Water Requirement of Wheat Crop in Pakistan

Ghazala Naheed[1], Arif Mahmood[1]

Abstract

Pakistan is an agriculture country and wheat is staple food of this region. Wheat is a Rabi crop and sown almost through out the country. Rabi season starts from October and normally ends in April. Water requirement of wheat followed variations in terms of location and time of the season. But due to shortage of water, wheat is normally sown in November and December. The northern half of the country receives good rains during monsoon (July-September), which not only fulfill the water requirement of Kharif season but also provide the better conditions of soil moisture for sowing of Rabi crops. Therefore, the preliminary water demand (for sowing and early stages etc) meets through post monsoon conserved soil moisture. The winter rainfall also proves to be very helpful for wheat crops when it is on flowering stage in most of the rainfed areas. This rainfall fulfils the crop water requirement to some extent not only for flowering but up to maturity stages of wheat crop as well. After this stage hot and dry weather conditions are the pre-requisite for attaining rapid maturity as well as ripening. To workout the water requirement, FAO Modified Penmen Monteith method is employed to estimate reference crop evapotranspiration (ETo). The maps drawn for optimum level have shown that the southern half of the country always requires irrigation while in the northern half at most of the places wheat can be grown with out supplementary irrigation. The areas lies between 33°N to 36°N have moist to humid climate where wheat can be grown successfully under rainfed conditions. Due to more elevated plains, some valleys in northern mountain-ranges also experience dry conditions. For successful growth and effective utilization of water from the soil, the available soil moisture must be at least 50% level which corresponds approximately to half of evapotranspiration of crop level, forming optimum limit.

Keywords: Water Requirement, Effective Utilization of water, Evapotranspiration, Optimum Limit, Rabi Growing Season.

Introduction

Pakistan is an agriculture country which has variable climate and almost two third of the regions show arid type of climate. Only a narrow belt of sub mountainous regions show humid climate. Most of the areas in the central and southern Pakistan are highly arid, while the northern part of the country is humid except the extreme northern mountains which are relatively dry. The mountainous regions with sub mountain hill in the northern and northeastern sides experience the types of climate having similarities with temperate climate and some areas in the south experience the arid and semi arid climate with low precipitation and high temperature. (Chaudhry and Rasul, 2004).

Agriculture in Pakistan relies not only on rainfall but also on the water, which comes from melting of snow and ice. When this water reaches the dams, rivers and canals, it irrigates most parts of the agricultural land. Pakistan makes the western border of the peninsula bound by the Arabian Sea on its south and covered on the north by Himalaya, Karakoram and Hindukush. These mountains are the water tanks over the roof, which provides supply of water when required. The environment has given the operational control of this tank in the hands of temperature after the strong buildup of greenhouse gases. Temperature is surpassing its normal limits not only due to natural processes but also mainly because of non-environment friendly anthropogenic activities. Growing population caused accelerated deforestation, which believed to be the main cause of environmental heating among others. Snow and ice extent is shrinking must faster than ever now, as a whole, on the HKH mountainous terrain (Rasul et al., 2006).

High temperatures may have a positive impact on agriculture in the mountain areas, like shrinking of growing period for the winter season crops. Most of the time winter crops like wheat, in the high mountain areas cannot even reach to maturity and the crops are harvested premature to be used as fodder.

[1] Pakistan Meteorological Department

The shortening of the growing season length due to higher temperature could be beneficial in the mountain areas as it would help the winter crops in timely maturity and as such would allow the crop to mature in the optimal period, with positive effects on cropping area and final yields as well. However, this increase in temperature is not fruitful in southern parts of the country because it increases the water demand due to which most of crops are suffering. Past temperature trends in the high mountain, areas (e.g., Chitral district) have already led to the shortening of the growing season length, which certainly has helped in increasing wheat yield as well as crop area in these high mountain areas. (Hussain and Mudasser, 2004).

The crop water requirement calculated for the period from emergence to wax maturity. This shows that after wax ripens practically there is no need of irrigation because the hot and dry conditions are desirable to achieve rapid hard maturity. As the wheat growing areas are located at different altitudes which affect the length of the growing season, due to variations in temperature. The wheat in areas at or above 1000 meters above sea level ready for harvest during May as compared to March/April at most of the agriculture plains of the country. The sowing of wheat generally starts from mid of October and continues up to end of December. (Rasul, 1993)

In Pakistan, the total cultivable area is 34.54 Mha (39.3 % of total land area), of which 23.38 Mha areas is under cultivation. An area of approximately 4.22 Mha (4.8 % of the total land area) is under forest cover (GoP,2008).On average in Pakistan agriculture sector contributes about 25% to gross domestic product (GDP) and almost 44% of the country's working force is being engaged directly or indirectly. The largest cropped area is under wheat cultivation, which is over 8.6 Mha. (GoP, 2008)

Areas that are always moist and warm are not suited for wheat crop. Higher precipitation causes lodging and diseases and interferes with field operations of planting to harvesting, Late planting of wheat can be done up to the middle of December, after which further delay in sowing reduces yield drastically. Wheat sowing in last decade of November can cause a reduction of 15-20 kg per acre yield during each subsequent day. There are two critical periods, during which water stress reduces yield greatly; the period from the development of adventitious roots to the start of tillering, and the period from anthesis to the milk maturity stage. Well-drained clay loams, loams and sandy loams are the best soils for wheat. (Khan and Hanif, 2007)

Objective

Global warming and climate change are influencing not only the socio-economic sector but also the agriculture sector throughout the world. Developing countries like Pakistan is also facing problems like glacier melting, flash floods, drought, heat index and inadequate water for crops etc. National agricultural products not only fulfills the food requirement of the country but also exported throughout the world to earn foreign exchange. Being an important crop, it is important to determine the water demands for wheat in the country. In warming climatic conditions, water requirement is likely to increase accordingly. It will serve the purpose of future policy making and planning filed activities.

This study will make it possible to determine when and where the wheat crop can be cultivated under rainfed conditions. It will play a key role for better management of water resources as well. This study will provide closer approximation of water needs at different development stages of wheat crop’s life cycle. Such assessment will also be helpful in management of drip irrigation system wherein the water loss through evapotranspiration is substituted. Considering a wide prospect, climatic approach is employed to estimate water requirement of the wheat crop on monthly basis under various agro-climatic conditions of Pakistan.

Materials and Methods

To measure the water requirement of wheat crop, Climatic Normals (1971-2000) used for precipitation, mean temperature, relative humidity, relative sunshine hours and wind speed of fifty-eight meteorological

stations of Pakistan. Monthly reference crop evapotranspiration (ETo) calculated by using FAO modified Penmen Monteith method.

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 (Rasul; 09). 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:

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

Where

ETo	=	reference evapotranspiration (mm per day)
R_a	=	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.

Calculation of Crop Water Requirement

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

ETcrop = Kc. ETo

Or CWR = Kc. ETo

Crop coefficient (Kc) is actually the ratio of maximum crop evapotranspiration to reference crop evapotranspiration. For wheat, this ratio becomes 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 wax maturity. After wax ripens practically there is no need of irrigation because the hot and dry conditions are desirable to achieve rapid hard maturity.

A schematic variation of the crop coefficient related to different crop development stages under normal conditions is given in figure 1.

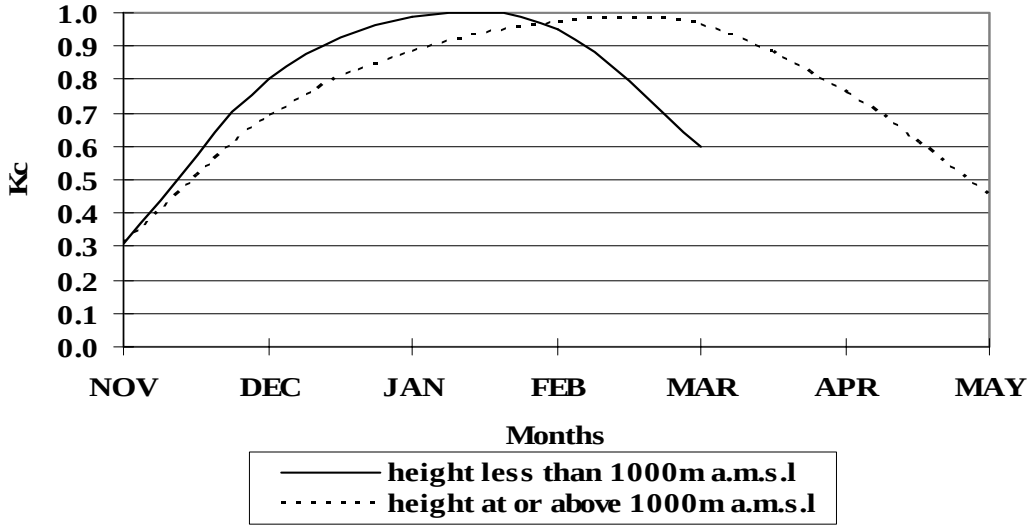

Fig 1: March of Crop Coefficient (Kc) for normal duration of Wheat growing season (Emergence to Wax-Maturity)(Rasul.1993)

The water requirements calculated in millimeters, which may be converted into cubic meter per hectare. The loss of water through evaporation and transpiration, the compensation of this loss by precipitation was also considered. Then the four levels of water demand were established as humid (H), moist (M), moderately dry (MD) and dry (D).

Normally most of the plants grow successfully and utilize water for the soil at 50% and above available soil moisture. The maximum demand (daily or seasonal) may be equal to the reference crop evapotranspiration (ETo) which is utilized through soil moisture. If the soil is charged through rains or irrigation water to the extent, so that all the water evaporated is totally substituted i.e. P (Precipitation) > WR marking 100%, it means WR of the crops is fully satisfied by the precipitation. They presumably correspond to the soil moisture regions with 100%, 50%, 25% and 12.5% available soil moisture approximately under no ground storage charge condition to meet the actual evapotranspiration.

Table- 1: Climatic Regions Based on Water Requirement and Precipitation.

S.No.	Equation	Region	Conditions	Symbol	Satisfaction Index (%)
1.	P>WR	Humid	Net Water demands	H	100
2.	WR > P> ½ WR	Moist	Optimum water demand	M	50
3.	½ WR > P> ¼ WR	Moderately Dry	Growth retardation level	MD	25
4.	¼WR >P<1/8 WR	Dry	Severe moisture stress	D	12.5

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 (Rasul; 1993). 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. (Raman and Murthi; 1971)

Satisfaction index (%) is the indicator which shows the available moisture to sustane 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.

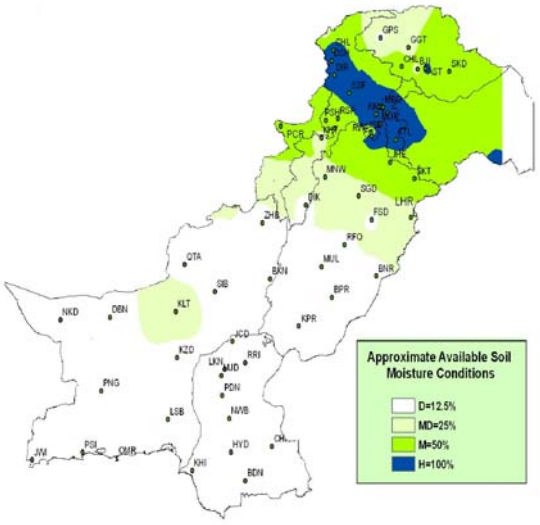

Fig 2. Monthly water requirement of wheat for November

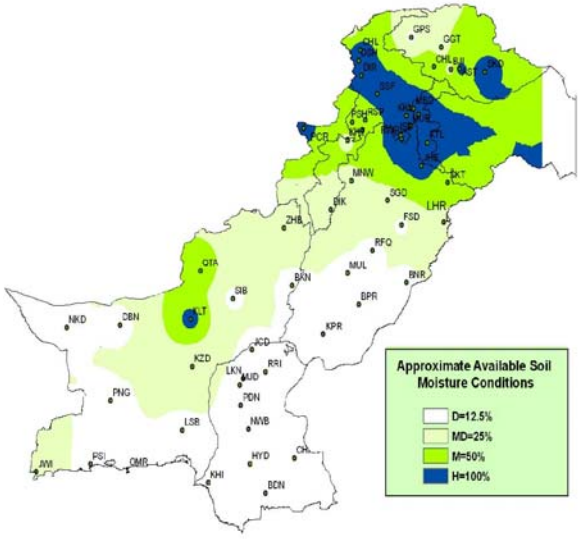

Fig 3. Monthly water requirement of wheat for December

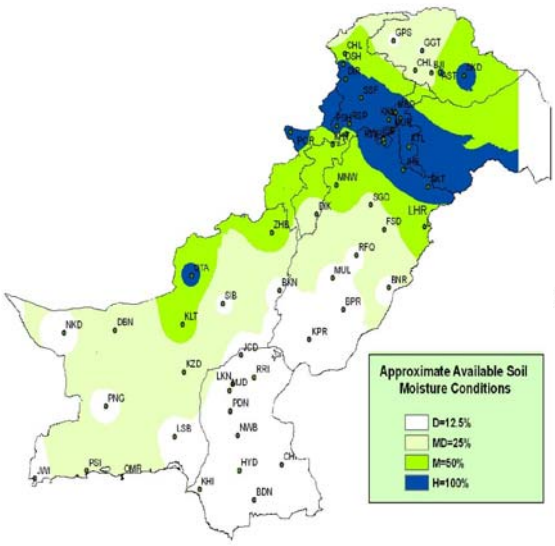

Fig 4. Monthly water requirement of wheat for January

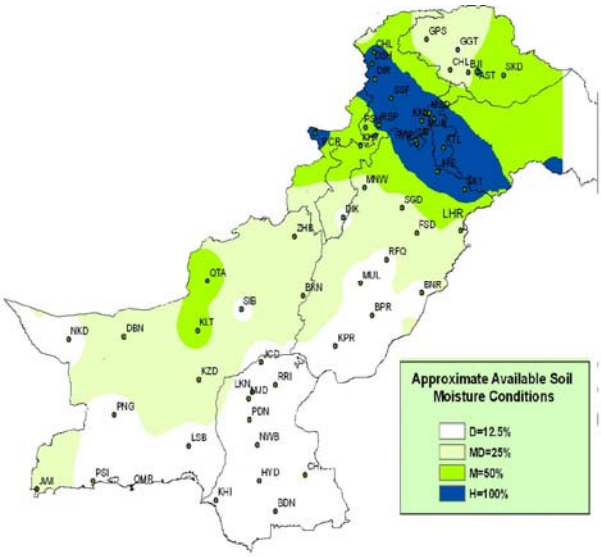

Fig 5. Monthly water requirement of wheat for February

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. Under moderately dry (MD) and dry (D), the irrigation must be arranged for the proper maintenance of crop growth.

November is the sowing month for wheat crop in most parts of the country and called the driest month and transition period in between summer to winter in the country. Water requirement in most of the northern parts of the country remains satisfactory however, In southern parts proper irrigation is required as shown in figure -2.

During the month of December, winter weather systems commonly known as "Western Disturbances" become active over the country. Generally the northern half of the country receives precipitation more frequently and with more amount as compare to the southern half, under the influence of western disturbances. In some western parts of Balochistan, including Quetta and Kalat regions, moisture conditions became favorable and water stress reduces. Most of the southern Pakistan remains dry and has not favorable condition while most parts of Northern part of the country are suitable for Winter wheat. Water requirement remains satisfactory in Azad Kashmir, Northern areas, Upper Punjab and NWFP regions, while Sindh and most parts of Balochistan always require irrigation fig-3

January is the peak of Winter in which temperature decreases below zero in some parts of Pakistan especially in Balochistan, upper NWFP, Northern areas and Kashmir regions. Most of the upper and western parts of the country receive rainfall during this month. Due to decrease in evaporative demand, this rainfall becomes very helpful to reduce water demands in most regions of Pakistan as shown in figure 3. Southern parts of the country remain dry and under water stress, while Northern parts have favorable moisture conditions for wheat crop (fig-4).

In February, wheat crop has entered to its Heading or Flowering stage. This month is very important for wheat crop because the water requirement exceeds than the previous month. The water requirement continues to increase up to wax maturity; if stress observed during this month then yield of crop may suffer. In most parts of Balochistan, water stress observed due to which wheat crop suffer while some regions like Quetta, Kalat and Zhob conditions remain favorable during this month. The reason behind is long dormancy period specially when the temperature below zero is observed. The growth and evaporative demand of crop ceased. This month proved to be helpful in rainfed areas because, it overcome the water demand. In Northern Areas, conditions start to retardation level in which most dry condition exists. Northern parts have favorable crop condition for wheat while in southern parts condition becomes worse under rainfed condition as shown in fig-5.

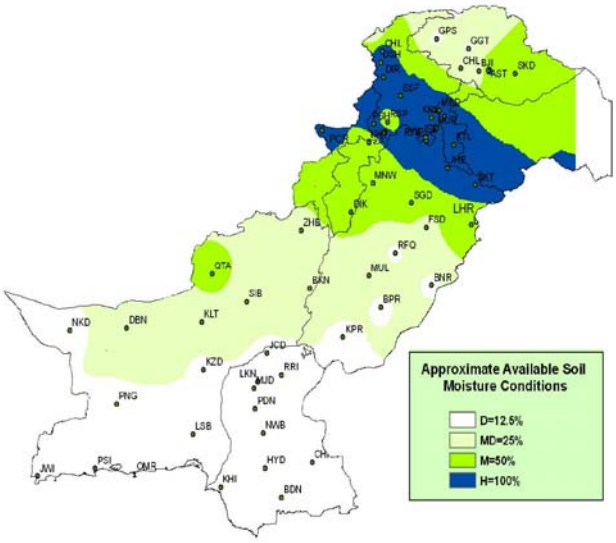

Fig 6. Monthly water requirement of wheat for March

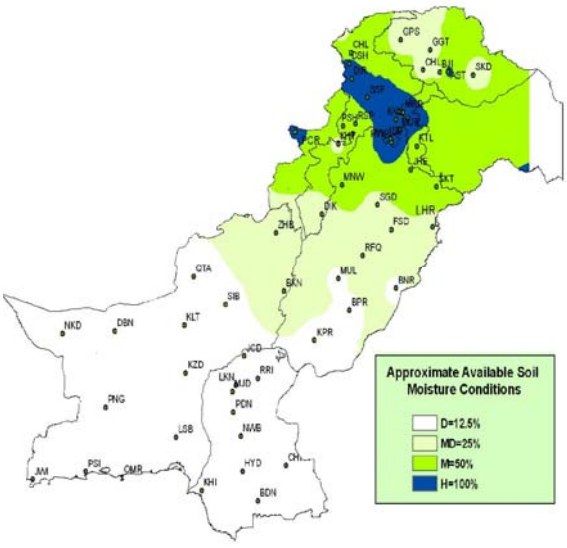

Fig 7. Monthly water requirement of wheat for April

March is normally the wettest month of winter season. Heating starts over the subcontinent due to increasing solar angle and the sun shine. During this month, in most parts of the country wheat reaches to its maturity stage, due to which decrease in water demand is observed. However, in the areas where mean temperature remains almost zero (heaving long dormancy period) crop does not reach to its maturity stage. Optimum water demand fulfill in upper Punjab, Azad Kashmir and NWFP as shown in fig-6.

April is generally a transition month and start of summer. During this month, water demands start to increase almost through out the country. In Balochistan, due to dryness of air, low humidity, and high value of ETo, water requirements start rising due to which water demand also increases. This month is very important in Balochistan region for wheat crop. Water requirement start to decrease through out the country but still it remain favorable in upper parts of the country while in lower parts dry conditions prevail. Generally, in most parts of the country, wheat is harvested except those areas which have long dormancy period or crop sown late. April is normally the end of Rabi Season in most parts of country.

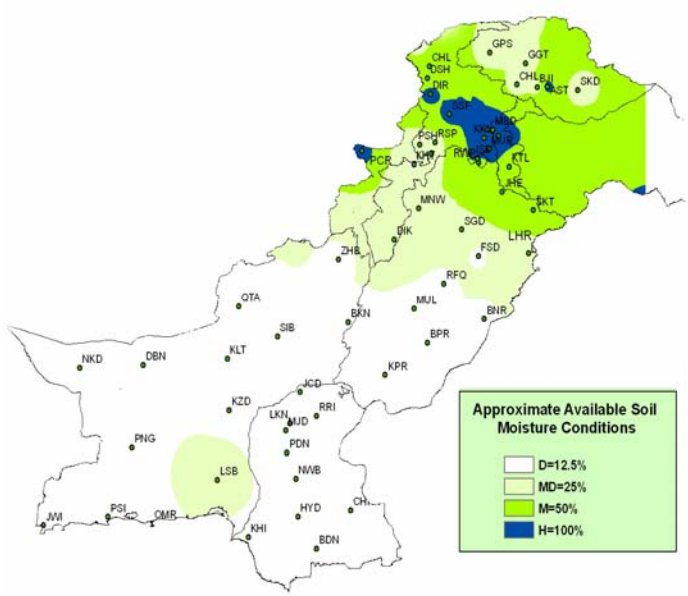

Fig 8. Monthly water requirement of wheat for May

During May, the hottest month of the year, optimum water demand decreases than the previous month through out the country. Gales and dusty winds blow due to which water demands increases. Wheat crop of those regions harvested which have long dormancy period especially in Balochistan, Northern area, Upper NWFP and Kashmir regions.

Conclusions

After analysis, following conclusions have made;

- During the vegetative stage (November-January), due to low temperature, moderate humidity and calm conditions, the ETo remain lower than in early summers in most of the upper parts of the country, especially in some parts of Balochistan regions(Quetta, Zhob and Kalat). While in rest of the country irrigation is required.
- Areas like Upper NWFP, Northern Areas and some parts of Balochistan (Quetta, Kalat regions) which have long dormancy period; wheat is harvested from April to May. With shortage of rainfall water demand increases and most of the time crop yield may suffer in these regions.

- Under advection conditions during summer (March to April and some where in May) with hot and windy weather, the ETo values generally shoot up. Generally the wheat crop at this time is in grain formation stage (the period of highest water requirement), therefore frequent irrigation is required.
- Most of the southern half of the country always requires irrigation while in northern half at most of the places; wheat can be grown with out supplementary irrigation.
- Areas lie between 33°N to 36°N including upper NWFP, Kashmir and Potohar region except some parts of Northern Areas (Gilgit, Gupis and Chillas) have most favourable conditions for wheat crop.

References

1. **Chaudhry, Q. Z., G. Rasul., 2004:** Agroclimatic Classification of Pakistan, Science Vision (Vol.9, No.1-2&3-4), (July-Dec, 2003 & Jan-Jun, 2004), Page.59.
2. **Climatical Normal (1971-2000) of Pakistan., 2005:** Pakistan Meteorological Department. Karachi.
3. **GoP., 2008:** Economic Survey of Pakistan (2007-08), Ministry of Finance, Government of Pakistan, Pakistan.
4. **Howard, A ., 1924:** Crop Production in India, Ch. XI: 'Wheat'.
5. **Hussain, S. S., M. Mudasser., 2004:** Prospects for wheat production under changing climate in mountain areas of Pakistan-An econometric analysis. Water International, 2004, Vol. 29, No. 2, 189-200.
6. **Khan, I., M. Hanif., 2007:** Weather and Wheat Development in Faisalabad Region Rabi Season (2006 – 2007).
7. **Raman, C. R. V., B. S. Murthi, 1971:** Water availability periods for crop planning (Rep. No. 173), India Meteorological Department, Poona.
8. **Rasul, G., 1993:** Water requirement of wheat crop in Pakistan. Journals of energy and applied sciences, Vol.12, No.2, July-Dec, 1993.
9. **Rasul, G., 2009:** "Performance Evaluation of Different Methods for Estimation of Evapotranspiration in Pakistan's Climate". Pakistan Journals of Meteorology, Vol.5, No.10, Jan-Jun, 2009.
10. **Rasul, G., Dahe, Q., Q.Z.Chaudhry., 2008:** Global Warming and Melting Glaciers along Southern Slopes of HKH Ranges.
11. **Rasul, G., Q.Z. Chaudhry, 2006:** Global Warming and Expected Snowline Shift along Northern Mountains of Pakistan.Proc. of 1st Asiaclic Sympos. Yokohama, Japan.

Annexure

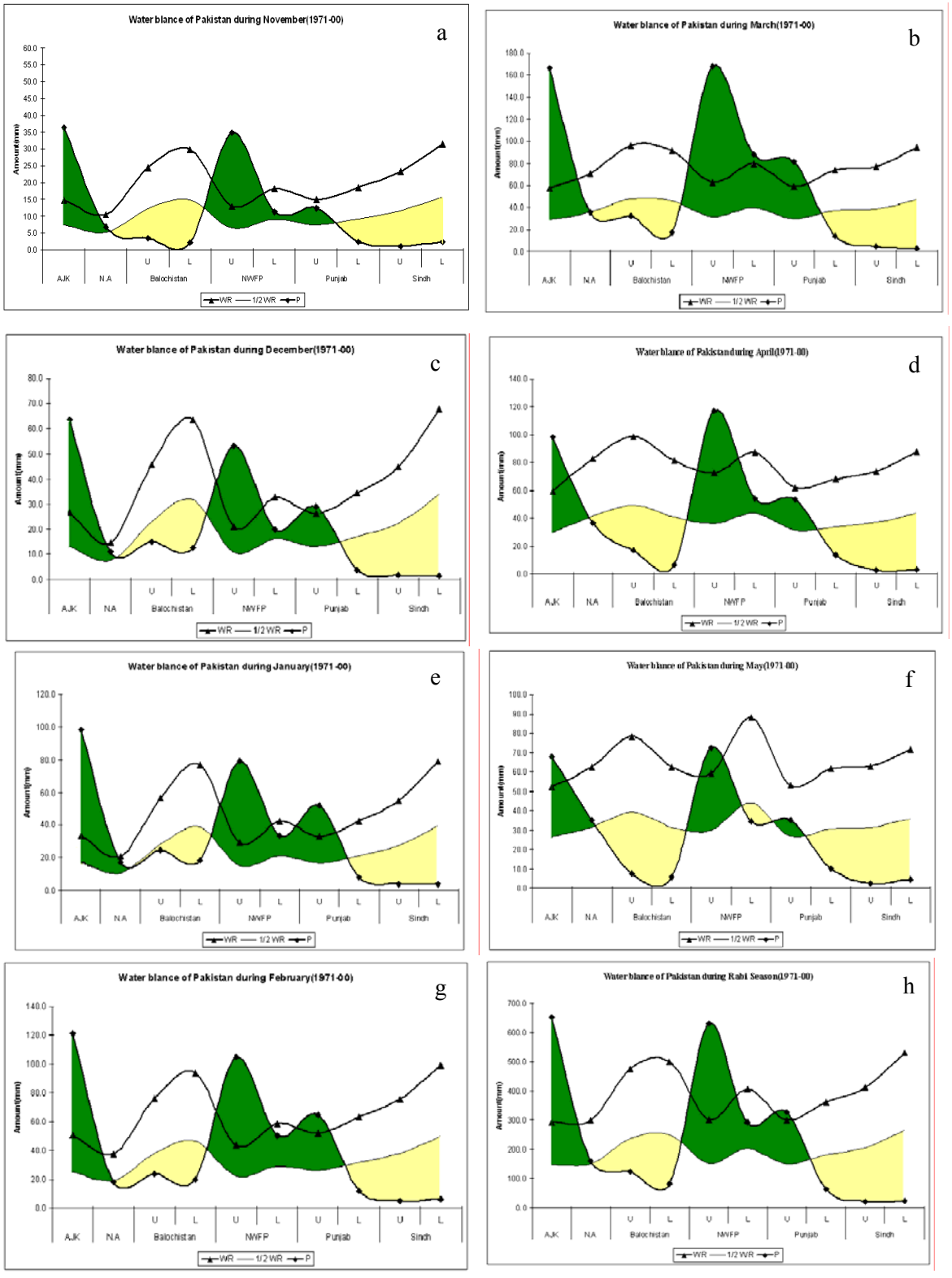

Figure (a-h): Black colour represents water surplus while grey colour shows the water deficit.