Water Balance Conditions in Rainfed Areas of Potohar and Balochistan Plateau During 1931-08.

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Abstract: Rainfed regions are those where crop production is exclusively dependent upon rainfall. Rainfed agriculture plays an important role in Pakistan’s economy and makes 17 percent of the total crop growing area in the country. Pakistan rainfed regions cover Potohar and Balochistan plateau and they exist in different climatic zones (extremely arid to very humid). Water balance (difference between rainfall and evapotranspiration) of both plateaus calculated of two crop growing season i.e. Rabi (October to April) and Kharif (May to September). FAO-modified Penmen Monteith method was employed to calculate reference crop evapotranspiration by using different climatological data from 1931 to 2008. The results drawn during 1961-1990, which shows that, the conditions for sowing of seasonal crops were relatively more favourable in both plateaus, i.e. Potohar (Rabi and Kharif) and Balochistan (Rabi). Annual water deficit was 4.3mm/month and 111mm/month for Potohar, Balochistan plateaus respectively and now it has further increased due to increase in evapotranspiration. During 1991-08, conditions are replicating, as it was 1931-60 while during some months of the year, the situation has become worse especially in Balochistan during Kharif season. Water surplus has improved during December while water deficit has increased during March. In potohar plateau, water surplus has significantly increased during June (Kharif) due to increase in rainfall. Monthly Probability of occurrence of rainfall for both plateaus was also calculated for better crop planning and water management. By analysis the probability and water balance map, It is recommended that Rabi crops especially wheat may be sown during mid of November rather than December in Balochistan plateau. Proper preservation of rainfall water during December to February may help to overcome the water stress in the coming summer months in both plateaus. Cultivation of Kharif crop is not recommended in Balochistan plateau unless proper preservation of water loss from evapotranspiration.

Key words: Rainfed • Plateau • Water balance • Evapotranspiration • Probability

INTRODUCTION

Pakistan is an agricultural country whose agriculture mostly depends upon rainfall along with canal irrigation. Rainfed regions are those where cultivation mostly depends upon rainfall. Two famous plateaus (Potohar and Balochistan) of Pakistan also fall in rainfed regions. A plateau is a big highland area of considerably level land segregated from neighbouring parts of land by steep slopes. Rainfed agriculture plays an important role in Pakistan’s economy and these regions account for 17 percent of the total crop growing area in the country.

The Potohar plateau covers an area of about 5,000 square miles (13,000 square km) and lies at an elevation of some 1,200 to 1,900 feet (350 to 575 meters). The land resources of Potohar characterized with fragmented land holdings. The contribution of agricultural activities is about 10 percent of total agricultural production. More than 1200kg/acre of wheat have reportedly produced in barani (rainfed) land, which reveals a high potential for crop production [1]. Unfortunately, this land has often been underestimated.

The Balochistan plateau starts from the middle of Pakistan covering the western borders and continues to the south of Arabian Sea. It mainly covers the arid regions...
Fig. 1: Study Area

of Balochistan province. It is described as one of the most desolate landscape on the face of earth, resembling the moon, an inhospitable land of dry lakes and riverbeds interspersed with steep hills and barren mountains [10].

Water is the only limiting factor for sustainable agricultural development in these areas. The occurrence of rainfall in barani (rainfed) areas is unpredictable with high spatial and temporal variation. About 3.4 million acre-feet (MAF) is the annual water loss through surface runoff and most of the rainfall occurs during monsoon (July to September) [2]. Due to this uncertainty of rainfall, farmers are always reluctant in investing on crops and use lesser inputs to reduce the risk of loss in the event of drought. Water scarcity coupled with land fragmentation has lowered the income of the farmers to such an extent that depends mostly on off-farm income. The crop yields could be increased many folds by adopting proper water resource development, harvesting and management practices [1].

We have investigated the three districts of potohar region (i.e. Islamabad, Rawalpindi and Jehlum) and eight districts of Balochistan plateau (i.e. Zhob, Qilla Saifullah, Pishin, Qilla Abdullah, Ziarat, Quetta, Mastung and Qalat) shown in Figure 1.

Rainfed areas of Potohar and Balochistan plateau lie in semi-arid to sub-humid zone of ecological region with hot summers and cold winters except Murree, which falls in humid zone of climatic region in most time of the year [4].

Potohar plateau receives rainfall not only in winter but also large amount of rainfall is received during summer monsoon. The range of mean annual total rainfall in potohar plateau varies from 900 to 1900 mm, maximum in Murree. However, the high rainfall is received in Balochistan during December to March while very small amount of rainfall received during summer. In Balochistan plateau, mean annual total rainfall range is 150 to 300 mm, maximum in Zhob [5]. Pakistan receives about 55 to 60 percent of total annual precipitation during monsoon while the rest in spring and winter seasons [3].

MATERIALS AND METHODS

The study was conducted during 2009 in Potohar and Balochistan plateau. Three Climatic normals were used (1931-60, 1961-90 and 1991-08) of rainfall of Potohar (Murree, Jhelum and Rawalpindi/Islamabad) and Balochistan plateau (Quetta, Qalat and Zhob). FAO-Modified Penman Monteith [11] method used to calculate reference crop evapotranspiration of these periods. Reference evapotranspiration is the rate of evapotranspiration from a hypothetical reference crop with an assumed crop height (12 cm), a fixed crop surface resistance (70 s m-1) and albedo (0.23), closely resembling the evapotranspiration from an extensive surface of green grass cover of uniform height, actively growing, completely shading the ground and with adequate water [6]. Water balance calculated from the difference between rainfall and evapotranspiration.
FAO-Modified Penman Monteith Method: Richard, et al., 1998 derived FAO-penman equation from the original Penman equation and equations of aerodynamic and surface resistance, which is as follow:

\[
ET_o = \frac{0.408\Delta (R_e - G) + \gamma \frac{900}{T + 273} u_2 (e_s - e_a)}{\Delta + \gamma (1 + 0.34u_2)}
\]

Where
- ETo reference evapotranspiration [mm/day],
- Rn net radiation at the crop surface [MJ m-2/day],
- G soil heat flux density [MJ m-2/day],
- T mean daily air temperature at 2 m height [°C],
- u2 wind speed at 2 m height [m/s],
- es saturation vapour pressure [kPa],
- ea actual vapour pressure [kPa],
- es-ea saturation vapour pressure deficit [kPa],
- \(\Delta\) slope vapour pressure curve [kPa °C-1],
- \(\gamma\) psychrometric constant [kPa °C-1].

In this equation, climatical data of air temperature, humidity, radiation and wind speed may be used on daily, weekly or monthly basis. For this specific work we have utilized the monthly data sets. It should be ensured that weather measurement be made above an extensive surface of green grass, shading the ground and not short of water at 2m (or converted to that height). It should also be kept in mind that readings of all the parameters are recorded at the same standard time and under same environment. As discussed in [7] FAO-Penman equation gives best result than the rest method not only for arid climate but also for humid climate. This method shows the minor deviations from the actual evapotranspiration data in Pakistan through out the year.

RESULTS AND DISCUSSIONS

Water balance is defined as “the difference between rainfall and evapotranspiration”. If amount of rainfall is greater than evapotranspiration than it is called surplus otherwise deficit.

After analyzing the data of climatic normals of rainfall and evapotranspiration from 1931 to 2008, it has been observed that during 1961-90 conditions were more favourable from December to April while optimum water requirement remained during 1931-60 and 1991-08 in potohar plateau. During Rabi season (1931-60), Evapotranspiration range was 39.3 to 137mm/m, lowest observed in January and highest in April respectively. The amount of rainfall ranged 15.4 to 100.7mm, lowest in November while highest in March. Lowest water deficit was 82mm/m observed during April while highest water surplus was 40.3 mm/m during January as shown in (Figure-2a) in appendix.

During 1961-90 Rabi season, the amount of rainfall ranged 20.1 to 109mm, lowest in January while highest during March. While evapotranspiration ranged was 38.2 to 132mm/m, lowest during December and January while highest in April. Lowest water deficit during April while 36mm/m was the highest surplus observed during February (Figure-2b).

During Rabi 1991-08, rainfall ranged was 20.3 to 100.7mm lowest in November and highest during March while evapotranspiration ranged from 41.3 to 146mm/m lowest in December and highest in April. Lowest water deficit observed during April, which was 78mm/m while the highest surplus was 42mm/m during February (Figure-2c).

The analysis shows that due to the increase of evapotranspiration and decrease in amount of rainfall especially February to April during 1991-08, conditions are not as good as it was earlier. Conditions became better during 1961-90 than 1931-60 but during 1991-08, as the water deficit is increasing during Rabi season except January and February where more surplus are observed. It has become worse in most time of the season as shown in Figure-2 (a to c).

During Kharif 1931-60, lowest amount of rainfall received 34.7mm during May and highest 285.6mm during August. Similarly, during 1961-90, 54.3mm and 285.8mm observed during May and August respectively. In 1991-08, period, lowest amount of rainfall was 51.3mm in May while highest 305.3mm observed in July. During 1931-60, 107mm/m was the lowest ETo observed in September, while the highest 181.9mm/m in May. During 1961-90, lowest ETo was 103mm/m in September and highest175mm/m in June. During, 1991-08, 118mm/m and 198.4mm/m was the lowest and highest ETo observed during September and May respectively. The lowest water deficit observed 147mm/m during May and highest surplus during August, which was 146.5mm/m. increase on evapotranspiration, observed during the whole Kharif season (1931-08). However, rainfall has increased significantly during June and July. It has observed that water balance in terms of surplus increased during June while the rest of the months of season it declined as shown in Figure-2 (d-f).
Appendix

Comparision R and ETo of Kharif Season during 1961-90 of Potohar Plateau

Comparison of rainfall and evapotranspiration of potohar plateau during 1931-08.

Figure-2 (a-c) *Rabi* season.

Figure-2 (d-f) *Kharif* season.

Note:

Single circle shows where conditions became worse while double circle represents where it improved.
Comparison of rainfall and evapotranspiration of Balochistan plateau during 1931-08.

Figure-3 (g-i) Rabi season.
Figure-3 (j-l) Kharif season.
Monthly probability of occurrence of rainfall.

Figure-4 Potohar plateau, Figure-5 Balochistan plateau

m

Annual Water Balance (R-ET) mm/month of Potohar Plateau during 1931-08

n

Annual Water Balance (R-ET) mm/month of Balochistan during 1931-08

Figure-6(m-n) m = Potohar plateau, n = Balochistan plateau.
In Balochistan plateau, during Rabi (1931-60) season, lowest amount of rainfall received 2.8mm during October while the highest 48mm in January (Figure-3g). During 1961-90, lowest rainfall was 2.6mm in October while the highest during March, which was, 42.9mm. In 1991-08, the rainfall was 6.9mm in October while 42mm in February. The value of lowest ET, in January 1961-90, which was 45.5mm/m while the highest 156mm/m observed in April, 1991-08. The lowest water deficit observed 144.4mm/m during April 1991-08. According to climatic normals of 1991-08, Evapotranspiration was higher during November and April while the amount of rainfall increased during December and has decreased during March. There is no surplus is observed during these periods however, conditions have slightly improved during October to December while the rest months it behaves as it was earlier as shown in Figure-3.

Monsoon rainfall during Kharif does not reach this part of the country. This region receives very little amount of rainfall. Due to low parentage of relative humidity and high temperatures, evapotranspiration remains very high. Water loses rapidly through evaporation and highest water deficit observed in this part of the country. The water deficit range was 143mm/m to 213mm/m observed during 1931 to 2008 as shown in figure-3(k to n). This is the reason due to which Kharif crops cannot sow during this season. Due to immense amount of water loss through evaporation, it is difficult to sow crops with suitable and proper irrigation. Therefore, cultivation of Kharif crop is not recommended here.

It has been observed in Potohar plateau that water surplus increased during June (Kharif) while water deficit in April (Rabi) has become worse than ever. In Balochistan plateau, similarly in December water balance (surplus) improved while during March more water deficit observed than earlier periods. The conditions during Kharif season remained same as it was earlier no significant improvement observed in Balochistan.

Monthly probability of occurrence of rainfall for Potohar and Balochistan plateau at different percentage level is shown in figure-4 and5. These probabilities will give a better assessment of rainfall pattern in these regions. Figure-4 indicates that the summer season in potohar region has the highest probability for the occurrence of rainfall because of monsoon rainfall in this season, while figure-5 is indicating that in Balochistan plateau the highest probability of occurrence of rainfall is in winter season due the western disturbances. The western disturbances normally formed at Mediterranean Sea and bring moisture to the western borders of Pakistan in winter season. This fact is important for the management of crop-grown areas.

Water balance remains satisfactory, if amount of rainfall is greater than or equal to evapotranspiration. Similarly, R-1/2ET is water satisfaction index level where crops may be sown without irrigation and R-1/4ET is the water balance situation where supplementary irrigation is required, if not, then proper irrigation system is required. The annual water balance on monthly basis during 1931 to 2008 of potohar and Balochistan plateau is as shown in figure-6(m-n) that indicates that evapotranspiration is significantly increased.

CONCLUSION

After analysis the climatic normals of Potohar and Balochistan plateau following conclusions are drawn. In Potohar (Rabi and Kharif) and in Balochistan (Rabi) plateau during 1961-90, conditions were more favourable among the rest periods. Evapotranspiration is increasing in both plateaus but increase in rainfall trounces this increase during most time of the year. Annual as well as seasonal water balance was lowest during the months (1961-90). During 1991-08, conditions are same as it were in 1931-60 and even becoming worse in Balochistan plateau during Kharif season. However, water balance (surplus) has improved during December while amount of rainfall has decreased during March. In Potohar plateau, water surplus has increased during June due to increase in rainfall and Kharif season is still favourable for crops.

Recommendations: It is recommended that Rabi crop especially wheat may be sown during November rather than December in Balochistan plateau. Water deficit normally observed during March and April. Therefore, excess water obtained in the form of precipitation during December to February may be stored for supplementary irrigation. Probability of occurrence of rainfall may help for long-term crop planning and water management in both plateaus. Water loss through evapotranspiration is very high in Balochistan plateau during Kharif season. Therefore, it is suggested not to sow Kharif crops unless proper preservation of water loss from evapotranspiration. For Potohar Plateau, the conditions are now favorable in the month of June, so the Kharif crops may be cultivated in the last decade of May or in the first decade of June and Rabi may sown in the start of November.
REFERENCES


