AGRO-CLIMATIC CLASSIFICATION OF PAKISTAN

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ABSTRACT

This paper presents the climatic classification of Pakistan, particularly with a focus on agricultural activities. Modified Thornthwaite approach adopted by Reddy and Reddy (1973) was applied to identify the characteristics of Pakistan's climate, using reference crop evapotranspiration (ETo) rather than potential evapotranspiration (PET). It is found that about 2/3 of the total area lies under arid climate. A moisture-indicator originally related to water-balance is developed, which characterizes different regions, in relation to available moisture for crop-production. The analysis on seasonal basis shows that 10% more area can be cultivated in Kharif season than in Rabi. Most of the southern half lies under arid climate, where crop-production is not possible without irrigation. Only a narrow belt of north eastern plains have sub-humid climate where crops can be grown successfully under rainfed conditions. Because of extended elevation plains, some valleys in northern mountain-ranges also experience arid climate.

INTRODUCTION

A wide range of approaches for climatic zonation exist in the literature. The aim here is directed towards agriculture. Climates of Pakistan's territory, can be divided into a few groups, such as arid, semi-arid, sub-humid and humid on a broad scale from a drier to wetter; frequent and heavy rains in a humid zone exposes the rainfed agriculture to a great risk. In between these two extremes, the climates may be designated more or less crop-failure risk-free zones. The purpose of climatic classification is to identify those features of climate that distinguish a region from neighboring region. It helps to study the influence of a variety of climatic factors on human beings, animals and plant-life confined to that particular area. The identification of climatic characteristics of a region helps in the assessment of agro-climatic potential of the area, the plant and animal species suited to that area and selection of crop-varieties, capable of producing high yields. In an environmental context, it allows areas to be characterized and boundaries to be drawn on areas that can be regarded as homogeneous in certain respects. Broad areas exist with climatic homogeneity, which allows a simple classification to be an aid to study the human settlements, animal adaptation and respective plant-species.

In dividing a region (or the world) into a number of climatic zones, the boundaries are shown as sharp delineations, whereas actually there is a gradual transition in climates on both sides. For a general climatic classification to be realistic, boundaries should at least conform to known distribution of plants (Willsie and Shaw, 1954). Good (1953) states that the facts of plant-geography everywhere show that plant distribution is basically dependent on climate. Climatic classification determines the potential of crop-production of an area, as well as the adaptability potential of different species of animals and plants from other areas.

MATERIAL AND METHODS

Most of the procedures that are widely used are annual indices, such as given by Koppen (1936), Thornthwaite (1948), Thornthwaite and Mather (1955), Budyako (1956), Papdakis (1975). According to Meher-Homji (1962), when some of these approaches were applied to 78 representative stations in India, none of these methods gave entirely satisfactory results. Under the classification by Koppen (1936), the zones show vast variations within themselves (Berry et al; 1973, Hashemi et al; 1981). Thornthwaite (1948) introduced the term PE (potential evaptranspiration) and degree of moisture for climatic classification, which was modified by Thornthwaite and Mether (1955). The main emphasis of Koppen's classification is on the temperature limits, whereas Thornthwaite classes are based on the effectiveness of rainfall.

Thornthwaite also introduced the soil-moisture factor, which was also used by Papadakis, in 1975; and Eagleman, in 1976. It was not realistic for broad zonation, as there are wide variations in soil-factors even at the micro level. In fact, the moisture index computed with and without soil-factor does not show any significant difference under dry climates. Hargreaves (1974) stated that, "a composite-index based upon soil and climate might be developed,

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however, due to the complexity of soils in many areas, such combined index might be difficult to use in climatic classification, and these refer to climatic conditions of a region only and not to soil and climate.

Reddy and Reddy (1973) suggested some modifications to Thornthwaite's scheme in order to develop more homogeneous types – hereafter called "modified Thornthwaite's approach". In this method, the soil-term was eliminated in the computation of moisture-index using the potential evapotraspiration (PE) and rainfall(R). Here, in this research investigation, reference crop evapotranspiration (ETo) is used, instead of PE, hoping for better results in relation to natural vegetation.

The equation used to compute moisture-index for classification is given as:

MI = [(R – Eto) / ETo]

where MI = The annual / seasonal moisture-index (%)

R = The mean annual / seasonal rainfall in millimeters.

ETo = The mean annual / seasonal reference crop evapotranspiration.

ETo is defined as the rate of evapotranspiration from an extended surface of 8 – 15 cm tall green grass cover of uniform height, activel growing, completely shading the ground and not short of water.

Data from climatic normals (1961- 90) for Pakistan, prepared by Pakistan Meteorological Department (PMD), were used to compute Reference Crop Evapotranspiration (ETo) on annual basis, as well as for both season Rabi (October-April) and Kharif (May-September) crop growing in Pakistan. The same weights are given both for humid and arid-terms and uniform limits are used on both wet and dry sides of the scale, as in modified Thornthwaite approach (Reddy and Reddy, 1973).

Calculation of ETo

Blaney-Criddle Method:

Recommended Relationship:

The following relationship gives the monthly values:

ETo = c[p (0.46T + 8)] mm/day

where

ETo = reference crop evapotranspiration in mm/day for the month considered

T = mean daily temperature in °C over the month considered

p = mean daily percentage of total annual day time hours obtained from Table-1 for a given month and latitude.

c = adjustment factor, which depends on minimum relative humidity, sunshine hours and daytime wind estimates.

Figure-1 can be used to estimate ETo graphically, using calculated values of p (0.46T + 8). The value of p (0.46T +8) is given on the X-axis and the value of ETo can be read directly from the axis. Relationships are presented in Figure-1 for: (i) three levels of minimum humidity (RH min); three levels of the ratio of actual to maximum possible sunshine hours (n/N); and (iii) three ranges of day-time wind conditions, at 2 m height (Uday). Information on general monthly or seasonal weather conditions and approximate range of RH min, n/N and UDay for a given site may be obtained from published weather descriptions, or extrapolation from nearby areas or from local information. The nomenclature used to depict general levels of humidity, sunshine and wind is given under climatological nomenclature in the introductory pages of this publication.

After determining ETo, the ET crop can be predicted using the appropriate crop-coefficient (kc) or ETcrop=kc.ETo(1.2).

RESULTS AND DISCUSSION

The criteria described in modified Thronthwait approach, adopted by Reddy and Reddy (1973) for climatic classification of India and some parts of Africa, was employed, to classify various climatic features of Pakistan. The moisture-indicator has been calculated with available climatic data for more than 50 stations in Pakistan. The moisture limits for different climatic zones on broad scale are given as follows. Pakistan is located in northern hemisphere, it extends from about 24°N to 37°N latitude and 61° E to 76° E longitude. Its agricultural plains are located at varying altitudes ranging from a few meters above mean sea-level in the south to more than 3,000 meters in the north. High mountain ranges in northern and western parts of the country enhance precipitation activity on windward side, whereas it leaves the leeward side

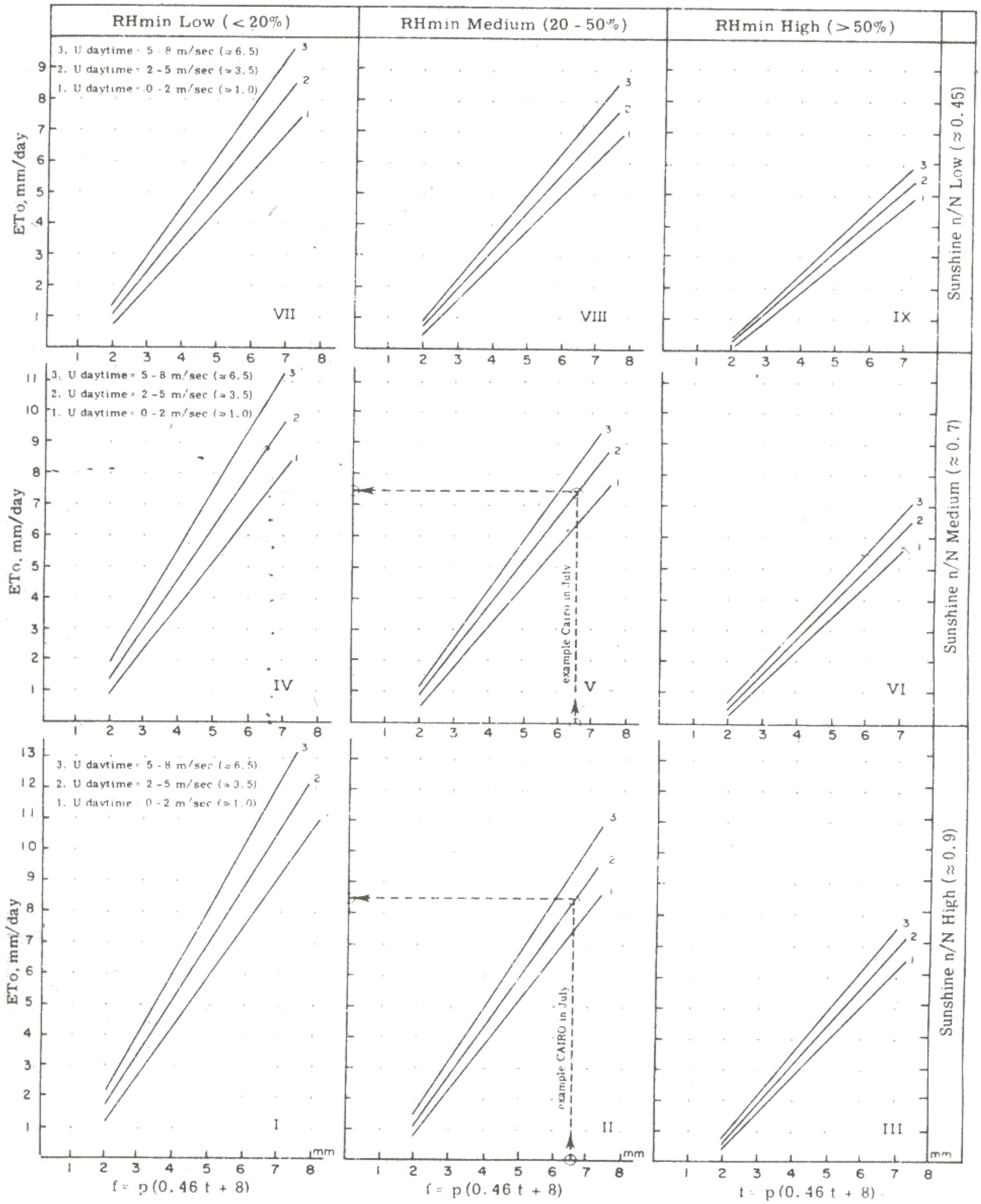

Figure - 1: Prediction of ETo from Blaney-Criddle f-factor for different conditions of minimum relative humidity, sunshine duration and day-time wind

Table - 1: Mean Daily Proportion of Total Annual Daytime Hours

North latitude South latitude 1/	Jan July	Feb Aug	Mar Sep	Apr Oct	May Nov	Jun Dec	Jul Jan	Aug Feb	Sep Mar	Oct Apr	Nov May	Dec Jun
60	.15	.20	.26	.32	.38	.41	.40	.34	.28	.22	.17	.13
58	.16	.21	.26	.32	.37	.40	.39	.34	.28	.23	.18	.15
56	.17	.21	.26	.32	.36	.39	.38	.33	.28	.23	.18	.16
54	.18	.22	.26	.31	.36	.38	.37	.33	.28	.23	.19	.17
52	.19	.22	.27	.31	.35	.37	.36	.33	.28	.24	.20	.17
50	.19	.23	.27	.31	.34	.36	.35	.32	.28	.24	.20	.18
48	.20	.23	.27	.31	.34	.36	.35	.32	.28	.24	.21	.19
46	.20	.23	.27	.30	.34	.35	.34	.32	.28	.24	.21	.20
44	.21	.24	.27	.30	.33	.35	.34	.31	.28	.25	.22	.20
42	.21	.24	.27	.30	.33	.34	.33	.31	.28	.25	.22	.21
40	.22	.24	.27	.30	.32	.34	.33	.31	.28	.25	.22	.21
35	.23	.25	.27	.29	.31	.32	.32	.30	.28	.25	.23	.22
30	.24	.25	.27	.29	.31	.32	.31	.30	.28	.26	.24	.23
25	.24	.26	.27	.29	.30	.31	.31	.29	.28	.26	.25	.24
20	.25	.26	.27	.28	.29	.30	.30	.29	.28	.26	.25	.25
15	.26	.26	.27	.28	.29	.29	.29	.28	.28	.27	.26	.25
10	.26	.27	.27	.28	.28	.29	.29	.28	.28	.27	.26	.26
5	.27	.27	.27	.28	.28	.28	.28	.28	.28	.27	.27	.27
0	.27	.27	.27	.27	.27	.27	.27	.27	.27	.27	.27	.27

Note: 1/ *Southern latitudes: apply 6-month difference as shown*

Table - 2: Mean Daily Duration of Maximum Possible Sunshine Hours (N) for Different Months and Latitudes

Northern latitude Southern Latitude	Jan July	Feb Aug	Mar Sep	Apr Oct	May Nov	Jun Dec	Jul Jan	Aug Feb	Sep Mar	Oct Apr	Nov May	Dec Jun
50	8.5	10.1	11.8	13.8	15.4	16.3	15.9	14.5	12.7	10.8	9.1	8.1
48	8.8	10.2	11.8	13.6	15.2	16.0	15.6	14.3	12.6	10.9	9.3	8.3
46	9.1	10.4	11.9	13.5	14.9	15.7	15.4	14.2	12.6	10.9	9.5	8.7
44	9.3	10.5	11.9	13.4	14.7	15.4	15.2	14.0	12.6	11.0	9.7	8.9
42	9.4	10.6	11.9	13.4	14.6	15.2	14.9	13.9	12.6	11.1	9.8	9.1
40	9.6	10.7	11.9	13.3	14.4	15.0	14.7	13.7	12.5	11.2	10.0	9.3
35	10.1	11.0	11.9	13.1	14.0	14.5	14.3	13.5	12.4	11.3	10.3	9.8
30	10.4	11.1	12.0	12.9	13.6	14.0	13.9*	13.2	12.4	11.5	10.6	10.2
25	10.7	11.3	12.0	12.7	13.3	13.7	13.5	13.0	12.3	11.6	10.9	10.6
20	11.0	11.5	12.0	12.6	13.1	13.3	13.2	12.8	12.3	11.7	11.2	10.9
15	11.3	11.6	12.0	12.5	12.8	13.0	12.9	12.6	12.2	11.8	11.4	11.2
10	11.6	11.8	12.0	12.3	12.6	12.7	12.6	12.4	12.1	11.8	11.6	11.5
5	11.8	11.9	12.0	12.2	12.3	12.4	12.3	12.3	12.1	12.0	11.9	11.8
0	12.1	12.1	12.1	12.1	12.1	12.1	12.1	12.1	12.1	12.1	12.1	12.1

Table - 3: Values of Weighting Factor (W) for the Effect of Radiation on ETo at Different Temperatures and Altitudes

Temp ° C	2	4	5	8	10	12	14	16	18	20	22	24	26	28	30	32	34	36	38	40
W at altitude (m)	0.4	0.5	0.5	0.5	0.6	0.6	0.6	0.6	0.7	0.7	0.7	0.7	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.9
0	0.5	0.5	0.5	0.5	0.6	0.6	0.6	0.7	0.7	0.7	0.7	0.7	0.8	0.8	0.8	0.8	0.8	0.8	0.9	0.9
500	0.5	0.5	0.5	0.6	0.6	0.6	0.6	0.7	0.7	0.7	0.7	0.8	0.8	0.8	0.8	0.8	0.8	0.9	0.9	0.9
1000	0.5	0.5	0.6	0.6	0.6	0.6	0.7	0.7	0.7	0.7	0.8	0.8	0.8	0.8	0.8	0.8	0.9	0.9	0.9	0.9
2000	0.5	0.6	0.6	0.6	0.6	0.7	0.7	0.7	0.7	0.8	0.8	0.8	0.8	0.8	0.8	0.9	0.9	0.9	0.9	0.9
3000	0.6	0.6	0.6	0.6	0.7	0.7	0.7	0.7	0.8	0.8	0.8	0.8	0.8	0.8	0.9	0.9	0.9	0.9	0.9	0.9
4000																				

barren depending upon season. That is the reason various narrow belts with similar climatic characteristics may be found in northern agricultural plains, ranging from very humid to extremely arid regions.

The arid zone towards the drier extreme of climates represents sandy grasslands (e.g. Nokkundi), where food-crop production is economical under rainfed conditions. The other extreme on wetter side of climate, representing rain-forests (e.g. Murree), is termed as humid zone. In between these two extremes, the major food-crop production zone can be categorized comprising semi-arid to sub-humid climates, which possess optimum agronomic characteristics. The period of availability of sufficient moisture is limited to less than half the length of growing-season and also the distribution of rainfall is highly uneven over the time-scale. It increases the risk of crop-failure.

The areas above 32°N to 36°N latitude fully experience winter and, some of them, summer rains, due to their topography and geographical features. Below 32°N both the rainy systems do not effectively produce rain; however, sometimes these weather-systems extend down to southern latitudes. The temperatures follow an increasing trend from north to south, which results in rapid loss of moisture, through evaporation and transpiration. This continuous loss of moisture compared to scarcity of precipitation leaves the water-balance of these areas in deficit. These areas are designated as arid, where mean annual rainfall fails to meet 75% to 90% of mean annual ETo. In an arid-zone, economical agriculture is not possible without irrigation. Figure-2 presents the broad climatic classification of Pakistan on annual basis.

Rabi-crop growing-season start from October and generally extends upto April/May and wheat is its major food-crop, which is the essential food-requirement of each family. Rabi season matches with

Table - 4: Mean Annual Percentage of Annual Day-Time Hours for Different Cities In Pakistan

P-VALUES

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Peshawar	.232	.25	.27	.29	.31	.32	.318	.30	.28	.252	.232	.222
Rawalpindi (Chaklala)	.233	.25	.27	.29	.31	.32	.317	.30	.28	.253	.233	.223
Jhelum	.234	.25	.27	.29	.31	.32	.316	.30	.28	.254	.234	.224
Sargodha	.236	.25	.27	.29	.31	.32	.314	.30	.28	.256	.236	.226
Lahore	.237	.25	.27	.29	.31	.32	.313	.30	.28	.257	.237	.227
D.I. Khan	.236	.25	.27	.29	.31	.32	.314	.30	.28	.256	.236	.226
Faisalabad	.237	.25	.27	.29	.31	.32	.313	.30	.28	.257	.237	.227
Multan	.24	.25	.27	.29	.31	.32	.31	.30	.28	.26	.24	.23
Khanpur	.24	.253	.27	.29	.307	.317	.31	.297	.28	.26	.243	.233
Quetta	.24	.25	.27	.29	.31	.32	.31	.30	.28	.26	.24	.23
Sukkur	.24	.255	.27	.29	.305	.315	.31	.295	.28	.26	.245	.235
Hyderabad	.24	.259	.27	.29	.301	.311	.31	.291	.28	.26	.249	.239

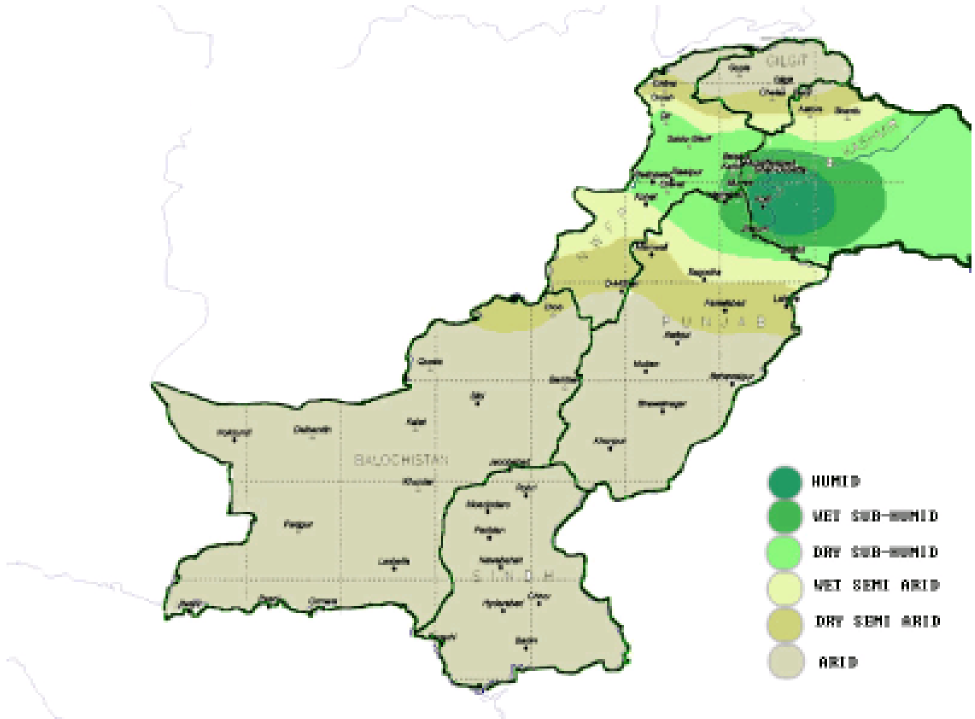

Figure - 2: Broad Climatic Zones of Pakistan on Annual Basis

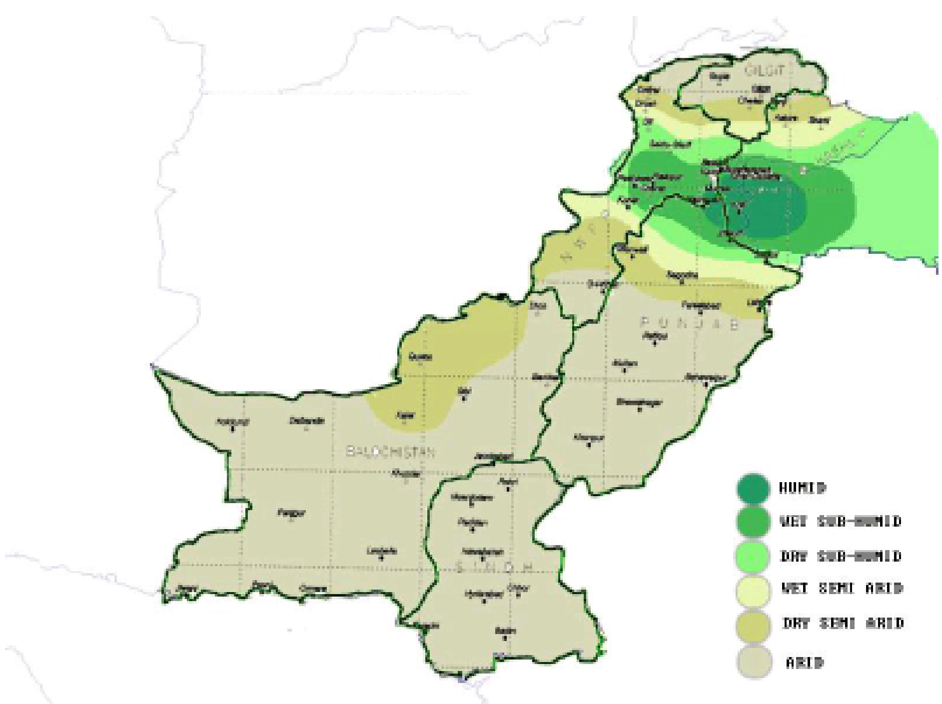

Figure - 3: Broad Climatic Zones of Pakistan During Rabi Season

Table - 5: Broadzones, Symbols and their MI Limits

BROAD ZONES		SYMBOL	MI LIMITS (%)
Arid		A	<-80
Semi-Arid	Dry Wet	SA 1	-80 to -56
		SA 2	-55 to -26
Sub-Humid	Dry Wet	SH 1	-25 to 0
		SH 2	0 to -25
Humid		H	> 25

winter-rains (December to March), whose effectivity is still restricted due to higher latitudes and windward sides of the mountain ranges. The analysis based on seasonal moisture-index (Figure-3) shows that the percentage of arid area in rabi season is increased, as compared to the area demarcated in annual classification. The driest months of this season are October and November, which are basically incharge of rain crop- production in rainfed areas, because the sowing and initial crop-establishment depend upon this precipitation. Later in the season, long dry spells prevail, sometimes matching with the critical stage of the crop-development and results in poor yield. In arid zone crop-failure is most probable if grown under rainfed conditions.

Kharif season commences with rabi harvest, i.e. from May and completes by the end of calendar year. Cotton, rice and sugarcane are the important field-crops. The start of Kharif season, like rabi, also tallies with the driest month (May & June) of the year. However, the monsoon-rain, which generally starts with the beginning of July and continues till mid-September, modertes the moisture-stress conditions a little, on the average. Although, growing season for Kharif crop consists of the hottest months (May to August), but the moisture-laden monsoon-winds keep the evaporative demand of the atmosphere low, by increasing the atmospheric humidity in areas covering Northern half, which experience the monsoon-precipitation effectively. The Southern half of the country receives meager amount of rainfall, which is insufficient to compensate for the loss of moisture through evapotranspiration, due to high temperature and drier atmosphere. Country-wide regionalization of climate

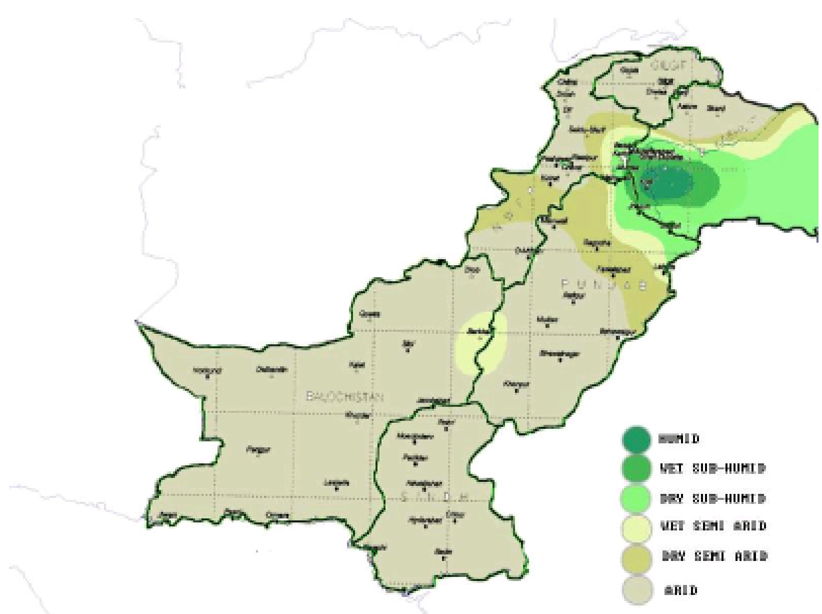

Figure - 4: Broad Climatic Zones of Pakistan During Kharif Season

during kharif season is given in Figure-4. The areas under arid zone during Kharif season is about 10% less than that during the Rabi season.

CONCLUSION

Pakistan experiences many types of climates, ranging from arid to humid. Unfortunately, 3/4th of the total area lies under arid zone and only a small patch comes under humid climate. For good crop-production, water is the major limiting factor in the arid and the semi-arid zones, while excessive rains are the major constraint in the sub-humid and the humid zones. The best suited area is mainly located between 33°N and 35°N latitude, where the food-crop production is possible under rainfed conditions. Above and below these latitudes, the agricultural production is possible only when supplementary irrigation is made available.

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