as a static matter needing no further explanation, but those who adhere to the latter must postulate a cyclic forcing function or a dynamic cause. Since data of sufficient quality and quantity to test the several hypotheses do not exist, there has been ample opportunity for many different theories to be developed, creating a lively debate among climatologists in our time (*8*).

Currently, there is much speculation among some of the leading climatologists that a worldwide cooling trend is under way (*9*). If the world is in a gradual cooling trend, it follows that the circumpolar vortex should expand, causing the mean prevailing westerlies to shift to lower latitudes. Likewise, there could be a shift in the trade wind systems as well as the equatorial retreat of the intertropical convergence zone's annual penetrations into each hemisphere. Such shifts in worldwide atmospheric circulations could produce the current North African droughts. It would also suggest a reason for the mean midlatitude jet flow staying south of the Himalaya Mountains a few days later than normal in the Northern Hemisphere's spring season as has been recorded often during the past decade (*9*). This delayed seasonal migration of the "jet" has been associated with the delays as well as the lack of penetration of the monsoonal rains in India. A delay in the onset of the monsoons usually produces a less desirable distribution in seasonal rains in all parts of the subcontinent of India and the remainder of the southeast Asian monsoonal areas. This can cause droughts as well as floods in the same season. Further, this seasonal delay in the Asiatic monsoon is often associated with a similar seasonal delay in the onset of spring rains in the grassland (steppe) climates of the U.S.S.R. Even though these patterns have been observed repeatedly in the last decade or so, this is a very small sample of time from which to conclude that a worldwide climatic change is indeed under way. It is a matter of record that the 1930's were the warmest period recorded in recent history. But there remains the question of whether these are contrasting periods of extreme deviations from normal random fluctuations in weather or real trends. At this time there is not an abundance of evidence either way. Only additional research will clear up this question, and such research will require considerable time.

## Alleviation of Food Shortages

Regardless of whether climates are truly changing or merely fluctutating in a year-to-year random manner, there is much agricultural technology and other scientific knowledge that can and must be set in motion if the tragedy of mass human suffering is to be held to a minimum.

There is one principle in climatological deviations that must be considered in any extensive planning. Climate, in a general way, obeys the law of conservation. That is, whenever one large area is getting too little precipitation, another is getting too much. The same holds for most other climatic factors as well, such as temperature deviations, pressure, and cloud cover. Further, in areas where the climatic gradient is steep, often the regions of greatest contrast between too much and too little rainfall lie adjacent to one another. This is especially true in the tropical wet and dry climates. By introducing agricultural technology that would allow quick shifts in crop production patterns between areas, plus means of adequate storage and transportation, much of the mass human tragedies witnessed in recent months could be avoided in the future. Shift in production could be done if accurate reporting of crop failures could be relayed to the nearby agricultural production areas. Such information is paramount in planning increased crop production in nearby favorable areas since the timing of the production growing seasons is often only days or weeks different in onset. Many of the present tragedies of West and East Africa have been preceded by several seasons of crop failure before relief and other measures were requested. Current accurate reporting of crop conditions is a must in any planned shifts in seasonal crop production to fulfill failures in other areas.

Even slight shortages of food bring amazing problems to human population, particularly in some of the developing countries of Africa and Asia. Government price controls fail to work to prevent these shortages and great frustrations set in for both the consumers and the governmental officials. It is well known that people tend to respond to even slight food shortages with hoarding and holding out for higher prices. Such behavior accentuates the shortage and makes more difficult the distribution of whatever supplies are available, and those who suffer are generally the poor, the old with lower incomes, and the young with the greater protein needs. Even in times of relative plenty, the protein needs of these groups are hard to meet because of the almost universally higher prices of edible legumes and animal products.

While it is not possible to predict exact drought intensities for certain seasons and for numbers of years ahead, certain zones on each continental land mass are known to be much more variable and hazardous than others. Therefore, much could be achieved by adequate planning of food production practices and by improving storage facilities, transportation, and marketing procedures. Such planning would have to include estimates of the availability of agricultural inputs such as seed stocks and fertilizers. Thus, such planning would only be possible after a considerable amount of research investment has been made. Statistics on agricultural production would have to be gathered along with the necessary climatic, soil, and other production input data for each zone.

If a particularly unfavorable climatic period were to hit a certain zone, then the inputs could be changed (for example, instead of corn being planted, sorghum could be used; or instead of sorghum, millet) in an attempt to produce at least some food supplies during this period. Although it might only be possible to produce crops of limited size within a "disaster" zone itself, the biggest opportunity of all may lie in enlarging the capacity of the very favorable moisture zones that normally lie relatively near the dry zones. These wetter zones, although they have much higher food crop production potentials, also have inherent problems of their own, such as more weeds, diseases, insects, and wild animal feeding. With proper agricultural inputs beginning with research effort, investment in management, plus such physical inputs as storage improvement and transportation development, a less variable food supply could be cultivated across large geographical areas where high year-to-year variations in agricultural production are prevalent.

Weeds deserve special mention because of their significance in wiping out gains in food crop production in the wetter areas of the tropics and subtropics. With the increased moisture, the crop yields should be much higher where adequate soil fertility is present—except that the weeds also grow more vigorously and can reduce yields 30 to 40 percent commonly and often much more. "Too little, too late" in weeding procedures whether by hand, mechanically, or with chemicals is all too common. All too often, actual production in these zones is little higher than it is in the "disaster" or drought zones. Production losses of mature staple seed crops as a result of their being damaged in the field by birds, rodents, and weather are often 30 percent or more. A further loss of 30 percent or more can occur in storage. The largest losses during storage are caused by insects. Crop diseases caused by various fungi and bacteria also play a major role, both in the field and in storage, in reducing the amount of food that is ultimately available to mankind. The development of proper grain storage facilities is a much-needed technology in the majority of the developing countries. All of these practices can play a significant role in alleviating "disaster" in the seasonally humid tropics.

The climatically favored areas should be able to produce not only enough food for their own needs but enough to have some left over for more variable marginal areas. Many countries, such as Ethiopia, Nigeria, and India, have both drought areas and favorable humid areas within their borders, and the distribution of available food should not be difficult. In other areas, however, such as a large part of the Sahel in West Africa, international cooperation would be necessary to establish effective means of food distribution. Cooperation would also be required if relief were to be provided to nomadic peoples. In many cases the distances between dry and humid zones are not great, but lack of transportation, inadequate foreign exchange methods, and tribal differences are major barriers to adequate food production and distribution. Efforts should also be made to produce enough food in the favorable zones to permit storage from season to season, and from year to year, of quantities that could be used both in the event of unforeseeable crop losses and as buffers for the nearby stress zone. Because of more favorable grain storage conditions in the hotter and drier areas, the location of storage facilities in these areas should be encouraged. However, such production efforts will require adequate inputs in both material and management technology that are available only through international assistance in most instances.

Many people are inclined to criticize the "Green Revolution" by pointing out the high cost and the unavailability of the best package of materials and management. Proper amounts of essential elements are necessary for satisfactory crop yields regardless of the genetic origin or background of the crops grown. Supplying the necessary phosphorus, potassium, and the micronutrients through the application of chemically constituted fertilizers requires satisfactory marketing and delivery practices and, in many underdeveloped areas, transportation systems yet to be developed. The production of nitrogenous fertilizers depends on the availability of energy for fixation; production costs are, therefore, related to fossil fuel prices. The use of symbiotic nitrogen-fixing legumes or other biological systems of supplying nitrogen would thus seem to be much more important in the immediate future. The development of adequate seed stocks of superior responsive varieties, together with new management techniques and inputs, is essential. The development of new crop varieties, and the release of new varieties to farmers, must be a continuous process so that there will always be available plants with adequate resistance (to disease, insects, and drought) for cultivation in particular regions and during times of stress. Also, it must be possible to shift these varieties rapidly when disasters, biotic or climatic, develop.

## Summary

Most areas of famine could be greatly reduced with proper planning. Improvements in food production in nearby relatively favorable areas could alleviate the present situation whereby a disastrous food shortage must become "newsworthy" throughout the world before the ponderous machinery of international assistance and very expensive intercontinental staple grain shipments are made. Such planning would allow man to be far less at the mercy of the annual whims of seasonal weather for his food supply.

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