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Drought and Human Adjustment in Saudi Arabia

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ABSTRACT: Drought is one of the natural hazards which causes death and damage for property particularly in drylands of the world. Drought as a natural hazard tends to limit and disrupt human activities. On the other hand, man has tried to adjust his living conditions to this hazard. The adjustment to drought is different from one country to another. Adjustment to drought is affected by culture, income, and by the political system in the country. In the case of Saudi Arabia adjustment to drought hazard is usually the work of both individuals, and government. The Saudi Arabian government has spent large sums of money to reduce impact of drought hazard.

Introduction

Saudi Arabia is located in the SW portion of Asia. Aridity is the most dominant climatic feature in the country. The prevailing climate over most of the country is classified as hot, dry desert. Due to aridity, rainfall is scarce and unpredictable in most parts of the country.

In addition to the scarcity of rainfall, temperature, and evaporation averages are extremely high as a result of which rainfall becomes ineffective, and as such there is a soil moisture deficit in most parts of Saudi Arabia throughout the year.

As a result of widespread aridity, the grazing land area in the country is estimated to be about 57% (130 million ha) of the total area (230 million ha) (Tag El-Din 1989).

Aridity, does not stop grazing activites in the country, and herders are still raising a large number of livestock, but the number of these animals has been decreasing considerably since World War II as resulting from successive years of drought. For instance, in the central, and eastern regions of Saudi Arabia herders lost between 50–90% of their livestock during the hazardous drought which occurred during 1958–1966. In the 1950's camel grazing provided work for about 30% of the population of the Kingdom (Allred 1968). Most of the grazing land is, however, fit only for camel herding, and it is likely that some nomads will continue to raise camels in these sub-marginal areas in the future. Recently, nomads were estimated to be less than 15% of the total population of the country (Ministry of Municipal and Rural Affairs 1991).

Dracup (1980) indicated that drought should be looked upon in the context of a period of low water supply which affects society's productive and consumptive activities. But, the concept of drought is different from one region to another. Butler (1978) stated that a country with heavy rain the whole year considers drought over a short period, while a country with light rain considers drought over a long time span.

Drought can cause several ecological disasters including loss of human, and animal life, crop failures, large-scale population migration, starvation and famine, international conflicts, and severe health problems. The socioeconomic impacts of drought in any given region include disruption of economic activity, large-scale unemployment and socio-political instability.

In 1973 the world began to hear about starvation and suffering as a result of drought in such places as Ethiopia, and Sahelian region of Africa. In the Sahelian zone the death of people was estimated at about 100,000. With respect to the effect of drought in Mali, about 1,000,000 out of 5,000,000 (20%) of livestock was lost in 1973. In NSW Australia sheep numbers were reduced because of drought by 16% and in Queensland by 22%.

The loss of cattle or sheep involves not only the loss of their monetary value, but also the loss of their breeding ability to compensate animal losses (Dubis 1975).

From an economic point of view the effect of drought in Australia was estimated at the total cost of $ 1,500 million. Exports of Australian wool for 1965–1966 fell by $ 27 million, and the estimated increase in prices for urban-dwellers was about $ 1 million in the food items alone (Butler 1978).

The negative impact of drought is not only economic, but also environmental. Deterioration of the environment may occur through heat waves, water salinity, and dust storms. Socially, drought causes demographic instability as reflected by mass population migration (White 1974).

	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991
Eastern Region							121.0	17.4	60.4	82.3	27.3	59.6	61.6	146.4	73.9	14.8	13.8	105.3	33.0	181.3	74.2	68.4	24.4	148.4	59.4	107.2	80.2	9.9	9.5
Riyadh Region		163.6	57.0	27.1	95.5	125.7	122.3	12.3	90.3	120.5	54.7	70.3	123.0	175.1	43.2	29.2	53.7	67.2	26.8	148.8	64.4	70.7	92.6	146.5	53.0	76.4	97.9	39.6	38.3
Qassim Region					98.3	83.6	121.0	111.6	96.8	166.0	117.0	116.5	38.4	176.8	49.6	91.3	111.0	106.6	79.7	340.4	107.6	64.4	102.8	142.4	146.4	69.0	89.4	42.2	107.8
Hail Region				76.3	72.0	150.6	168.8	101.0	86.0	164.8	39.4	134.4	106.9	259.4	95.5	36.6	106.9	65.2	81.6	113.6	70.4	231.2	153.3	126.2	61.0	54.0	111.2	58.4	125.7
Northern Region										25.1	51.0	89.9	85.5	38.7	63.0	2.5	70.3	80.0	49.6	111.1	38.6	64.5	67.6	75.9	100.7	130.9	70.7	46.4	92.4
Al-Jouf Region								75.0	29.3	59.2	37.7	127.1	64.3	42.1	14.5	5.4	34.6	37.0	14.8	109.2	13.8	40.5	79.8	86.0	99.0	86.8	56.2	23.4	48.4
Al-Qurriyyat Region										79.4	16.7	81.4	66.5	42.5	20.9	21.0	45.6	107.6	21.2	84.1	13.2	28.7	51.6	50.0	75.0	98.0	12.6	36.2	63.4
Tabuk Region				56.4	65.0	134.5	110.0	45.7	52.6	34.7	20.0	85.8	43.5	1.5	39.2	9.7	60.3	29.0	2.2	65.5	5.3	27.5	79.4	49.9	42.1	80.1	46.0	3.7	67.7
Mandinah Region				27.0	10.0	72.2	82.9	10.0	103.8	60.2	1.0	77.9	20.0	34.8	17.0	27.8	58.0	6.8	52.4	79.0	25.3	74.1	111.2	47.4	39.3	16.4	108.4	39.0	64.3
Makkah Region	496.0	92.0	198.5	157.0	146.0	281.1	206.5	108.7	172.5	213.0	103.5	74.8	181.2	115.7	108.3	107.0	144.5	77.1	66.2	217.0	142.6	87.5	283.5	174.4	141.6	99.0	275.4	78.4	185.3
Al-Baha Region				200.8	443.1	471.9	436.6	414.6	186.4	584.6	323.5	357.4	740.7	434.5	419.5	395.0	520.1	322.6	307.6	422.7	448.1	175.0	453.6	223.2	285.6	180.0	364.2	314.8	312.0
Annir Region				158.5	557.8	611.0	420.7	328.1	302.4	457.8	183.2	354.0	327.5	372.9	376.3	220.0	256.3	3788.	409.2	410.4	558.2	215.8	508.7	368.3	393.0	329.8	332.1	391.7	142.1
Gizan Region				64.0	24.0	22.0	18.5	15.0	13.6	8.5	58.7	68.9	48.1	41.2	171.3	28.1	159.1	30.6	104.3	191.0	105.1	5.2	62.9	31.6	43.1	150.9	69.9	94.9	42.3
Najran Region											22.8	56.6	191.6	45.6	194.8	70.4	44.7	19.0	57.9	73.6	80.4	17.6	76.6	80.5	18.0	44.3	49.0	16.5	15.3

Source:
(1) Ministry of Agriculture and Water, Department of Water Resources Development, Hydrology Division.
(2) Ministry of Defence and Aviation Meteorology & Environmental Protection Administration.

Tab 1 Annual rainfall (mm) in agricultural regions in Saudi Arabia

The impact of drought on the physical, and cultural landscapes depends on the following factors: (1) magnitude of the natural event (2) duration which refers to length of time over which hazard event persists (3) Areal extent which refers to the space covered by a hazard event, and (4) frequency which asserts how often the event occurs during a period of time (White 1979).

Based upon the information mentioned above we now know that drought as a natural hazard causes loss of life and property to the affected people. In these cases, we should think of the best solutions to protect or reduce the impact of drought on man and his property.

Study Objectives

The purpose of this study is to determine the following:

1) Rainfall variability, and drought probability in Saudi Arabia.
2) Classify Saudi Arabia into rainfall regions
3) The aridity index, dominant plant, and climatic classification of Saudi Arabia.
4) Human adjustment to drought.

Research Method

The main objectives of this research can be achieved by adapting the following procedures:

1) The cumulative percentage frequency of annual rainfall (probability of rainfall). This can be obtained by applying the following formula:

$$Fi=(m/n+1) \times 100$$ (Dunne and Leopold 1978).

Where: Fi= The cumulative percentage frequency of annual rainfall.
M= Rank of the rainfall by giving the smallest rainfall value rank= 1.
N= Year of record.

Tab 2
Statistical descriptive of the rainfall in regions of Saudi Arabia

Region	Mean	S.D.	Min.	Max.	Dry years Number	Wet years Number	Pr. of non-exc. %	Pr. of exceed %
Eastern Region	68.70	49	9.5	181.3	12	9	4	96
Riyadh	82.00	44	12.0	175.1	15	11	3	97
Quassim	111.10	59	38.0	340.4	12	6	4	96
Hali	109.63	55	36.6	259.4	12	9	4	96
N. R.	67.70	30	2.5	130.9	9	8	5	95
Jouf	54.00	34	5.4	127.1	12	8	4	96
Qurri.	50.78	30	12.6	107.0	10	8	5	95
Tabuk	48.36	33	1.5	134.5	12	12	4	96
Madin.	48.70	33	1.0	111.2	13	11	4	96
Makka.	163.26	90	66.2	496.0	17	9	3	97
Baha	374.54	131	175.3	740.7	13	12	4	96
Assir	360.20	120	142.1	611.0	11	13	4	96
Gizan	63.65	53	5.2	191.0	16	9	4	96
Najran	62.00	52	15.3	194.8	10	7	5	95

Pr. of non-exceeding = probability of the low value (minimum value occurrance
Pr. of exceeding = probability of exceeding low value occurrance
Dry years = rainfall is less than average
Wet years = rainfall is more than average

2) Determination of aridity index is done by applying De Martonne equation which is defined by:

Drought index = (P/T+10) (Walton 1969).

Where: P = Mean annual precipitation in mm.
T = Mean annual temperature in centigrade.

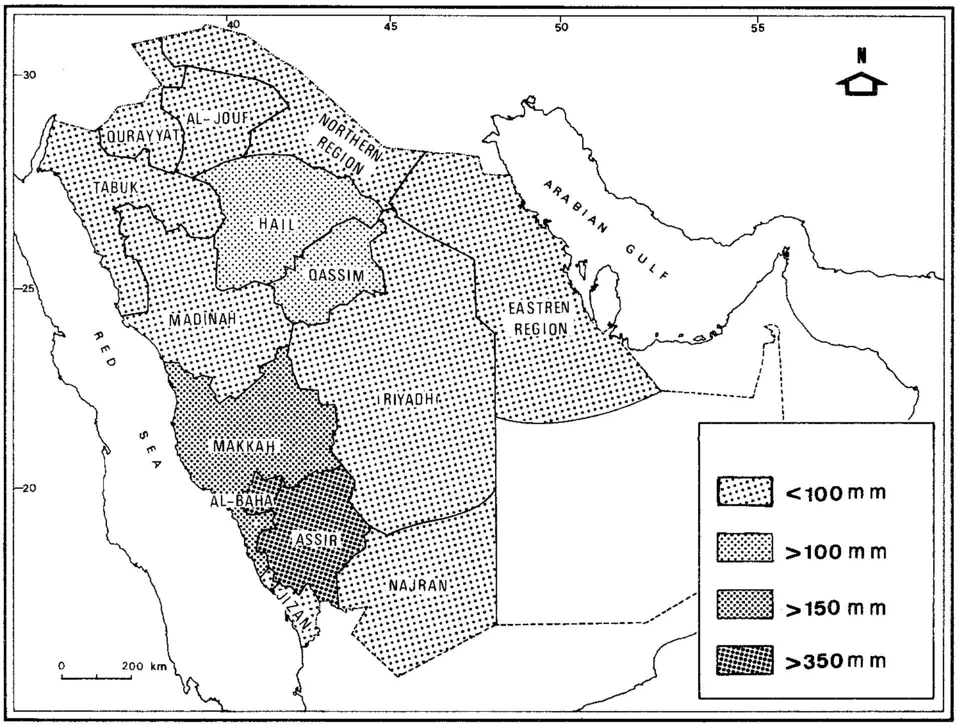
Discussion and Analysis of the Results

The results obtained from this study are discussed as follows:

Characteristics of Rainfall in Saudi Arabia

Most of Saudi Arabia is located in the arid zone. The rainfall is therefore characterized by considerable variability both in amount, and temporal and spatial distribution (Tab 1). A further characteristic of rainfall in this country is that rain frequency occurs in a short period of time. Annual rainfall in Saudi Arabia averages between 48.36 mm (Tabuk region) and 374.54 mm (Al-Baha region) throughout most of the regions. Only in the southwestern region (mountainous area) in Al-Baha and Assir averages

Fig 1
Rainfall regions in Saudi Arabia



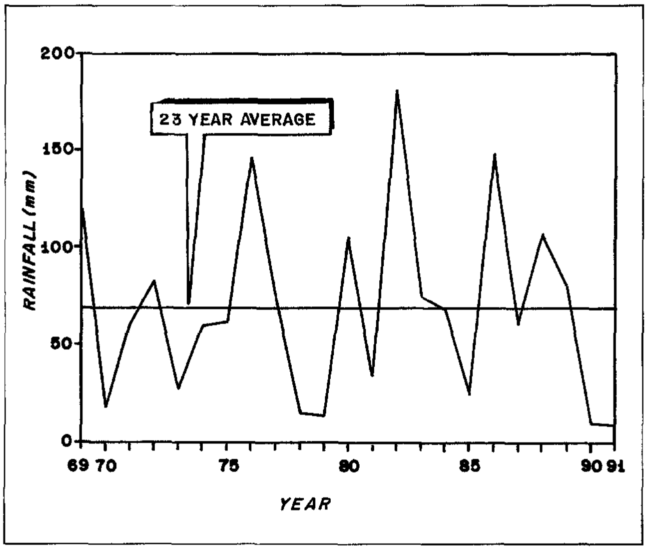


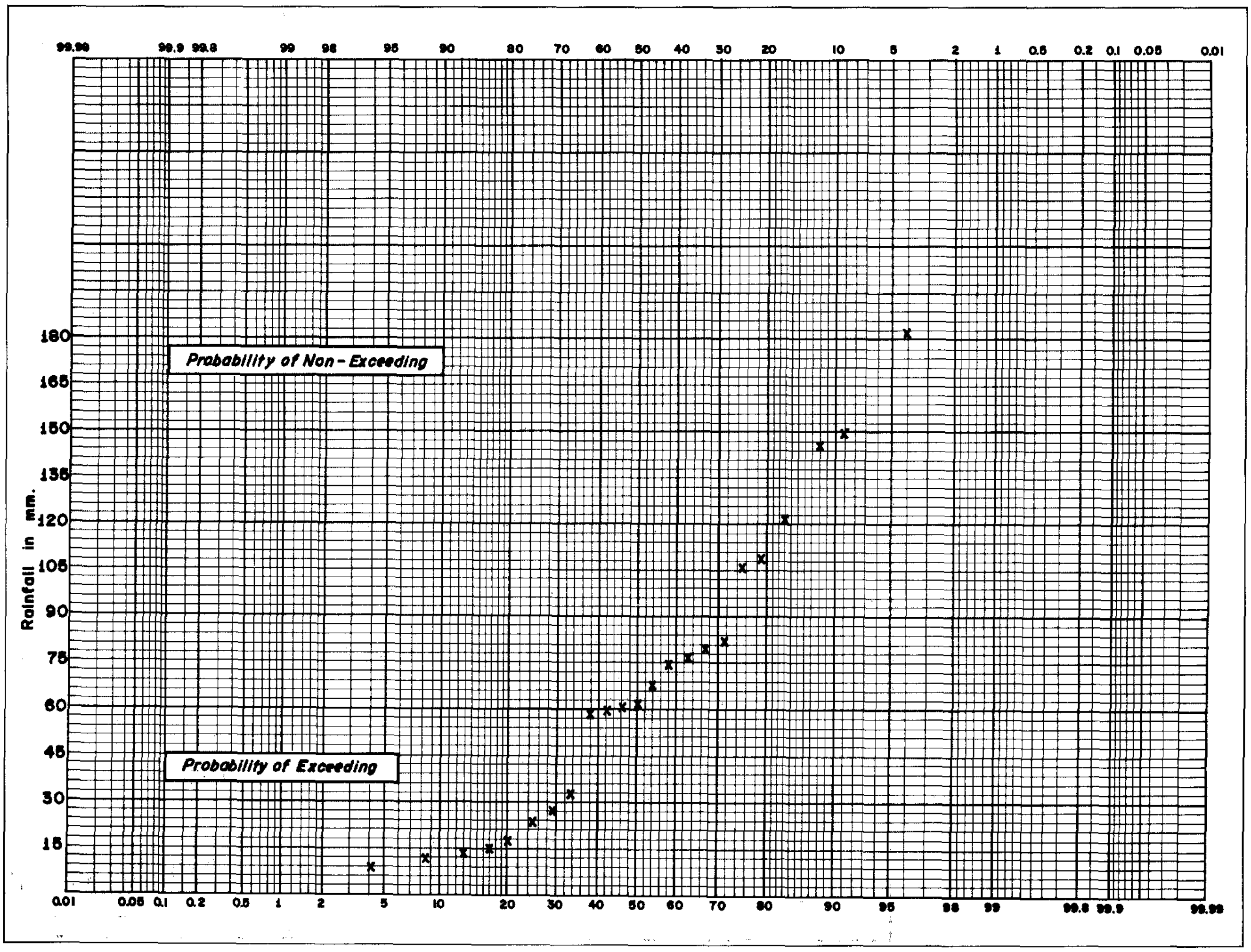
Fig 2 Annual rainfall in eastern agricultural region (Al-Hufuf station)

exceed 350 mm. Average annual rainfall tends to be higher in the SW mountainous area and lowest in the NW coast, and the Eastern region. The lowest value of annual rainfall was recorded in Madinah (1.0 mm), Tabuk (1.5 mm), Northern region (2.5 mm), Gizan (5.2 mm), and in Al-Jouf (5.4 mm). On the other hand, the highest value of annual rainfall was recorded in Al-Baha (740.70 mm), Assir (611.00 mm), and in Makkah (496.00 mm). The total number of dry years in all regions of Saudi Arabia is more than the total number of wet years (Tab 2).

Saudi Arabia is divided into 14 agricultural regions. But in terms of rainfall amount the country can be divided into four rainfall regions (Fig 1).

1) The first rainfall region includes the Eastern region, Riyadh, Northern region, Al-Jouf, Al-Qurriyyat, Tabuk, Madinah, Gizan, and Najran region where the average annual rainfall is less than 100 mm. The average annual rainfall in Tabuk, and Madinah regions is 48.36 mm, and 48.70 mm respectively. These two regions have the lowest value of average annual rainfall in Saudi Arabia. The

Fig 3 Probability of annual rainfall at eastern agricultural region (Al-Hufuf station)



average annual rainfall in the Eastern region, Riyadh, Northern region, Al-Jouf, Al-Qurriyat, Gizan, and Najran is 68.70, 82.00, 67.70, 54.00, 50.70, 63.65, and 62.00 mm resectively. Rainfall variability is extremely high in these regions indicating the degree to which rainfall of individual years greatly departs from the mean value over along period. For instance, in Eastern region in 1982 (181.30 mm) departed from the mean value by 112.60 mm, and in 1991 (9.50 mm) departed from the mean value by 59.20 mm. The difference between the highest value (181.30 mm) of rainfall in 1982, and the lowest value (9.5 mm) in 1991 is 172.80 mm. The standard deviation value is 49 (Tab 2). Through the 23 year-period, 12 of the years had rainfall less than the average (dry years where the value of annual rainfall is less than average) and 9 years had rainfall more than the average (wet years where the value of annual rainfall was more than average), and 2 years had the value about average (Fig 2).

The probability of annual rainfall in the Eastern region can be understood by refering to Fig 3 which is used to

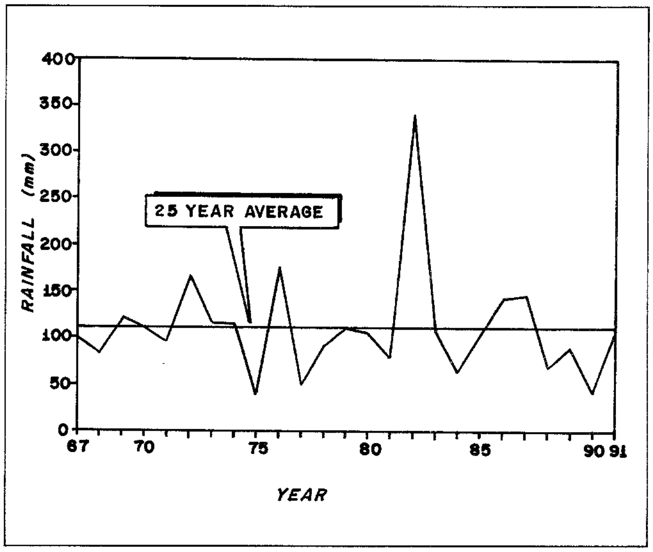
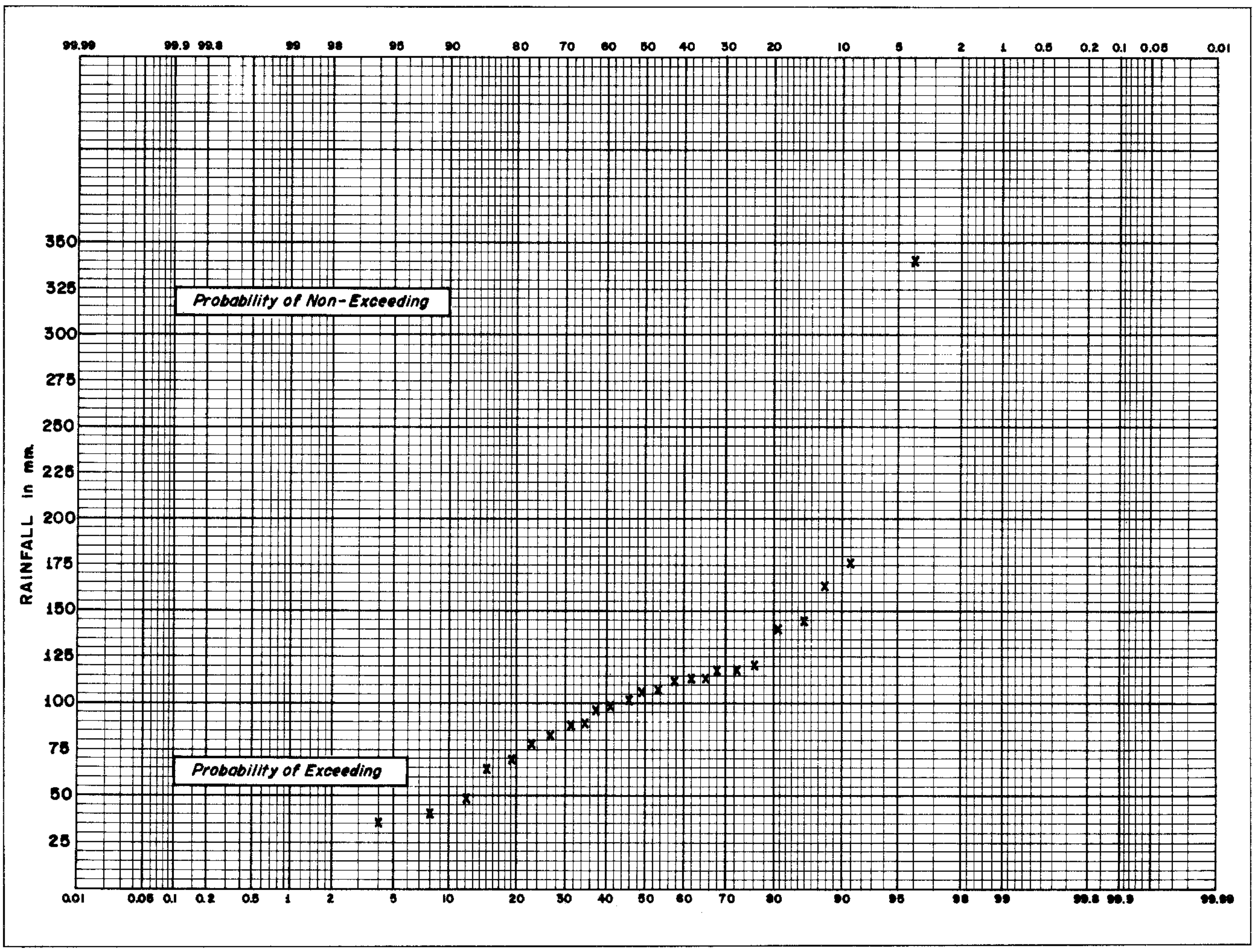


Fig 4 Annual rainfall in Qassim agricultural region (Unayzah station)

Fig 5 Probability of annual rainfall at qassiem agricultural region (Unayzah station)



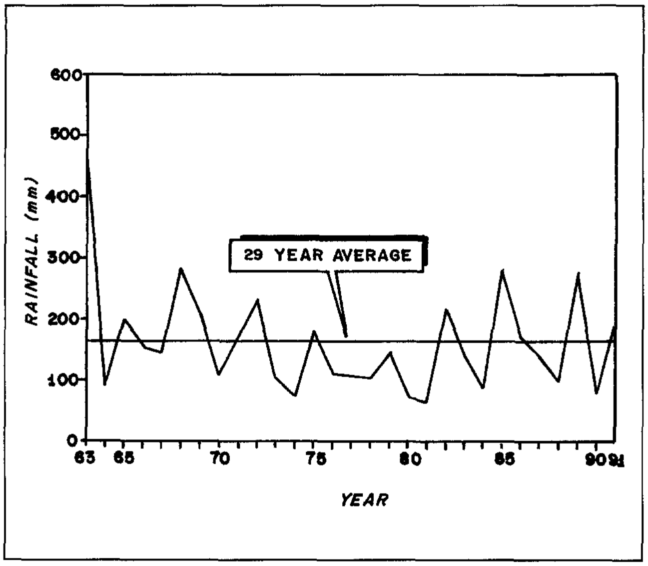


Fig 6 Annual rainfall in Makkah agricultural region (Taif station)

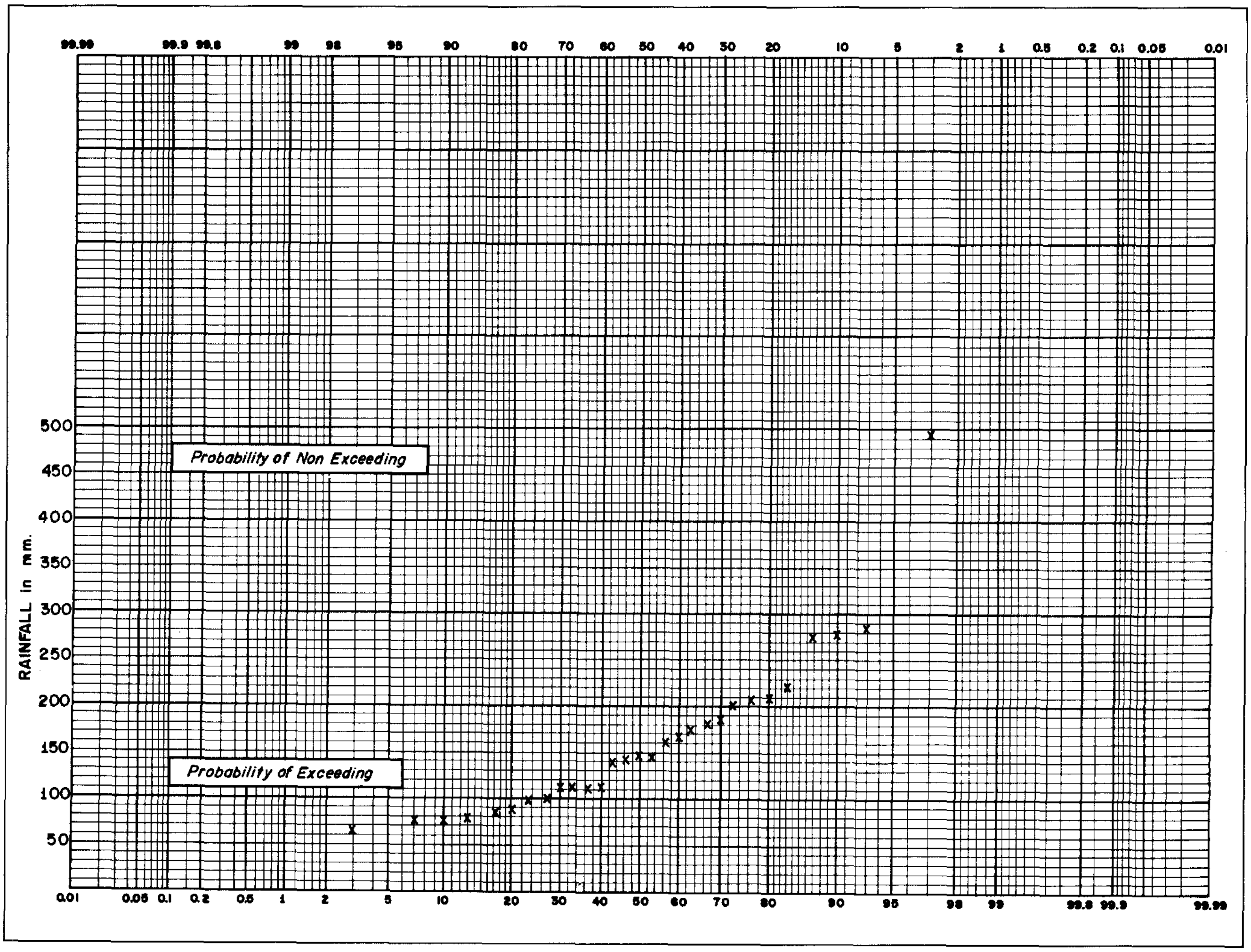
determine the probability occurrence of rain in the year. There is a 4% chance that the rainfall of any year in the Eastern region will be less than 9.5 mm. Conversely, there is a 96% chance that rainfall will exceed 9.5 mm.

Variability, and probability of annual rainfall in Riyadh, Northern region, Al-Jouf, Al-Qurriyat, Tabuk, Madinah, Gizan, and Najran region can be understood by refering to Tab 2, and appendix 1.

In this region the total number of dry years is more than that of wet years.

2) The second rainfall region includes Qassim, and Hail where the average annual rainfall is more than 100 mm. Variability of rainfall is extremely high in this region, for instance, in Qassim the difference between the highest value (340.40 mm), and the lowest value of rainfall (38.00 mm) is 301.90 mm. This means that the departure from the mean value is also very large. Annual rainfall in 1975 (38.00 mm) departed from the mean value by 72.10 mm, and annual rainfall in 1982 (340.40 mm) departed from the mean by 230.30 mm. The standard deviation is 59 (Tab 2).

Fig 7 Probability of annual rainfall at Makkah agricultural region (Taif station)



Throughout the 25-year period, 12 years had rainfall values less than average (dry years), and 6 years had rainfall values more than the average (Wet years), and 7 years had values about average (Fig 4). Fig 5 illustrates the probability of annual rainfall in Al-Qassim region. There is a 4% chance that the rainfall of any year during the record period will be less than 38.40 mm. Conversely, there is a 96% chance that rainfall will exceed 38.40 mm.

Variability, and probability of annual rainfall in Hail is illustrated in Tab 2.

In this region the total number of dry years is more than that of wet years.

3) The third rainfall region is Makkah region where the average annual rainfall is 163.26 mm. The difference between the lowest (66.20 mm), and the highest (496.00 mm) value of the annual rainfall in this region is 429.80 mm. Therefore, the variability of the annual rainfall in Makkah region is extremely great. Annual rainfall in 1963 (496.00 mm) departed from the mean value by 332.74 mm, and annual rainfall in 1981 (66.20 mm) departed from the

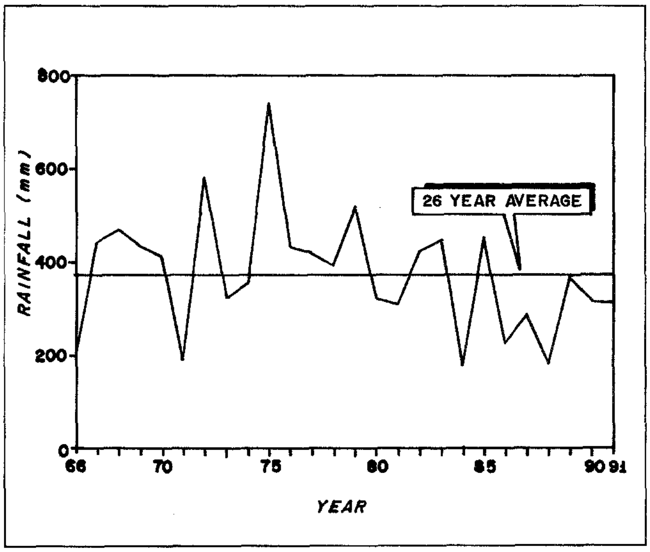
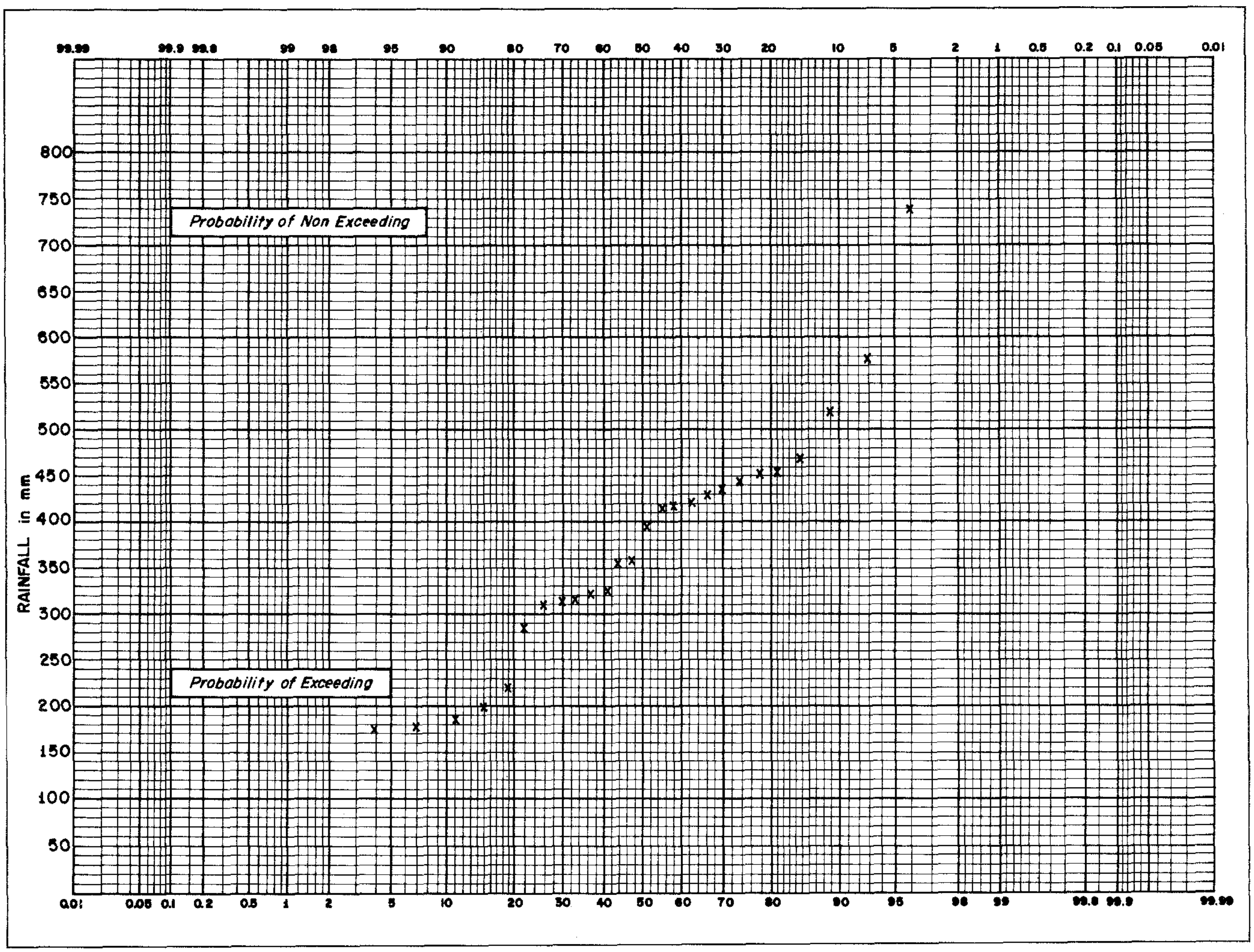


Fig 8 Annual rainfall in Al-Baha agricultural region (Biljurshi station)

Fig 9 Probability of annual rainfall at Al-Baha agricultural region (Biljurshi station)



Region	Station	Years of record	Rainfall (mm)	Temp. (C)	Drought index	Dominant plant	Climat. classi.
Eastern	Hufuf	69-1991	68.70	25.5	1.96	Desert Plant	Arid
Riyadh	Riyadh	64-1991	82.00	24.65	2.37	Desert Plant	Arid
Qassim	Unayzah	67-1991	111.10	24.10	3.26	Desert Plant	Arid
Hail	Hail	66-1991	109.63	22.10	3.42	Desert Plant	Arid
North. Region	Arar	72-1991	67.70	21.00	2.20	Desert Plant	Arid
Jouf	Sakaka	70-1991	54.00	22.60	1.70	Desert Plant	Arid
Qurriy.	Qurriy.	72-1991	50.78	20.12	1.68	Desert Plant	Arid
Tabuk	Tabuk	66-1991	48.36	21.87	1.52	Desert Plant	Arid
Madinah	Madinah	66-1991	48.70	28.03	1.28	Desert Plant	Arid
Makkah	Makkah	63-1991	163.26	22.36	5.05	Poor Grasses	Semi-Arid
Al-Baha	Biljur.	66-1991	374.54	18.89	12.96	Steppes	Sub-Humid
Assir	Abha	66-1991	360.20	17.00	13.34	Steppes	Sub-Humid
Gizan	Gizan	66-1991	63.65	29.98	1.59	Desert Plant	Arid
Najran	Najran	73-1991	62.00	24.39	1.80	Desert Plant	Arid

Aridity Index

< 5	Arid
5-10	Semi-Arid
10-20	Sub-Humid
20-30	Humid
> 30	Very Humid

Tab 3
The aridity index, dominant plant, and climatic classification in regions of Saudi Arabia

mean value by 97.06 mm. The standard deviation value was 90 (Tab 2).

Through the 29-year period, 17 years had rainfall less than average (dry years), and 9 years had rainfall more than average (wet years), and 3 years had the value of the average (Fig 6). Fig 7 exemplifies the probability of the annual rainfall in Makkah region. There is a 3% chance that the rainfall of any year during the recorded period will be less than 66.20 mm. Conversely, there is a 97% chance that rainfall will exceed 66.20 mm.

In this region the total number of dry years is more than that of wet years.

4) The fourth rainfall region includes Al-Baha, and Assir regions where the average rainfall is more than 350.00 mm (Tab 2). This region has the highest average annual rainfall in the Kingdom. To illustrate rainfall variability in this region Al-Baha region will be taken as example. In Al-Baha area annual rainfall values in 1975 (740.50 mm), and in 1984 (175.00 mm) departed from the mean value by 365.96 mm, and 199.54 mm respectively. The difference between the annual rainfall of 1975, and that of 1984 was 565 mm. The standard deviation value is 174.3 (Tab 2). Through the 26 year-period, 12 years had rainfall less than average (dry years), and 13 years had rainfall more than average (wet years), and one of the years had the average value (Fig 8). In this region the total number of wet years is more than of dry years.

Fig 9 illustrates the probability of annual rainfall in Al-Baha region. There is a 4% chance that the rainfall of any year during the record-period will be less than 175.00 mm. Conversely, there is a 96% chance that rainfall will exceed 175.00 mm.

Variability, and the probability of the annual rainfall in Assir region is illustrated in Tab 2.

Probability of Drought in Saudi Arabia

Drought is the occurrence of lower than average precipitation in that year in which ample precipitation usually occurs. The average annual rainfall for most parts of Saudi Arabia is around 70 mm except in Makkah, Al-Baha, and Assir regions where the average exceeds 150 mm, 374.54 mm, and 350 mm respectively. In terms of the occurrence of drought Saudi Arabia can be grouped into five major regions. Region one includes Makkah, Al-Baha, and Assir where the probability of obtaining less than 70 mm of rain in any given year is 00–15%. The second region includes Al-Qassim, and Hail where the probability of obtaining less than 70 mm of rain in any year is 15–30%. Riyadh is the third region where the probability of obtaining less than 70 mm of rain in a year is 30–45%. The fourth region consists of the Eastern and Northern regions where the probability of obtaining less than 70 mm of rain in year is 45–60%. The fifth region consists of Najran, Al-Jouf, Madinah, Al-Qurryyat, and Gazan where the probability of obtaining less than 70 mm of rain in a year is 60–75% (Fig 10).

Aridity Index in Saudi Arabia

Tab 3 illustrates the value of aridity indices, dominant plants, and climatic classification in Saudi Arabia. The value of aridity index is less than 5 in all regions except for Makkah, Al-Baha, and Assir regions where the aridity indexes are 5.05, 12.96, and 13.34 respectively (Fig 11). Desert plants are the dominant plants in most of Saudi Arabian regions. Poor grass is the plant in Makkah region. Steppes are dominant plants in Al-Baha, and Assir (Fig 12).

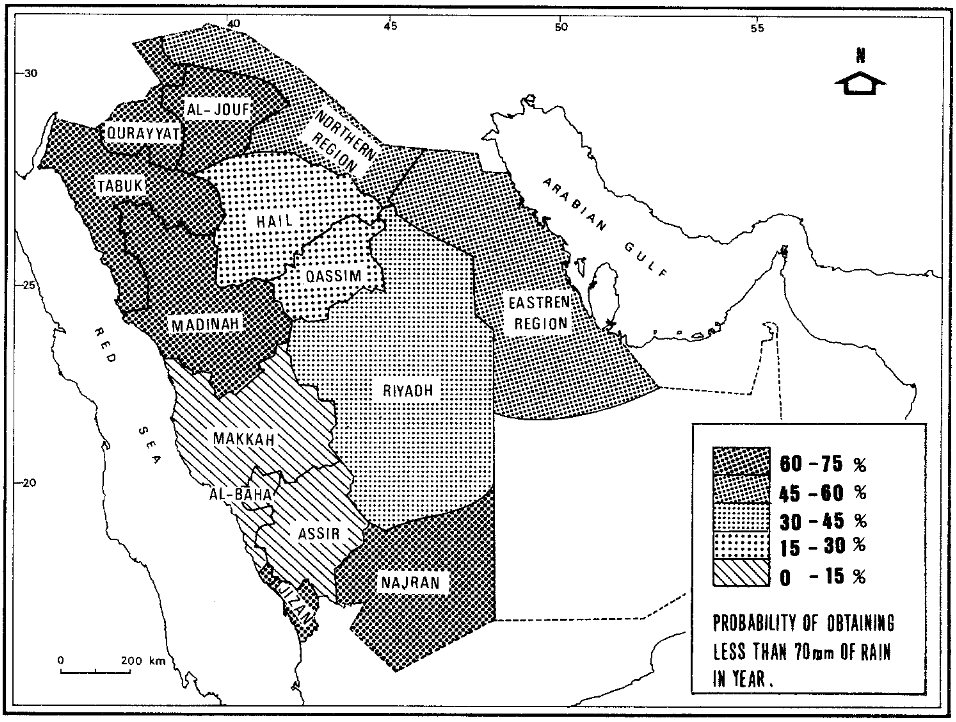


Fig 10
Map of drought probability in Saudi Arabia

The climatic classification of Makkah region is semi-arid according to aridity index. In Al-Baha, and Assir the climatic classification is subhumid. Aridity is considered to be the dominant climatic feature of the most regions in Saudi Arabia (Tab 3).

Adjustment to Drought

From the foregoing characteristics of annual rainfall averages in Saudi Arabia it is clear that drought is the greatest natural hazard for most human activities in the study area. The question that can be raised is how the people and government can deal with the problem of drought.

Adjustment to drought by animal herders in the past prior to oil production in Saudi Arabia can be summarized as follows:

1) Doing nothing which means bearing the loss. Birks (1981) indicates that "Resilience that used to be displayed by nomadic societies in the face of drought has been lost". 2) Sending their livestock to other rich rangelands 3) Selling some of their livestock to reduce livestock numbers, and avoid overgrazing. 4) Reduce their seasonal movement within the rangeland, this will allow the plants in grazing land to grow rather than being grazed by livestock. 5) Alternating movement of livestock in grazing land. 6) Taking up farming. 7) Moving near Oases to secure fodder, and water for herds. 8) Working in the agricultural sector for wages. 9) Moving settlement on temporary basis in case of severe drought to areas with better grazing. 10) Joining government settlement schemes (Al-Hijar). Birks (1981) stated that "the best-known settlement scheme to induce sedentarization of nomads in the Middle East is the Al-Hijar scheme of Saudia Arabia which was instituted in 1912. The Al-Hijar scheme had settled some 250,000 nomads by the 1930's. Lipsky (1959) stated that by 1927 there were more than a hundered settlements scattered throughout the Kingdom many of which still exist. The new settlers were provided with land, seed, and money. At the same time old wells and irrigation systems were required, and new irrigation projects were constructed.

Tab 4 Desalination water in Saudi Arabia during 1970–2000 (million m^3/yr)

Year	m^3/yr
1970	7.101.440
1975	17.836.090
1980	50.000.000
1985	330.000.000
1990	540.000.000
2000*	1.198.000.000

Sources:
(1) Ministry of Planning, Fifth Development Plan for 1985–1990, and 1990–1995, Saudi Arabia.
(2)* Bowen-Jones, H., and Dutton, R. (1984). Agricultural production and/or rural development, Arabian Gulf Journal, 4, 51–64.

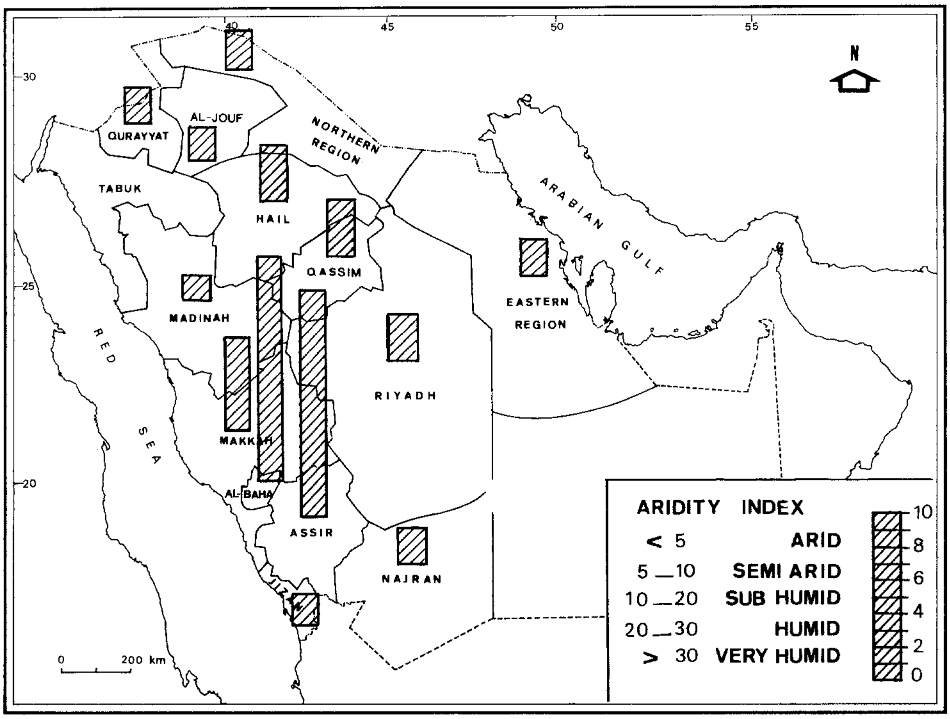


Fig 11
Aridity index value in the agricultural regions of Saudi Arabia

Adjustment to Drought after Oil Production

Since the early 1970's the Saudi Arabian government began investing the huge oil revenues to develop, and modernize the economy. To overcome the impact of drought Saudi Arabia has applied several methods among which:

1) Digging wells in the grazing areas such as the new wells along the oil pipe line (Tapline). These wells provided water for the nomads and have made it possible for the northern bedouins to raise their herds.

2) Sedentarization of nomads in modern settlement projects. The best example of a recent settlement project to reduce the effect of drought is the King Faisal settlement project at Haradh. The main objectives of this project are: (a) To settle around 1,000 bedouin families. (b) Raising sheep for marketing in nearby centres. (c) provide jobs to bedouins. (d) Training nomads to take over the administration of the project. (e) The ultimate target to be attained by the early 1980's was to have a herd of 150,000 sheep producing over 200,000 lambs per year (Looney 1982).

3) Setting up about 24 desalination plants on the Arabian Gulf, and Red Sea to supply most of Saudi Arabian cities with drinking water. The total water produced by these desalination plants increased from 7,101,440 m^3 in 1970 to 540,000,000 m^3 in 1990, and it is expected to reach 1,198,000,000 m^3 in the year 2000 (Tab 4). The other purpose of constructing desalination plants is to save groundwater for agriculture and livestock raising as well as increasing groundwater recharge.

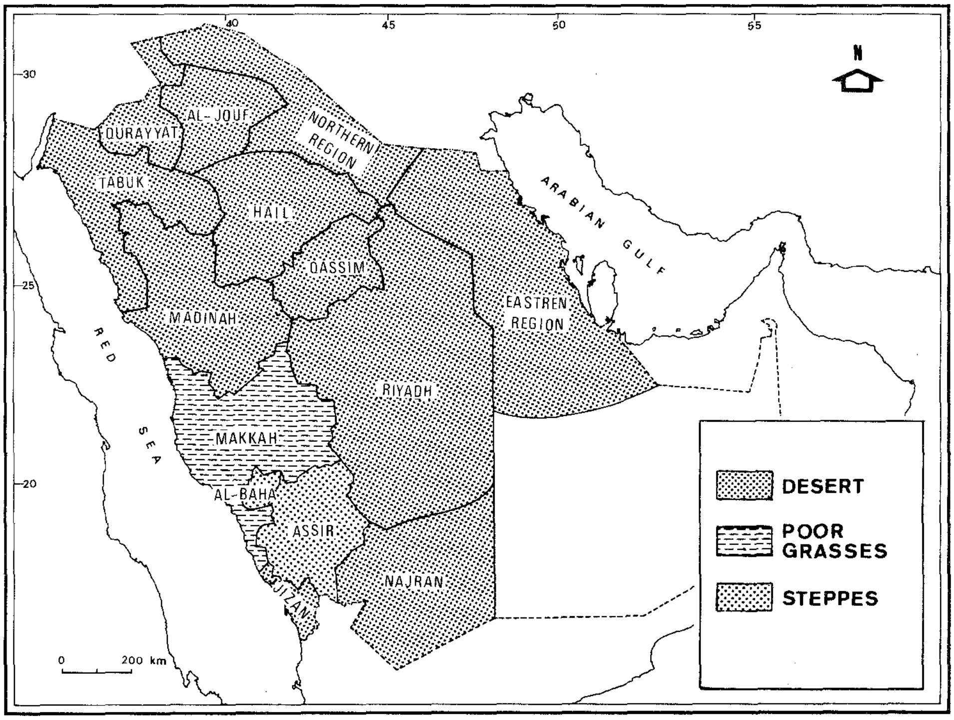
4) Reclaim waste water, the total reclaimed waste water increased from about 100 million m^3 in 1985 to about 110 million m^3 in 1990 (Ministry of Planning 1990-1995). In Al-Hassa Oasis the total recycling of drainage water for agricultural use increased from 4.397 million m^3 in 1983 to 24.684 million cubic meters in 1990(Hassa Irrigation and Drainage Authority 1991).

5) Establishment of meteorological stations. More than 100 stations were established in the country to record meteorological data, these data could be used to understand and assess the climatological situation of each part of Saudi Arabia and for predicting rainfall, and determining the probability of drought to avoid its impact.

6) Fodder subsidization programs such as the subsidization for barley and corn. Tab 5 illustrates the amount of forage subsidization by the government during 1980-1985. The total amount of forage subsidization increased from 519,000 tons in 1980 to 6,592,000 tons in 1985.

7) The availability and wide use of modern equipments such as cars, and tankers made it possible for farmers to irrigate their farmlands by tankers in years of drought, and grazers carrying water to rangelands to their livestock. As a result of subsidization the effects of drought hazards have been reduced. Also the availablity of cars, and trucks made the nomads' movement from one grazeland to another not essential as fodder can now be brought to the animals.

Fig 12
The dominant plants in the agricultural regions of Saudi Arabia



8) Construction of water dams to make use of the limited rainfall. There are two types of water dams, the cement water dams, and the earth water dams. The total number of cement water dams in the country is estimated at 184 dams. The capacity storage of these water dams is about 422,662,250 m^3 (Al-Shareef 1989). But the total number of the earth dams is about 32 in the country. The total area which may benefit from these dams is about 1746 ha (Agricultural Magazine 1992).

9) Making contour furrow system. The Ministry of Agriculture and Water did contour furrows in 71 different places in 18 regions of Saudi Arabia covering about 24,235 ha. The purpose of this work is to conserve soil moisture for plant growth.

10) Establishment of grazeland reservation scheme has protected 20 areas in Saudi Arabia having a total area of about 20,000 ha.

11) Provide buildings for fodder storage. The Ministry of Agricultural and Water built 14 stores for fodder to supply livestock during drought season. The capacity of these stores is about 168,000 tons of fodder.

12) Insuring supply of seeds. The Ministry of Agriculture and Water has insured about 16,523 kg of seeds for 44 varieties of trees and grass.

13) Planting the grazeland with fodder seeds. The area of grazeland planted by the Ministry of Agriculture and Water is about 102,000 ha.

14) Estimation of grazingland resources by using airphotos and remote sensing to determine total capacity and the way of developing it. The dry matter production of the grazeland in Saudi Arabia is estimated to be 7,759,000 tons/year. This amount can be used to feed about 2 million sheep, 3.4 million goats, 200 thousand head of cows, and about 400 thousand camels for a year (Agricultural Magazine 1992).

15) Introduction of high irrigation efficiency methods such as drip irrigation in the greenhouses, and center pivot and sprinkler irrigation methods in the wheat fodder fields.

Conclusions

The results of this study lead to the following conclusions:
(1) The lowest amount of annual rainfall during the study period (1963–1991) in Saudi Arabia was recorded in Madinah (1 mm) in 1973, Tabuk (1.5 mm) in 1976, Northern Region (2.5 mm) in 1978, and in Al-Jouf (5.40 mm) in 1978. (2) The lowest average annual rainfall was recorded in Tabuk (48.36 mm), and in Madinah region (48.70 mm). (3) The highest average annual rainfall was recorded in Assir (360.20 mm), and in Al-Baha (374.54 mm). (4) In most of Saudi Arabian regions dry years were more than wet years. (5) Average annual rainfall in most regions is less than 100 mm. (6) Permanent drought is found in most of the regions where the average annual rainfall is less than plants' water need. Plants in most parts of the country are adapted to the dry conditions. (7) Aridity is the dominating climatic

Year	Barley	Corn	Total
1980	337.000	182.000	519.000
1981	1.364.000	497.000	1.861.000
1982	2.977.000	482.000	3.459.000
1983	3.799.000	882.000	4.681.000
1984	2.580.000	341.000	2.921.000
1985	6.260.000	332.000	6.592.000

Sources:
Al-Manif, Toward an evaluation of agricultural subsidies in Saudi Arabia, 1987.

Tab 5 The amount of forage subsidization by the government of Saudi Arabia 1980–1985

character of most of Saudi Arabian regions. (8) As to the factors causing drought they are numerous, and complex. Thus complete eradication of drought becomes extremely difficult. However, people, and government of Saudi Arabia continue their attempts to use a wide range of technological devices to mitigate the serious impacts of drought. (9) The effects of drought in Saudi Arabia have been reduced to a certain degree by investing some of the oil revenues, and by applying some preventive policies, methods, and techniques.

Recommendations

Based on the study findings, the following recommendations can be proposed to reduce the effect of drought hazards in Saudi Arabia:
(1) Farmers, and grazers should not be allowed to settle in areas where there is a high probability of drought, and should be encouraged to settle in lands where water is plentiful. (2) Graze animals which are more able to cope with dry conditions such as camels should be kept. (3) Determination of the rangeland carrying capacity. (4) Introduction of dry farming system in areas where rainfall are limited. (5) Planting should be encouraged in low-lying lands that have a high amount of soil moisture. (6) Undertaking extensive cloud-seeding over drought striken areas as an effective measure to produce man-induced rain. (7) Setting up more desalination plants along the coastal area to produce water for domestic and agricultural purposes. (8) Expanding the capacity of recycling sewage water plants for agricultural usages. (9) Establishment of a national drought research institute responsible for research on aspects of drought and for supervising the implementation of the respective results. (10) Teaching courses on weather, and climatic conditions as a major part of school courses in the dry land areas in the world and emphasizing the direct and indirect effects of drought on the human activities.

References

Al-Hassa: Irrigation and Drainage Authority. Water Research Department, Hydrology Section, 1990.

Al-Manif, M.: Toward an evaluation of agricultural subsidies in Saudi Arabia 1987.

Allred, B.: Range Management Training Handbook for Saudi Arabia. FAO, Rome 1968.

Al-Shareef, A. K.: The role of the Ministry of Agriculture and Water in development and revegetation of deserts in the Kingdom of Saudi Arabia. Workshop on Desert Studies in the Kingdom of Saudi Arabia, King Saud Univ., Center for Desert Studies, 1989.

Birks, Stace J.: The Impact of Economic Development on Pastoral Nomadism in the Middle East. In: Clark; Howard (eds.), Change and Development in the Middle East 1981.

Bowen-Jones, H.; Dutton, R.: Agricultural production and/or rural development. Arabian Gulf Journal 51–64 (1984)

Butler, John E.: Natural Disasters, 1978.

Dracup, John A.; Lee, Kil Seong; Edwin, J. R. G.: On the definition of drought. Water Resources Research 16, 2, 297–382 (1988)

Dubois, Victor D.: Drought in West Africa: Temporary Famine or Chronic Deficiency. Common Ground V, 1, 3, 35 (1975)

Dubois, Victor D.: The Drought in West Africa. Common Ground V, 4, 3, 49 (1978)

Dunne, T.; Leopold, L. B.: Water in Environmental Planning. W. H. Freeman, and Company, San Francisco 1978.

Lipsky, G. A.: Saudi Arabia, its people, its society, its culture. Harf Press, New Haven 1959.

Looney, Robert E.: Saudi Arabia's Development Potential. Lexington Books, 1982.

Ministry of Agriculture and Water. Agriculture Magazine 23, 1 (1992–1993)

Ministry of Agriculture and Water, Department of Water Resources Development, Hydrology Division.

Ministry of Defence and Aviation, Meterology and Environmental Protection Administration.

Ministry of Municipal and Rural Affairs Magazine, Ministry of Municipal and Rural Affairs, Saudi Arabia, 17 (1990)

Ministry of Planning, Fifth Development Plan for 1985–1990, and 1990–1995, Saudi Arabia.

Schumacher, C. M.: The Great Plains Wet or Dry. Journal of Soil and Water Conservation 29, 4 (1974)

Tag El Din, S. S.: Range Development in the North of the Kingdom of Saudi Arabia. Workshop on Desert Studies in the Kingdom of Saudi Arabia, King Saud Univ., Center for Desert Studies 1989.

Walton, K.: The Arid Zone. Hutchinson and Co. Ltd., 1969.

White, Gilbert F.: Natural Hazards. Oxford University Press, Inc., 1974.

White, Gilbert F.; Burton, Ian; Kates, Robert W.: The Environment as Hazard. Oxford University Press, Inc. 1979.