Recent Water Requirement of Cotton Crop in Pakistan

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Abstract

Cotton is one of the foremost crops which are grown in the kharif season and it plays a very important role in Pakistan's economy, around two third of the country's export earnings are from the cotton. Like all crops, a cotton plant's water requirement vary by the age as well as the environment it grows in. The dryer and hotter the environment, the more water the plant requires. Cotton is very drought tolerant and uses about the same amount of water as other crops like millet and sorghum etc. Cotton is mainly grown in Punjab and Sindh as it likes hot and dry climate . FAO-modified Penmen Monteith method was used to estimate the water requirement of cotton crop by using the climatic data (1971-2000) of mean daily temperature, relative humidity, relative sunshine hours and wind speed of sixteen meteorological stations of Pakistan. Precipitation data was used to calculate the supplementary water requirement to compare the deficit .After analysis it was observed that only the upper parts of Punjab cotton may be sown under rainfed conditions but it is very rare in this area. In central Punjab, cotton may not be sown under rainfed conditions without supplementary irrigation in May. In southern Punjab and Sindh regions, cotton requires supplementary irrigation throughout its life cycle. Therefore, proper irrigation is required to fulfill the water needs of the cotton crop throughout its life cycle for successful growth. It has also been seen that water requirement has also increased in recent decades relative to the change occurred in climate .Water demand of the atmosphere which is closely related to the thermal regime has followed the warming trend of climate. Following the similar methods which were incorporated in the past, the recent requirement of water for Cotton will not only provide the quantitative assessment of irrigation water needs but also serve to take adaptation measures for coping the challenges of climate change ensuring sustainable crop production.

Keywords: Water Requirement, Evapotranspiration, Rainfed, Irrigation, Climate change & Cotton

Introduction

Pakistan is a country with diversified topography and extremely variable climate. The climate of the territory varies from very humid in some parts of North to extremely arid region in South. Pakistan has rich and vast agriculture resource base, covering various ecological and climatic zones and has great potential for producing many types of food and fiber. Unfortunately, ¾th of the total area lies under arid zone and only a small patch under humid climate [1]. In arid zone, food crop production is uneconomical under rainfed conditions, where as frequent and heavy rains in a humid zone exposes the rainfed agriculture to a great risk. In between these two extremes, the climates may be designated more or less crop failure risk-free zones. Due to this complexity of the weather, water requirement through out the country is not distributed uniformly. As the southern part and extreme north regions of the country remain dry due to which the seasonal crops could not be sown under rainfed conditions [2].

Cotton commonly known as "white gold" is an important cash crop for Pakistan and normally grow in agriculture plains of Punjab and Sindh. It contributes 8.2 percent of the value-added share in national agricultural and about 3.2% to GDP; around two third of the country's export earnings come from the cotton made-up and textile which adds over $2.5 billion to the national economy; while hundreds of ginning factories and textile mills in the country heavily depends upon cotton [3]. Primarily millions of farmers are dependent on this crop, in addition to millions of people employed along the entire cotton value chain, from weaving to textile and garment exports. The area under the cultivation of cotton crop has been increased significantly in the last 30 years - around 7.85 million acres in 2005-06 as compared to 7.2 million acre in 2002-03[4]. Besides being the world's fourth-largest cotton producer and the third largest exporter of raw cotton and a leading exporter of yarn in the world our yield per acre ranks 13th in the world. As a result Pakistan annually imports around 1.5-2.00 million bales of cotton to meet growing demand from local textile mills; therefore it has become vital for Pakistan to increase its yield potential.

1 Pakistan Meteorological Department

Like all crops, a cotton plant's water requirement mainly dependent on the environment. The dryer and hotter the environment is, the more water plant requires. Cotton has been wrongly cited as a water intensive crop, but it is very drought tolerant and uses about the same amount of water as other major crops like millet, sorghum etc [5] . Cotton's global water foot print is about 2.6% of the world's water use, lower than other commodities (e.g., Soybeans 4%, Maize 9%, Wheat 12%, Rice 21%)[6].

Cotton is mainly grown in Punjab and Sindh .About 80% of Cotton grown area is in Punjab and the Cotton belt in Sindh comprising of the left bank of Indus accounts for only 19% ,whereas 0.72% area lies in rest of the country[7]. Cotton growing areas of Pakistan, percentage of crop cultivated areas in province and crop calendar is shown in figure 1(a-c).

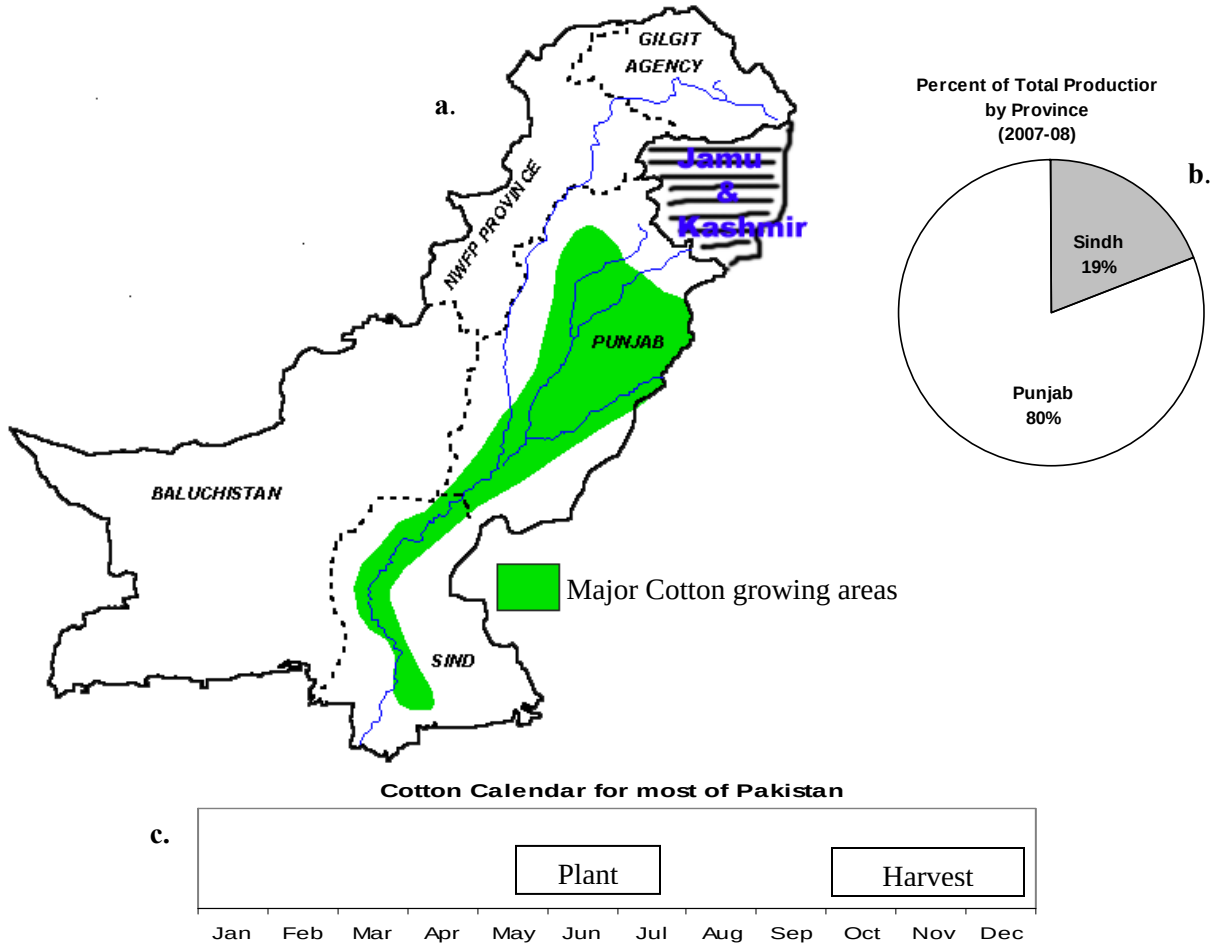

Figure 1: a. Cotton growing areas of Pakistan. **b.** Province wise area under Cotton Crop. **c.** Crop Calendar followed in Pakistan

Climate change due to global warming has greatly affected the agricultural activities not only in Pakistan but also our the globe. An increase in temperature observed in the country, especially during the last few decades it is very sharp. Future trend is also showing the rapid increase in temperature Fig-2. This increase in temperature will directly influence the evapotranspiration rate and water requirement of crops, in the country. Previous study on water requirement of cotton crop was conducted by Rasul and Farooqi, 1993 in which it was concluded that cotton crop generally grows better on low elevated plains. The increase in temperature is being observed in the southern parts of the country which lies in low latitude. Good rainfall received in southern parts but due to its less quantity there is always shortage of water [9]. By Keeping in view above and importance of cotton in the country along with rapid increase in temperature during the last decades it was necessary to calculate the recent water requirement. This study

will help the farmers and agriculture scientists to cope with the current and future challenges of water management issues for cotton.

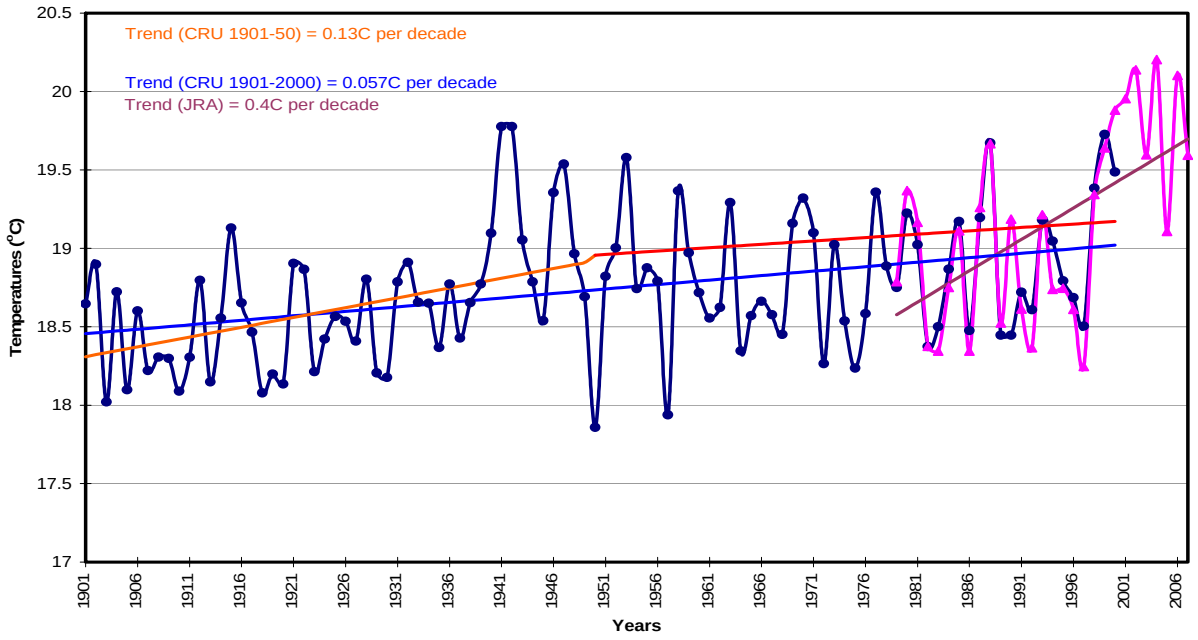

Figure 2: Average Temperature of Pakistan during 1901 - 2008.

Methodology

Materials and Methods

To measure the water requirement of cotton crop, Climatic Normals (1971-2000) used for precipitation, mean temperature, relative humidity, relative sunshine duration and wind speed of fifteen meteorological stations of Pakistan located in cotton zone (Table 1) and their geographical location is shown in fig-3. Monthly reference crop Evapotranspiration (ETo) was calculated by using FAO modified Penmen-Monteith method.

Table 1: List of Stations of cotton Growing Areas in Pakistan

Station Name	Latitude	Longitude	Altitude (m)	Station Name	Latitude	Longitude	Altitude (m)
Bahawalnagar	29.95	73.25	161	**Hyderabad**	25.38	68.42	40
Bahawalpur	29.40	71.78	116	**Jacobabad**	28.25	68.47	55
Faisalabad	31.43	73.10	183	**Larkana**	27.53	68.20	174
Lahore	31.50	74.40	215	**Moen-jo-Daro**	27.37	68.10	52.1
Khanpur	28.65	70.68	87	**Nawabshah**	26.25	68.37	37
Multan	30.20	71.43	122	**Padidan**	26.85	68.13	46
Sargodha	32.05	72.67	187	**Rohri**	27.70	68.90	66
Badin	24.63	68.90	10				

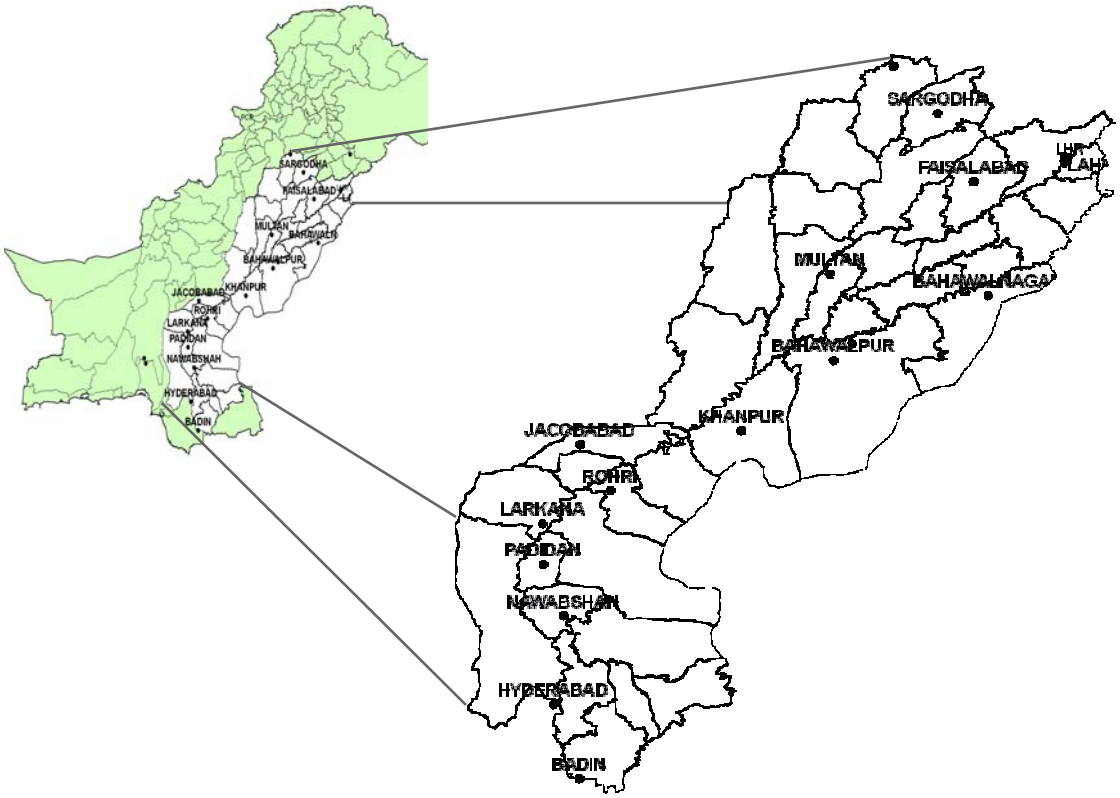

Figure 3: Map of the Study Area

FAO Penman-Monteith Equation

As Pakistan has diversified type of climate and over all performance of FAO Penman-Monteith has shown better results than other evapotranspiration calculation method. This method shows the minor deviations from the actual evapotranspiration data through out the year in climate of Pakistan [11]. The FAO Penman-Monteith equation is a close, simple representation of the physical and physiological factors governing the evapotranspiration process. The mathematical expression for the sake of calculation simplified as follow:

$$ETo = \frac{0.408\Delta(R_a - G) + \gamma \frac{900}{T+273} u_2 (e_s - e_a)}{\Delta + \gamma(1 + 0.34u_2)}$$

Where:

ETO, reference evapotranspiration (mm per day)
Ra, net radiation at the crop surface (MJ/m² per day)
G, soil heat flux density (MH/m² per day)
T, mean daily air temperature at 2m height (°c)
U_2, wind speed at 2m height (m/s)
E_s, saturation vapor pressure (kPa)
E_a, Actual vapor pressure (kPa)
$e_s - e_a$, saturation vapor pressure deficit (kPa)
Δ, Slope of vapor pressure curve (kPa per °C)
γ, Psychometric constant (kPa per °C)

The equation uses standard meteorological records of solar radiation (sunshine), air temperature, humidity and wind speed. To ensure the integrity of computations, the measurements of weather parameters should be made at 2m (or converted to that height) above an extensive surface of green grass, shading the ground and not short of water. It is important to note that all the parameters recorded at the same place, standard hours and under the same environment [12].

Calculation of Crop Water Requirement

After determining ETo, the ET_{crop} or Crop Water Requirement (CWR) can be calculated using the appropriate crop-coefficient (Kc)

$$ET_{crop} = Kc.\ ETo$$

or

$$CWR = Kc.\ ETo$$

Crop coefficient (Kc) is actually the ratio of maximum crop Evapotranspiration to reference crop Evapotranspiration[13]. For Cotton, this ratio becomes greater than 1 during the reproductive cycle (heading to grain formation) otherwise it remains less than 1 bearing minimum values during the early age of the crop and at maturity. The crop water requirement was calculated for the period from emergence to maturity. The sowing of cotton starts from the month of May and picking of cotton starts with the end of the summer season and continue till the peak of winter. A schematic variation of the crop coefficient related to different crop development stages under normal conditions is given in figure 4.

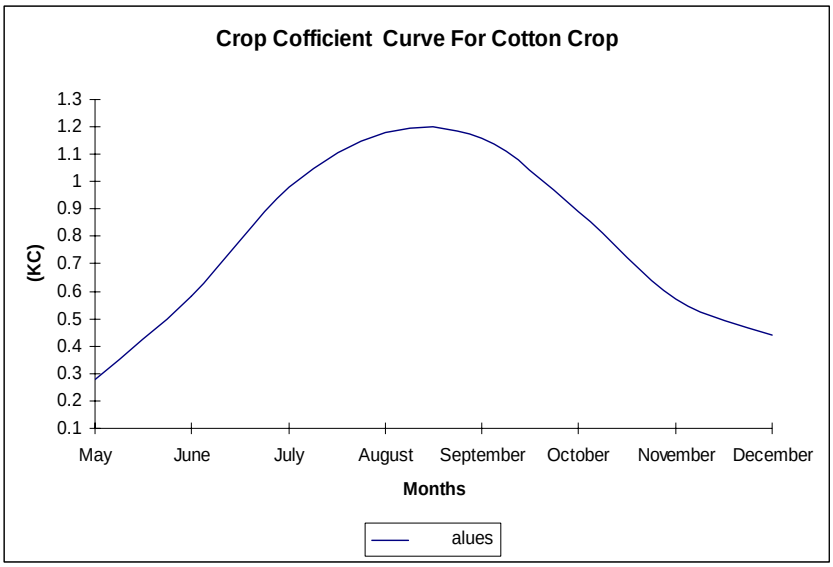

Figure 4: March of Crop Coefficient (Kc) for normal duration of Cotton growing season (Emergence of Maturity)(Rasul. 1995)

Results and Discussions

Water Requirement is mainly dependant on climatic factors such as air temperature, solar radiation, relative humidity, wind velocity etc. and agronomic factors like stage of the crop development as well[14]. It is possible for a crop to utilize soil moisture when rainfall (P) is more than the water requirement (WR) or P is less than half of WR. But when P will be less than one fourth of WR or one-eight of the WR, the crop experiences water stress and both the crop growth and final yield are affected [14].

Satisfaction index (%) is the indicator which shows the available moisture to sustain growth and development of Wheat crop under different moisture regimes. Humid (H) regions reflect the areas having

amount of rainfall greater than crop water requirements means rainfall fulfills 100% of the crop water requirement and sufficient amount of water is available for crops. The areas showing moist (M) situation represent the optimum growth i.e. rainfall is meeting 50% of the crop water requirement responding towards the fair growth means optimum demand level of water on which crops may sustain itself. Under moderately dry (MD) and dry (D), representing the crop retardations and severe moisture stress level where supplementary along with proper irrigation must be arranged for the proper maintenance of crop growth respectively[15].

May is one of the hottest months in the region. Temperature approches maximum values and low precipitation occurs in the month. According to long term average, Central Punjab remained 10 mm to 25 mm and rest of the agricultural plains of the country less than 10 mm. The evaporative demand of the atmosphere during May normally shoot up as compared to April. May is normally the sowing month of cotton crop in the country. Water requirement in Sindh, central and lower Punjab remain dry to moderately dry.(Fig -5).

June is generally the hottest and driest month of the year in Pakistan except some pre-monsoon showers. Due to intense heating and relatively clear skies, the evaporative demand of atmosphere increases sharply. Due to westerly trough and pre-monsoon system,more than 50mm of rainfall observed in northern parts of the country, 25 to 30mm of rain fall in central Punjab and about 10mm rainfall over lower Sindh and southern Punjab is observed. Upper Sindh normally remains partially dry. Water requirement in upper parts of punjab remain good, but in some of central Punjab and central Sindh, moderately dry conditions prevails while rest of the cotton growing areas, dry conditions prevails due to which proper irrigations is required for the cultivation of cotton.(Fig -6)

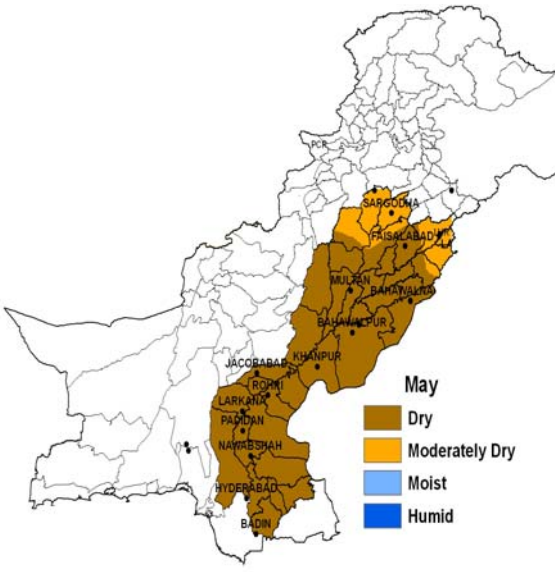

Figure 5: Monthly water requirement of Cotton during May

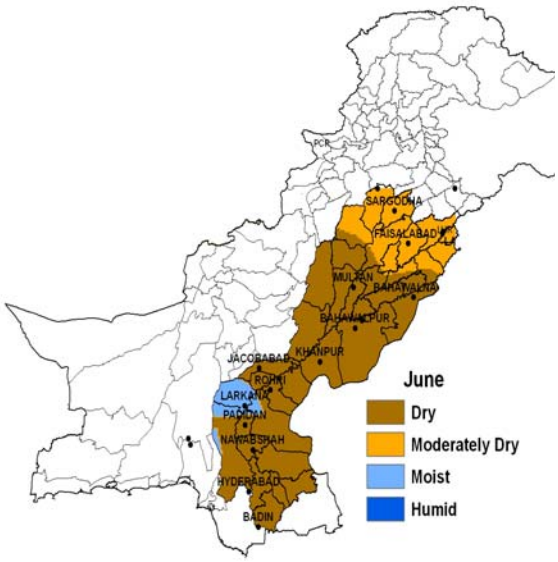

Figure 6: Monthly water requirement of Cotton during June

July is normally the starting month of monsoon season in Pakistan. Northern parts of Punjab, which lies in the monsoon track receive more than 200 mm precipitation, Central Punjab about 100 mm and southern Punjab around 80 mm. Sindh gets adequate amount of precipitation in Agro- meteorological point of view i.e. less than 25 mm during this month. Evaporative demand of the atmosphere is likely almost equivalent to the level of June, which is close to normal in temperature and wetter than the normal. Due to high amount of rainfall, central and upper parts of Punjab remains moist to humid while some parts of lower Sindh and southern Punjab remains moderately dry. Most parts of Sindh remain dry and needs proper irrigation(Fig-7).

August is the peak month of monsoon rain with heavy precipitation in most parts of the country. These rains are of immense importance for the farmers regarding the crop requirements. In the absence of proper land management, the heavy rains may erode the upper soil layers and fertility of the soil is sometimes badly affected. If soil conservation and soil moisture conservation measures are employed, the farmers of the area may have benefit through the available moisture for sowing and early growth of Rabi crops. Higher rainfalls are normally observed i.e. exceeding 300 mm in Northern Punjab, 90 mm to 165 mm over Central Punjab, whereas over Southern Punjab 40-100 mm of rainfall during the month. Lower Sindh receives precipitation less than 50 mm while Upper Sindh receives upto 40 mm. The evaporative demand of the atmosphere decreases as compared to July due to less solar radiation intensity and increasing level of humidity. Water requirement remains satisfactory in upper Punjab while in central Punjab and lower regions of Sindh needs supplementary irrigation and rest of the Sindh and Southern Punjab requires proper irrigation. (Fig-8)

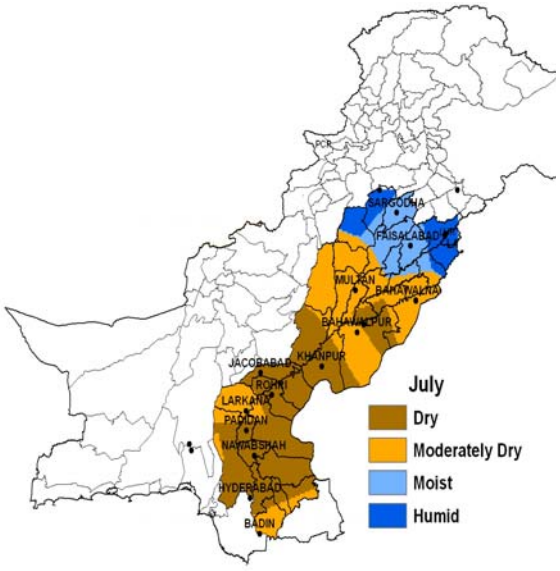

Figure 7: Monthly water requirement of Cotton during July

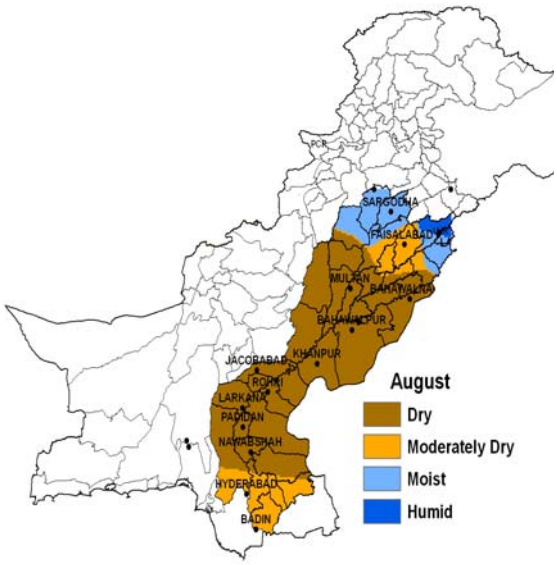

Figure 8: Monthly water requirement of Cotton during August

September is normally the end of monsoon season in Pakistan. The amount of rainfall decreasing throughout the country as compare to August.In Sindh and Southern Punjab, rainfall ranges from few millimeters to 30 mm. Over Northern and North Eastern Punjab, precipitation ranges between 80 mm to 110 mm. Despite some drop in air temperature and smaller day length, the evaporative demand of the atmosphere generally increases as compared to August. In upper Punjab, moderately dry conditions prevail while rest of the regions remained dry (Fig-9).

October is generally the transition month between the summer and winter weather systems and also the driest month of the year. The tropical maritime air mass is replaced by modified sub-polar continental air mass over this region. Summer monsoon airmass practically recedes resulting in a sharp decrease in precipitation over the area as compared to monsoon season. Quantitatively, Northern Punjab receives 30 mm to 100 mm of rainfall while rest of the country remain dry in Agrometeorological perspect i.e. average rainfall is not likely to exceed 10 mm. Despite the shorter days, cooler atmosphere and less intense solar radiation, evaporative demand of the atmosphere decreases. The water requirements exceeds in upper Punjab as dry conditions surrounds more areas, while rest of the country remains dry as in September. (Fig-10)

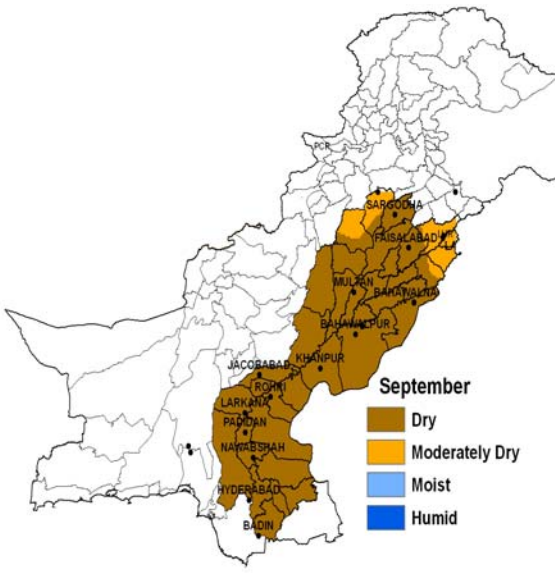

Figure 9: Monthly water requirement of Cotton during September

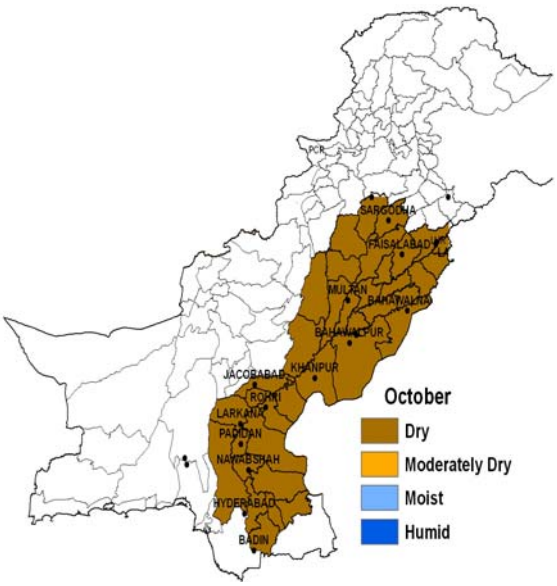

Figure 10: Monthly water requirement of Cotton during October

November like October is considered the driest month and transition period in the country. Due to shorter days, lower solar intensities and light winds are as compared to October, the evaporative demand of atmosphere is expected to fall but whole cotton growing regions needs proper irrigation (Fig-11).

During the month of December, winter weather systems commonly known as "Western Disturbances" become active over the country. Under the influence of western rain bearing systems, northern Punjab receives precipitation between the ranges of 25mm to 45mm while in rest of the country it may range from few millimeters to 15 mm. Due to low temperature the evaporative demand remained low. During this month, only in the upper parts of Punjab water requirement is satisfactory to favorable conditions are observed (Fig-12).

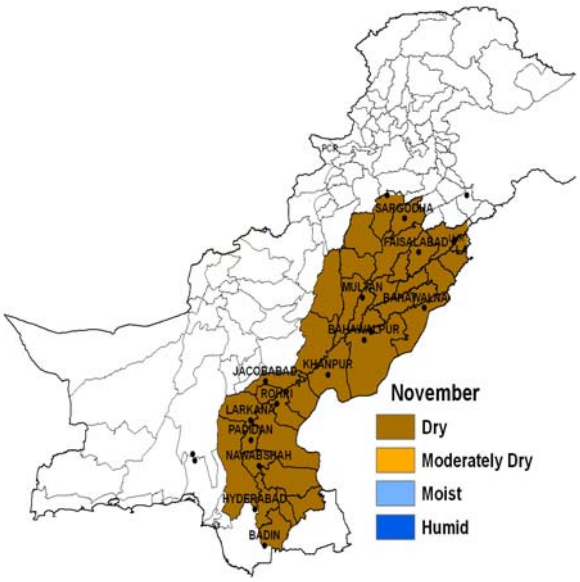

Figure 11: Monthly water requirement of Cotton during November

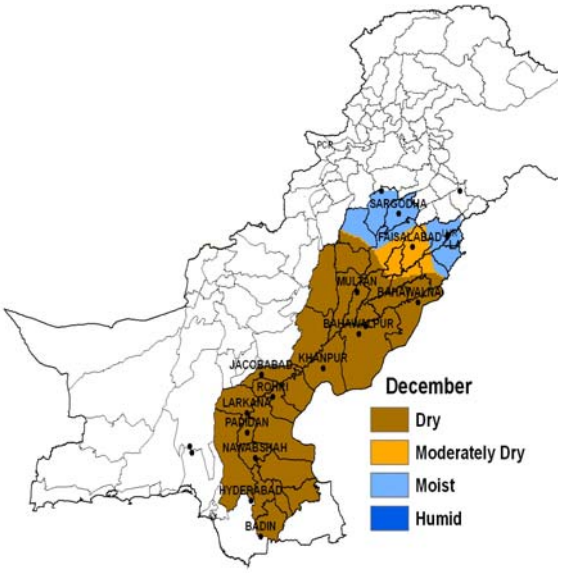

Figure 12: Monthly water requirement of Cotton during December

By comparing the water requirement of cotton crop calculated for the period 1961-90 and 1971-00, it is observed that it has quantitatively increased due to increasing temperature over the last few years. The overall increase in the water requirement of cotton in Punjab and Sindh province is as shown in table-2

Table 2: Quantitative Increase of Water Requirement during the Period (1971-2000) than the Period (1961-1990)

S.No.	Months	Punjab (mm/month)	Sindh (mm/month)
1	May	7.7	7.4
2	June	12.3	3.0
3	July	26.1	24.2
4	August	3.4	24.9
5	September	39.6	36.2
6	October	35.4	32.3
7	November	34.2	34.9
8	December	13.9	20.1

Conclusion

* From the above analysis it is observed
* Cotton cannot be grown under rainfed condition unless supplementary / proper irrigation is required to fulfill the needs of the water required by cotton.
* Because of high evapotranspiration at lower latitudes, water requirement is high at lower latitudes.
* In Sindh, water requirement is high as compare to the Punjab.
* Water requirement of cotton is highest during August and September.
* Maximum increase in water requirement has observed during September to November.

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