Chapter

# Environment, Agriculture, and Land Use Pattern

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## Abstract

This study aimed at the environment, agriculture, and land use pattern and in the arid region of Pakistan. Physiography and location of the study area with respect to coastal region are the key factors that control the climate. There are a number of factors that have their influence on the cropping pattern in the area apart from climate. They include the type of soils, availability of irrigation water, government policies, socioeconomic condition, advance technologies, market value, human demand, etc. The soil of irrigated plain in lower Punjab and Sind is more suitable for the agriculture than other parts, where the water is insufficient for cultivation.

**Keywords:** environment, agriculture zones, arid region, land use pattern, soil, natural vegetation

## 1. Introduction

The chapter covers the environment of the arid region in relation to agriculture and land use pattern. The carrying capacity of any area in the biosphere to produce enough food and other crops for the human population and domesticated animals depends a lot on environmental conditions and human technical capabilities. The work elaborates the environmental conditions in the arid region of Pakistan and how the farming patterns have been adjusted to these conditions. It has been divided into four sections. The first section on physical setting explores the landform, soil, climate, and natural vegetation and their role in agriculture of the arid region. The second section on human environment discusses the distribution of population, human settlements, and the socioeconomic setup and their relationship to agriculture sector. Furthermore, the third section discusses the agroecological zones and its characteristics with reference to agricultural. The concluding section highlights the findings of the chapter.

The arid region extends northeast to southwest from latitude 37°N into $23^{1}/_{2}$°N and longitude 60°E to 75°E. The northeastern and northwestern part of the arid region consists of high mountain ranges like the Himalayas [1], Hindu Kush, and Karakorum with highest peaks like K-2 (8475 m), Rakaposhi (7665 m), and Tirich Mir (7569 m). The study area covers about 63 districts and total area of 676,400 $km^2$ (77.1%) on which approximately 78.7 million population resides (**Figure 1**).

It extends from the Arabian Sea to the interior of Pakistan, while in the extreme north, it covers the whole Gilgit-Baltistan province and a part of the Chitral and Dera Ismail Khan district in Khyber Pakhtunkhwa. The arid region of Pakistan includes southern and central Baluchistan, southern Punjab, southern and northern Khyber Pakhtunkhwa, Sind, and the Gilgit-Baltistan province. The well-known deserts of the arid region comprises of Cholistan, Thar, Thal, and Kharan Desert.

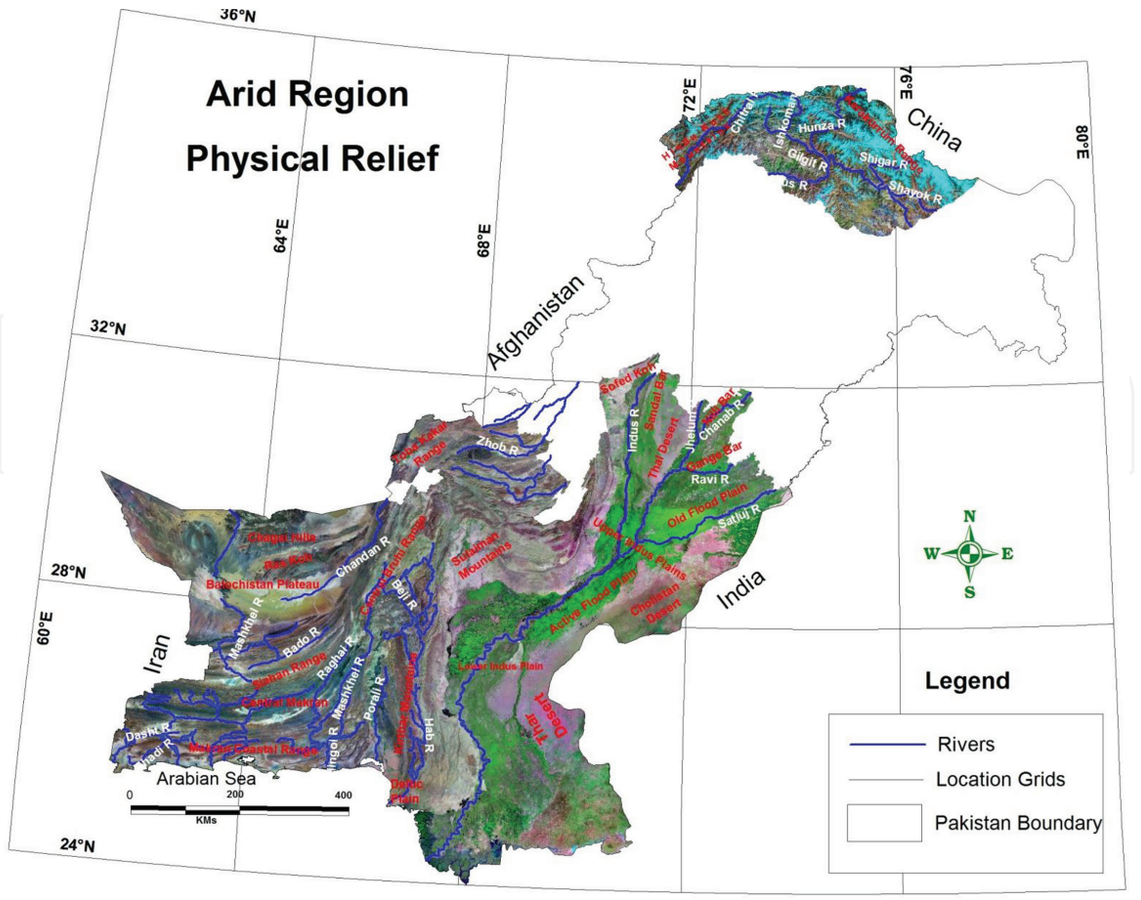



**Figure 1.**
*Arid Region Location, GoUSA [2], online, ftp://ftp.glcf.umiacs.umd.edu.*

## 2. Physical setting

The physical features of the earth play a vital role in controlling of temperature, precipitation, natural disasters, evapotranspiration, etc. The temperature decreases from low to high altitude, while it is converse for precipitation. The moisture contents of the soil decrease from high to low altitudes that influence the crop productivity at low lands. Besides, the height of trees and crops and the length of cropping seasons also somehow depended on the topography of the area. In most cases, the crops in arid and semiarid areas are confined to isolated patches, where the soil is fertile and the water is available. There are two arid regions identified in Pakistan, that is, the southern and northern arid region, separated by a wide zone of semiarid, subhumid, and humid region of central and upper Punjab and Khyber Pakhtunkhwa provinces. Therefore, it is necessary to discuss the physiography of the arid regions in Pakistan.

The southern arid region covers Sind, Baluchistan, lower Punjab, and Dera Ismail (DI) Khan as well as Chitral district of the Khyber Pakhtunkhwa province. The landforms of the southern arid region have three main units—the northwestern highland, Baluchistan plateau, and the Indus plain (**Figure 1**). The northwestern highland of Baluchistan consists of two parallel regions of Toba Kakar extending from northeast to southwest in Baluchistan and another parallel range of Sulaiman-Dera Bugti mountains along the Indus plain. The second major physiographic unit is the Baluchistan plateau that lies between the Toba Kakar ranges and the Sulaiman-Kirthar mountains and is also a dry rugged area with harsh environment. Mainly, pastoral agriculture is practiced on the Baluchistan plateau. Crops are grown only in those areas where water is available [3].

The third major landform unit is the Indus plain, which lies south of the Himalayas and the Salt Range stretching southward to the Arabian Sea. The Sind province and lower Punjab of the Indus plain fall in the arid region. This is the main agricultural area, where the canal irrigation has developed during the nineteenth century. A deltaic plain that has developed at the mouth of the Indus River is also an important agricultural area. The rolling sand plain covers an extensive area to the southeast of the canal-irrigated arid region covering Cholistan and Thar Deserts in Sind and lower Punjab. To the west of Kalat Plateau is the rolling sand plain of Kharan and Chaghi, while in the southwestern Baluchistan, there are dry and arid mountain ranges of the Makran coastal region. They are not very conducive to agriculture because of their dryness and rough topography, but agriculture is practiced to some extent in the Dasht River valley around Turbat in Kech district.

The northern arid region covers the extreme north of Pakistan, consisting of the Transhimalayas or the Karakoram and Hindu Kush mountains. The slopes are very steep, and natural hazards particularly the landslide are frequent, and the agriculture land is confined to the narrow belts along the rivers and streams in the valley. Therefore, in this rugged mountainous belt, agriculture is practiced mainly in the valleys primarily in the form of terraced cultivation (**Figure 1**).

## 3. Weather and climates

The term climatology is a Greek word, which literally means "inclination," i.e., inclination of the sunrays to the ground, to denote the mean weather condition. The word climate refers to the mean or normal condition over a long period, such as 20, 30, and 100 years [4]. According to Petterson [5], *"climatology or statistical meteorology determines the statistical relations, mean values, normal, frequencies, variation distribution, etc., of the meteorological elements, such as temperature, pressure, precipitation, wind speed and direction, humidity, sunshine, cloudiness and number of rainy days etc."*

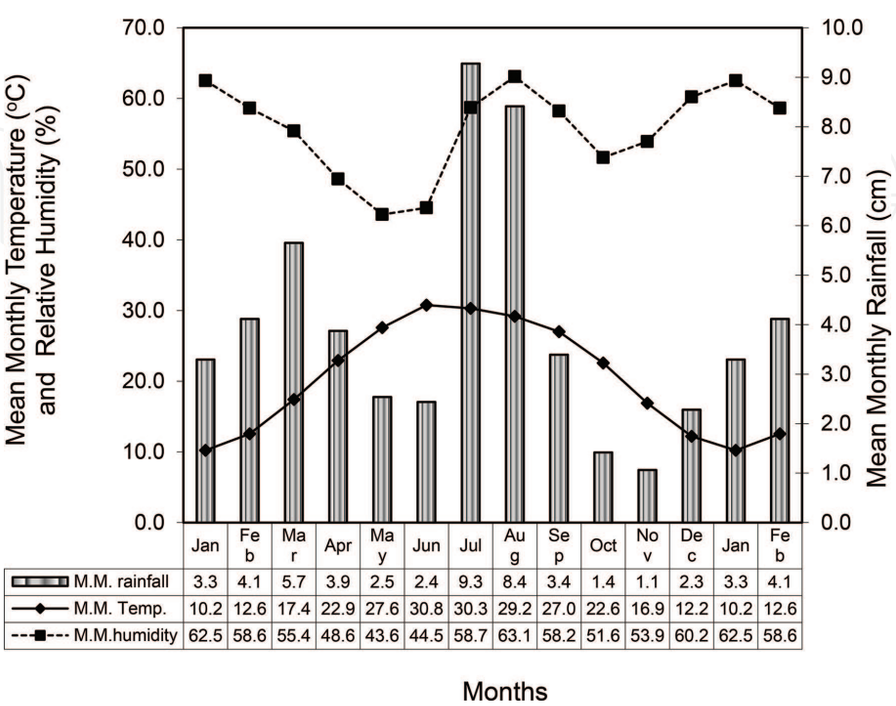
Blair [6] has defined the climate as "*The summation of weather conditions in historical time*" or "*Climate is the summary of all the manifold weather influences.*" Miller [7] is of the opinion that the science that discusses the weather condition of the earth surface is known as climate. Thus, the wind, temperature, humidity, precipitation, vegetation, sunshine, etc. are subjected to continuous variations, which are more or less invariant at a given place. According to Oliver [8], "*climate is the aggregate of weather at a given area for a given time period*." The term weather refers to the more or less instantaneous conditions of these elements over a relatively short time period. The generalized picture of weather is called climate [9]. Climatology deals with atmospheric conditions over a longer time period and, as a result, is often defined inadequately as "*average weather*."

### 3.1 Seasonal division

This section covers the temporal and areal climate divisions and climate regions. The temporal division is based on the division of the year into various seasons and the description of each season. The areal division is based on classifying the climate of region only and thus dividing arid region of Pakistan into areas of similar climate/physical features.

The distinct period into which the year may be divided, in terms of duration of daylight and climate conditions, as a result of changes in duration and intensity of sunshine and rainfall, is termed as season [10]. According to Moore [11], season is

defined as, "Those periods of the year, which are characterized by special climate conditions, mainly caused by the inclination of the earth's Axis to the plane of the Ecliptic and the revolution of the earth about the sun." In order to study the seasonal variation of weather elements, the year has been divided into two main seasons, that is, summer and winter. The interrelation of factors affecting climate of the arid region in Pakistan shows that the summer month in coastal areas may not be the summer month inland and a summer month in plain may not be that of the mountains. Therefore, months of the year having mean temperature of above 22°C, maximum temperature of above 34°C, and minimum temperature of above 10°C are suggested as summer months, otherwise winter (**Figure 2**). In spite of this, months having positive deviation from the mean temperature are considered as summer months, whereas months having negative deviation from the mean temperature have been placed in winter season. Generally, in plain the summer lasts from April to October and winter from November to March. In highland, the summer has a span from May to September and winter from October to April. These two main seasons are further condensed into four sub-seasons that are cold, hot, warm, and monsoon seasons. The cold season of the country is from mid-November to mid-April with all months' mean monthly temperature below 20°C, rainfall below 6 cm (2.4 inches), moderate humidity, high pressure, minimum sunshine period, and low evapotranspiration. The hot season varies from mid-April to June with each month's mean monthly temperature of above 30°C; low rainfall, humidity, and pressure; maximum sunshine period; and high evapotranspiration. The monsoon season ranges from July to mid-September with all months' mean monthly temperature below 30°C, rainfall above 6 cm (2.4 inches), moderate humidity, low pressure, and high sunshine period and evapotranspiration. Nonetheless, the warm season remains from mid-September to mid-November, with mean monthly temperature below 25°C, low rainfall and humidity, moderate pressure and sunshine period, and high evapotranspiration. However, November is completely the winter month in hilly areas, while April is the summer month in plain. These months are thus divided into two parts, and the average of 15 days has been added to each season.




| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Jan | Feb |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| M.M. rainfall | 3.3 | 4.1 | 5.7 | 3.9 | 2.5 | 2.4 | 9.3 | 8.4 | 3.4 | 1.4 | 1.1 | 2.3 | 3.3 | 4.1 |
| M.M. Temp. | 10.2 | 12.6 | 17.4 | 22.9 | 27.6 | 30.8 | 30.3 | 29.2 | 27.0 | 22.6 | 16.9 | 12.2 | 10.2 | 12.6 |
| M.M.humidity | 62.5 | 58.6 | 55.4 | 48.6 | 43.6 | 44.5 | 58.7 | 63.1 | 58.2 | 51.6 | 53.9 | 60.2 | 62.5 | 58.6 |

**Figure 2.**
*Pakistan arid region temperature (°C), rainfall (cm) and relative humidity (%) 1931–2017.*

The average rainfall indicates that it increases with a decrease in temperature from December to March, while at the rise of temperature, a decrease occurs from March to June. In July it exceeds 9 cm (3.6 inches) and then decreases till September and onward up to November (below 3 cm or 1.2 inches). The annual variation of rainfall and humidity also shows two-time positive and negative deviation from the mean condition (**Figure 2**). From September to November, the arid region of Pakistan is covered by anticyclone and reversible monsoon lows. These months, with moderate temperature and low rainfall, constitute as warm season. Generally, the local thunderstorms give high rainfall in the Northern Areas and constitute as a rainy season of the northern arid region in Pakistan. The month of the year having a mean monthly rainfall below 3 cm and temperature above 17°C has been suggested as a dry month, otherwise moist. The characteristics of each season are as follows [12].

### *3.1.1 Cold season*

The cold season lasts from mid-November to mid-April, which is completely winter months in the hilly areas. It is the season when, because of the prevalence of anticyclone, air subsides over Pakistan and the weather is feeblest. A cross section of the atmosphere about 78° east meridian shows the southern branch of the jet stream over northern Pakistan and India just south of the Himalayas, with the middle latitude westerly reaching down to the surface or, nearly so, north of about 25° [13]. The modest winter rainfall over northern Indo-Pakistan is associated with disturbances, which enter the area in the extreme northwest, after passing through Iraq, Iran, and Afghanistan. These disturbances reach their maximum development in winter when the jet stream lies south of the highlands, but they also occur though less frequently, in fall and spring. On the surface synoptic charts, the western disturbances usually first appear in the northwest in the vicinity of the surface polar front [7]. A cold continental air from eastern Europe and Western Asia break through the lower highland and spills out on the Indus lowlands. The front form between the continental polar air and the dry but warmer air of the Pakistani lowlands may not in the beginning be very active weather-wise. If the resulting depression acts to pull in a vigorous inflow of humid tropical maritime air mass from the Arabian Sea, the convergence is likely to produce extensive light rains. These are mid-latitude disturbances, a good proportion of that are not well-developed cold or warm fronts either at the surface or aloft.

The rainfall generated by these western disturbances of the cooler season is usually fairly widespread and light to moderate. It is locally heavy where thunderstorms are associated with the disturbances particularly in hot dry season. This fall in the cool season, when losses from evaporation are low, is highly effective for the growth of winter crops. On the plain, the total fall for the three winter months is only 1–3 inches, and yet this is of vital importance. Such storms also provide a much larger amount of winter precipitation in the form of snow and ice in the highland, whose water melts in hot season (summer) and furnishes the indispensable irrigation water for the Indo-Gengetic plain. These disturbances give high rains over the northwestern parts of Pakistan, which progressively decrease toward southeast and west. This variation, in general, leads to its long trajectory over land areas [12].

The season is usually characterized by cold weather with low mean monthly temperature, moderate rains, high humidity and pressure, low sunshine period, and gentle breeze. In cold season, most of the rains are caused by low-pressure depressions called western disturbances. These waves travel from the Mediterranean Sea and enter to Pakistan at the western margin after passing through Iraq, Afghanistan,

and Iran. These low-pressure waves give 3.83 cm (1.5 inches) average rainfall in the arid region of Pakistan. Areas located at the western border of the country record high rains in cold season as compared to other seasons. The highest rainfall from these winds is recorded at Dir (24.22 cm or 9.7 inches) in March, which is the moistest month of the season. The highest mean monthly total precipitation of the season is 83.5 cm or 33.4 inches at Dir, and lowest is 0.8 cm or 0.32 inches at Mohenjo Daro with highest relative humidity recorded at Ormara and lowest at Khuzdar. The lower Indus plain has almost recorded high temperature, while it decreases up to −7.8°C at Astore. Most of the Northern Areas receive rain from these winds as compared to other sources. The rainfall from western depression progressively decreases from the northern mountainous region, toward northwest and southeast due to long trajectory of these lows over continental areas. Most of the highland receives rain in the form of snow, which is a guarantee for the agriculture activities in the hot season. The temperature of the country decreases from southwest toward northeast, but sometime cold waves are caused by heavy snowfall in mountains and decrease temperature after sunset below freezing point in Baluchistan plateau and the lowlands, influencing plant growth and human activities.

### *3.1.2 Hot season*

The season ranges from mid-April to June and is characterized by high temperature and aridity. It is sometime called as the hot dry period to distinguish it from the cool dry season of winter and the hot wet season of summer and early fall. From April to June, the anticyclone subsidence and clear skies, characteristic of the winter months, still prevail, and this in combination with a much stronger solar radiation sets the weather pattern for the season. Temperatures are high, and a heavy, dry haze envelops in the interior, but drought still grips most of the country particularly upper and lower Indus plain.

The areal rainfall distribution in hot season is not fundamentally different from that of winter. The upper and lower Indus plain as well as Baluchistan, where maximum subsidence prevails, is still the driest parts of the country, and the Northern Areas with mountainous north are the wettest. The most perceptible areas of rainfall increase are the northern mountains and Azad Jammu and Kashmir, while most of the plains have less than 2 cm rains in these particular months.

According to Trewartha [13], in the far south, the added rainfall reflects the creeping northward with the sun of the ITC and the equatorial westerly. The increased rainfall in the north is furnished by the western disturbances. These perturbations are able to produce much precipitation in the more humid air of the north, they yield much more abundant rainfall, and some of it is associated with strong convective systems.

The hot season, in general, is characterized by violent weather, in the form of thunder squalls in the northern part of the country. In the drier land of Pakistan, the rainfall accompanying this vigorous convective system is low, but occasionally well-developed cumulonimbus clouds are generated with strong squall wind and violent dust storms.

In hot season, the mean monthly temperature exceeds 30°C with rare rains, low humidity and pressure, and high sunshine duration, evapotranspiration, and wind speed. These are the specific determinants, which cause parching of leaves in plants and evaporation of sweats from human bodies. In hot season, the western depression continues to travel along the northern latitude of Pakistan, which caused thunderstorms (with some rains) over the mountains and dust storms or dust-raising winds over the plain and Baluchistan plateau. The cold waves are rare in April, but hailstorms are frequent in April and rare in May, which caused widespread

damages to fruit trees in the western and Northern Areas of Pakistan. June is the driest month of the season with mean monthly rainfall of 2.42 cm or 0.96 inches and also the hottest with mean monthly temperature of above 30°C. The highest mean monthly total precipitation of the season is 35.1 cm or 14.04 inches at Garhi Dupatta, and the lowest is 0.1 cm (0.04 inches) at Mohenjo Daro (arid region). The highest mean monthly humidity is recorded at Ormara, and the lowest is at Chilas and Dalbandin (arid region). The highest mean monthly temperature of the season is recorded at Sibi, and the lowest is at Astore. In hot season, the Northern Areas of the country receive rainfall above 10 cm or 4 inches, which decreases toward south. This high temperature in the southern part of Pakistan produces a trough of low pressure, which attracts monsoon depression in the hot moist season. The variation in temperature, generally, shows the same pattern as in cold season. As the hot season progresses, the belt of highest day temperature takes over Pakistan from south to north. Moreover, in this season the average rainfall of Pakistan is 2.9 cm or 0.99 inches, which is insufficient for vegetation growth and human activities [12].

### *3.1.3 Monsoon season*

According to Moore [11], the term monsoon is derived from the Arabic word "mausim" which literally means "season." Originally, it was applied to the regular winds of the Arabian Sea, blowing for 6 months from the northeast and for the remaining 6 months from the southwest. Now generally, the term is applied to those and some other winds that blow with considerable regularity in different seasons of the year, due to the seasonal reversal of pressure over land masses and their neighboring oceans. In the typical area of the Indian subcontinent and southeast Asia, it is the seasonal inflowing moist winds that bring rains; hence, the monsoon season is considered as synonymous with the rainy season, and the term monsoon is applied to the rain without reference to the winds. The monsoon season of Pakistan ranges from July to mid-September, while in some areas it continues up to October. The deflected monsoon currents, generally, travel westward along the foothills of the Himalayas and reach Pakistan in July and are well established by the middle of that month [10]. The Arabian Sea branch of monsoon reaches to Sind-Makran coast by the end of June. However, it is of low vertical extant and, generally, produces stratus clouds in the coastal areas. The monsoon currents remain steady till it begins retreating toward the beginning of September. The second monsoon current enters Pakistan at upper Indus plain and gives more rains in Punjab, upper Sind, and northeastern Baluchistan. The third branch of the monsoon lows arrives at Kashmir Vale and the northern mountainous region of the country. Due to mountain trigger and high moisture index, these areas record high rains from these lows as compared to other regions of Pakistan. The rainfall from these winds generally decreases from northeast to southwest. This variation in rainfall intensity from monsoon is due to its long trajectory decreasing the moisture index of these depressions as they travel over continental areas. These winds are the only source, saving the lower Indus plain of Pakistan from aridity. In monsoon season, the mean monthly temperature of Pakistan drops below 30°C with high rainfall of 3–9 cm (1.2–3.6 inches) and humidity, low pressure, maximum sunshine period, and high evapotranspiration and wind speed. These winds give torrential rains with showers and caused damages to residential areas, crops, and vegetables. It gives above 7 cm or 2.8 inches of rainfall in Pakistan, which is higher than the other seasons. The maximum rainfall from these winds has been recorded at Balakot in July being the moistest month of the season with mean monthly rainfall of above 9 cm or 3.6 inches. However, in some areas especially in the mountainous north, August is the moistest month of the season. The highest mean monthly total precipitation of the season is recorded

at Murree and lowest at Nok Kundi (arid region), with highest mean monthly humidity at Jiwani and lowest at Chilas. The lower Indus plain as well as Baluchistan (arid region) has recorded high temperatures, while the lowest is at Murree and the adjoining areas of Malakand and Mansehra divisions (humid region). The rainfall of Pakistan, in monsoon season, generally, decreases from northeast to southwest [12].

In Pakistan, the transition from the relatively dry and weather less spring to the cloudy, rainy season of summer, with its numerous perturbations, is abrupt and is usually associated with strongly disturbed weather. The so-called monsoon rains begin over Burma in May or even late April [13], but in Pakistan, they arrive from 15th of June in coastal areas, and the first week of July in mountainous north, and are well-established up to the mid-July in the whole country. Usually, the advance of the monsoon currents toward north over India and Pakistan is accompanied by turbulent weather in the form of thunderstorms, but its frequency decreases after the summer circulation is established. The monsoon begins to retreat from northern Pakistan in late August, and the withdrawal continues southward through September and October [12].

The later arrival of monsoon currents in Pakistan may result from the fact that during the winter and spring, there is an orographically determined upper trough, oriented Northsouth at about 85°E, over the western Bay of Bengal. It acts to accelerate the southwesterly monsoon flow over Burma located east of this trough while at the same time retarding it over Indo-Pakistan to the west [14]. As the subcontinent is heated intensively in April and May, the zonal westerly's over northern India and Pakistan begin to move northward, and it changes its direction under the influence of the mountain ranges, toward southwest. As a result, the jet stream, which had been south of the highland at about 30°N during winter and spring, tends to disappear and then reappear alternately south of the mountains. Disappearance becomes more frequent as the season advances, and each disappearance is associated with a northward surge of the summer monsoon. Finally, in late May or early June, the jet disappears completely over northern Pakistan and takes up a position at about 40°N of the Himalayas and Tibet. Simultaneously, there occurs a shift of the low-latitude trough and ridge positions, and the upper trough which previously was located at about 85°E quickly moves westward some 10° and takes up a position over western Indo-Pakistan subcontinent at approximately 75°E. With the disappearance of the jet over northern India and a westward shift of the upper trough, the equatorial westerly, or summer monsoon, surges northward over India accompanied by unsettled weather. The heating of the subcontinent and the development of a surface pressure trough are unable to produce a northward advance of the ITC until large-scale dynamic features of the circulation aloft become favorable [13]. When the jet stream reappears south of the Himalayas, again in fall, the summer monsoon again retreats southward and is called reversible monsoon.

### *3.1.4 Warm season*

The season varies from mid-September to mid-November and is characterized by pleasant weather with moderate temperature and low rainfall. As the thermal trough over northern Pakistan weakens, paralleling a decline in insulation, the flow of southwesterly equatorial air across Indo-Pakistan subcontinent and up to the Bay of Bengal likewise weakens; the ITC, as well as the paths of the monsoon depressions, retreats slowly southward; and rainfall declines in the north [7]. With this retreat of the equatorial westerly, a greater intrusion of the north Pacific trades into the Bay of Bengal and over Indo-Pakistan. By the late fall, the trough of low pressure, separating the easterly and westerly air currents, becomes established over the

southern part of the Bay of Bengal and adjacent to southern Indo-Pakistan subcontinent. Along the discontinuity between the equatorial westerly and the zonal easterly, various kinds of perturbations develop ranging all the way from weak monsoon depressions to hurricanes. The depressions follow less well definite tracks than in summer, but in general, their progress is westward so that their rainfall effects are concentrated in coastal region of Pakistan, which lies in close juxtaposition to the earth's most active region of cool season tropical cyclogenesis, located in the southwestern part of the Bay of Bengal.

Within Pakistan and India, severe hurricane storms are more numerous in this season particularly in the coastal region of Pakistan and Bay of Bengal. Some of these storms, in weakened form, appear to have the western north of the Arabian Sea regenerating over coastal areas of Indo-Pakistan.

During the fall months, the dynamic features of the circulation aloft, including jet stream and the orographically imposed troughs and ridges, begin to approach their cool season positions, with the reappearance, south of the mountainous north of Indo-Pakistan subcontinent in October or November of the middle latitude westerly and the jet stream, and the re-establishment of the polar front in the extreme northwest of Pakistan. The western disturbances once more become an important control of weather in northernmost India and Pakistan [13].

In warm season, the temperature of the country falls below 30°C with low rainfall and humidity, moderate pressure and sunshine, high evapotranspiration, and gentle breeze. In these months the monsoon lows give way to those of winter currents (western depression), and most of the rains are caused by thunderstorms, which develop due to local low pressure, especially in mountainous areas. The retreat of monsoon from the north Arabian Sea is marked by disappearance of the stratus clouds with a gradual increase in daytime temperature over Sind-Makran coast [10]. The highest mean monthly total precipitation of the season is recorded at Sialkot, while the lowest is at Nok Kundi with highest relative humidity at Ormara and lowest at Chilas (Arid region). The highest temperature of the season marked at Las Bela with lowest at Astore. In warm season, the rainfall of Pakistan decreases from northeast to south, while the temperature decreases from south toward north.

### 3.2 Climates of the arid region

The arid climate is characterized by low rainfall and covers a vast region in the southern as well as northern parts of Pakistan, where the annual total rainfall is between 0–10 inches. According to Hasan and Khan [12], the arid region of Pakistan is classified into the following subregions.

#### *3.2.1 Hot long summer and mild short winters (HsMw')*

The region is designated by hot and arid climates with mean temperature of the hottest month, June, above 32°C and warmest month, November, 10–21°C with average summer temperature more than 25°C. This climate type is divided into the following micro-regions.

##### *3.2.1.1 Winter dry and summer rainfall with average day humidity of 55–60% (wx')*

The region consists of Hyderabad, Mirpur Khas, and parts of Dadu District. The annual total rainfall of the area is 5–10 inches with summer concentration and annual day relative humidity of 55–60%. The mean monthly evapotranspiration is 7.1 mm or 0.28 inches at Hyderabad with annual sunshine of 8.2 h/day. The subregion has long, hot, and moist summers and short, mild, and dry winters. The mean

monthly summer temperature exceeds 25°C, and the winter temperature is less than 15°C. June with mean temperature of above 32°C is the hottest month of the region, and January with mean temperature of less than 20°C is the coldest month. The mean monthly temperature of the area varies between 25°C and 30°C, with 35°C–40°C maxima and 10°C–15°C minima. The mean daily range is above 10°C, with 30–35°C daily maximum and 20°C–25°C daily minimum temperature.

The region is characterized by severe summers and moderate winters having 50°C ever recorded maximum temperature at Hyderabad in June, while the lowest minimum temperature of 1°C recorded in January. This subregion has 8.9 numbers of rainy days, while the average wind speed is 5.1 knots.

High-loam and clayey soil characterizes the zone with some pediment plain near the foothill of Kirthar mountains. High water table has caused waterlogging and salinization problems, depressing crop growth or making land unproductive for agriculture. However, areas having well-developed canal system and less salinization are characterized by intensive agriculture. Agriculture is the main activity in this zone, but there are also areas of rough grazing, riverine forests, and tracts of flooded backswamps. Wood resources come from riverine and thorn forests and trees of farmlands, much of which are used for firewood.

*3.2.1.2 Winter dry and summer rainfall with relative humidity of 60–65% (wv)*

The subregion includes Badin and northeastern part of Thatta. June is the hottest month with mean monthly temperature above 32°C, while January is the coldest month with mean temperature less than 20°C. The summers are hot, long, and moist, while the winters are short, mild, and dry. The area receives much of rainfall from monsoon lows particularly from the Arabian Sea branch. The annual total rainfall of the area is 5–10 inches with summer concentration, and average day relative humidity is 55–60%. The mean temperature of the region is 25°C–30°C, with 35°C–40°C maxima and 15°C–20°C minima. The mean daily range of temperature varies between 10°C and 15°C, with 30°C–35°C daily maximum and 15°C–20°C daily minimum temperature. The extreme maximum temperature of the subregion is 49.4°C recorded in June, and the lowest minimum is −2°C recorded in January. The annual evapotranspiration is 7 mm or 0.28 inches with annual sunshine of 8.2 h/day. The number of rainy days is 9.2 with average wind speed of 6.7 knots.

The region is characterized by sandy clayey soil, which is not suitable for agriculture, and therefore, the area has very little agriculture activities excluding those parts where water is easily available for irrigation. The water logging and salinization are the dominant factors of low agriculture production of the region. Vegetation resembles that of arid desert, with the addition of thorn scrub and light scrub forests. The land is mostly used for grazing of cattle, sheep, and goats. Moreover, the groundwater is acidic and is not suitable for drinking as well as vegetation growth.

*3.2.1.3 Uniform rains with summer concentration and relative humidity of 55–60% (Usx')*

Thal Desert and Dera Ismail Khan districts belong to this subregion, where the mean temperature of the coldest month that is January is above 10°C and hottest month that is June exceeds 32°C. The area receives both summer and winter rains, but the contribution of summer rains particularly from monsoon lows is high as compared to winter rainfall. The annual total rainfall of the region is 5–10 inches with average day relative humidity of 55–60%. The evapotranspiration of the region is 4.3 mm or 0.17 inches with annual sunshine of 8.4 h/day, which makes the summer of the region hottest as compared to the adjoining regions. The mean temperature

of the subregion particularly at Dera Ismail Khan is 20°C–25°C, with 36.7°C maxima and 13°C minima. The area has high range of temperature both in summer and in winter seasons. The annual range of temperature is 10°C–15°C, with 30°C–35°C as the mean daily maximum and 15°C–20°C as the daily minimum temperature. The extreme maximum temperature of the region is 50°C, recorded in May, the hottest month of the region, while the lowest minimum temperature is −3°C, recorded in January. The number of rainy days is 18.2 with average wind speed of 2 knots.

The area is characterized by low agriculture practices due to nonavailability of water and poor soil. In some areas of Dera Ismail Khan, soil is fertile and having good agriculture, while most of the Thal Desert has sandy soil with some loams. The summer's "loo" (hot wind) is the important characteristic of the region, which not only increases the temperature of the region but also affects plant growth and its production, due to high evapotranspiration. The area has subtropical thorn forests with some irrigated plantation near canal banks and is used, in general, as a grazing land for livestock.

*3.2.1.4 Summer dry and winter rainfall with average relative humidity of 45–50% (sy')*

Panjgur and Turbat (Baluchistan) are included in this subregion, where the summers are long and dry, while the winters are short and moist. The annual total rainfall is less than 5 inches with winter concentration particularly from western disturbances. The area has severe summers and mild winters. The mean temperature varies between 20°C and 25°C, with 30°C–35°C maxima and 5°C–10°C minima. The mean daily range exceeds 15°C, with 25°C–30°C daily maximum and 10°C–15°C daily minimum temperature. The ever-recorded maximum temperature of the region is 45°C, recorded in June, the hottest month, while the lowest minimum temperature is −7.8°C, recorded in December, the coldest month of the year. The number of rainy days of the area is 10.2, while the wind speed is 4.5 knots with average day relative humidity of 45–50%.

Hot arid desert covers the area in the border with Iran and areas near the Makran coast. The soil of the area is sandy with sand dunes, badly eroded by running water. Vegetation is closely related to soil moisture, with grass along "nullah" (seasonal rivers) and on piedmont plain, associated with small trees and shrubs. The main species are *Pistacia* spp. and *Quercus ilex* with evergreen oaks occurring above 1200 m. Woodlands here provide fuel wood, nuts, fruits, and brows for camels. Wetter areas have relatively good grazing for livestock.

The land is used mainly for grazing. Pockets of cultivation are fed by water from karez system or spate irrigation along rivers. Vegetation is extremely variable, from completely barren ground to medium-density shrub and tree cover. Any well-watered land is cultivated, and all the vegetation are grazed, browsed, or cut for domestic requirements, particularly near urban centers.

*3.2.2 Hot long summer and cool short winters (HsCw')*

It is generally characterized by warm desert, where the June temperature exceeds 32°C, while the mean January temperature is between 0°C and 10°C with mean summer temperature of above 25°C. It is further divided into the following subregions [12].

*3.2.2.1 Summer dry and winter rainfall with average day relative humidity of 30–35% (sz)*

Parts of Chaghi and Kharan districts (Nok Kundi) belong to this region, where the annual total rainfall is less than 5 inches. The lowest rainfall of

Pakistan that is 1.4 inches has been recorded in this region, and the average day relative humidity varies between 30 and 35%. The area receives more rains in winter season, while the summer season is dry, with two dry spells in a year: the first is from mid-April to June, while the second is from mid-September to mid-December. The summers are long and hot, while the winters are moist and cool. The annual evapotranspiration is 5.4 mm or 0.22 inches with mean sunshine duration of 8.5 h/day. The mean temperature of the region is 20°C–25°C, with 35°C–40°C maxima and 10°C–15°C minima. The mean daily range is above 15°C with mean daily maximum temperature of 30°C–35°C and with a daily minimum above 15°C. The number of rainy days of the subregion is 4 with annual wind speed of 7.6 knots. The ever-recorded maximum temperature exceeds 45°C in June, while the lowest minimum temperature is less than −10°C in December, due to cold Siberian currents.

The soil of the region is sandy with arid piedmont plain and barren Chaghi hills. It constitutes as the western Baluchistan rangelands. The land is used, in general, for grazing, but some patches of cultivated land are also located in the karez-fed areas. The land is badly eroded by geomorphic agents due to sparse vegetation. Vegetation varies from barren ground and mountains to medium-density scrubs and trees, with acacia and jajoba as the main species. The forests are mostly used for domestic purposes and browsed for camels.

#### *3.2.2.2 Summer dry and winter rainfall with average day relative humidity of 35–40% (sz')*

Parts of Kharan and Chaghi districts (Dalbandin) are the specific areas of the region. The summers are long and dry, while the winters are short and moist. The area receives most of the rains in winter from western disturbances with annual total rainfall below 5 inches. The evapotranspiration of the area is 5.1 mm or 0.2 inches with annual sunshine duration of 8.6 h/day and the average day relative humidity of 35–40%. The mean monthly temperature of the area is 20°C–25°C, with mean maximum temperature of 35°C–40°C and minimum temperature of 5°C–10°C. The annual daily range varies between 15 and 20°C with mean daily maxima of 30°C–35°C and mean daily minima of 10°C–20°C. The highest maximum temperature of the area is above 50°C, recorded in June, and the lowest is below 10°C, recorded in December, due to Siberian cold winds. The number of rainy days of the area is 8.7, and the average wind speed is 3.2 knots.

The physiography and soil of the land are the same pattern as given in 2.1. subregion. However, the area is badly eroded and having barren mountains, particularly the Chaghi hills. Most of the areas near Dalbandin are piedmont plain, while toward south, the area is sandy, and sandy dunes cover a vast area with scrubs and bushes. The land is mostly used for grazing and browsed for camels. Due to sandy soil, agriculture practices are confined to isolated patches in the area. The barren Chaghi hills increase the daytime temperature while decrease the nighttime temperature of the region due to high absorption, deflection, reflection, and releasing of solar energy.

### *3.2.3 Hot long summer and short warm winters (HsWw')*

The region is a hot desert, where mean temperature of the hottest month June is above 35°C and that of coldest month January is between 21°C and 32°C. The mean summer temperature of the area exceeds 25°C. It is further divided into the following sub-climatic regions [12].

#### *3.2.3.1 Winter dry and summer rainfall, with average day relative humidity of 55–60% (wx′)*

Bahawalpur, Bahawalnagar, Mianwali, and Multan districts are included in this region. The area is characterized by hot long moist summers and short warm dry winters. The annual total rainfall varies between 5 and 10 inches with average day relative humidity of 55–60%. The mean evapotranspiration of the region is 5.5 mm or 0.22 inches, with annual sunshine of 8–10 h/day. The number of rainy days is 10–15, while the wind speed is 2–4 knots. The mean monthly temperature ranges between 25°C and 30°C, with 35°C–40°C maxima and 10°C–20°C minima. The mean daily range of temperature is 10°C–15°C, with 30–35°C daily maximum and 15–20°C daily minimum. The extreme maximum temperature of the region varies between 45°C and 51°C, recorded in May and June, while the lowest minimum temperature is 0°C to −5°C, recorded in January. May and June are the hottest months, whereas January is the coldest month of the region.

It is the extension of the Rajasthan Desert, but due to well-developed canal system, intensive agriculture is practiced in parts of the region. The area has sandy soil, but alluvial soil has also developed near the banks of Indus and its tributaries. The eastern part of the region has sandy loams with terraces of the "Hakra River" (India), sand ridges, inter-dune valleys, and saline lakes and flats.

Natural vegetation comprises xerophytic trees, shrubs, and grasses, but some irrigated plantations have also been grown along the river−/canal banks. The pressure on these limited tracts of shrubs vegetation from fuel woodcutters is intense. Land, otherwise, is used only for livestock production, hunting, and agriculture. Due to rapid deforestation, temperature of the region increases with passage of time and the area continuously going toward severe aridity.

#### *3.2.3.2 Winter dry and summer rainfall with relative humidity 40–45% (wy)*

Kach-Sibi areas fall in this region. It has hot long moist summers and warm short dry winters. The mean annual total rainfall of the area varies between 5 and 10 inches, with average day relative humidity of 40–45%. The mean annual evapotranspiration of the region is 4 mm or 0.16 inches, with mean sunshine duration of 8.2 h/day, number of rainy days 12.1, and wind speed of 2.9 knots. The mean temperature of the area is 25°C–30°C, with 30°C–35°C maxima and 10°C–15°C minima. The mean daily range of temperature varies between 15 and 20°C, with 35–40°C daily maximum and 15°C–20°C daily minimum. In Sibi, more than 50°C maximum temperature has been recorded for three times in June, making it the hottest region of the country. The lowest minimum temperature of the area is −3.3°C, recorded in January, the coldest month of the region.

Aridity prevail the whole region, with less fertile sandy soil. Kachhi plain is a desert, with no vegetation. However, in the irrigated areas, the natural vegetation in general is xerophytes with shrubs and grasslands, with medium size trees. The area is mostly used for grazing, where there are karezes and there are some agriculture patches of land.

#### *3.2.3.3 Winter dry and summer rainfall with relative humidity of 50–55% (wx)*

The region consists of Khanpur and the upper irrigated Sind. The annual total rainfall of the region is less than 5 inches with annual day relative humidity of 55–60%. The summers are long hot and moist, while the winters are warm short and dry. The annual evapotranspiration is 6.7 mm or 0.27 inches (Jacobabad),

and sunshine is 8.7 h/day. The number of rainy days is 5–10, with a wind speed of 2–4 knots. The mean monthly temperature varies between 25°C and 30°C, with 35°C–40°C maxima and 10°C–20°C minima. The mean daily range is 10–15°C, with 30–35°C daily maximum and 15–20°C daily minimum temperature. The highest maximum temperature of the region is 45°C–52°C recorded in May and June, while the lowest minimum temperature is 0°C to –5°C, recorded in January and December.

The soil of the region used to be subjected to annual flooding before the river embankments were constructed, and because of this, the soils are rich loamy and clayey. High water tables have caused water logging and salinization problems, and the land is unproductive for agriculture growth.

Agriculture is the main activity in this zone, but there are also areas of rough grazing, riverine forest, and tracts of flooded backswamps. Wood resources come from riverine forests and trees on farmlands, much of which is used for firewood or send to Baluchistan as a mining timber.

#### *3.2.3.4 Winter dry and summer rainfall with average day relative humidity of 60–65% (wv)*

The region consists of Nawabshah and Padidan in central Sind. The total rainfall of the region varies from 5 to 10 inches with summer concentration, while the winters are short and dry. The average day relative humidity varies from 60–65%, with evapotranspiration of 6.9 mm or 0.28 inches and sunshine of 8.8 h/day. The mean monthly temperature varies between 25 and 30°C, with 35–40°C maxima and 10–15°C minima. The mean daily range of temperature is 15–20°C, with 35–40°C daily maximum and 15–20°C daily minimum temperature. The maximum temperature exceeds 50°C in June, while in January, it falls below freezing. The number of rainy days is 5–10 per year, with average wind speed of 0–5 knots. The soil and natural vegetation as well as physical relief of this climatic zone are the same as given in 3.3 climate type.

#### *3.2.3.5 Winter dry and summer rainfall with relative humidity of 45–50% (wy')*

Thar Desert in Sind and Cholistan in Punjab constitute in this micro-region. It has long hot moist summers and short warm dry winters. The annual total rainfall of the area varies from 5 to 10 inches, but in Cholistan, it is less than 5 inches. The average day relative humidity of the region is 45–50%, with annual evapotranspiration of above 5 mm or 0.2 inches and sunshine duration of more than 8 h/day. The mean monthly temperature varies between 25–30°C, with 35–40°C maximum and 10–15°C minimum temperature. The mean daily range is 15–20°C, with 30–35°C daily maximum and 15–20°C daily minimum temperature. The extreme maximum temperature of the region is above 50°C, recorded in June, and the lowest minimum temperature is 0–5°C, in January.

Arid desert covers the eastern part of Sind and lower Punjab. These major landforms of the region are a series of parallel and linear sand dunes "bets" oriented northwest to southeast. Valleys between these dunes cover about 30% of the area. There are also salt lakes fed by water. Natural vegetation is of two types, *Cenchrus-Panicum* dune type and *Eleusine-Cenchrus* inter-dune type. Livestock is the mainstay of the region, with some secondary dryland farming in inter-dune valleys. Cholistan has sandy soil and is the extension of the Great Indian Desert that includes terraces of Hakra River, sand ridges, inter-dune valleys, and saline lakes and flats. Natural vegetation is xerophytic trees, shrubs, and grasslands. The region, in general, is used for hunting and grazing, with some patches of rainfed agriculture.

### *3.2.4 Warm long summers and mild short winters (WsMw')*

This sub-climatic type is characterized by mean temperature of the hottest month June which is 21–32°C and the warmest month November which is 10–21°C, with mean summer temperature of above 25°C. It is further divided into the following sub-types.

#### *3.2.4.1 Winter dry and summer rainfall with relative humidity of 55–60% (wx')*

The region characterizes by Marine continental climates with an annual total rainfall of 5–10 inches and average day relative humidity of 55–60%. It includes Las Bela and Dadu. This sub-type is characterized by short warm dry winters and long hot moist summers. The annual evapotranspiration of the area is 4.4 mm or 0.18 inches, with sunshine duration of 8.1 h/day, number of rainy days 14.5 per year, and average wind speed of 3 knots. The mean monthly temperature varies between 25–30°C, with 35–40°C maxima and 10–15°C minima. The mean daily range is 10–15°C, with 30–35°C daily maximum and 15–20°C daily minimum temperature. The ever-recorded maximum temperature of the area is 51°C at Las Bela, recorded in May, the hottest month of the region, while the lowest minimum temperature is below freezing recorded in January.

Vegetation of the region is closely related to soil moisture, with grasses along streams and seasonal rivers. Woodlands here provide fuel wood, nuts and fruits, and brows for camels. Wetter areas have relatively good grazing patches for livestock. The land is mainly used for grazing. Pockets of cultivation are fed by water from karez systems or from spate irrigation along streams and seasonal rivers. Vegetation is extremely variable, from completely barren ground to medium-density shrubs and tree cover. Any well-watered land is cultivated, while the vegetation is grazed, browsed, or cut for domestic purposes, particularly near Karachi and Dadu.

#### *3.2.4.2 Uniform rains with winter concentration and relative humidity of 65–70% (Uwv')*

Karachi west belongs to this region, where the mean annual total rainfall is 5–10 inches, with average day relative humidity of 65–70%. The area receives both summer and winter rains, but the contribution of winter rains is more than summer season. It has long warm summer and short mild winters with sea and land breezes throughout the year. June is the hottest month, with maximum temperature of above 32°C, and January is the coldest month, with minimum temperature of less than 5°C. The mean evapotranspiration of the area is less than 4 mm or 0.16 inches, with sunshine duration of more than 8 h/day, number of rainy days 5–10 per year, and wind speed of 6.6 knots. The mean monthly temperature of the region is 25–30°C, with 35–40°C maximum and 15–20°C minimum temperature. The mean daily range varies between 10 and 15°C with 30–35°C daily maximum and 20–25°C daily minimum temperature. The highest maximum temperature of the region is 45°C, recorded in June, and the lowest is 0°C, recorded in January. The physiography, soil, and natural vegetation are the same as given in A.4.5. sub-type.

#### *3.2.4.3 Summer dry and winter rainfall with average relative humidity of 70–75% (su)*

The region is marine coastal has climates with annual total rainfall of less than 5 inches and with average day relative humidity of 60–75%. Pasni and parts of Jiwani belong to this region. It has warm long summers and mild short winters with winter rainfalls, but summers are also not dry. The annual evapotranspiration is above

4 mm or 0.16 inches with annual sunshine duration of 8.3 h/day, number of rainy days 6.5 per year, and wind speed of 6.9 knots. The mean monthly temperature varies between 25°C and 30°C, with 35°C–40°C maxima and 15°C–20°C minima temperature. The annual daily range of temperature is 10°C–15°C, with 30°C–35°C daily maximum and 20°C–25°C daily minimum temperature. The highest maximum temperature of the area is 47°C, recorded in June, the hottest month of the year, whereas the lowest minimum is 2°C, recorded in December, the coldest month of the region.

The region is also characterized by land and sea breezes with saline sandy soil, sparsely covered by scrub trees particularly of Bela forest (medium size trees). Due to low soil fertility, agriculture is not very important, and most of the area is used for grazing and woodlands.

*3.2.4.4 Summer dry and winter rainfall with relative humidity of 75–80% (su')*

The region consists of Ormara and Jiwani with warm long dry summers and short mild moist winters. Sometime, Ormara receives both summer and winter rains, while the intensity of winter rains is high at Jiwani as compared to summer. The annual total rainfall of the area varies between 5 and 10 inches, with mean evapotranspiration of less than 5 mm or 0.2 inches and sunshine duration of 9 h/day. The average day humidity is 75–80%, with number of rainy days between 5 and 10 per year and wind speed of 5–8 knots. The mean monthly temperature of the area varies between 25°C and 30°C, with 30°C–40°C maxima and 15°C–20°C minima. The mean daily range of temperature is 5°C–10°C, with 30°C–35°C daily maximum and 20°C–25°C daily minimum temperature. The highest maximum temperature of the region is 48°C, recorded in June, and the lowest minimum temperature is 0°C–5°C, recorded in January. June is the hottest month of the area, while January is the coldest month. The general characteristics of the region particularly of soil and vegetation are the same as stated in A.4.3. subregion.

*3.2.4.5 Uniform rains with summer concentration with relative humidity of 65–70% (Usv')*

Marine coastal, Indus Delta (Thata), and eastern Karachi are included in this region. Both summer and winter rains are received in the area, but the contribution of summer rains is higher than winter. The annual total rainfall of the area varies from 5 to 10 inches with annual evapotranspiration of 4.9 mm or 0.2 inches and sunshine duration of 8.1 h/day. The average day relative humidity varies from 60–65%, with number of rainy days less than 10 per year and wind speed of 6.6 knots. The mean monthly temperature of the area is 25°C–30°C, with 35°C–40°C maxima and 15°C–20°C minima. The mean daily range of the area varies from 10°C–15°C, with 30°C–35°C daily maximum and 20°C–25°C daily minimum temperature. In May, the maximum temperature reaches to 48°C and falls to 0°C till January.

The Indus Delta has its apex some distance northeast of Thata, where the distributaries fan-out to form the deltaic plain near Thata. Two of the large distributaries are Ochito and the Gungro. Many of the channels perform the dual function of distributaries and estuaries. The channel beds and their levees are higher than the adjacent lands, and the shallow troughs between them are often filled with water, resulting in swamps. The tidal delta is submerged at high tide and has mangrove swamps and tamarisk groves in its western section. The eastern section is Rann of Kutch, a saline marshy land. The coast is low except between Karachi and Cape Monze, where the Pab hills approach the shore.

The Karachi plain has a thin mantle of soil over weathered bedrock. A few low hills rise above 15 m. Shallow depressions are known as Dhand. One of these, Heleji Dhand, is used as water reservoir for Karachi city. The vegetation of the region is mostly Bela, with some irrigated plantation on Indus banks and roadsides. The area is characterized by sea and land breeze with poor sandy soil, due to which very rare cultivation is practiced in the area. The forests, in general, are used for grazing and domestic purposes.

*3.2.5 Warm short summers and cool long winters (Ws'Cw)*

The region includes areas having mean temperature of the hottest month June between 21°C and 32°C and mean temperature of the coldest month January as 0°C–10°C, with mean winter temperature of above/equal to 15°C. The region has further been divided into the following sub-types.

*3.2.5.1 Summer dry and winter rains, with relative humidity of 40–45% (sy)*

The region includes Kalat in the south and Chaman and Loralai in the north. These areas have short warm dry summers and cool long moist winters. The mean annual total rainfall of the area varies between 5 and 10 inches, with average day humidity of 40–45%. The annual evapotranspiration of the sub-region is 5 mm or 0.2 inches, with sunshine duration of 8.7 h/day, number of rainy days 15–20 per year, and wind speed of 3 knots. The mean temperature of the area varies between 15°C and 20°C, with 25°C–30°C maxima and 0°C–5°C minima. The mean daily range is 15°C–20°C, with 20°C–25°C daily maximum and 5°C–10°C daily minimum temperature. The highest maximum temperature recorded at Kalat is 38°C, in June, while the lowest is 0°C to −18°C, recorded in January.

The region is characterized by extensive woodlands of *Juniperus*, *Pinus gerardiana* (*chilgoza*), etc., with many shrubs including a well-known medicinal plant, e.g., *Ephedra nebrodensis*. Excessive timber and fuel woodcutting has completely degraded these woodlands, leaving many former forest areas as shrubby and grassy steppes. The relatively higher productivity of forest in these areas has encouraged denser populations, and consequently greater human exploitation of scrub and woodlands has declined the stocks of wood. The soils, in general, are regosols and lithosols with some fertile alluvial soils in the valleys. Terrace agriculture is practiced in the valleys; otherwise, the area is used for grazing. The topography of the region is mostly rough with steep slopes and narrow valleys, intensively eroded by running water.

*3.2.5.2 Summer dry and winter rainfall with relative humidity of 30–35% (sz)*

Nushki and its surrounding in the Chaghi district falls in this sub-type, where the annual total rainfall is between 0 and 5 inches, with average day humidity of 30–35%. This low relative humidity of the region causes high evapotranspiration from plants as well as the human skin. The summers are, in general, hot long and dry, while the winters are mild cool and moist. The cold Siberian winds in winters decrease the temperature of the area up to freezing. The mean annual evapotranspiration is less than 5 mm or 0.2 inches with sunshine duration of 8 h/day. The mean temperature of the region is 20–25°C, with 30°C–35°C maxima and 5°C–10°C minima. The mean daily range is between 15°C and 20°C, with 25°C–30°C daily maximum and 15°C–20°C daily minimum temperature. The soils consist of shingles, pebbles, and sands (regosols) and are very poor for cultivation. However, some

agriculture patches are located in karez-feeding areas. The forests are mostly scrubs with grasslands and also having barren lands and mountains.

*3.2.5.3 Uniform rains with summer concentration and relative humidity of 35–40% (Usz')*

The climatic region includes Khuzdar, which receives both summer and winter rains with summer concentration. The summers are long and warm, while the winters are cool and short. The annual total rainfall of the region is 5–10 inches, with average day relative humidity of 35–40%. The annual evapotranspiration is less than 5 mm or 0.2 inches with mean sunshine duration of less than 8 h/day. The number of rainy days is 19.3 per year, with wind speed of 3 knots. The mean temperature of the region is 20°C–25°C, with 30°C–35°C maxima and 5°C–10°C minima. The daily range of temperature is 10°C–15°C, with 25°C–30°C daily maximum and 10°C–15°C daily minimum temperature. The extreme maximum temperature of the area is 43°C, recorded in July, the hottest month of the year, whereas the lowest minimum temperature is −5 to −10°C, recorded in January, the coldest month of the year.

The region characterized by steep slopes having some grasslands and sparse shrubs but have mainly barren. The mainstay of the land is grazing, with pockets of cultivation fed by tube well irrigation. Farmers grow mainly fruits such as apples, apricots, grapes, peaches, and plums. The vegetation is mainly used for domestic purposes and livestock. Due to rough topography, some patches of terrace agriculture are at the tube-well-fed areas.

*3.2.6 Warm short summers and cold long winters (Ws'C*w)*

In this region the mean temperature of the hottest month June is between 21 and 32°C, with the coldest month January having temperature below freezing and the mean winter temperature above 15°C. It is further divided into the following sub-climate types.

*3.2.6.1 Winter dry and summer rainfall particularly from local thunderstorms with relative humidity of 40–45% (wty)*

The region consists of Gupis in the Northern Areas, where the annual total rainfall is less than 5 inches with cold long dry winters and short moist summers. In winters low precipitation mostly in the form of snow and ice is received, whereas the summer rains are high, particularly from the local thunderstorms. The winters are very cold, while the summers are warm. The evapotranspiration of the region is 2.8 mm or 0.11 inches, with annual sunshine of 6.6 h/day, while the average day relative humidity is 40–45%. The mountain slopes are mostly covered by snow particularly in Ishkoman valley, while the ground and lower mountain slopes are barren. The physiography is generally rough with sparse vegetation and cultivation. The mean temperature of the region is 10–15°C, with 20°C–25°C maxima and 5°C–10°C minima. The daily range of temperature is between 10°C and 15°C, with 15°C–20°C daily maximum and 5°C–10°C daily minimum temperature. The highest maximum temperature of the region is 41.1°C, recorded in July, the hottest month of the area, while the lowest minimum temperature is −10 to −15°C, recorded in January, the coldest month of the year. The number of rainy days of the region is 13.8, while the wind speed is 2.6 knots.

The zone is characterized, in general, by glacier feed areas, deep narrow valleys, fans, and terraces. Upper mountain slopes have poor soils, but valley bottoms have deep, clay-rich soils overlying the colluviums on lower slopes, fans, and terraces. Crops can be cultivated on those fertile fans and terraces, irrigated by the streams.

Slopes rely on rainfall to produce maize, wheat, and orchards. Energy demands are high because of the cold winters. The forests are, in general, orchards with medium size trees, which are mostly used for domestic purposes.

*3.2.6.2 Summer dry and winter rainfall with relative humidity of 50–55% (sx)*

The region consists of Skardu, Ladakh, in occupied Kashmir and the adjoining areas of China (Tibetan Plateau). The annual total precipitation varies from 5 to 10 inches, particularly in the form of snow and ice in winter season. However, the summers are not dry, and the region receives more than 1 cm or 0.18 inches rainfall in April and May from local thunderstorms. The annual evapotranspiration is 4.4 mm or 0.18 inches, with annual sunshine of 6.8 h/day, while the average day relative humidity is between 50 and 55%. The mean temperature varies from 10–15°C, with 20–25°C maxima and 0°C minima. The mean daily range of temperature is between 15 and 20°C, with 15–20°C daily maximum and 5–10°C daily minimum temperature. The highest maximum temperature of the region is 41°C, recorded in August, and the lowest minimum is −20 to −25°C, recorded in January. The mean temperature in January as well as December reaches below the freezing point. Solar energy is needed for the plant protection particularly in winter season. The number of rainy days of the region is 21.5 per year, with wind speed of 1.1 knots.

The area is characterized by barren mountains and glaciers. The soils are poor at higher mountain slopes and are fertile near foothills. The agriculture is practiced only on terraces in well-watered areas. The mountains are, in general, barren due to glaciations; however, some deciduous forests have grown at the foothills and riverbanks.

*3.2.7 Hot long summers and cool short winters (HsCw')*

The region is characterized by hot climates, with June temperature above 32°C and with January temperature between 0 and 10°C, while the mean summer temperature exceeds 25°C. The climatic zone is further divided into the following sub-types.

*3.2.7.1 Winter dry and summer rainfall particularly from local thunderstorms with relative humidity of 40–60% (wtY)*

Gilgit district and Bunji, located close to Hunza and Indus Rivers, fall in this region. The annual total rainfall of the area varies from 5 to 10 inches. This sub-type receives both summer and winter rains with summer concentration particularly from local thunderstorms. The evapotranspiration of the area is 2.7 mm or 0.11 inches (Gilgit), with annual sunshine of 6.5 h/day and average day humidity of 40–60%. The summers are hot and moist, while the winters are cool and dry. The mean temperature of the region varies between 15 and 20°C, with 25–30°C maxima and 0–10°C minima. The mean daily range is 10–15°C, with 20–25°C daily maximum and 5–15°C daily minimum temperature. The highest maximum temperature of the region is 45–50°C, recorded in July and August, while the extreme minimum temperature is –5 to −15°C, recorded in December and January. The number of rainy days varies between 14 and 20 per year, with annual wind speed of 0–3 knots.

The region consists of major valleys and high permanent snowcapped mountains. Snowfall received is between 2 and 6 m/year. Vegetation at 3800-4000 meters is alpine scrub of small deciduous and evergreen forests. Between 3500 m and 3800 m,

vegetation is mixed coniferous forests. High alpine scrub is important for summer grazing, but livestock also enter the forests, and large tracts of forests have been cleared. Rainfed cultivation from the valleys and lower slopes is expanded upward, when fertile land is no more available in the valleys. The soil at foothills is usually fertile, but due to the lack of water, agriculture is confined to well-watered areas.

*3.2.7.2 Uniform rains with summer concentration from local thunderstorms and relative humidity of 35–40% (Ustz')*

Chilas in the Northern Areas and parts of Kohistan district are included in this region, where the annual total rainfall varies between 5 and 10 inches. Rainfall is received both in summers and winters, with summer concentration especially from local thunderstorms. Physiography is rough with high barren mountains and glacial topography. The evapotranspiration of the region is 3.3 mm or 0.13 inches, with annual sunshine of 6.5 h/day and average day relative humidity of 35–40%. The mean temperature of the region is between 20 and 25°C, with 30 and 35°C maxima and 5 and 10°C minima. The mean daily range varies between 10 and 15°C, with 25–30°C daily maximum and 10–15°C daily minimum temperature. The highest maximum temperature of the region is 48.1°C, in August, and the lowest minimum is −4.4°C, recorded in January. The number of rainy days is 17.3 per year, with average wind speed of 1 knot.

The upper mountain slopes have poor soils, but the valley bottom has deep clay-rich soils overlying the colluviums on lower slopes, fans, and terraces. Crops can be cultivated on these fertile fans and terraces, obviously irrigated by the streams. Slopes rely on rainfall to produce maize, wheat, and orchards of walnuts, apricots, and plums. The forests are usually deciduous with most of the barren mountains and lands. Agriculture is mostly confined to rainfed areas.

## 4. Soil

Agriculture and climate of the arid region have also been greatly influenced by the soil composition and structure. "The soil has three distinct constituents, which are solid particle, air, and water." These three major components have also great effects on the climate and crop productivity of a region. For example, salts, minerals, and organic matters help in the reflection, deflection, and absorption of solar radiation; consequently, the temperature of the earth surface and atmosphere fluctuates [3].

The arid region of Pakistan has peculiar types of soil due to its topography, climate, vegetation cover, parental materials, and time period of formation (main factors of soil formation). Based on structure and composition, the soil of the arid region can be classified into "soil of the flood plain, loamy soils of bar uplands, loamy and clayey, partly saline soils of the piedmont plains, rolling to hilly sandy soils of Aeolian desert, highlands, Baluchistan plateau." The soil of the floodplain is subclassified into loamy and some sandy stratified soil of recent river plains, mainly loamy and clayey soils of subrecent river plains, mainly loamy saline soils of estuary plains, and mainly salty and clayey wet saline soils of tidal plains.

The loamy and clayey soils are rich in soil contents and suitable for agriculture activities. Such soil is located at the bar upland in lower Punjab and also on both sides of the Indus River in Sind (arid region), and both of the areas produced a major part of the agriculture economy on national level. Most of the arid region of Baluchistan, eastern Sind, and lower eastern Punjab is characterized by the rolling to hilly sandy soils, which are poor for crop cultivation, while the remaining areas are converted to cultivated lands after establishment of better irrigation system that originated from Indus and its tributaries (**Figure 3**).

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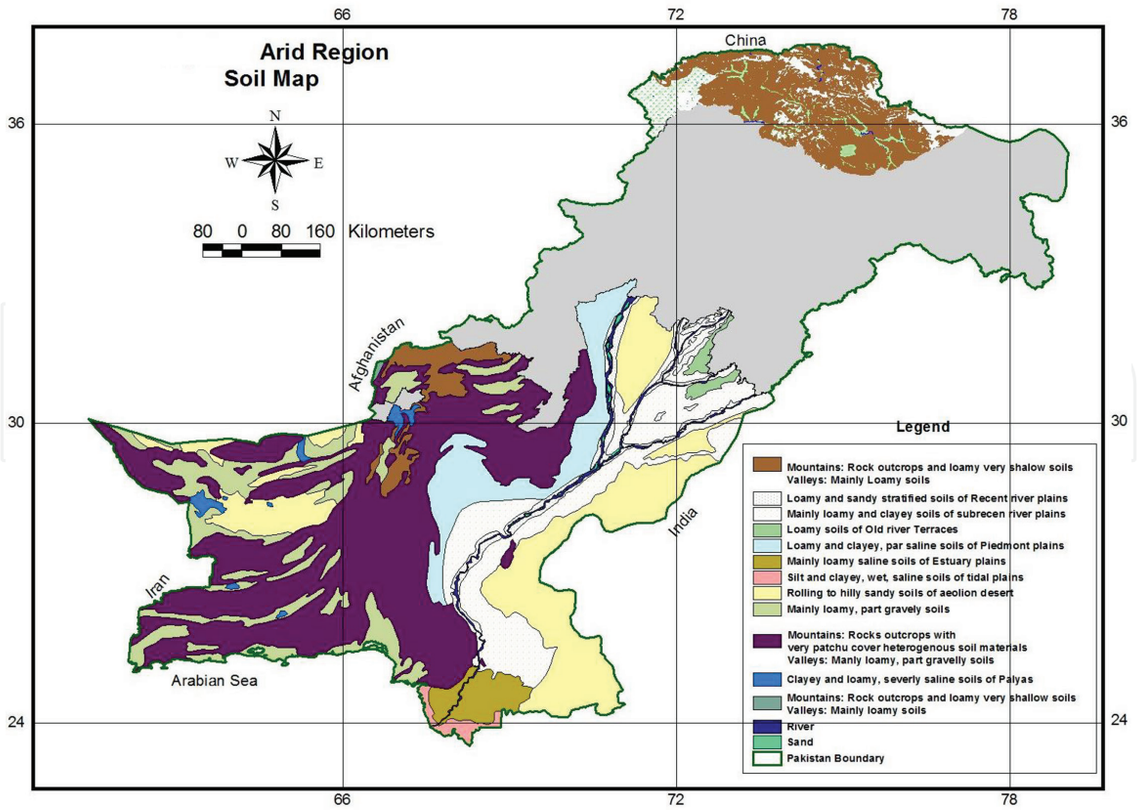


**Figure 3.**
*Soil map of the arid region, GoP [15].*

## 5. Natural vegetation

It is one of earth's most vital natural resources that provide food, fiber, and fuel for the sustainability of human life, while vegetation preserves biodiversity and soil and plays an outstanding role in the hydrological cycle. The inhabitants of the arid region of Pakistan have cleared the land surface by cutting the natural vegetation cover for the cultivation of crops. While the vegetation cover controls the soil erosion, storage and filtration of water, and wildlife habitat, playing a key role in the transfer of gasses between the atmosphere, soil, and water bodies is basic to the crop cultivation, production, and growth.

Dense forests can influence the local climate to some extent. Temperature is lower in a region of dense forests, light is reduced greatly, and the soil is several degrees colder. Humidity is greater, and dew and fog are formed readily over the adjoining fields. Evapotranspiration from the soil and wind velocities under a forests covered area are greatly reduced and also increase the capacity of water storage of the soil. The barren land and mountains have inverse climate condition.

In arid region, there is a variety of natural vegetation due to variation in climates, topography, and soil condition. "Natural vegetation covers about 4.8% of the total area of Pakistan, while about 20–25% of forests are needed for the balanced economy of a country" [3]. The province-based distribution shows that Khyber Pukhtunkhwa has the leading percentage (15.6%), followed by Sind (2.1%), Gilgit-Baltistan (13.5%), and Azad Jammu and Kashmir (13.6%) and the remaining 55.2% in Punjab and Baluchistan province. The arid region has two distinct types of forests, that is, natural vegetation and the plantation forests (**Figure 4**).

The natural vegetation consists of different type of forests including alpine forests, coniferous forests or subtropical pine forests, subtropical dry forests, tropical thorn forests, and coastal mangrove forests. Plantation forests are divided into riverine and irrigated forests that are located at the roadsides, canals, and rivers.

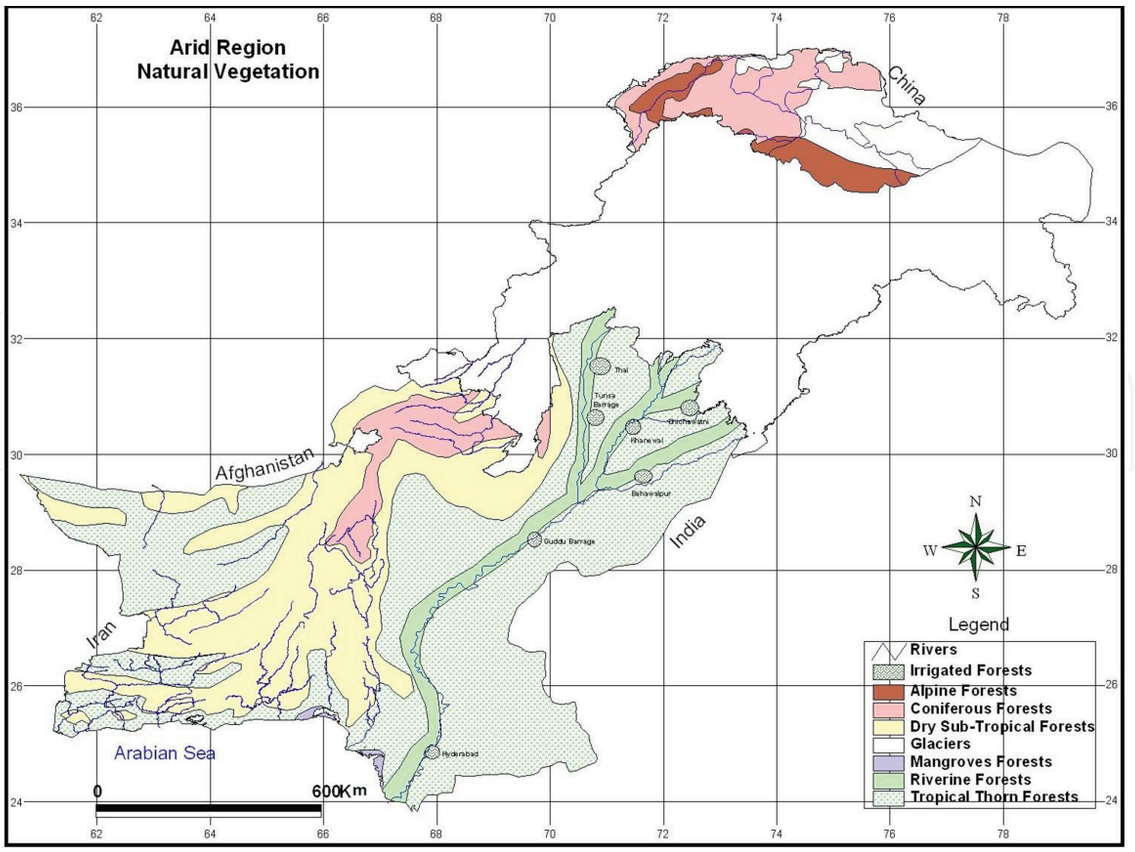


**Figure 4.**
*Natural vegetation of the arid region, Pakistan, Khan [3].*

## 6. Human environment

Agriculture is practiced in diverse economic, social, and environmental conditions. Hence, great diversity has developed in agriculture practices and products. In some areas of the arid region, farming is carried out to meet the local demand; in others it is primarily cultivated for commercial purposes. "The different types of farming in the arid region of Pakistan are intensive subsistence farming, dairy farming, plantation farming, truck farming, and extensive herding" [16]. Among the factors that have influenced the type of farming include distribution of population and human settlements, as well as socioeconomic conditions.

### 6.1 Population

Pakistan has sustained significant population growth in the past century. In early 1891, the population of the country was 18.4 million, which dropped to 16.6 million in 1901. Then the population was estimated at 19.4 million in 1911, which increased to 21.2 million in 1921 and 23.6 million in 1931, while in 1941 it again increased up to 28.3 million. According to the first well-organized census in 1951, Pakistani population was 33.7 million having 6 million urban and 27.8 million rural population. In 1961, this figure was increased to 42.9 with 9.6 million urban and 33.3 million rural inhabitants. Onward, in 1971, it i up to 65.4 million with 7.6 million urban and 48.8 million rural population. The increase in population continues in 1981, where population of the country reached to 84.3 million having 23.9 million urban and 60.5 million rural population. As per 1998 census, the population had quadrupled to 132 million inhabitants and almost double (207.8 million in 2017) (**Figure 5**, **Table 1**).

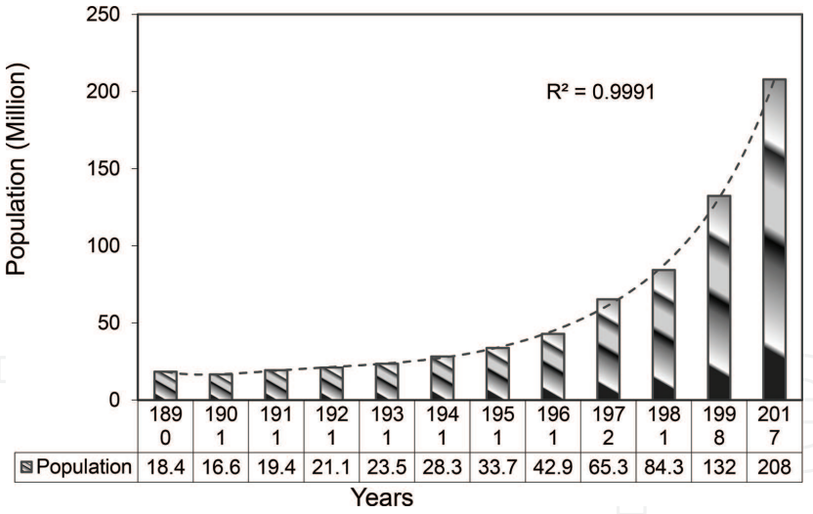


**Figure 5.**
*Pakistan population 1890–2017.*

| Year | Population | Year | Population density | Year | Annual growth | Year | Urban | Rural |
|---|---|---|---|---|---|---|---|---|
| 1890 | 18.4 | 1890 | NA | 1890 | NA | 1890 | NA | NA |
| 1901 | 16.6 | 1901 | 20.8 | 1901 | 1.6 | 1901 | 9.8 | 90.2 |
| 1911 | 19.4 | 1911 | 24.4 | 1911 | 0.8 | 1911 | 8.7 | 91.3 |
| 1921 | 21.2 | 1921 | 26.5 | 1921 | 1.1 | 1921 | 9.8 | 90.2 |
| 1931 | 23.6 | 1931 | 29.6 | 1931 | 1.9 | 1931 | 11.8 | 88.2 |
| 1941 | 28.3 | 1941 | 35.9 | 1941 | 1.8 | 1941 | 14.2 | 85.8 |
| 1951 | 33.8 | 1951 | 42.4 | 1951 | 2.4 | 1951 | 17.7 | 82.3 |
| 1961 | 42.9 | 1961 | 53.9 | 1961 | 2.3 | 1961 | 22.5 | 78.0 |
| 1972 | 65.4 | 1972 | 82.1 | 1972 | 3.3 | 1972 | 28.3 | 71.7 |
| 1981 | 84.3 | 1981 | 105.8 | 1981 | 3.3 | 1981 | 28.3 | 71.7 |
| 1998 | 132.4 | 1998 | 166.3 | 1998 | 2.7 | 1998 | 32.5 | 67.5 |
| 2017 | 207.8 | 2017 | 256.0 | 2017 | 2.4 | 2017 | 36.4 | 63.6 |

*Source: GoP [17].*

**Table 1.**
*Arid region of Pakistan demographic characteristics.*

In early 1994, the population of Pakistan was estimated to be 126 million, making it the ninth most populous country in the world. Its land area, however, ranks 32nd among nations. Thus, Pakistan has about 2% of the world's population living on less than 0.7% of the world's land. The population growth rate is among the world's highest, officially estimated at 3.1% per year but privately thought to be closer to 3.3% per year by many planners involved in population programs (**Table 1**).

The total population of the arid region in 1998 was 60.2 million comprising 31.5 million male and 28.7 million female. It is estimated that the projected population of the arid zone will be 78.7 million including 41.2 million male and 37.5 million female populations by the year 2010.

The population density of the arid region is 137 persons/km$^2$ area in 1998, while it is expected that the projected population will be 179 persons/km$^2$ by the year 2010.

## 6.2 Population distribution

The distribution of rural population brings out the man-land relationship effectively in an agriculture area like Pakistan. The pressure of population on land in arid region has been increasing with passage of time. The population density of the arid region has been categorized into the following major classes.

### *6.2.1 Thinly populated region*

The thinly populated areas of the arid region mostly cover the entire area of Baluchistan and Gilgit-Baltistan provinces. These areas comprise of hills, mountains, and barren sandy lands. Most of the land consists of rainfed areas having scared agriculture activities (**Figure 6**).

### *6.2.2 Moderately populated region*

Moderate population varies from 101 to 200 persons/km$^2$. The moderate population is mostly located in the northwestern part of Baluchistan (Pishin district), parts of Sind, and lower Punjab provinces. Most of the agriculture is based on rainfall or canal system with low productivity (**Figure 6**).

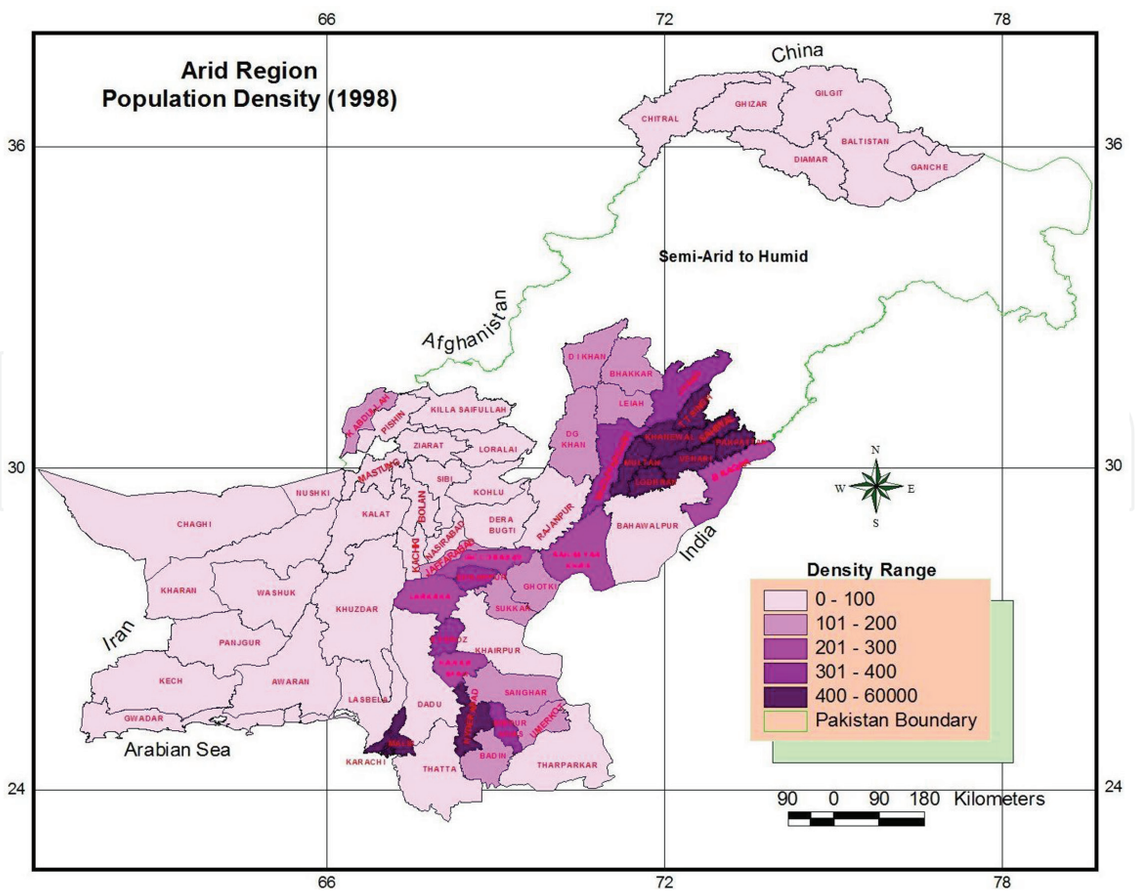


**Figure 6.**
*Arid region projected population (2011–2012), GoP [18].*

*6.2.3 Thickly populated region*

The range for this class has been considered between 201 and 300 persons/km$^2$ area. The arid areas having thick population mostly cover the fertile land of Sind and Punjab. These are the areas, where intensive agriculture is carried out with a high productivity (**Figure 6**).

*6.2.4 Very thickly populated region*

The very thickly populated region varies from 301 to 400 and comprises parts of Punjab and northwestern Sind. Most of these areas are characterized by fertile soils and located close to the major cities. These are the most important agriculture lands forming source of food for the entire region (**Figure 6**).

*6.2.5 Most thickly populated region*

There are 13 most thickly populated districts in the arid region where the population density is above 400 persons/km$^2$. These are located around the major cities and fall in the old floodplains of the Punjab and active floodplain of Sind excluding Karachi (**Figure 6**).

## 7. The agroecological zones and land use pattern

The agriculture sector continues to play a basic role in the arid region economy. "It is the second largest sector, accounting for over 22% of GDP, and remains by far the largest employer, absorbing 45% of the country's total labor force. Nearly 62% of the country's population resides in rural areas, and is directly or indirectly linked with agriculture for their livelihood" [18].

About nine different agroecological zones have been identified in the arid region of Pakistan by GoP [19], and the map produced has been updated on the basis of the recent data. The general description, physiography, land use, and environmental condition of each agroecological zone have been given below.

### 7.1 Indus Delta

The region comprises of the Indus Delta and the surrounding areas of Thatta, Badin districts, and parts of Hyderabad that are formed through successive advancement of land into the sea. The tall grasses and salt bushes had hampered the spread of agriculture in large areas. The changing nature of the Indus distributaries, floods, and marshes makes the reclamation of the land a major challenge (**Figure 7**). The region is characterized by arid tropical marine climate with moderate hot summers and very mild winters. However, due to prevalence of sea breeze during summer, the day temperatures are not very high.

There are two types of soils in the region comprising of clayey and salty soils. The clayey soils cover about one half of the area (**Figure 8**). Generally, the saline and clayey soils of the region are barren. Parts of clayey soils are under irrigated cultivation to grow mainly rice and some sugarcane and pulses. Berseem fodder has high potential in the rotation of the crops. Locally, banana and orchards are also located on clayey soils.

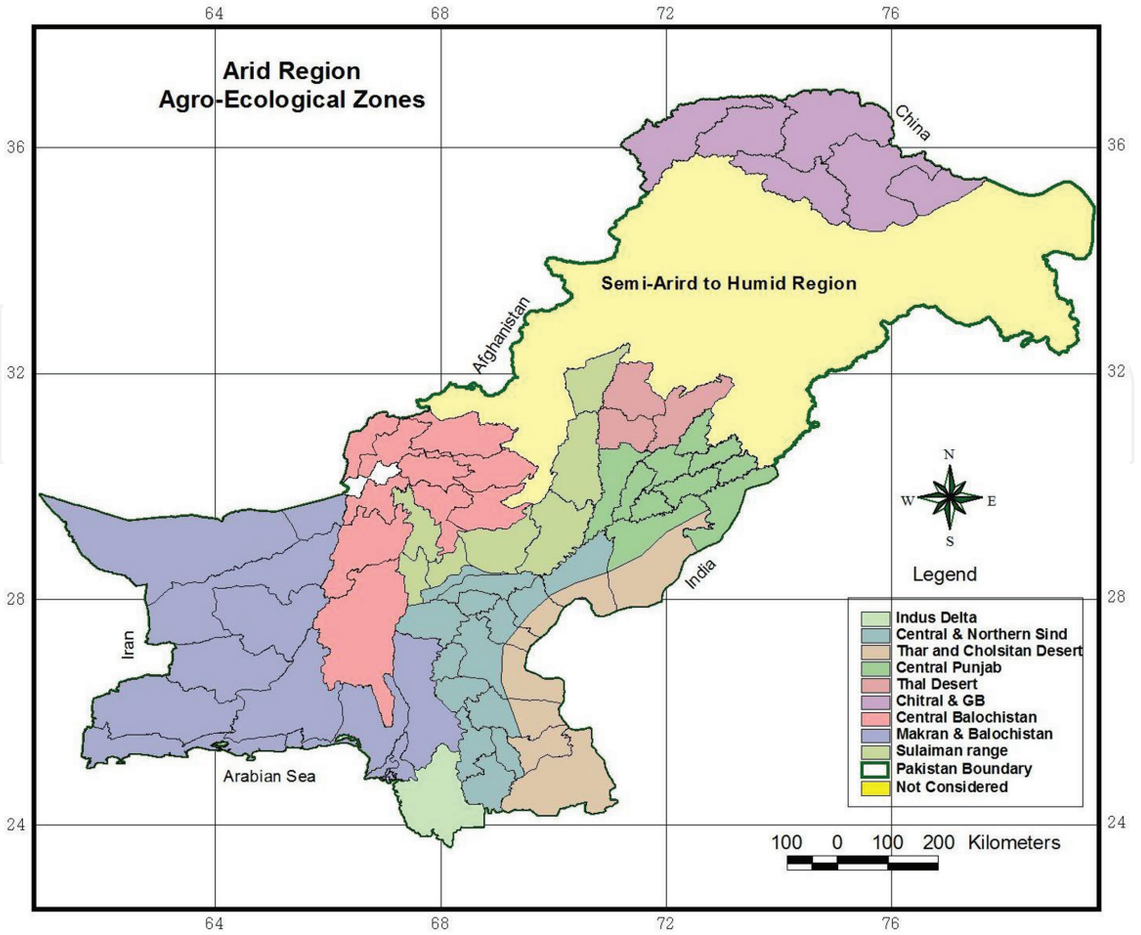


**Figure 7.**
*Agro-ecological zones of Pakistan, GoP [19].*

## 7.2 Central and northern Sind

The region consists of Hyderabad, Badin, Tharparkar, Sanghar, Dadu, Khairpur, Larkana, Nawabshah, Jacobabad, Sukkur, and Shikarpur in Sind, Nasirabad in Baluchistan, and Rahim Yar Khan of Punjab (**Figure 7**).

The climate is arid subtropical continental with hot summer and mild winter. The zone could be subdivided into northern and southern regions. The northern region is extremely hot in summer with mean daily maximum temperature of above 40°C. The precipitation of the region varies from 16 to 20 mm. The minimum temperature in winter remains below 10°C with lowest mean monthly of 2.4°C.

The region is characterized by three main soil types with loam as a common feature. Along the river one meets the silt and sandy loam soils associated with the active floodplain. Outside the range of active floodplain in the upper part of the region, calcareous, loamy, and clayey soils cover vast stretches. In the rest of the region, soil texture is almost the same, but there are saline patches (**Figure 8**).

Most of this area comprises of arable irrigated land, with small patches of unused land under rough grazing. There are distinct cropping patterns that emerged with varying availability of irrigation water.

Canal-irrigated agriculture is the predominant land use of the region. Cotton and wheat, colza (mustard), sugarcane, and berseem fodder are the main crops in the area on the left bank of the Indus. Rice, wheat, gram, and berseem fodder are the main crops in the area on the right bank. *Sorghum bicolor* is the main crop in southern part of Dadu district because of water shortage.

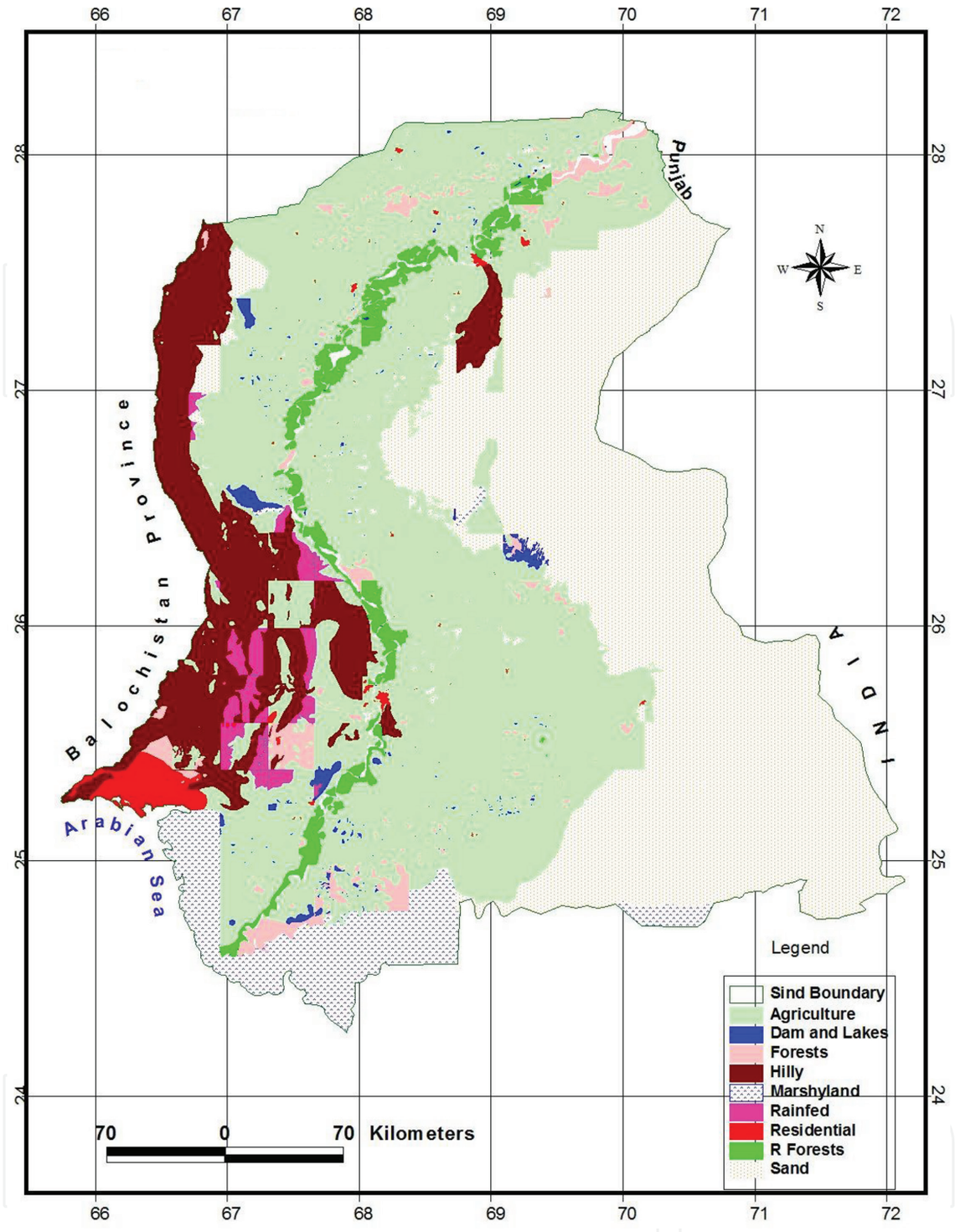


**Figure 8.**
*Sind province land use.*

## 7.3 Thar and Cholistan Desert

Parts of Tharparkar, Khairpur, Nawabshah, and Sanghar in Sind and Rahim Yar Khan and Bahawalpur in Punjab cover this region, which is a part of the Great Indian Desert. The area is higher than the adjoining Indus plain, characterized by elongated sand ridges formed by wind process. The desert is covered by thorny bushes.

The inter-dune areas are devoid of shifting sand. During the rainy season, the runoff from the adjoining dunes is collected in the central part providing enough moisture to support some scanty agriculture in the south eastern Sind. Most part of

the desert is rainfed. The depth of the underground water is at several 100 m and difficult to support the fauna, agriculture, and human needs. The climate of the desert is tropical with hot long summers and short warm winters. The climate is desert type with very hot days in summer and cold nights in winter with frost and fogs. Dust storms are common during summer season (**Figure 7**).

The area is characterized by the sandy soils and moving sand dunes. The valleys between the dunes have sandy loam, but these cover a very small proportion of the area. However, in the southern part, sandy loam soil covers considerably large patches of land. The western part of this region has long strips of clayey soils formed in the deposits of Hakra River.

The region comprises of the pastures for the grazing of sheep, goats, camels, and cattle. In the southern part jowar millets are important crops, which are grown in years of favorable precipitation. In the southeastern part of the region, where rainfall is about 300 mm (Tharparkar), wheat is also an important crop on loamy soils and castor on sandy loam soils (**Figure 8**).

### 7.4 Central Punjab

The region consists of Bahawalnagar, Rahim Yar Khan, Multan, Vehari, Muzaffargarh, Sahiwal, and Jhang districts of the south central Punjab, famous for the agriculture activities. The area is arid (steppe) with subtropical continental climates. The mean monthly temperature of the area remains above 35°C, whereas the winter minimum temperature is above 10°C. The area is characterized by hot summers and warm winters with dust storms in the month of June and July (**Figure 7**).

The soils are sandy loam to clayey loams [10]. Along the rivers, narrow strips of recent alluvium are deposited during the rainy season when the flow remains high. In the southern and central parts of central Punjab, dominating soils are calcareous salty loams having weak structure, whereas clayey soils occur in minor patches.

The area is covered by canal system for irrigation. Both *rabi* and *kharif* crops are cultivated in the region with high productivity. The main crops of the region are cotton, sugarcane, maize, and wheat. The area is also famous for the fruit orchards of citrus and mangoes throughout the arid region (**Figure 9**).

### 7.5 Chitral and Gilgit-Baltistan province

The region comprises of Gilgit-Baltistan province and part of Chitral district in Khyber Pakhtunkhwa. Enclosed by high mountains, the valleys located in Chitral, Gilgit-Baltistan, are characterized by extreme aridity. However, a large number of glacier-fed streams bring abundant water, which is used for irrigation of terraced agriculture. The terraces formed of fluvioglacial materials are highly fertile. The higher slopes of these valleys and the mountains in the neighborhood of snow line are covered with a narrow belt of pine forests (**Figure 7**).

The climate of the region varies from arid climate to undifferentiated highlands. The tops of high mountains are covered with snow generally for the greater part of the year. The summers are mild and the winters are cold.

"The soils are generally deep, clayey and are formed in colluvial material accumulated on lower parts of mountain slopes and in alluvial deposits in narrow valleys." [10]. Most of the area is used for grazing, and a part is under the scrub forest. Deep soils of valleys and lower parts of the mountains are used for growing maize and wheat under rainfed cultivation. Locally, in favorable condition rice is also grown with irrigation. Fruit orchards are confined to flanks of streams where irrigation water is available (**Figures 10** and **11**).

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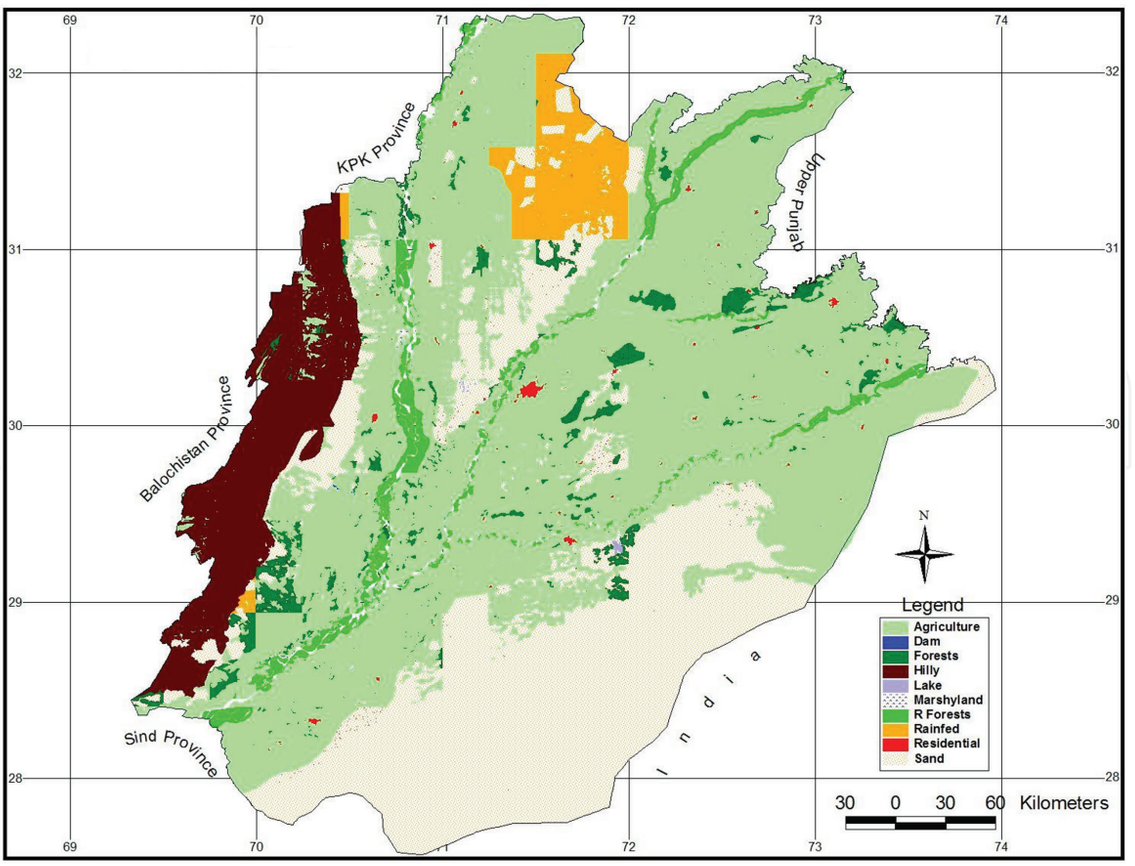


**Figure 9.**
*Lower Punjab land use.*

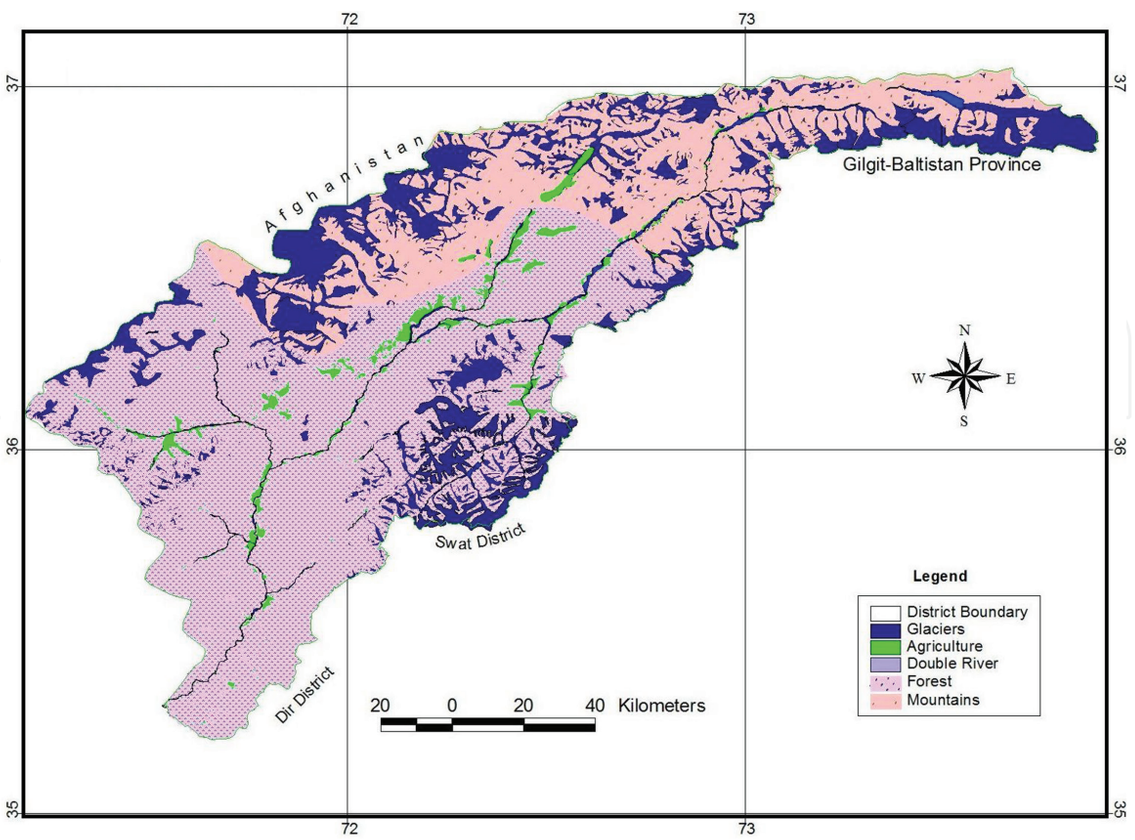


**Figure 10.**
*Chitral district land use.*

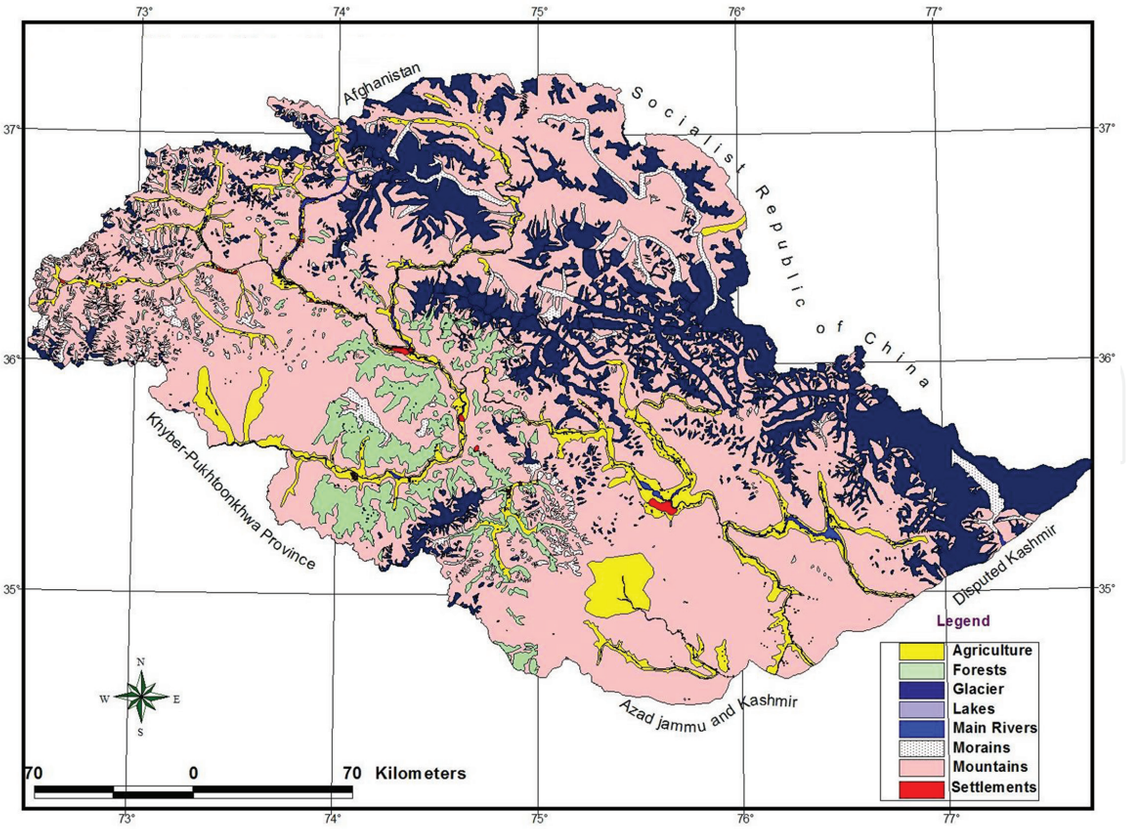


**Figure 11.**
*Gilgit-Baltistan province land use.*

## 7.6 Central Baluchistan

The region consists of Northern and central Baluchistan having barren hills with steep slopes, intervened by valleys filled with Pleistocene deposits and gravels, alluvium, and loessic materials in Kachhi plain.

Due to steep slopes, soil erosion is severe and extensive. Most of the land is almost devoid of vegetation except some xerophyte bushes and poor grasses, which are being worn down by human and animal exploitation. There are numerous hill torrents that carry flashfloods and occasionally cause considerable damage to land and population. The area is mountainous having an arid climate with mild short summers and cold long winters (**Figure 7**).

The area is mountainous with deep valleys. The main soils of the valleys are strongly calcareous but deep and loamy, with weak subangular blocky structure and low organic matter content of 0.3–0.5%. Only at high altitudes, the virgin soils have 1–1.5% organic matter content. The higher parts of valleys have gravelly soils; the lowest parts are occupied by plains containing strongly saline soils and in between are loamy. The mountains have either very shallow soils or bare rocks with soil materials only in crevices (**Figure 12**).

Predominant land use of the area is grazing. Parts of the loamy soils of the valleys are, however, used for growing wheat under a system of spate irrigation by diverting torrent floods into fields having high embankments. A very small proportion of the area is under irrigated fruit orchards, mainly apples, peaches, plums, apricots, and grapes. Also grown under the irrigation are crops of wheat, maize, and alfalfa.

## 7.7 Makran coast, southwestern Baluchistan, and Sind

This agroecological zone covers Karachi and Dadu districts in Sind and Gwadar, Kharan, Chaghi, and Las Bela districts in Baluchistan. The climate of the region

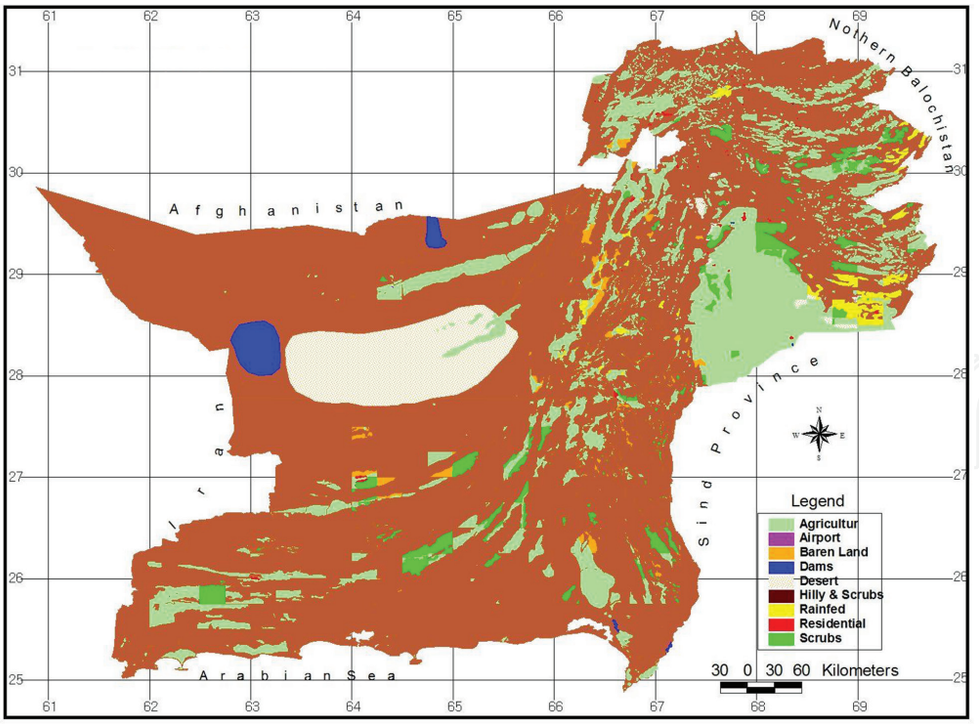


**Figure 12.**
*Baluchistan province land use.*

comprises of long hot summers and mild short winters with dust storms in June and July. The winter precipitation is higher than the summer monsoon. The area is characterized by the mountains with intermountain basins, plateaux, and desert. It is the watershed between the Indus drainage system and the rivers that drains directly into the Arabian Sea including Porali, Nall, Hingol, and Dasht Rivers of Baluchistan. In the north and the west, it has inland drainage system (**Figure 7**) with isolated patches of agriculture scattered in the area.

The valleys generally have their floors covered with recent and subrecent deposits of alluvium derived from the adjoining hill ranges. Most of the non-perennial streams from these valleys in the area converge on Hamun-e-Mashkel and conspicuous salt pan in western Kharan Desert.

The soils of the plain area in this region are deep, strongly calcareous silt loams with weak structure. The slopes of the mountains and hills comprise either bare rocks or have very shallow soils. The lower parts of hills and higher parts of the plain have gravelly soils with a strong zone of lime accumulation at 30–40 cm of depth. Vegetation is xerophytes and is characterized by thorny scrubs and poor grasses in the lower regions. On higher altitudes there are forests of junipers and wild olive, which merge with barren lands with scanty bushes and grasses in low-lying areas (**Figure 12**).

The most important land use of the area is grazing. Cultivation on deep valley soils depends mainly on spate irrigation practiced by diverting torrent water into fields, which have high embankments for pending of water. The soil is soaked with 30–50 cm of water to grow the crop. In the north wheat is the main crop but some melons are also grown. In the south *Sorghum bicolor* and millets are the important crops along the coast; castor bean is grown quite extensible. Fruits, vegetable, and wheat are grown wherever water is available from springs or karez.

### 7.8 Piedmont zone of the Sulaiman range

The region contains Dera Ismail Khan in Khyber Pakhtunkhwa, Dera Ghazi Khan and Rajanpur of the Punjab, and Dera Bugti, Nasirabad, Jhal Magsi, and Bolan

districts in Baluchistan. The piedmont plains of the Sulaiman range are sloping toward the Indus River. A large number of alluvial fans have been built by the streams, which slope from the hills on to the piedmont slope. Barkhan, Dera Bugti, Nasirabad, and Jhal Magsi districts lie at the foot of the Sulaiman range to the west.

The piedmont deposits in this area show a generalized grading in texture, with gravel and boulders near the hills and silty material farther away. However, this grading of material is not in evidence everywhere, because it has been obscured by subsequent fine or course materials, producing geohydrological inequalities laterally and vertically in the deposits. Severe soil erosion, heterogeneity of soils, shifting of stream channels, lack of vegetation and meager, and highly variable rainfall have made it into one of the most desolate areas of the arid region. The weather is generally hot and arid with hot long summers and short cool winters.

The soils are loamy on gentle slope near mountains but clayey in level areas. All these soils are strongly calcareous and low in organic matter content. Strong salinity occurs only in narrow strip, which is the junction of piedmont plain and the river floodplain.

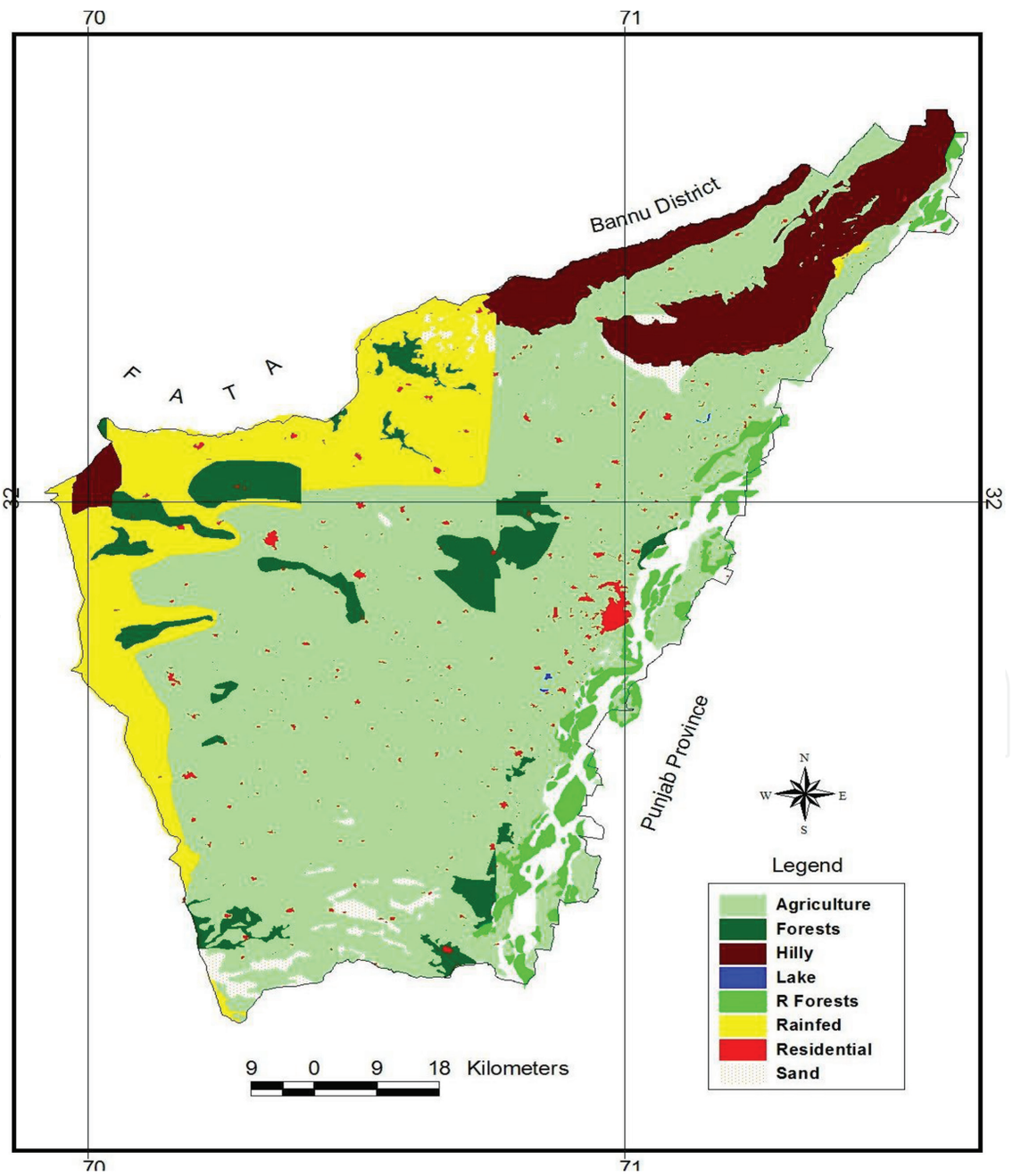


**Figure 13.**
*Dera Ismail Khan land use.*

Torrent-watered cultivation is the main land use, under which wheat, *Sorghum bicolor*, millets, and some gram are grown. Some parts of the clayey soils in the central part of the region are under canal irrigation, and *Sorghum bicolor* and colza are the main crops. Rice is grown in a narrow strip forming the junction of the piedmont and river plains. Extensive grazing is carried out in some parts, especially in torrent beds where coarse tall grasses grow (**Figure 13**).

### 7.9 Thal Desert

The region consists of Layyah, Bhakkar, and Khushab districts in western Punjab. This is a typical desert area with desert landforms including sand ridges, dunes, and sand sheets. However, it places silty and clayey deposits occurring in narrow strips. *The sand ridges are 5–15 m high* [19]. Between the sand ridges, there are depressions that turn into ponds after the rain. In the central parts of the desert, there are large elongated channels showing the palaeochannels the Indus. The desert is quite profusely dotted with vegetation comprising short trees and canals for irrigation. The climate is arid with hot long summers and warm short winters.

"This is an area of the stable sand ridges, which have sand and loamy fine sand soils" [20]. The hollows between the sand ridges have sandy loams and loams, which account for about 10% of the area. However, in the southwestern part of the area, the proportion of loamy soils increases. All the soils are moderately calcareous and have low organic matter content. In addition, there are some narrow strips of silty and clayey soils, which are moderately to strongly calcareous and locally saline. Predominant land use of the area is grazing of livestock especially goats, sheep, camels, and cattle (**Figures 9** and **10**).

A part of the area is used for dry farming of mainly gram and wheat, while cotton, sugarcane sorghum, millets, and wheat are also grown by canal irrigation.

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## References

[1] Kureshy KU. Geography of Pakistan. Lahore: National Book Service; 1968-1988. pp. 13-62

[2] GoUSA, Geodast Space Flight Center, Global Change Master Dictionary, The Global Land Cover Facility (GLCF) Data Products and Satellite Imagery, NASA, USA. 2005. Available from: https://gcmd.nasa.gov/records/01-global_land_cov_facility-00.html or ftp://ftp.glcf.umiacs.umd.edu [Accessed: 12 December, 2018]

[3] Khan FK. A Geography of Pakistan. Environment, People Economy. Pakistan: Oxford University Press Karachi; 1991-1993. p. 245

[4] Trewartha GT. An Introduction to Climate. 3rd ed. Mc Grawhill Book Company. Inc.; 1937, 1943, 1954. p. 395

[5] Petterson S. Introduction to Meteorology. New York, London: McGraw-Hills Book Company, Inc.; 1941. p. 260

[6] Blair TA. Climatology: General and Regional. New York: Prentice-Hall, Inc.; 1942. p. 478

[7] Miller AA. Climatology. New York: Mehtewn London and E.P. Dulton and Co. Inc.; 1959. p. 313

[8] Oliver JE. Climatology: Selected Applications. Bungay, Suffolk: Richard Clay Ltd; 1981. p. 260

[9] Anwar MM. Geography Pakistan. Islamabad and Lahore: Book-World; 1993. pp. 20-60

[10] Khan JA. The Climate of Pakistan. Karachi: Rahber Publishers; 1993. p. 79

[11] Moore WG. The Penguin Dictionary of geography. In: Definitions and Explanations of Terms Used in Geography. 6th ed. England: Penguin Book Ltd.; 1991. p. 370

[12] Hasan M, Khan S. Climate classification of Pakistan. In: BALWOIS Conference Proceedings, Ohrid, Macedonia. 2010. p. 42

[13] Trewartha GT. The Earth's Problem is Climates. Baltimore, Maryland: Waverly Press, Inc.; 1961. p. 334

[14] Yim TM. A synoptic aeorology study of the summer monsoon over India and Burma. Journal of Meteorology, Japan. 1949;**vi**:23

[15] GoP. Soil Distribution of Pakistan. Lahore: An Atlas of Soil Survey of Pakistan; 1998. p. 70

[16] Khan FK. Economic Geography. 9th ed. Karachi: Saleem Publishing House; 1989. p. 268

[17] GoP. Population Census of Pakistan. Islamabad: Population Census Organization, Statistical Division, Govt of Pakistan; 1998. p. 300

[18] GoP. Statistical Supplement of the Economic Survey. Chapter-2. Ministry of Finance, Govt of Pakistan, Islamabad. 2008-2009. pp. 21-60. Available from: http://www.finance.gov.pk/s_survey_0708.html

[19] GoP. Agro-Ecological Zones of Pakistan. Islamabad: Pakistan Agriculture Research Council; 1972. p. 70

[20] GoP. Climate Change Vulnerabilities in Agriculture in Pakistan. A Joint Report of the Ministry of Environment and IUCN, Islamabad. 2004. p. 6