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Extremities analysis over Parambikulam Aliyar project basin of Tamil Nadu

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सार – अध्ययन ने वर्ष 1981 से 2017 के लिए परम्बिकुलम अलियार परियोजना बेसिन में चरम तापमान और वर्षा मूल्यों के समकालीन अंतरिक्ष-समय पैटर्न के मूल्यांकन की जांच की। अलियार उप-बेसिन कैचमेंट क्षेत्र, अलियार उप-बेसिन कमांड क्षेत्र, पलार उप-बेसिन कैचमेंट क्षेत्र, पलार उप-बेसिन कमांड क्षेत्र, पीएपी पहाड़ी क्षेत्र, पीएपी मैदानी क्षेत्र, पीएपी संपूर्ण बेसिन में चरम सीमाओं की जांच की। परिणामों से स्पष्ट रूप से पता चला कि अलियार उप-बेसिन कैचमेंट क्षेत्र में लगातार सूखे दिनों में थोड़ी वृद्धि की प्रवृत्ति दिखाई दी (1981 में 56 दिनों से 2017 में 63 दिन तक) जो सूखे और मौसमी सूखे की संभावना के संकेतक के रूप में काम कर सकता है। पीएपी बेसिन के तहत पलार उप-बेसिन कैचमेंट क्षेत्रों में सरल वर्षा तीव्रता सूचकांक (SDII) के रुझान में मामूली ऊपर की ओर गति (7 से 8 मिमी/दिन) दिखी। कमांड क्षेत्र में सिर्फ rx5day ने 1.25 मिमी/वर्ष भिन्नता की बड़ी वृद्धि दिखाई। सेन के ढलान अनुमानक के अनुसार औसत दैनिक तापमान और औसत न्यूनतम तापमान में औसत कमी अलियार उप-बेसिन जलग्रहण क्षेत्र के लिए -0.011 °C/वर्ष और -0.003 °C/वर्ष और अलियार कमांड क्षेत्र के लिए -0.012 °C/वर्ष और -0.003 °C/वर्ष है। PAP पहाड़ी क्षेत्र और पूरे PAP के स्थानिक विस्तार ने वर्षा की चरम घटनाओं में थोड़ी बढ़ती प्रवृत्ति दिखाई। हालांकि, PAP के मैदानी क्षेत्रों में r20mm, rx3day और rx5day वर्षा सूचकांकों में मामूली कमी देखी गई।

ABSTRACT. Study examined the evaluation of contemporary space-time patterns of extreme temperature and precipitation values in Parambikulam Aliyar Project basin for the years 1981 to 2017. The investigation of extremes conducted in Aliyar sub-basin Catchment area, Aliyar sub-basin command area, Palar sub-basin Catchment area, Palar sub-basin command area, PAP hill region, PAP plain region, PAP whole basin. The results clearly revealed that represent consecutive dry days in Aliyar sub-basin Catchment area showed slightly increasing trend (from 56 days in 1981 to 63 days in 2017) which could served as an indicator of dryness and chance of seasonal drought occurrence. In the Palar sub-basin catchment areas under the PAP basin, consecutive dry days do not show any trend. With regards to consecutive wet days, PAP hill areas are showing a significant positive trend (P-Value of 0.038, and R^2 of 0. 432). The trend in the simple precipitation intensity index (SDII) showed slight upward movement (7 to 8mm/ day). In the command area, only rx5day showed a major increase of 1.25 mm/year variation. The mean reduction in the mean daily temperature and mean minimum temperature as per the Sen's slope estimator stands at -0.011 °C/ Year and -0.003 °C/ year for Aliyar sub-basin catchment and -0.012 °C/ Year and -0.003 °C/ year for Aliyar command area. Spatial extent of PAP hilly region and PAP as a whole showed a slightly rising trend in precipitation extreme events. However, in PAP plain areas, slight reductions were noticed in r20mm, rx3day, and rx5day precipitation indices. These findings highlight the importance of long term climate data analysis for decision making and adaptation strategies in the face of climate extremities.

Key words – Consecutive Dry Days (CDD), Consecutive Wet Days (CWD), PRCPTOT (Annual total precipitation on wet days), SDII (Simple precipitation intensity index).

1. Introduction

Climate change has become most significant global threat (Amirabadizadeh *et al.*, 2016) determined by various anthropogenic activities (Chang *et al.*, 2015) and natural processes. Historical records clearly show that the global temperature has been rising since 1950. The last 30 years have been consistently warmer than any previous

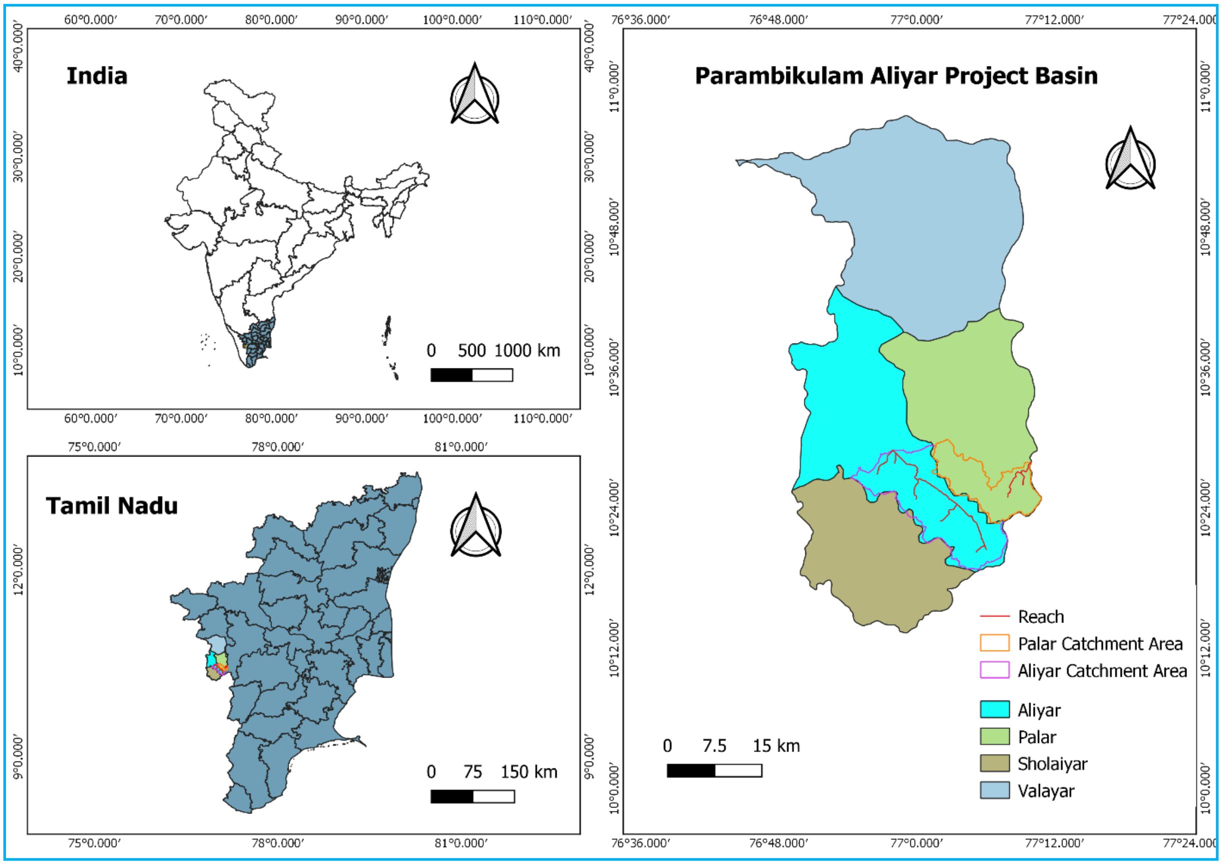


Fig. 1. Study area of Parambikulam Aliyar basin

decades and the first 10 years of the 21st century have been the warmest ever recorded (Stocker *et al.*, 2013). On average, the global temperature has gone up by 0.72 ℃. Since 1950. As the temperature increases there will be fewer cool days, cool nights, and frosty periods on the global scale (Fall *et al.*, 2021). Probably going to be more hot days, warm nights, summer days and heatwaves worldwide. (Donat *et al.*, 2013). The increases in frequency, duration, spatial extension, and intensity (Costa *et al.*, 2020) of heat waves, droughts (Ciais *et al.* 2005), floods, and heavy and prolonged rainfall (Rosenzweig *et al.*, 2002) will negatively affect the crop growth cycle (Van der velde *et al.*, 2012) and crop yield (Tubiello *et al.*, 2007) and the impacts are different in each region. India is one of the world's most populous and agricultural dependent nations expected to be seriously affected by various climatic factors (Dhanya & Ramachandran, 2016) like variations in temperature, humidity and precipitation.

Global warming also brings changes in the hydrological cycle (Li *et al.*, 2019 and Yang *et al.*, 2018) like more water vapor in the atmosphere, shifting rainfall patterns in regions (Bates *et al.*, 2008; Hartmann *et al.*, 2013). In some regions, there will be more intense and concentrated rainfall events leading to shorter but heavy rainfall (Knapp *et al.*, 2008), and in some regions, there were increased frequency and duration of dry periods (Groisman *et al.*, 2005). These changes will impact our environment and our way of life. Therefore, more focus is needed to assess the influence of climate change on water availability at the scale of individual river basins which would help to address the water requirements of human populations, agriculture and industries (Haleem *et al.*, 2022). Furthermore, the influence of climate change on water resources can vary from one river basin to another due to geographical locations, land cover, soil type, and climatic factors variations (Abeysingha *et al.*, 2020; Ich *et al.*, 2022).

This study endeavors to address the spatial and temporal analysis of extremities over the Parambikulam Aliyar Project (PAP) including the Aliyar sub-basin and Palar sub-basin, Tamil Nadu. Over the years, the demand for water in these areas has increased significantly, due to the expansion of population, agricultural activities, energy sector, and industrial growth. Consequently, it has become an annual struggle to cope with water scarcity in this region (Manikandan *et al.*, 2019). Due to its geographic and socioeconomic characteristics, the PAP is one of the most susceptible to the adverse impacts of climate change, with particular concern to the agricultural sector which exhibits a high vulnerability because most production systems are rainfed and based on monocultures (Arunvenkatesh *et al*., 2016). Therefore, it is necessary to constantly monitor rainfall extremities by identifying and analyzing quantitative indicators at the local scale and determining their possible impacts on the agricultural and hydrological sectors.

To achieve above mentioned goals, this study employs climate indices recommended by the Expert Group on Climate Change Detection and Indices (ETCCDI) under the purview of the World Meteorological Organization (WMO) (Peterson & Manton, 2008). These climate indices serve as valuable tools for assessing and understanding the changing climate patterns within the PAP basin, which could help in the formulation of effective strategies for mitigating their impacts on agriculture and hydrology.

2. Materials and methods

2.1. *Study area*

The PAP basin is an interstate water distribution project created by the states of Tamil Nadu and Kerala. It is situated in the southwest of the Indian subcontinent. The water from west flowing rivers is diverted by this project. The PAP basin region is located between latitudes 10° 10' 00" to 10°57'20" N, and longitudes 76°43'00" to 77° 12'30" E (Fig. 1). The three west-flowing rivers Periyar, Chalakkudipuzha, and Bharathapuzha, which originate in the Western Ghats, provide water to the Parambikulam Aliyar basin. Rainfall typically falls in the PAP basin during the South West Monsoon (SWM) and North East Monsoon (NEM) seasons, respectively. The PAP primary goal is to shift water from the west to the east for agriculture purposes. The PAP basin has four sub-basins: Aliyar, Palar, Sholaiyar and Valayar. Among these, Aliyar and Palar have command areas.

2.2. *Historic climate data*

The starting and boundary conditions for the Weather Research and Forecasting model (WRF) were derived from reanalysis Interim (ERA-I) data from the European Centre for Medium Range Weather Forecast (ECMWF) with a horizontal resolution of 0.75°.The data were generated for 37-year period (1981-2017) at a resolution of 17 km using the sequential re-initialization approach after assimilating all available satellite and in-situ observations. Automatic Weather Stations (AWS), which provide ground-level information on parameters like maximum temperature, minimum temperature and rainfall and Validated by comparing its forecasts with actual in situ measurements specific to the PAP basin.

TABLE 1

Extremity Indices with description

Index	Description
CDD	Annual maximum length of dry spell: maximum number of consecutive dry days with RR < 1mm
CWD	Annual maximum length of wet spell: maximum number of consecutive wet days with RR < 1mm
PRCPTOT	Annual total precipitation on wet days
SDII	Simple precipitation intensity index
r-10 mm	Annual count of days when PRCP < 10mm
r-20 mm	Annual count of days when PRCP < 20 mm
r-30 mm	Annual count of days when PRCP < 30 mm,
rx 1 day	Annual maximum 1-day precipitation
rx 3 day	Annual maximum consecutive 3-day precipitation
rx 5 day	Annual maximum consecutive 5-day precipitation
tmm	Annual mean daily mean temperature
txm	Annual mean daily maximum temperature
tnm	Annual mean daily minimum temperature

2.3. *Extremities of precipitation and temperature*

Trends in the precipitation and temperature extremes in the PAP basin were investigated with the help of extremity indices mentioned in Table 1. The Study area has been divided into Aliyar sub-basin Catchment area, Aliyar sub-basin command area, Palar sub-basin Catchment area, Palar sub-basin command area, PAP hill region, PAP plain region, PAP whole basin.

Aliyar Sub-Basin Catchment Area and Command Area

The Aliyar sub-basin catchment area represents the land from which water drains into the Aliyar River. It includes the upstream region where precipitation contributes significantly to runoff. The Aliyar sub-basin command area, on the other hand, refers to the land where water resources are managed and utilized. This area may include reservoirs, irrigation canals, and water distribution networks.

Palar Sub-Basin Catchment Area and Command Area

Similar to the Aliyar sub-basin, the Palar sub-basin catchment area encompasses the land that contributes runoff to the Palar River. The Palar sub-basin command area involves water management activities, such as irrigation, ground water extraction and reservoir operation, within the Palar River basin.

PAP Hill Region and Plain Region

The PAP hill region typically includes elevated terrain, which affects precipitation patterns, soil moisture, and runoff..The PAP plain region, conversely, comprises flatter areas where water flow is influenced by factors like land use, vegetation and human activities.

PAP Whole Basin

Considering the entire PAP basin as a whole allows for an integrated assessment of hydrological processes, climate variability, and extreme events.By analyzing the entire basin, researchers can identify spatial variations in precipitation and temperature extremes, which are crucial for water resource management and adaptation strategies.

3. Results and discussion

3.1. *Consecutive Dry (CDD) and Wet days (CWD) analysis*

3.1.1. *Aliyar sub-basin catchment and command area*

The present study highlights the changes in Consecutive Dry (CDD) and Wet days (CWD) over the PAP basin. The Indices that represent consecutive dry days in the Aliyar sub-basin Catchment area shows slightly increasing trend. It is not statistically significant as the predictor holds a higher P value. In a linear regression analysis, the predictor that holds a lower p-value is likely to be more meaningful addition to the model as a change in the predictor values are related to the changes in the response variable. However, the result showed that the annual maximum number of consecutive dry days with daily rainfall <1mm (CDD) is found to be rising from 56 days in the year 1981 to 63 days in 2017, it shows a gradual increase in the number of consecutive dry days over the years. These variations in the duration of CDD offer valuable insights into the inclination for drought occurrences (Orlowsky and Seneviratne, 2012). The increasing number of CDDs from 56 to 63 days could serve as an indicator of dryness and there is a higher chance of seasonal drought occurrence. Several drought studies have indicated the possibility of decreased streamflow or groundwater levels (Kohn *et al*., 2014, Laaha*et al.*, 2017), negative impacts on agriculture and forestry (Allen *et al*., 2010; Hlavinka *et al*., 2009) as well as constraints on energy production (Bono, 2004).

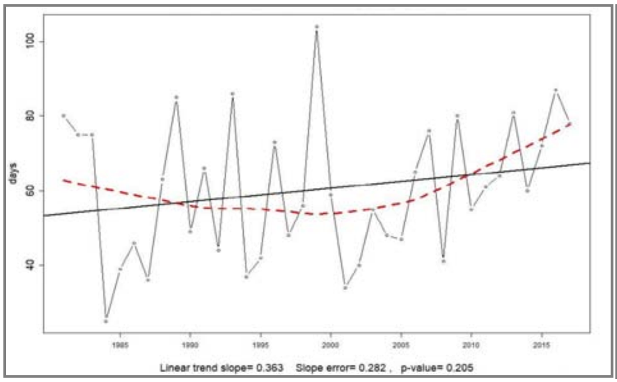
The rate of change in the number of consecutive wet days with daily RR>1 mm (CWD) shows a declining trend. During the period 1981, CWD was 13 days and by the end of 2017, it had reduced to 11 days in the Aliyar catchment area. This trend could significantly affect water availability in rivers, streams, reservoirs, and the overall hydrological balance in the region. The annual precipitation (when RR > = 1 mm) on a wet day (PRCPTOT) did not show any specific trend. It shows 800 to 900 mm of annual rainfall during the period. Simple precipitation intensity index (SDII) which is the annual total precipitation divided by the number of wet days (defined as PRCP > = 1 mm) shows a slight rising trend. The simple daily precipitation intensity index (SDPI) indicated a rise during the 1995 to 2008 year period among the 37 period duration with an intensity of 7 to 8 mm/ day. This statement clearly shows that number of rainy days may reduce but the intensity of rainfall events may be?? which potentially challenges water management and increases flood risk in the region. Such an increase in precipitation extremes will have an impact on agricultural yield, flash flooding, and ecosystems (Yaduvanshi *et al*., 2021). The combination of fewer but more intense rainy days is an important event to be considered while planning for adapting strategies for water resource management and flood mitigation.

In the Aliyar sub-basin command area, the trends in the number of CDD show slightly less increase than the catchment area from 49 days to 51 days annually for the period between 1981 to 2017. The rising trend in CDD is statistically non-significant as P value of the trend test is high (0.538). Similar to the catchment area, the rate of change in the number of CWD in the command area also shows a declining trend. It has reduced from 16 to almost 13 during 37-year period. This can impact agriculture in the nearby sub-basin area, A decrease in wet spells can have adverse effects on soil moisture and the availability of irrigation water for agricultural purposes which impacts crop growth and yield.

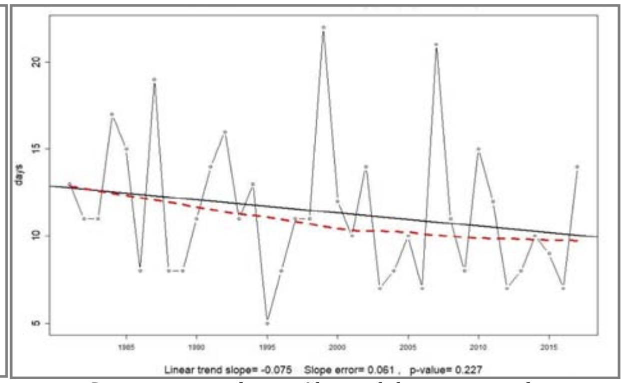
3.1.2. *Palar sub-basin Catchment and Command Area*

In the Palar sub-basin catchment areas under the PAP basin, the consecutive dry days do not show any trend. It remained almost the same throughout 37 year period. The linear trends showed that CDD values remained around 50 days from 1981 to 2017. However, the number of CWD showed a slightly declining trend. It was 11 days in a year during the year 1981 and reduced to 9 days in 2017. The results reveal that the days with intense precipitation become less intense during this period for the catchment area. It is significant to note that the number of CDDs in the Palar sub-basin command area

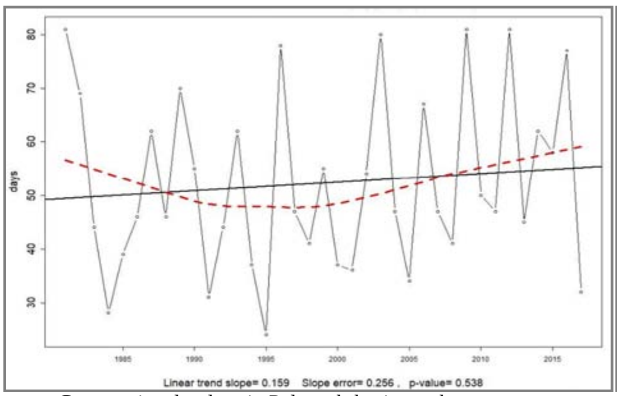
Consecutive dry days in Aliyar sub-basin catchment area



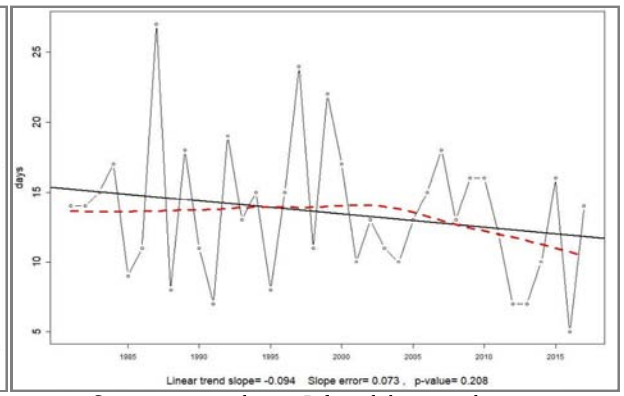
Consecutive wet days in Aliyar sub-basin catchment area



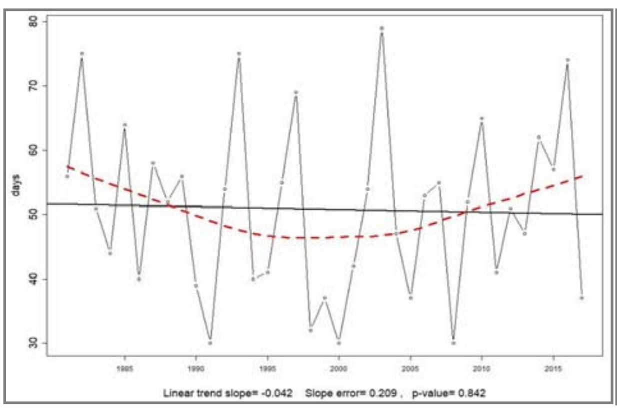
Consecutive dry days in Aliyar sub-basin command area



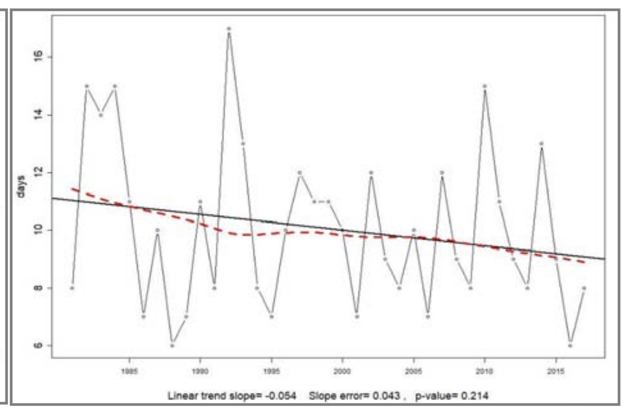
Consecutive wet days in Aliyar sub-basin command area



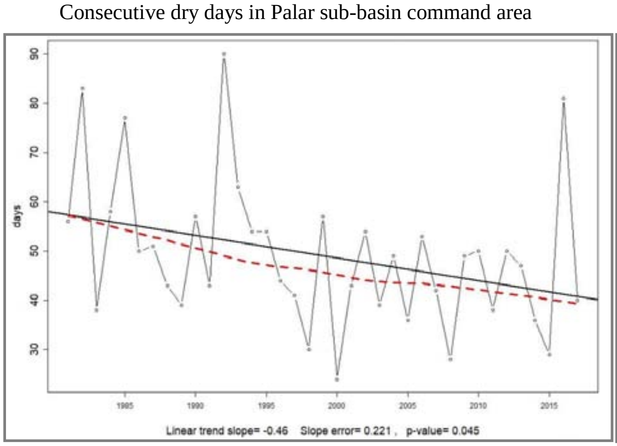
Consecutive dry days in Palar sub-basin catchment area



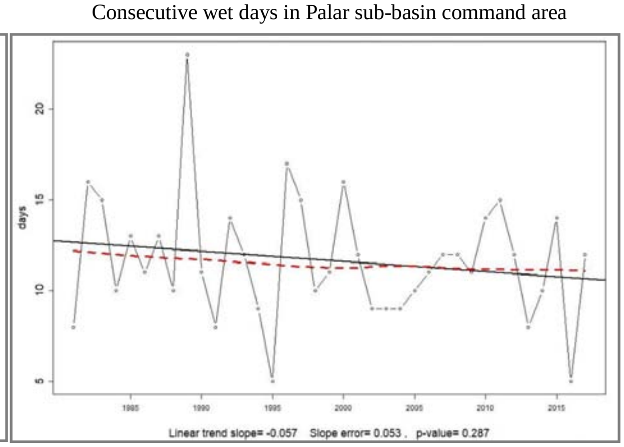
Consecutive wet days in Palar sub-basin catchment area



Consecutive dry days in Palar sub-basin command area



Consecutive wet days in Palar sub-basin command area



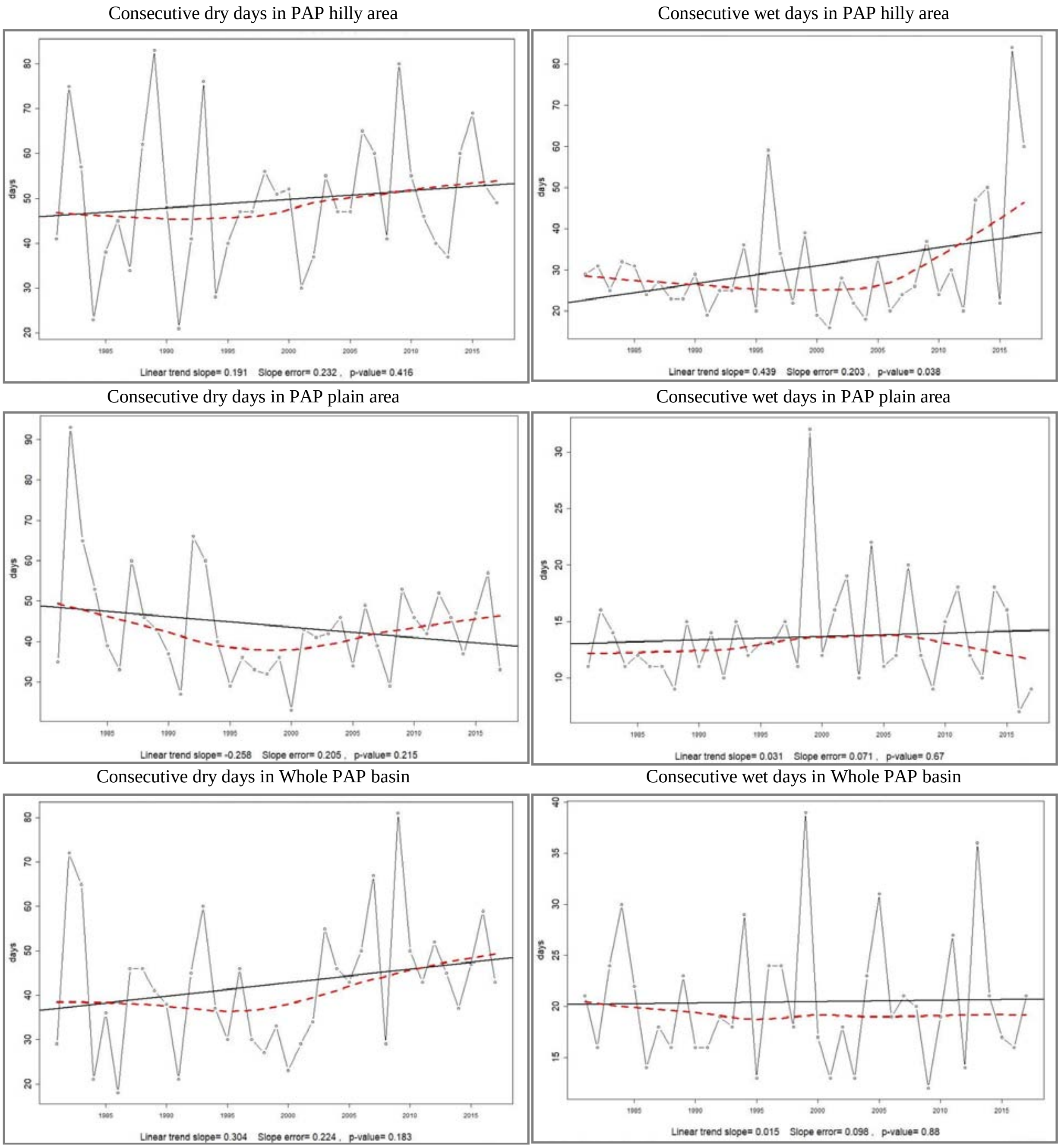
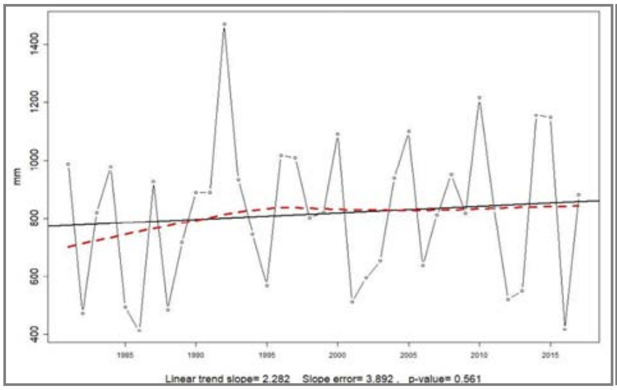


Fig. 2. CDD and CWD of PAP basin

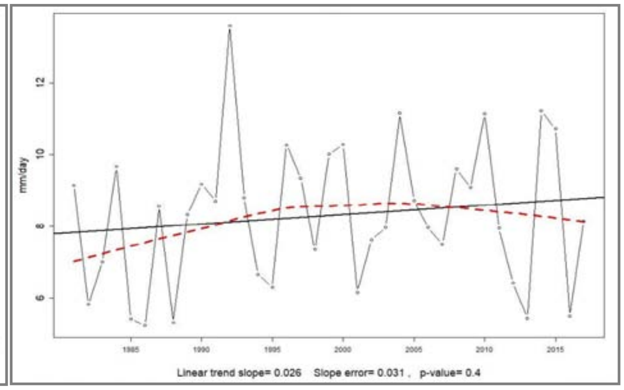
was declining for this period. The number of CDD in the year 1987 was 59 and it got reduced to 43 in the year 2017 with a statistically significant trend as the computed P value from the linear regression test was 0.045. However, the number of consecutive wet days in the Palar sub-basin command areas did not show any significant trend. This statement implies that the number of CWD remained relatively constant over the years.

The annual total precipitation (PRCPTOT) in the Palar sub-basin catchment and command areas exhibits a consistent linear trend over the study period. The precipitation totals in the Palar sub-basin catchment was found to be around 500 to 550 mm. Trend in the SDII showed slight upward movement. An upward trend in the SDPI during the period from 1990 to 2005 suggests an increase in precipitation relative to the long-term average.

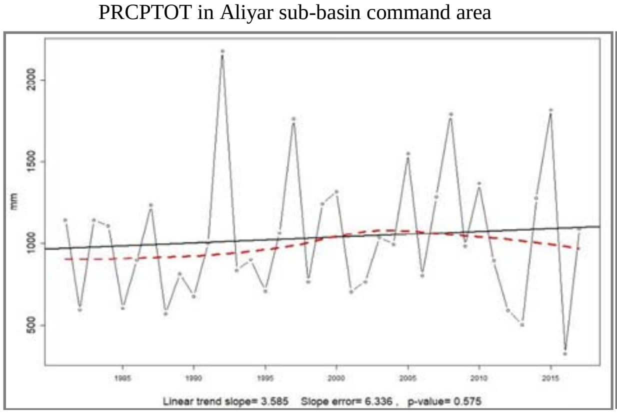
PRCPTOT in Aliyar sub-basin catchment area



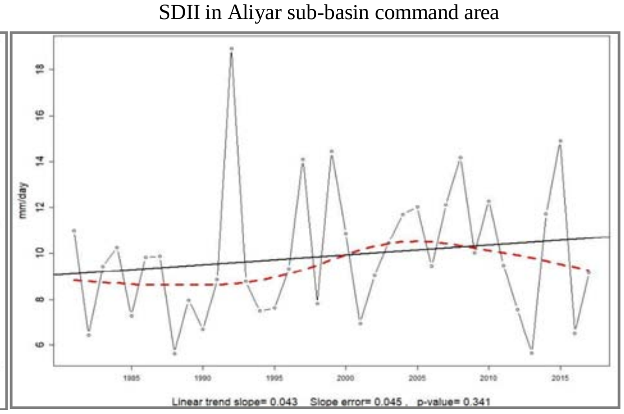
SDII in Aliyar sub-basin catchment area



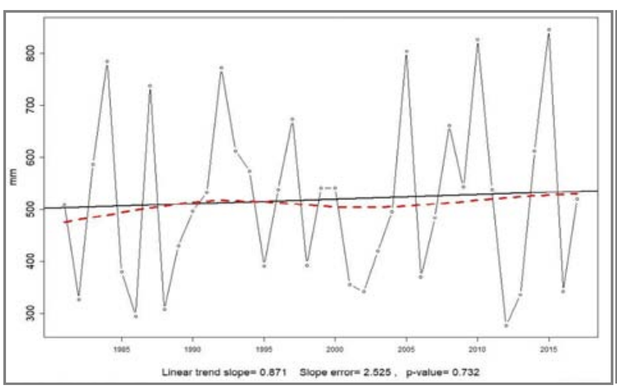
PRCPTOT in Aliyar sub-basin command area



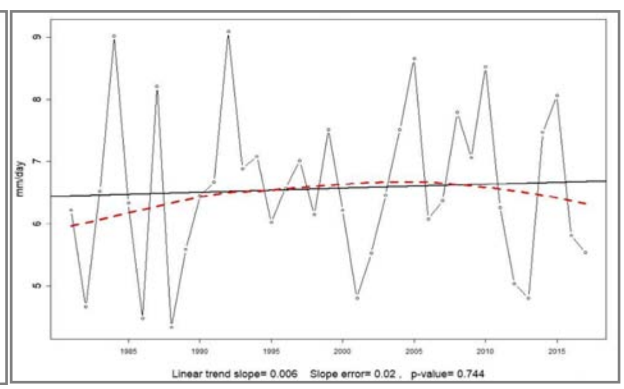
SDII in Aliyar sub-basin command area



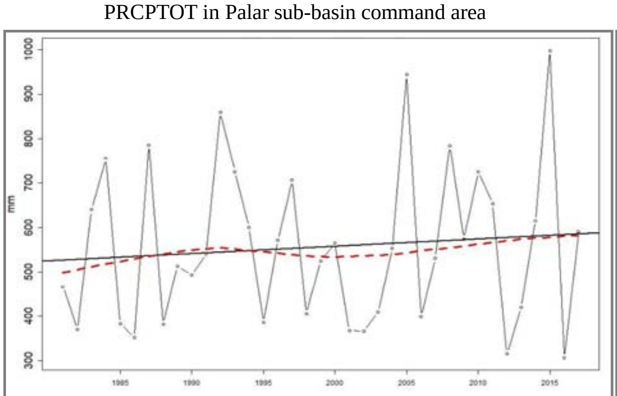
PRCPTOT in Palar sub-basin catchment area



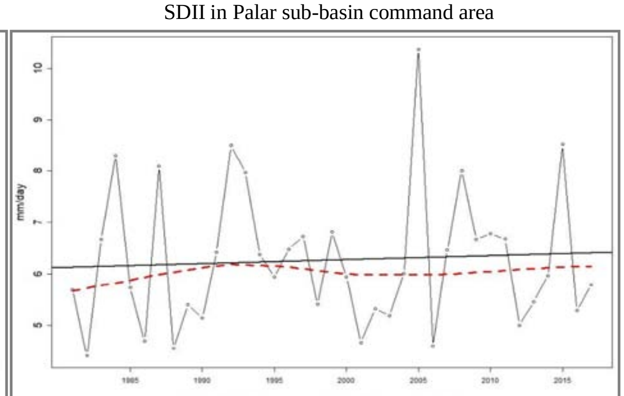
SDII in Palar sub-basin catchment area



PRCPTOT in Palar sub-basin command area



SDII in Palar sub-basin command area



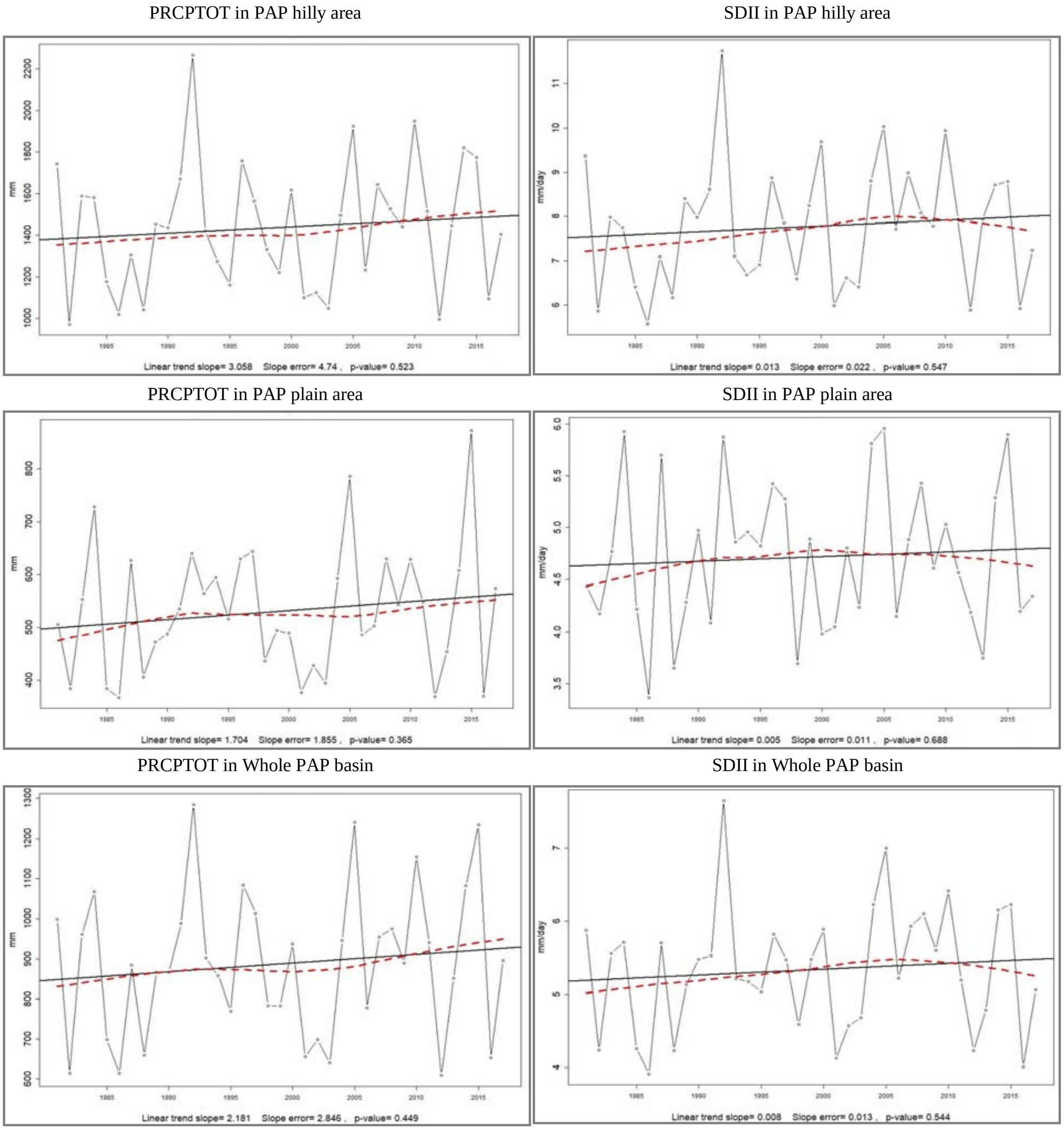


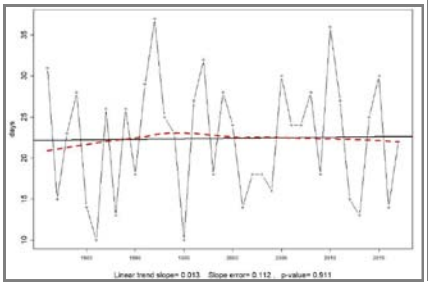
Fig. 3. PRCPTOT (Rainfall – total when rainfall >1 mm) and SDII of PAP basin

This trend could have significant implications for water availability, agriculture and ecosystem dynamics.

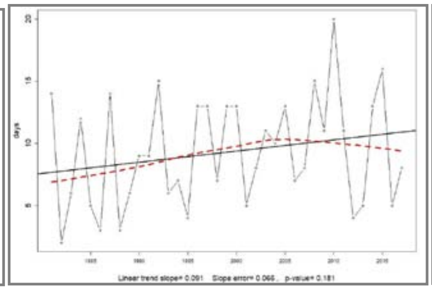
3.1.3. *PAP Hill area and plain region*

The results of the linear regression analysis shows that CDD did not show much increase. It was 46 days during 1981 which increased to 51 days in the beginning of rainfall. CWD over the catchment area shows a decreasing trend over the PAP hilly areas. However, the long time series trends of CDD are statistically non-significant. With regards to the consecutive wet days, PAP hill areas are showing a significant trend as the trend test shows a P-Value of 0.038 and an R^2 value of 0. 432. The increasing tendency of precipitation extremes such as consecutive wet days may impact the river flows and topsoil erosion over these areas. The long time series data shows that the number of CWD was 22 in the year 1981

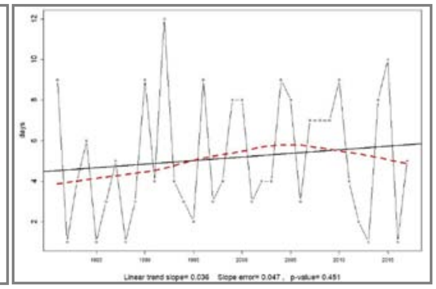
Annual count of days when PRCP >10mm in Aliyar sub-basin catchment area



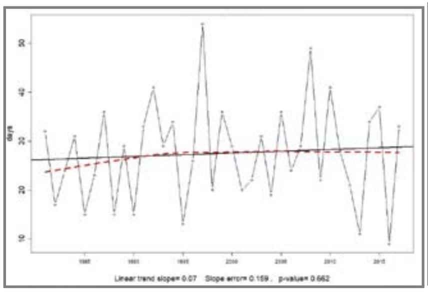
Annual count of days when PRCP >20mm in Aliyar sub-basin catchment area



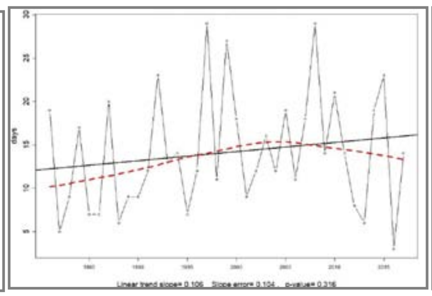
Annual count of days when PRCP >30mm in Aliyar sub-basin catchment area



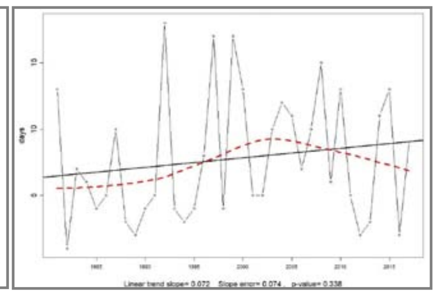
Annual count of days when PRCP >10mm in Aliyar sub-basin command area



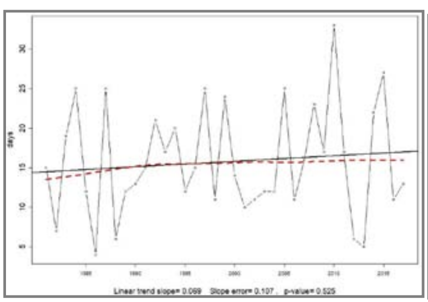
Annual count of days when PRCP >20mm in Aliyar sub-basin command area



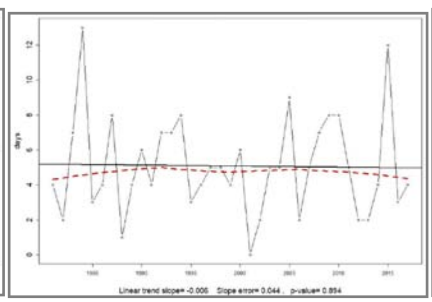
Annual count of days when PRCP >30mm in Aliyar sub-basin command area



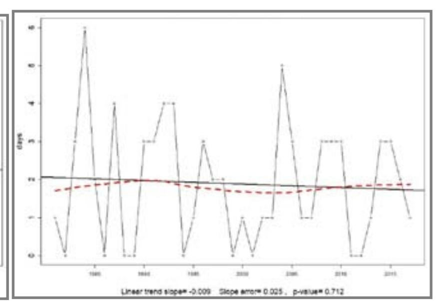
Annual count of days when PRCP >10mm in Palar sub-basin catchment area



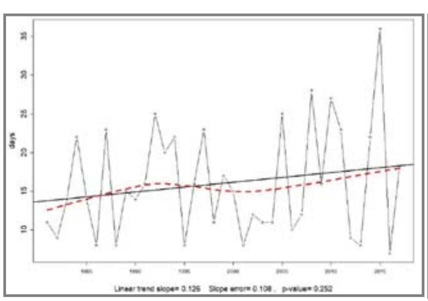
Annual count of days when PRCP >20mm in Palar sub-basin catchment area



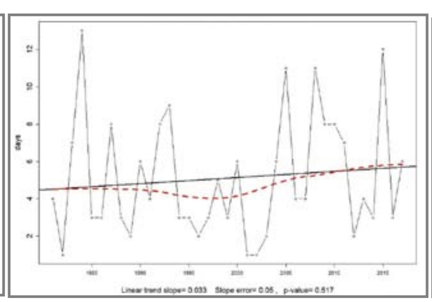
Annual count of days when PRCP >30mm in Palar sub-basin catchment area



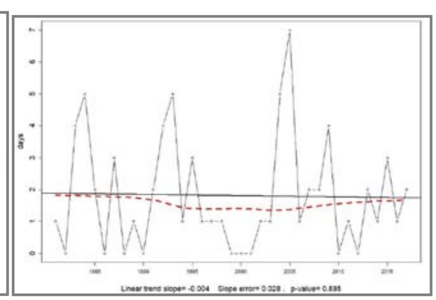
Annual count of days when PRCP >10mm in Palar sub-basin command area



Annual count of days when PRCP >20mm in Palar sub-basin command area



Annual count of days when PRCP >30mm in Palar sub-basin command area



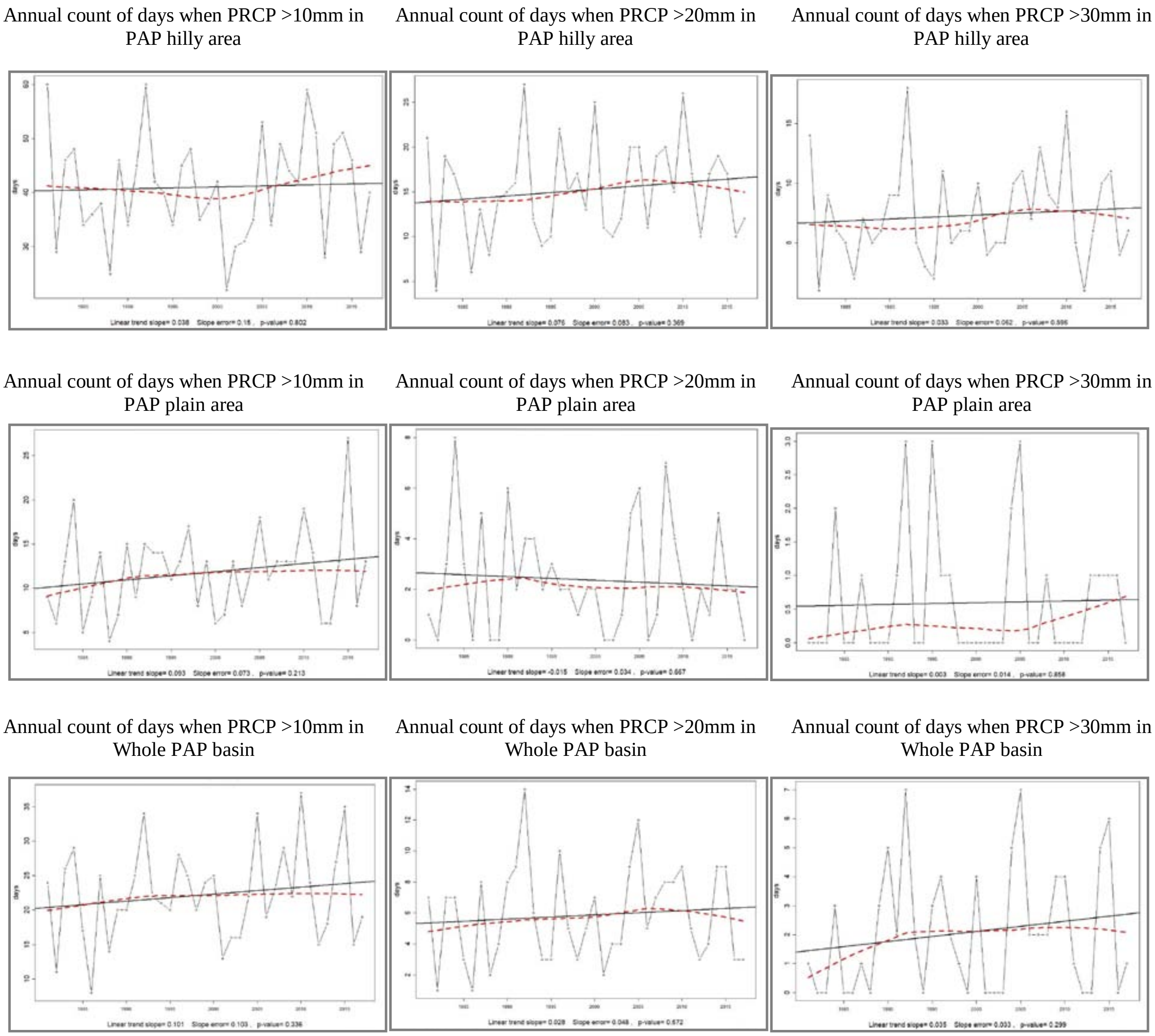


Fig. 4. Extremities on Rainfall (PRCP < 10mm, PRCP < 20mm, PRCP < 30mm) of PAP basin

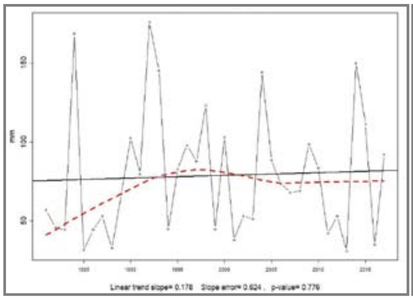
and has increased to 37 days by the year 2017. This could be due to the increase in southwest monsoon rainfall over the upper part of basin.

There is no trend noted in the consecutive dry days in the PAP plain region. The number of days with rainfall <1mm (CDD) is found to be around 13 to 14 days during the 37-year period. With respect to the consecutive wet days, plain areas of PAP showed a slight downward trend as the number of CWD days during 1981 was 49 and decreased to 41 days by the end of 37year period. In general, the Precipitation patterns are highly sensitive to changes in atmospheric conditions and local geography, which can result in regional variations. The PAP basin includes diverse landscapes of hilly and plains areas. These geographical variations can lead to different microclimates which results in different precipitation patterns. Hilly areas may receive more intense and variable rainfall due to orographic effects and convective clouds (Maheskumar *et al*., 2014), while plains may experience more stable conditions which receive less rainfall compared to hilly areas.

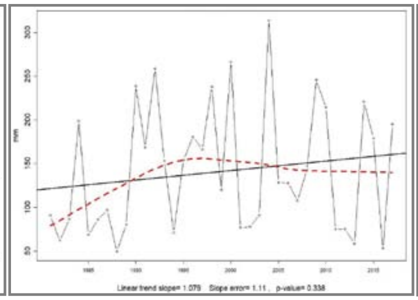
3.1.4. *PAP Whole basin*

In the whole PAP basin, an increase in trend in CDD is clearly seen during the analysed37 year duration. The total number of CDD days was 38 in 1981 and it tends to increase to 44 days during the year 1981. It can be noted that during the period 1990 to 2000, CDD was reduced.

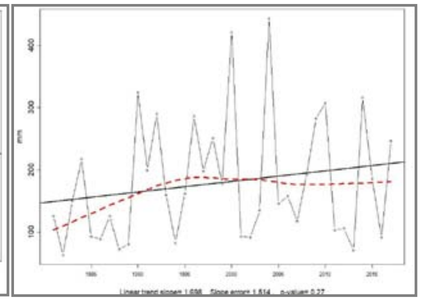
Annual maximum 1-day precipitation in Aliyar sub-basin catchment area



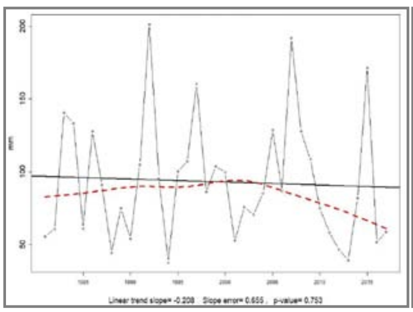
Annual maximum 3-days precipitation in Aliyar sub-basin catchment area



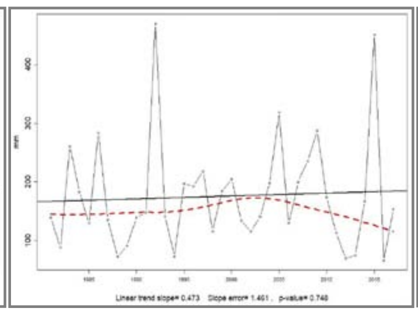
Annual maximum 5-days precipitation in Aliyar sub-basin catchment area



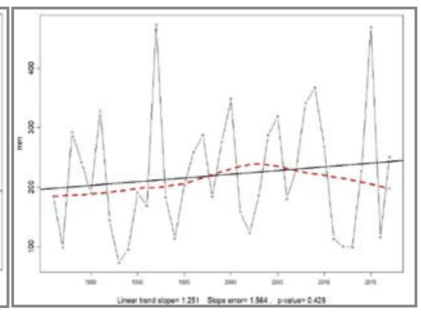
Annual maximum 1-day precipitation in Aliyar sub-basin command area



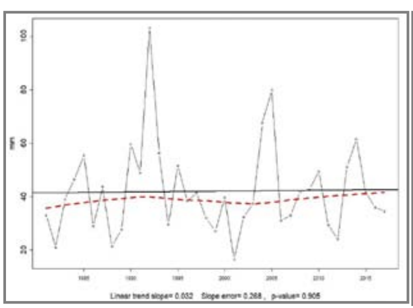
Annual maximum 3-days precipitation in Aliyar sub-basin command area



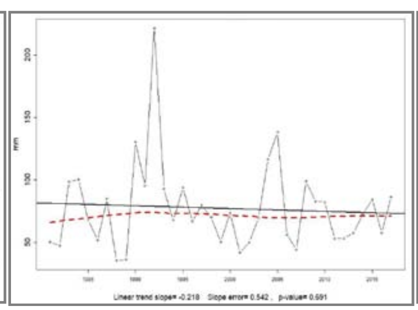
Annual maximum 3-days precipitation in Aliyar sub-basin command area



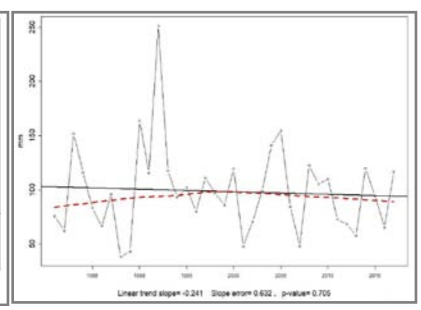
Annual maximum 1-day precipitation in Palar sub-basin catchment area



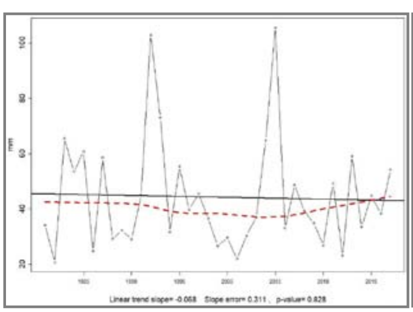
Annual maximum 3-days precipitation in Palar sub-basin catchment area



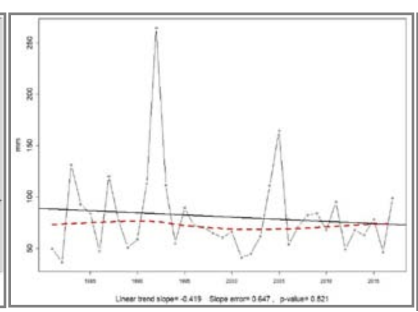
Annual maximum 5-days precipitation in Palar sub-basin catchment area



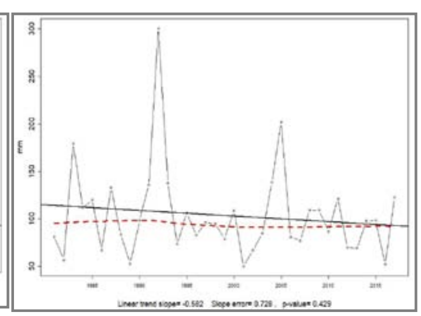
Annual maximum 1-day precipitation in Palar sub-basin command area



Annual maximum 3-days precipitation in Palar sub-basin command area



Annual maximum 5-days precipitation in Palar sub-basin command area



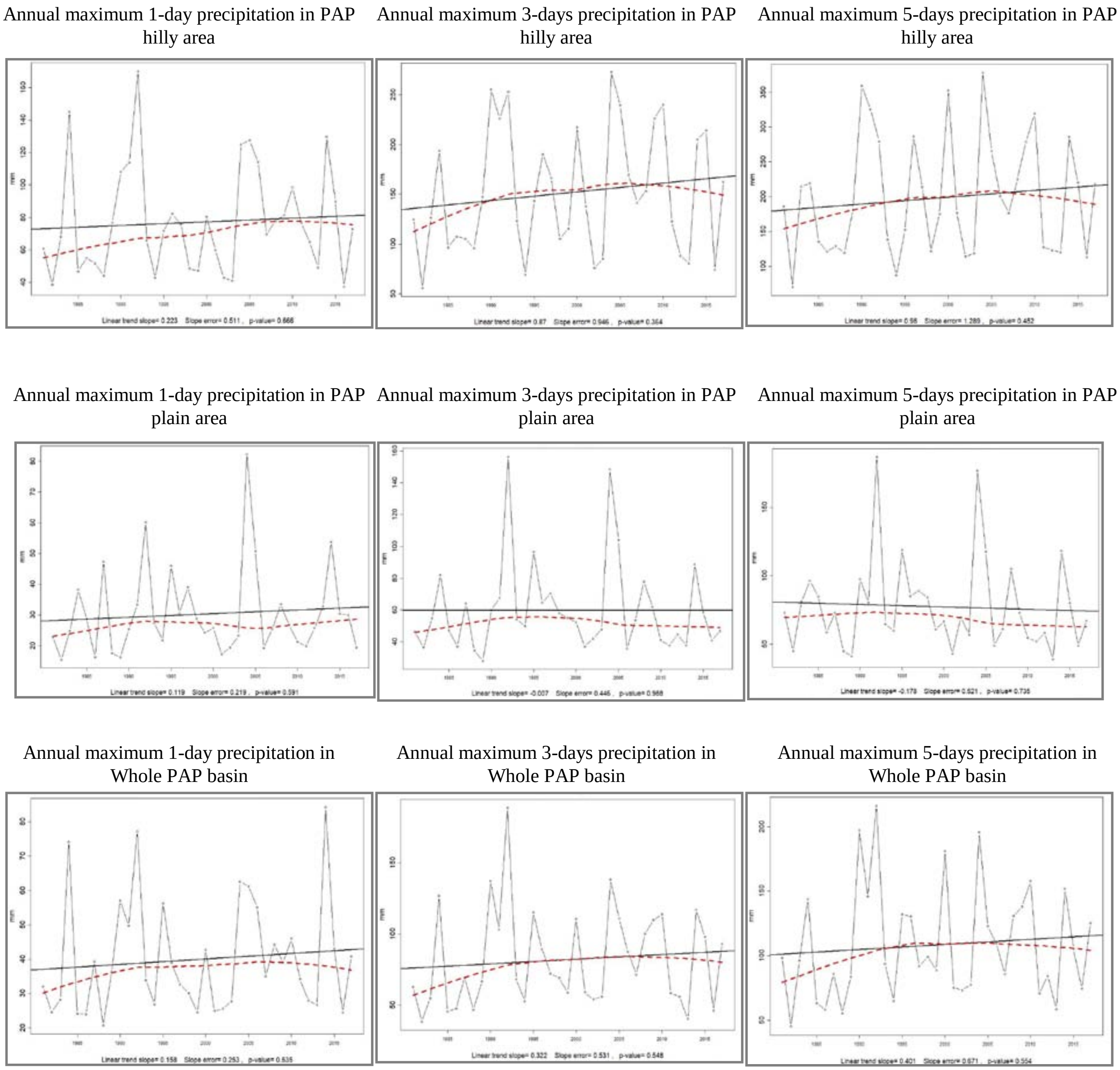


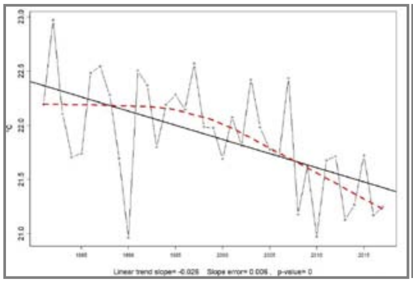
Fig. 5. Extremities on Rainy day (rx1day, rx3day rx5day) of PAP basin

However, from 2005 onwards, the dry days showed a remarkable increase. Consecutive wet days during the analysed period revealed no significant trend. CWD days remained around 20-21 days during the whole stretch of Fig. 2.

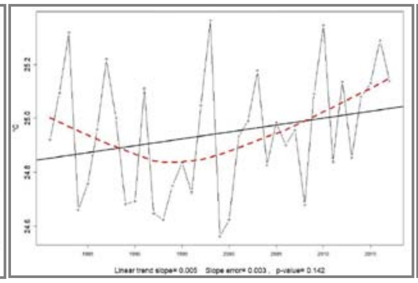
3.2. *PRCPTOT (Rainfall - total when rainfall >1 mm) and SDII) of PAP basin*

The annual precipitation totals in the PAP whole basin were found to be around 1400 to 1550 mm during the years 1981 to 2017. The trend in the simple precipitation intensity index (SDII) showed slight upward movement. The simple daily precipitation intensity index was 7 to 8mm / day with a slight upward trend. There is a huge variation noted in the PRCPTOT over the hilly areas and plain regions of the basin. The plain regions recorded only 500 to 550 mm of PRCPTOT rainfall, with a simple daily precipitation intensity index of 4.5 to 5 mm rainfall. PRCPTOT during the PAP whole basin shows no significant trend. The substantial differences in PRCPTOT between hilly and plain regions highlight the topographical influence on rainfall distribution within the basinClimate extreme indices events on PRCPTOT (Rainfall - total when rainfall > 1 mm) and SDII of the PAP basin are represented in Fig. 3.

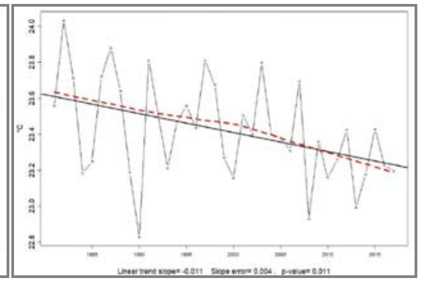
Annual mean daily minimum temperature of Aliyar sub-basin catchment area



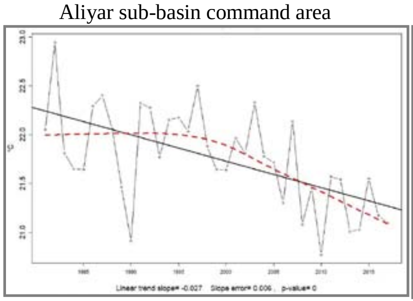
Annual mean daily maximum temperature of Aliyar sub-basin catchment area



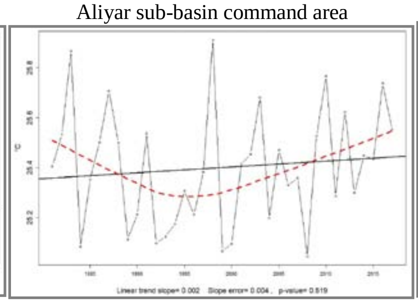
Annual mean daily mean temperature of Aliyar sub-basin catchment area



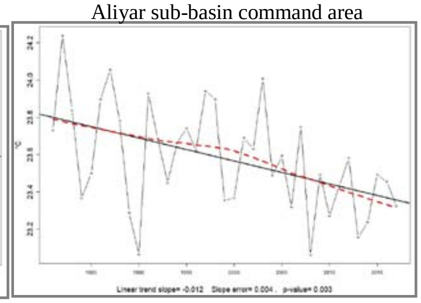
Annual mean daily minimum temperature of Aliyar sub-basin command area



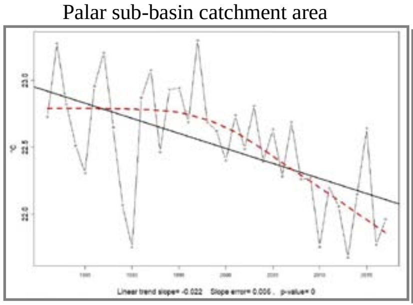
Annual mean daily maximum temperature of Aliyar sub-basin command area



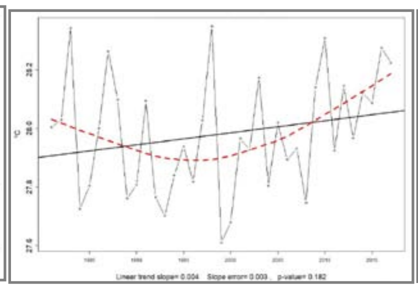
Annual mean daily mean temperature of Aliyar sub-basin command area



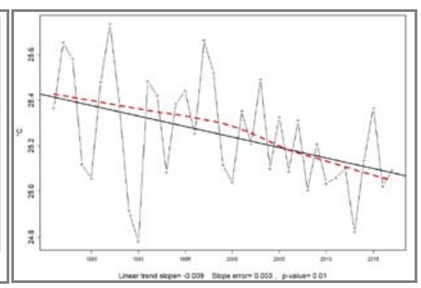
Annual mean daily minimum temperature of Palar sub-basin catchment area



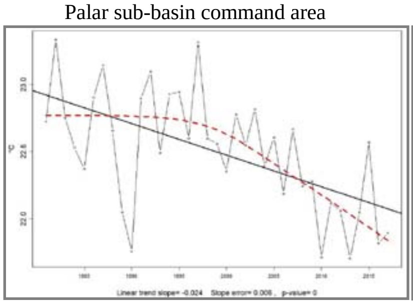
Annual mean daily maximum temperature of Palar sub-basin catchment area



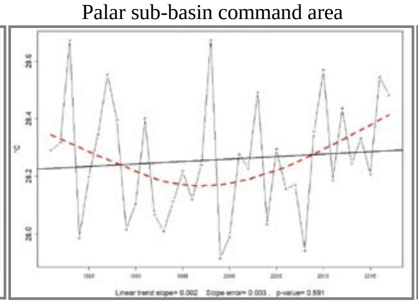
Annual mean daily mean temperature of Palar sub-basin catchment area



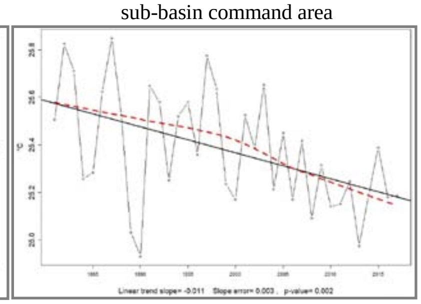
Annual mean daily minimum temperature of Palar sub-basin command area



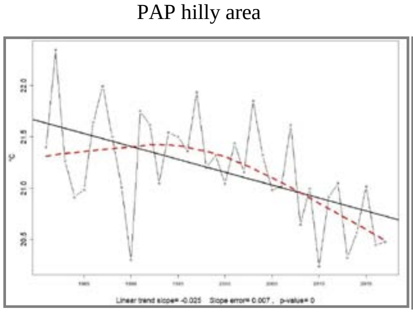
Annual mean daily maximum temperature of Palar sub-basin command area



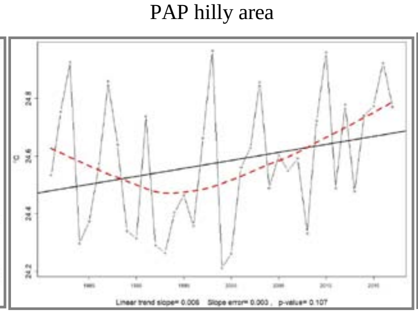
Annual mean daily mean temperature of Palar sub-basin command area



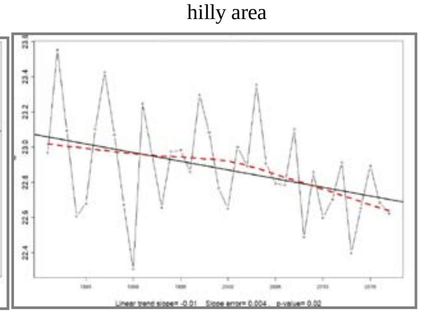
Annual mean daily minimum temperature PAP hilly area



Annual mean daily maximum temperature of PAP hilly area



Annual mean daily mean temperature of PAP hilly area



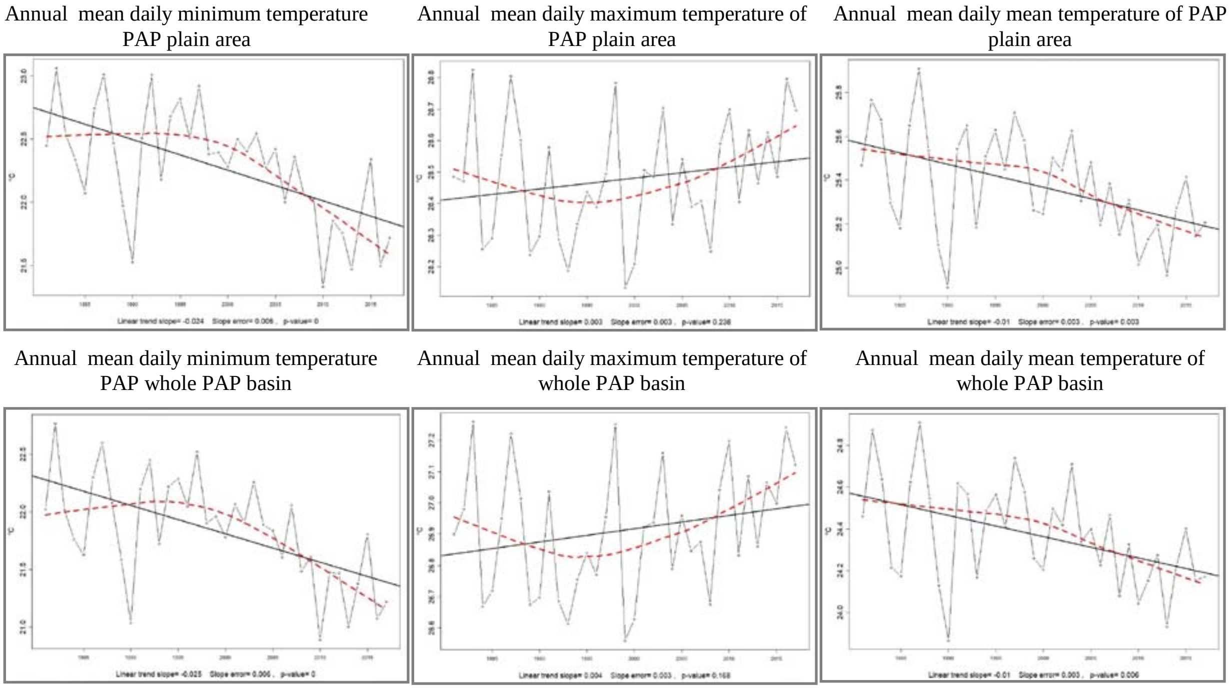


Fig. 6. Extremities on Temperature (txm, tmm, tnm) of PAP basin

3.3. *Extremities on Rainfall (PRCP < 10 mm, PRCP < 20 mm, PRCP < 30 mm) Rainy day (rx1day, rx3day rx5day) and Temperature (txm, tmm, tnm)*

The main objective was to analyse the Spatio-temporal variations in the temperature extremities in the PAP basin. Climate extreme indices like the annual count of days when PRCP < 10mm, PRCP < 20 mm, PRCP < 30 mm represented in Fig. 4, annual maximum 1-day precipitation, annual maximum consecutive 3-day precipitation and annual maximum consecutive 5-day precipitation are represented in Fig. 5. Annual mean daily mean temperature, annual mean daily maximum temperature and annual mean daily minimum temperature are represented in Fig. 6. These indices were calculated using RCl impact software on the 37 years daily temperature and precipitation data. As natural changes frequently occur in the climate systems, periodic analysis helps in understanding the current changes at a spatio-temporal scale. This long term time series analysis helps us in preparing long term water resources or crop cultivation planning etc. It helps in adaptation and mitigation strategies for areas that are both ecologically and economically significant.

3.4. *Aliyar Catchment and Command Areas*

Among all precipitation indices, annual maximum rainfall for 5 days, annual maximum rainfall for 3 days precipitation and Precipitation < 20 mm showed a maximum increase with Sen's slope estimator values of 1.6 mm/year, 1.07 mm/year and 0.09 mm/ year respectively in the Aliyar sub-basin catchment area. However, in the command area, only rx5day showed a major increase of 1.25 mm/year variation. This increasing trend indicates an increase in the intensity of extreme rainfall.

It is very interesting to note that annual mean daily mean temperature and annual mean daily minimum temperature showed a statistically significant downward trend, at a 5% level. The mean reduction in the mean daily temperature and mean minimum temperature as per the Sen's slope estimator stands at -0.011 °C / Year and -0.003 °C / year for Aliyar sub-basin catchment and -0.012 °C / Year and -0.003 °C / year for Aliyar command area. This shows a cooling trend in these regions, with nights becoming less warm in and around Aliyar. However, day temperatures showed a slight increase in both the catchment and command area, which could have implications for local climate and ecosystems.

3.5. *Palar catchment and command area*

Analysis of extreme precipitation indices showed negative trends for the Palar sub-basin catchment and command area. Except for r10mm indices and rx 1-day, all other indices showed a downward slope. The negative trend in the rx3day and rx5 day precipitation values ranged between -0.218 mm/year to -0.582 mm / year in the Palar sub-basin catchment and command area. It shows that the areas that have recorded a reduction in monsoon seasonal rainfall may have reductions in the extremities as well. Similar to the Aliyar sub-basin, a significant reduction in annual mean temperature and mean daily minimum temperature is observed in the Palar sub-basin as well. The estimated downward slope is - 0.009°C / year, -0.002°C / year in the catchment area, and -0.011°C and -0. 002°C / year in the command area respectively. Similar to Aliyar, maximum temperature showed a slight upward trend in both the Palar sub-basin catchment and command area. Furthermore, an increase in temperatures leads to increased evapotranspiration rates, which reduce surface water and dry out soils and vegetation. This phenomenon intensifies dry spells during periods of low rainfall and increases the chance of extreme drought frequency and severity (Dai, 2011, Vicente-Serrano *et al*., 2014) in the study area due to increased temperature or prolonged heatwaves (Hoy *et al*., 2017, Sedlmeier *et al*., 2018)

3.6. *PAP Hill, PAP Plain and Whole of PAP*

The spatial extent of the PAP hilly region and PAP as a whole showed a slightly rising trend in precipitation extreme events. However, in PAP plain areas, slight reductions were noticed in r20mm, rx3day, and rx5day precipitation indices. None of the rainfall indices showed a statistically significant trend. However, the annual mean daily mean temperature and annual mean daily minimum temperature showed significant downward trends. The rate of significant decrease observed in the temperature extremes, *viz*., tmm and tnm was estimated for PAP hilly areas as -0.01 °C / year and -0.003 °C / year, for PAP plain areas -0.01 °C / year and -0.002 °C / year and for the basin as whole it was, -0.01 °C / year and -0.002 °C / year respectively. However, all of these areas showed a slight increase in the daytime temperature.

4. Conclusion

The study reveals significant climate patterns across the PAP basin. In the Aliyar catchment area, the increasing trend of CDD suggests a heightened risk of drought occurrences, potentially impacting agriculture and water resources. Conversely, the declining CWD trend affects overall water availability and hydrological balance. Similar patterns are observed in the Aliyar command area, emphasizing the need for prudent water resource management. In the Palar sub-basin, CDD remains relatively stable over the 37-year period, while the declining CWD trend indicates less intense precipitation events. Notably, the PAP hilly areas experience a significant increase in CWD, which may impact river flows and soil erosion. Furthermore, the plain areas of PAP exhibit a slight downward trend in CWD, reflecting changes in precipitation patterns influenced by geography. Mean annual temperature and mean minimum temperatures show a cooling trend but an increase in day time temperatures in both Aliyar and Palar sub-basins. These variations in climate patterns underscore the importance of adaptation strategies for effective water resource management and flood mitigation.

Disclaimer : The contents and views presented in this research article/paper are the views of the authors and do not necessarily reflect the views of the organizations they belongs to.

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