# Climatic Zonation of Pakistan through Precipitation-Effectiveness Index

Nadeem Faisal[1] and Naeem Sadiq[1]

***Abstract***

*This paper attempts to describe the zonation of Pakistan using Precipitation-Effectiveness (PE) Index. In agriculture, soil moisture plays a key role that depends on the ratio of precipitation to evaporation, often expressed as the P/E ratio or PE index. PE index values for 46 stations for the period 1959-2008 have been calculated and analyzed. This study has shown that Pakistan is divided into four broad distinct Precipitation effective Index climatic Zones; first is Rain forest (Wet) where PE index values are between 50 to 148, second is Forest (humid) where index values ranges between 10-49, third is partly forest (less humid) with index values ranging from 20-33 and fourth one is Arid (dry) having values which are less than 20. Triple point area of NWFP, Punjab and Kashmir & its vicinity are in the climatic zone of rain forest. The surrounding of the same area covering some parts of upper Punjab and a very slight portion of Balochistan is considered to be as Forest (humid) zone. Some part of the northern Punjab, major part of southern NWFP and very little part of eastern Balochistan lies in partly forest (less humid) zone, while the rest of the country (southern Pakistan) lies in Arid (dry) climatic zone.*

**Keywords:** PE index, Climatic zonation, Triple point zone

## Introduction

Pakistan is an agricultural country and more than 70% of its population depends on agriculture and agricultural products which directly or indirectly depend on meteorological parameters e.g. soil moisture, soil temperature, air temperature, humidity, cloudiness, rainfall, fog etc. Soil moisture estimation often considered as being proportional to the Thornthwaite Precipitation-Effectiveness Index (ESS, 2000). Estimation of soil moisture is necessary for a number of natural resources and agricultural applications. It plays an important role for better agricultural production of a country. It is also used to estimate the plant growth. The potential use of this index will be in prediction of the spatial extent of selected soil properties, such as depth to carbonates or pH as they occur across the extent of the Series (Daniels and Johnson, 2001). In general PE index pattern is inversely related to evaporation pattern (Hussain 1995).

One application of PE index may be to provide a guide to refining the delineation of certain soil climate boundaries. Soil taxonomy (SSS, 1999) has detailed criteria for soil moisture regimes. For a particular place it depends on the rainfall and evaporation of that place. The ratio of precipitation to evaporation is related to the soil moisture content in the soil. Evaporation is directly related to air temperature; C.W Thornthwaite developed a formula (Thornthwaite, 1931) to calculate PE index in terms of the precipitation and temperature which is the sum of monthly indices that are calculated with the monthly precipitation (inches) and temperature (°F).

$$PE = \sum 115\left[ P/T - 10 \right]^{10/9} \qquad (1)$$

Deduced formula for precipitation in mm and mean monthly temperature in oC comes out as

$$PE = \sum 1.65\left[ P/T - 12.2 \right]^{10/9} \qquad (2)$$

Further calculation, tabulation and analysis has been done by using equation (2). Outcomes of this study will be helpful to the planners for land use and also for agriculturists, engineers, research workers, and weather forecasters etc. to develop the socioeconomic conditions of the country.

[1] Pakistan Meteorological Department

## Data & Methodology

We used total monthly precipitation in mm and average mean monthly temperature in °C of 46 stations' (Fig. 1) of Pakistan Meteorological Department (PMD) for 50 years (1959-2008). All the data used and processed in this study is provided by PMD. Out of these 46 stations, 19 are hilly and remaining 27 are plain stations, hence giving good coverage of entire Pakistan. All of these stations have nearly complete and good quality of data for the under study period. However very few missing values filled-up with long-term average values. Monthly PE index values calculated using mean monthly temperature and precipitation data for the said period. Summation of 12 months values are calculated to get the annual PE index values. Seasonal i.e. pre-monsoon, monsoon, post-monsoon and winter's index values are also calculated (Table-1) and analyzed (Fig. 2-6). On the maps, isolines are drawn at suitable intervals in order to observe the prominent desired features. Time series and trend analysis have also been carried out for the each three stations having strongest & weakest values respectively (Fig. 7-12).

## Findings

Analysis of seasonal and annual maps reveals important findings, which are mentioned below:

### Annual

The main features observed in the annual map (Fig. 2) are more or less similar to the seasonal maps except monsoon (Fig. 3). PE index is lowest over Sind, southern Punjab and almost all Balochistan excluding Quetta and Zhob (i.e. less than 10). In Sindh, there is slight increase from north (3.5 for Rohri) to south (8.9 for Badin). In Balochistan excluding Quetta and Zhob generally index values are increasing from west (1.8 for Nokkundi) to east (6.2 for Sibbi). In Punjab the values are decreasing from north to south. Further, two distinct types of distribution are found over rest of the country. The strongest one is covering the circle of Murree, Garhi Dupata, Kotli, Sialkot, Jhelum, Islamabad, Kakul and the adjoining areas of Balakot and Muzaffarabad (64-148). A small patch of high value lies over Parachinar is also noted. The other distribution covers the upper and lower areas of the said region. On the lower side, the limits are somewhat less in D I Khan, Zhob, Qutta, Sargodha and Faisalabad while on the higher side it is up to Skardu, Astore, Chilas, Gupis and Drosh (10-40). The highest value of PE index is found at Murree (148) and Balakot, has second highest value (102.7).

### Monsoon (July-September)

Monsoonal rainfall distribution plays an important role in rainfall pattern of Pakistan. Highest rainfall zone is elongated from Kashmir boundary covering some parts of Upper Punjab and north eastern NWFP. The second important feature of this season PE index distribution (Fig.3) is the spreadness of the humid area which is now up to the demarcation line of Bahawalnagar (4.7), DI Khan (5.7) and Zhob (4.7). Again during monsoon, evaporation is very less over Murree and its neighborhood in Pakistan. In monsoon season rainfall amount increases rapidly but evaporation decreases. Thus causes a sharp increase in PE index in this season. As usual PE index is highest over Triple point of Pakistan i.e. 54.3 (Murree), 39.3 (Balakot) and lowest over Nokkundi with 0 and Dalbandin with 0.1 value. It is noteworthy that lower Sindh covering Karachi, Hyderabad, Badin and Chhor are also lying in the humid zone during this season only.

### Winter (January-March)

In winter the PE index contours (Fig. 4) have almost the same pattern alike in pre-monsoon but the values are greater than the pre-monsoon, even Parachinar and Drosh also acquire the same contours pattern as in pre monsoon. The difference appears when the humid zonation extended itself up to Quetta by covering small western portion of NWFP and Balochistan, as seen in post monsoon season. The highest PE index value is 56 at Murree and 38.4 at Garhi Dupatta. The least value is 0.3 for the Badin, Chhor and Nawabshah while second lowest value is 0.5 for Hyderabad and Padidan.

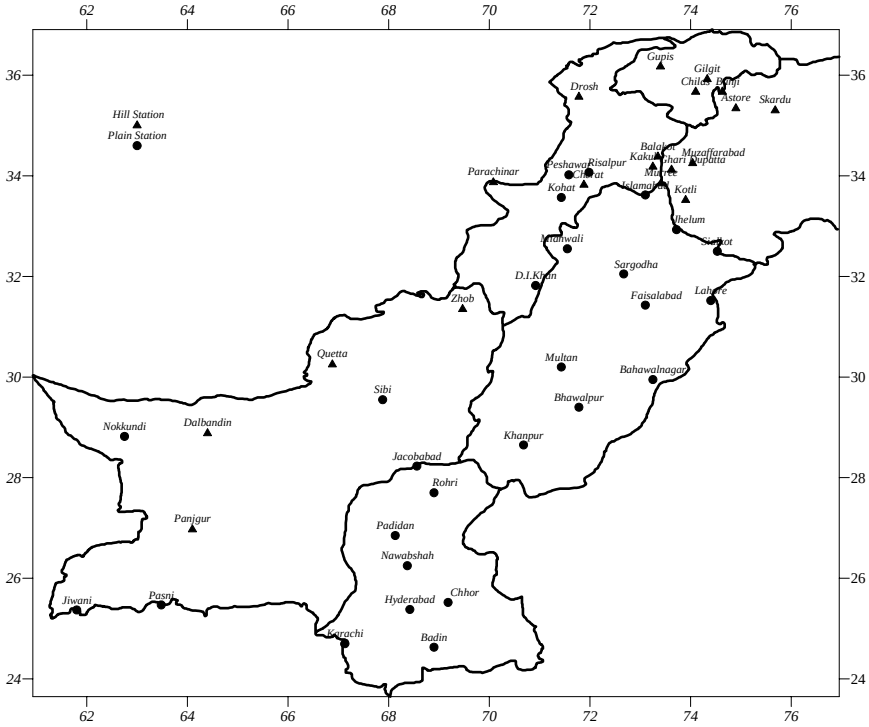


**Fig-1:** 46 PMD stations whose 50 years data used in this study

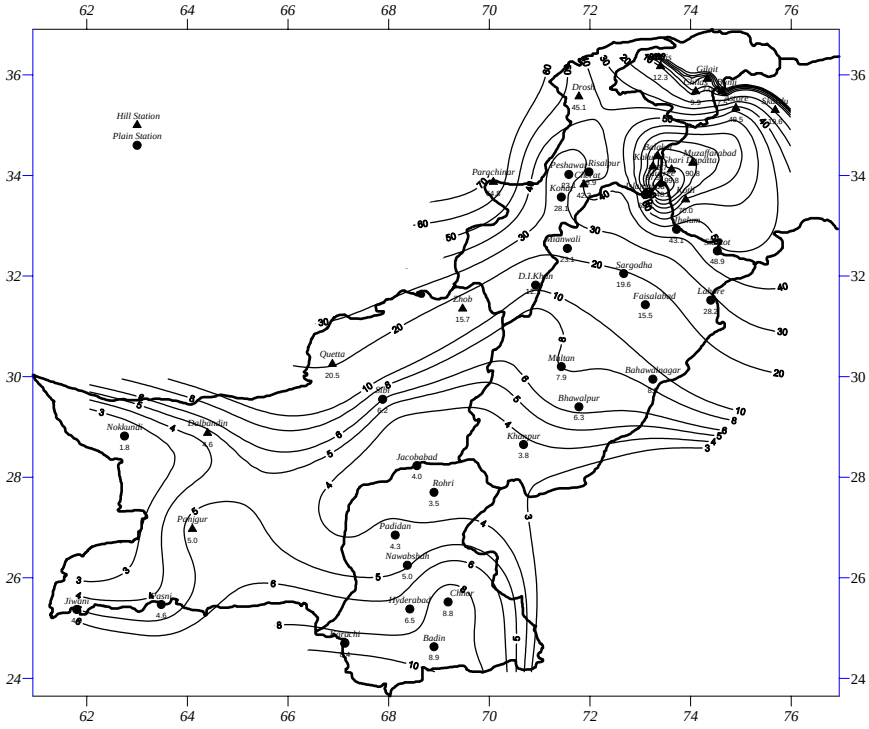


**Fig-2:** Annual PE index during period 1959-2008

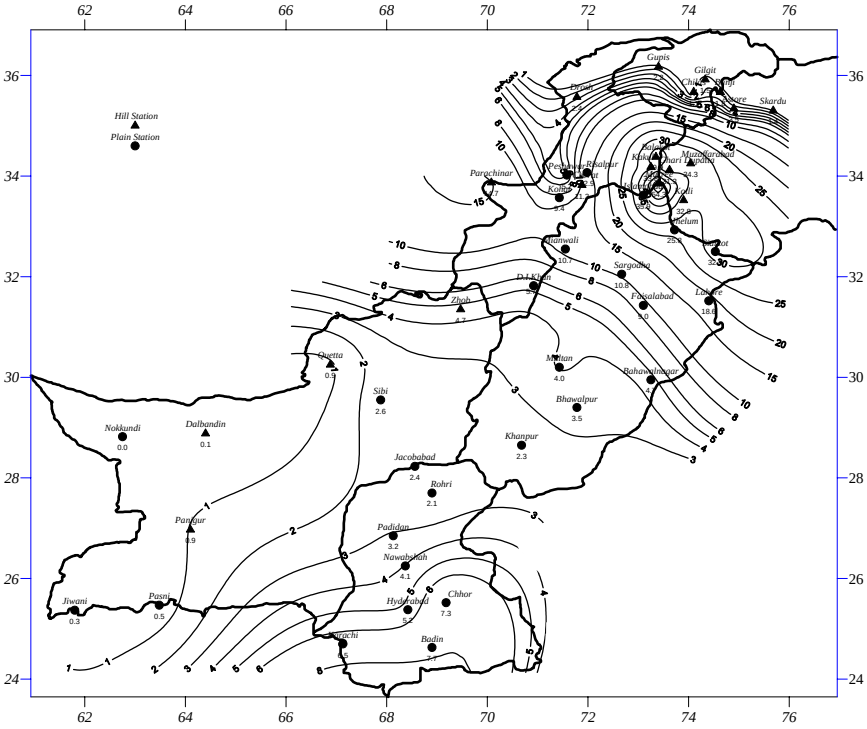


**Fig-3:** Monsoon PE index during period 1959-2008

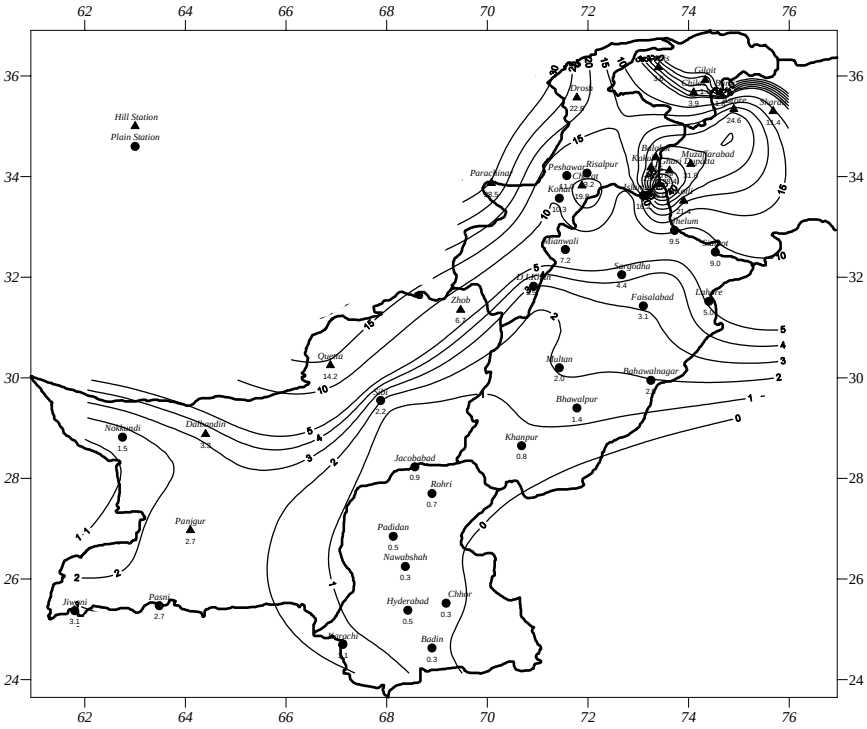


**Fig-4:** Winter PE index during period 1959-2008

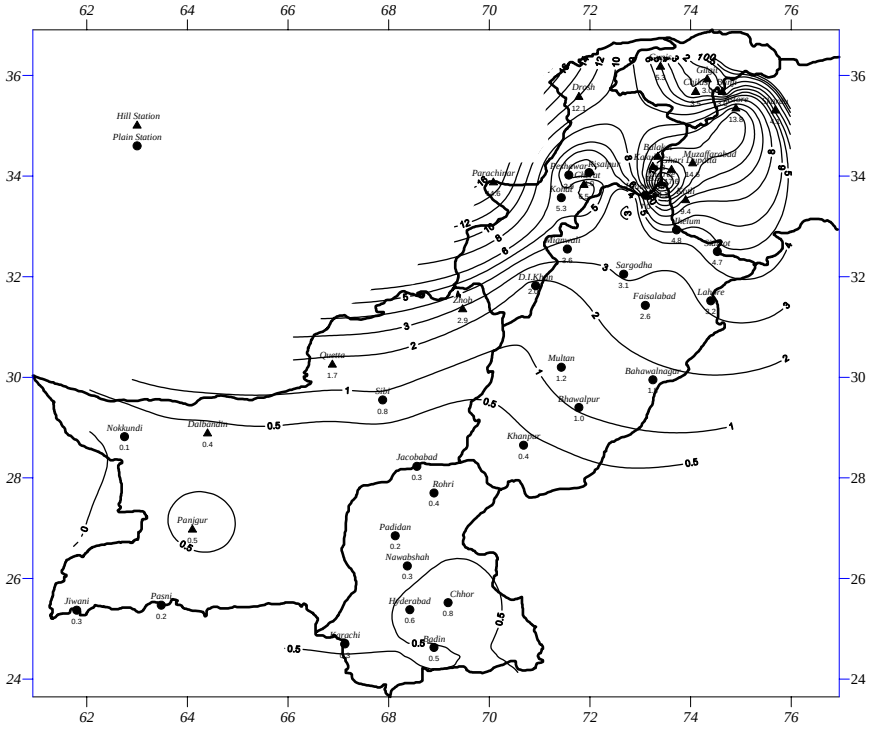


**Fig-5:** Pre-Monsoon PE index during period 1959-2008

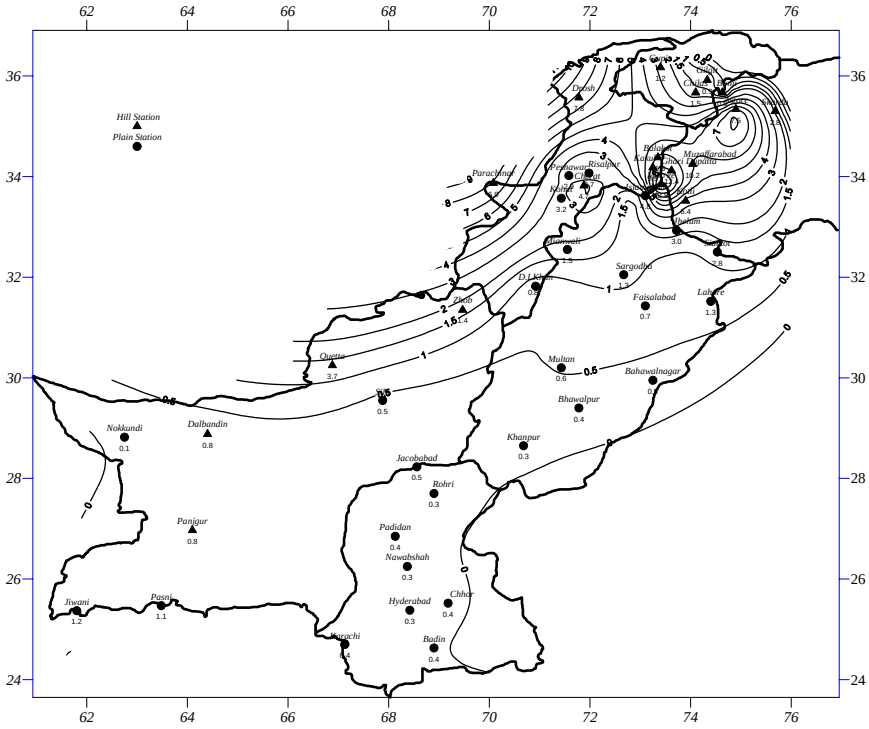


**Fig-6:** Post-Monsoon PE index during period 1959-2008

**Table-1:** Annual and Seasonal PE index of Pakistan over 50 years period (1959-2008)

| S.N. | Station | Annual | Monsoon | Winter | Pre- | Post- |
|---|---|---|---|---|---|---|
| 1 | Murree | 148.2 | 54.3 | 56.0 | 24.1 | 13.8 |
| 2 | Balakot | 102.7 | 39.9 | 35.5 | 15.8 | 11.5 |
| 3 | Garhi Dupatta | 99.8 | 31.3 | 38.4 | 17.6 | 12.4 |
| 4 | Muzaffarabad | 90.8 | 34.3 | 31.8 | 14.6 | 10.2 |
| 5 | Kakul | 87.9 | 33.8 | 28.7 | 15.5 | 9.9 |
| 6 | Kotli | 70.0 | 32.8 | 21.4 | 9.4 | 6.4 |
| 7 | Parchinar | 64.8 | 14.7 | 28.5 | 14.6 | 6.9 |
| 8 | Islamabad | 63.9 | 35.9 | 16.2 | 7.0 | 4.8 |
| 9 | Astore | 49.5 | 3.5 | 24.6 | 13.8 | 7.5 |
| 10 | Sialkot | 48.9 | 32.3 | 9.0 | 4.7 | 2.8 |
| 11 | Drosh | 45.1 | 2.4 | 22.8 | 12.1 | 7.8 |
| 12 | Jhelum | 43.1 | 25.8 | 9.5 | 4.8 | 3.0 |
| 13 | Cherat | 42.3 | 11.3 | 19.8 | 6.5 | 4.7 |
| 14 | Risalpur | 33.9 | 12.9 | 13.2 | 4.0 | 3.7 |
| 15 | Lahore | 28.2 | 18.6 | 5.0 | 3.2 | 1.3 |
| 16 | Kohat | 28.1 | 9.4 | 10.3 | 5.3 | 3.2 |
| 17 | Peshawar | 23.1 | 5.2 | 11.0 | 3.9 | 2.9 |
| 18 | Mianwali | 23.1 | 10.7 | 7.2 | 3.6 | 1.5 |
| 19 | Quetta | 20.5 | 0.9 | 14.2 | 1.7 | 3.7 |
| 20 | Skardu | 19.6 | 1.4 | 11.4 | 4.1 | 2.8 |
| 21 | Sargodha | 19.6 | 10.8 | 4.4 | 3.1 | 1.3 |
| 22 | Zhob | 15.7 | 4.7 | 6.7 | 2.9 | 1.4 |
| 23 | Faisalabad | 15.5 | 9.0 | 3.1 | 2.6 | 0.7 |
| 24 | Gupis | 12.3 | 2.2 | 3.6 | 5.3 | 1.2 |
| 25 | D-I-Khan | 12.1 | 5.7 | 3.5 | 2.0 | 0.8 |
| 26 | Chilas | 9.9 | 1.1 | 3.9 | 3.5 | 1.5 |
| 27 | Badin | 8.9 | 7.7 | 0.3 | 0.5 | 0.4 |
| 28 | Bhawalnagar | 8.8 | 4.7 | 2.0 | 1.8 | 0.5 |
| 29 | Chhor | 8.8 | 7.3 | 0.3 | 0.8 | 0.4 |
| 30 | Karachi | 8.4 | 6.5 | 1.1 | 0.3 | 0.4 |
| 31 | Multan | 7.9 | 4.0 | 2.0 | 1.2 | 0.6 |
| 32 | Bunji | 7.5 | 1.8 | 1.8 | 3.0 | 0.9 |
| 33 | Gilgit | 7.0 | 1.5 | 1.6 | 3.0 | 0.9 |
| 34 | Hyderabad | 6.5 | 5.2 | 0.5 | 0.6 | 0.3 |
| 35 | Bhawalpur | 6.3 | 3.5 | 1.4 | 1.0 | 0.4 |
| 36 | Sibbi | 6.2 | 2.6 | 2.2 | 0.8 | 0.5 |
| 37 | Panjgur | 5.0 | 0.9 | 2.7 | 0.5 | 0.8 |
| 38 | Nawabshah | 5.0 | 4.1 | 0.3 | 0.3 | 0.3 |
| 39 | Jiwani | 4.8 | 0.3 | 3.1 | 0.3 | 1.2 |
| 40 | Dalbandin | 4.6 | 0.1 | 3.3 | 0.4 | 0.8 |
| 41 | Pasni | 4.6 | 0.5 | 2.7 | 0.2 | 1.1 |
| 42 | Padidan | 4.3 | 3.2 | 0.5 | 0.2 | 0.4 |
| 43 | Jacobabad | 4.0 | 2.4 | 0.9 | 0.3 | 0.5 |
| 44 | Khanpur | 3.8 | 2.3 | 0.8 | 0.4 | 0.3 |
| 45 | Rohri | 3.5 | 2.1 | 0.7 | 0.4 | 0.3 |
| 46 | Nokkundi | 1.8 | 0.0 | 1.5 | 0.1 | 0.1 |

## Pre-Monsoon (April-June)

For this season, the pattern of distribution of PE index (Fig. 5) is shrunk comparative to the annual one, while overall index values are ranging from 0.1 (Nokkundi) to 24.1 (Murree) only. In this context, the regions of high PE index is slightly changed by including Astore in its forest zone. Drosh and Parachinar (most eastern and far distant parts) also included in this rain forest region. Humid zone

is shrunk from the southern side and now almost no part of Punjab or Balochistan is included in this zone, even DI Khan is out of this zone. Highest value of PE index is 24.1 at Murree, 17.6 at Garhi Dupatta and lowest PE index is 0.1 at Nokkundi.

**Post monsoon (October - December)**

In this season, with the withdrawal of monsoon, PE index value decreases rapidly with some changes in pattern of distribution (Fig. 6). The wet zone is now clearly detached from eastern boundary and extends up to the western boundary i.e. up to Drosh and its adjoining area. A far distinct, Parachinar is also included in the forest zone. Second important feature in this season is the thin elongation of humid zone up to Quetta (3.7) and its vicinity. The southern Sindh is now again lying in Arid zone along rest of the country. Highest value are over Murree (13.8) and Garhi Dupatta (12.4), while the lowest value is 0.1 over Nokkundi in Balochistan and in Sindh it is 0.3 over Hyderabad, Nawabshah and Rohri areas.

**Time distribution of PE index**

Annual cycles of PE index over 50 years period from 1959-2008, of three stations viz, Murree, Garhi Dupatta and Muzaffarabad, acquiring strongest PE index are taken into account (Fig. 7-9) respectively. The variability of annual PE indices of all three stations have been found inconsistent throughout the analyzed period. The stronger annual PE index cycles describes the higher influence of monsoon circulation and western disturbances into these northern areas of Pakistan. The linear trend analysis of these stations taken into account, shows that there is increasing trends in Murree (0.33 per annum), where as there is decreasing trend of 0.50 per annum in Garhi Dupatta. On the other hand Muzaffarabad shows almost unchanged trend.

Time series analysis of annual PE index over the study period, of three stations, having weakest PE index are also taken inaccount (Fig. 10-12). The stations fall in this category are Khanpur, Rohri and Nokkundi. Again the variability of annual PE indices of all three stations have been found inconsistent through-out the analyzed period. The linear trend analysis of all these stations reveals that there are increasing trends in all cases.

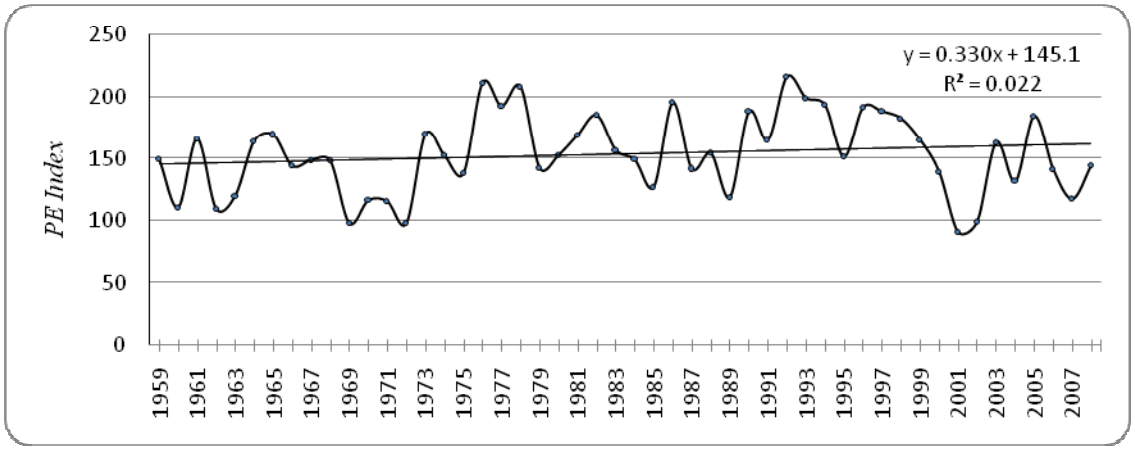


**Fig-7:** Annual Time series and trend of Murree having highest PE index

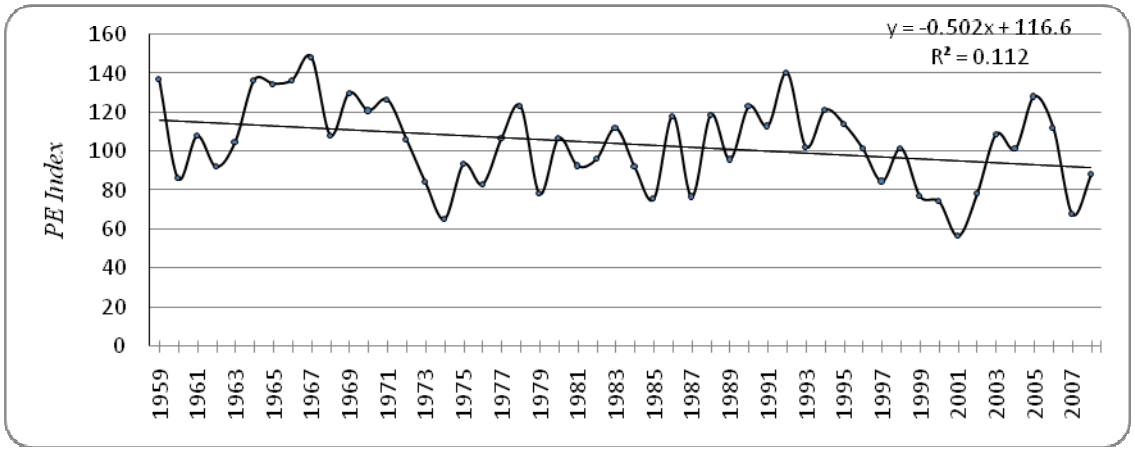


**Fig-8:** Annual Time series and trend of Garhi Dupatta having second highest PE index

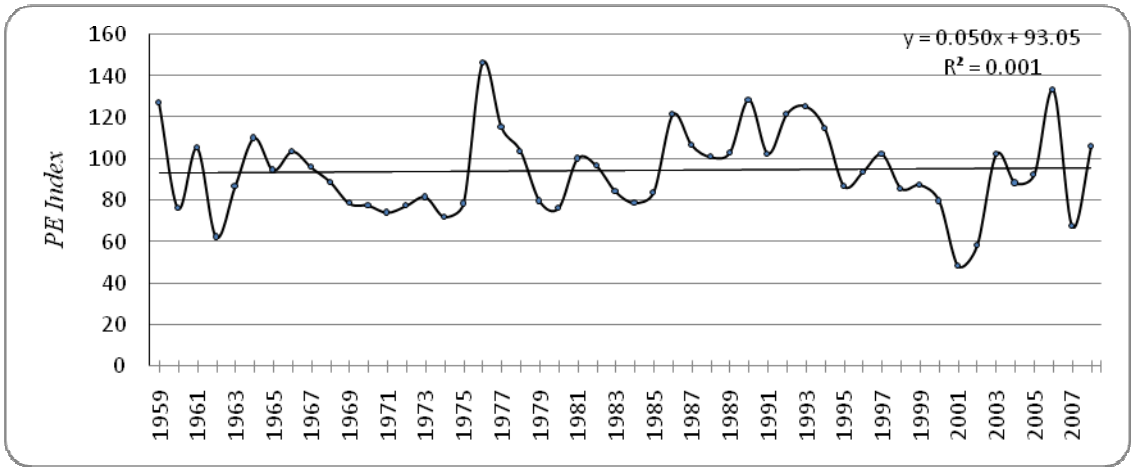


**Fig-9:** Annual Time series and trend of Muzaffarabad having third highest PE index

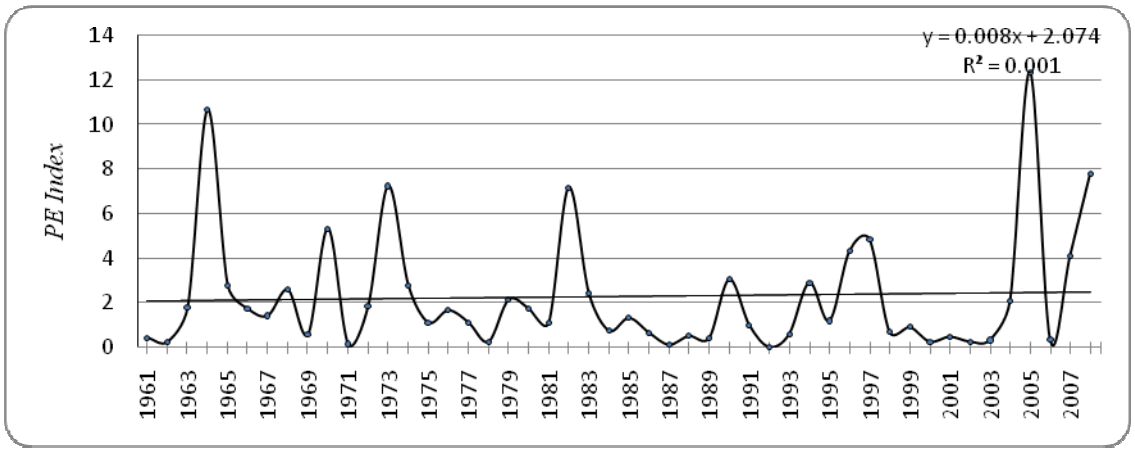


**Fig-10 :** Annual Time series and trend of lowest PE index over Nokkundi

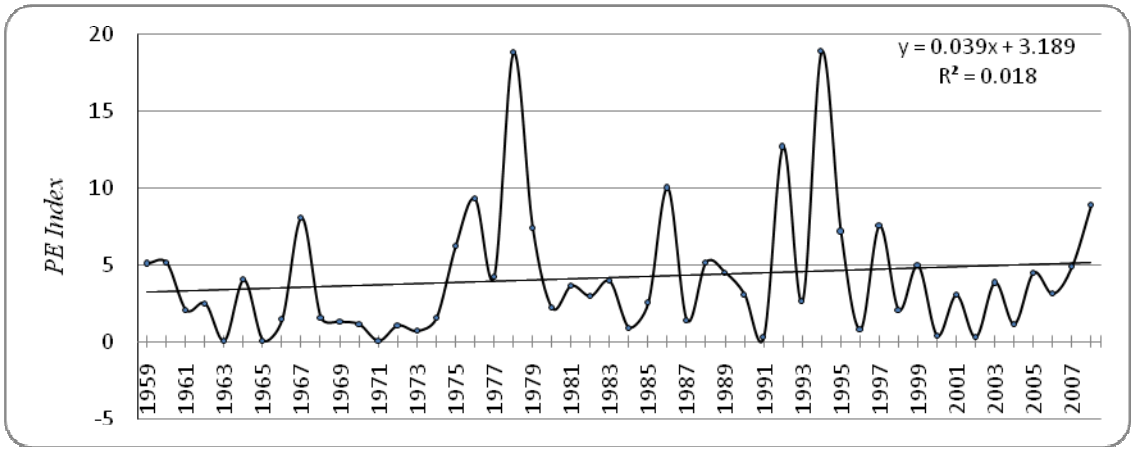


**Fig-11 :** Annual Time series and trend second lowest PE index overt Rohri

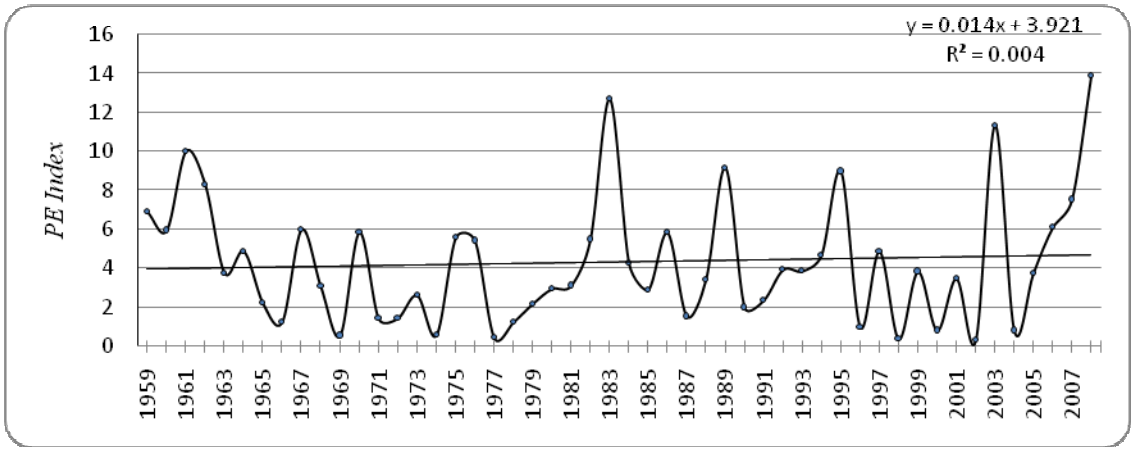


**Fig-12** : Annual Time series and trend third lowest PE index over Khanpur

## Conclusions

From the analysis of PE index values and maps it may be concluded that Pakistan is divided into following climate zones:

1. Rain Forest (wet) where PE index value is greater than or equal to 50
2. Forest (humid) where PE index value ranging between 34-49
3. Partly Forest (less humid) PE index values ranging between 20-33
4. Arid (dry) less than 20

Triple point region and its neighborhood including Murree, Balakot, Garhi Dupatta, Muzaffarabad, Kakul, Kotli, Parachinar & Islamabad are in the climatic zone of Rain Forest. Astore, Sialkot, Drosh, Jehlum, Cherat and Risalpur lies in forest (humid) zone. Lahore, Kohat, Peshawar, Mianwali and Quetta are in Partly Forest (less humid) zone while rest of the country's large portion is lying in Arid (dry) zone.

Due to rapid increase of rainfall in monsoon, indices sharply increase with respect to winter or pre-monsoon seasons. Similarly due to withdrawal of south-west monsoon rainfall amount decreases sharply and PE indices decreases significantly in post-monsoon. But the values of PE index for winter and monsoon are more or less similar, likewise pre-monsoon & post-monsoon values have similarities. Time

distribution of PE index values has no regular pattern and there is no increasing or decreasing tendency with respect to time except Garhi Dupatta which is an open problem.

## References

1. **Dwain D. and Greg J, 2001;** Development of a New Precipitation-Effectiveness Index, http://proceedings.esri.com/library/userconf/proc01/professional/papers/pap466/p466.htm
2. **Ecological Sciences Staff, 2000:** National Agronomy Manual 3rd Ed Exhibit 502-8a. NRCS-USDA.
3. **Hussain M.A. 1995:** PE index Distribution over Bangladesh, The Atmophere,1,1,19-23.
4. **Soil Survey Staff, 1999**, Soil Taxonomy: A basic system of soil classification for making and interpreting Soil survey Center, NRCS, USD. Handbook-436, Washington DC
5. **Thornthwaite, C.W. 1931:** The Climates of North America According to a New Classification. Geog. Review. 21: 633-655.