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Research Article

AN ANALYSIS OF SPATIAL AND TEMPORAL VARIATIONS OF TASMANIAN STREAMFLOW

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ABSTRACT

The Australian continent experiences high interannual climate variability, particularly in precipitation and rainfall rates. The variability in inflow to dams and catchments observed in long time over Tasmania. The main objective of this study is to examine trends by using Mann Kendall's tau test in seasonal streamflow data of Tasmania. These results indicate that Tasmania is generally getting drier. Systematic patterns were found in the trends of mean seasonal streamflows of Tasmania. These trends might be a part of the result of a climate change. Precipitation is a significant but not the only cause of streamflow changes in Tasmania. This analysis provides clear understanding and existing relation relationship between rainfall and streamflow because rainfall is a chief integrator of runoff streamflow. It will beneficiary for socio-economic activities and forecasting in Tasmania.

INTRODUCTION

Water cycle is one the important components of nature that remains a source of fresh water for all living beings. Among its components, precipitation is the chief integrator of hydrological pattern of rivers. The precipitation is also varied by the orography of the region as it is observed that high altitude regions bear more precipitation. The western part of Tasmania, Australia received approximately 2000-3000 mm precipitation while in the midlands and eastern regions it approaches to 500-600 mm annually. The high mountains in the west of Tasmania, Australia, attract the precipitation systems and these systems increase the stream flow inexorably than the midlands and east-coast rivers [1]. [2] investigated Tasmanian precipitation and found a declining trend since the mid of 1970s.The trend reached its minima during autumn in the north at the east of the state.[3] investigated 222 high-quality stream gauging stations having 30 years or more continuous unregulated stream flow records in Australia, they found that most of the stations of northwest Tasmania showed significant decreasing trends and stations of southern Tasmania showed no trends in annual stream flow.

The agriculture industry is the important feature of the low lands in eastern Tasmania despite the sharp east-west gradient of mean annual precipitation and its variability over the state. According to [1,4] the east-coast lows bring wet conditions over the eastern Tasmania and the lows are important for agricultural industry in the region[5]. Post *et al*. (2012)[6] found that the average annual runoff over central and northeastern highlands of the state is subjected to a significant decrease by 2030.

Hydrological Patterns of Tasmania

The state comprises on 19 major river systems where the areas of river basins (Catchments) ranges from 685 to 11700 km^2. Figure.1 depicts the river system of Tasmania. The Tamar, Derwent and Gordan are major river systems of Tasmania. Runoff over Tasmania starts decreasing from mid of the 1970s and the annual runoff is projected to increase in the eastern part, lower Derwent valley, lower South Esk and lower Macquarie while decrease over central highlands river catchments by 21st century is expected [1]. Tasmania comprises on approximately 150000 km water channels, 94000 water

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bodies and 8800 wetlands (Australia Water Resources Assessment 2012). Many rivers over Tasmania are perennial except the rivers over the eastern coast.

Climate changes have severe impacts on stream flow variability and these lead to challenge water management bodies for agriculture and hydro-electricity generation in the state, mainly because stream flow changes more rapidly than the changes in precipitations. Figure 2 Illustrates annual standard deviation of stream flow observations over the period from 1951-2013. The positive values show above average stream flow observed over the central highland to southwest of the state. The eastern coast region receives low stream flow than the western part of the state. The Tamar and Dervent river catchments are the major rivers systems of eastern part of the state; experience less annual flow than the other catchments of the state.

The southernmost and the smallest state of Australia experiences a cool temperate climate. The diverse precipitation distribution provides high precipitation in the western highland while comparatively low precipitation in the low lands and the eastern plains. On average, the state receives more than 500 mm median precipitation. The highlands receive more than 1000 mm median precipitation while it happens uniformly over the southeast and the median accumulated total remains below 800 mm besides the northeastern highlands. Tasmania receives most of its rainfall during winter. The precipitation mostly follows seasonal regime while thunderstorms common in Tasmania occurs by coastal lows and crossing cold fronts (Australian Water Resources Assessment 2012).

Tasmania also get snowfalls over highlands which occurs during late winter and early spring. In this season many rivers that associated with high lands increase their flow. Figure. 3 depicts the seasonal stream flow trends over the period of 1951-2013. The seasonal stream flow shows mostly a declining trend which is observed in autumn (March-May). A slight increasing trend is observed in spring. The spatial distribution of autumn time stream flow from 1951 to 2013 is shown in Fig. 4 Clearly, it is also evident that the western mountains attract the precipitation systems and cause more stream flow in the western rivers of Tasmania.

DATA AND METHOD

An essential requirement for obtaining desired research objectives was procurement of appropriate and related datasets. This study incorporates the monthly rainfall and stream flow observations over the state and the same datasets over the continent of Australia obtained from BoM of Australia with resolution (0.05°longitude by 0.05°latitude) developed by BoM [7]. NCEP reanalysis data of global climate indices such as ENSO, SOI and large scale atmospheric variables such as vector wind, SST and monthly MSLP with a resolution of 2.5 were used to calculate three of the objective indices based on the defined methodology. The pearson correlation and multiple regression method are employ to explore the trends and behavior of hydrological patterns are carried out in this study.

RESULTS AND DISCUSSION

A declining autumn stream flow trend in Tasmania is shown in (Fig. 3) over the period 1951-2013. The nonparametric Mann-Kendall (Mann, 1945) trend test was applied over the autumn time stream flow. It was found that the declining trend in autumn time stream flow is statistically significant (at $p < 0.05$) while the trends in the other seasons of the state, shown in (Fig.3) are not statistically significant (at $p<0.05$). The Mann-Kendall trend test applied to the spatial autumn time stream flow. The results obtained from Man-Kendall trend test are illustrated in Fig. 5 The areas bounded by values below-1.96 are significant at 0.05 level of significance from 1951-2013.

To find the association of the autumn time decrease in stream flow, the stream flow over the state was spatially averaged. The obtained autumn time stream flow was correlated with climate parameters used in this study. It was found from the correlation analysis that the autumn time stream flow over the state is significantly associated ($p<0.05$) with COA indices namely, IOH_P, IOH_LN and IOH_LT. The results obtained from the correlation analysis are listed in the Table 1. From Table 1, the correlation between autumn time stream flow over Tasmania is inversely correlated with IOH_P and IOH_LN with magnitude -0.32 and -0.61 respectively. The negative correlation coefficients with IOH_P and IOH_LN characterized to the decline in the stream flow due to the increase in the intensities of mean central pressure as well as its longitude variations from west-east fluctuations over the subtropical ridge respectively.

The positive association between autumn time streamflow over the state and IOH_LT with magnitude 0.38 may be characterized to the wet conditions due to the mean central pressure fluctuations over the subtropical ridge with slight equator-ward shifts during the autumn months. These fluctuations favor the low pressure systems from the south of 50 degrees of the subtropical ridge which may be conducive to the wet conditions over the state. It is also important to note that there is a weak relationship between IOH_P and IOH_LN with correlation coefficient 0.27 and for this reason these two predictors may be considered, to some extent, as independent variables.

The Figure 6 depicts the spatial distribution of the correlation coefficient between the autumn time stream flow over the state with the autumn time IOH_P and autumn time IOH_LN. The distribution of correlation coefficient indicates the influence of IOH_P and IOH_LN over the autumn time stream flow for the period from 1951 to 2013. The IOH_P is apparently more associated with the decline of stream flow over the western part of the state (Fig. 6a). In general, from the comparison of the Fig.6 (a-b) it is observed that IOH_LN's signature is apparent over the whole of the state's stream flow. It is observed from Fig 6 that the autumn time stream flow over the state is being considerably influenced by the zonal (longitude)variations of the IOH pressure system.

The above observations lead the analysis to quantify the stream flow by using multiple regression against IOH_P and IOH_LN indices, and derive the following relation:

Tasmania Streamflow (Mar-May) = 6429.27 -5.8* (IOH_P) - 3.87* (IOH_LN)

The multilinear regression result is depicted in (Fig. 7) which explains 38.75% of the stream flow variance. As might have been expected, however, the regression model for the most part underestimates the magnitudes in extreme stream flow years.

Fig. 7 suggests that the declining trend in the stream flow over the state is dominated by the increase in IOH_P, and its west to east fluctuationsin longitude positions contribute to the decline in stream flow over the state. Mann-Kendall trend test also shows that there is no significant increase in the IOH_LT (at $p<0.05$) while IOH_P and IOH_LN are significantly increased at 0.05 statistical level.

CONCLUSION

The increase in the intensities and expansion in the IOH_P suggest that the strengthening at the multi-decadal scales of the Indian High pressure system may be due to an increase in subsidence related to the Hadley Circulation. The obtained result agrees with the recent work done by (Grise *et al*. 2018) which shows that the intensification in the Hadley circulation is statistically significant throughout the second half of the 20th century. Nguyen *et al*. (2013) found that the rate of the expansion in Hadley circulation is 0.55° per decade and is significant during summer and autumn over each hemisphere during 1979 to 2009.

In above analysis, the variability in autumn time stream flow over Tasmania is discussed from 1951 to 2013. The decline in stream flow over the region is found significant in autumn than other seasons. The decline in autumn time stream flow is significantly associated with IOH pressure system over subtropical high pressure belt. This association is revealed in two ways, the intensities of IOH pressure system as well as its longitude positions over the subtropical high pressure belt. The increase in intensities of IOH is responsible to maintaining dry conditions over the state whereas the increase in the longitude positions holds the high pressure systems mostly to the west coast of the state. In this way, the high pressure system mostly remained near to the west coast of the state throughout time. For this reason, not only the intensities but also the zonal movements of the IOH pressure system contributes to the decline in autumn time stream flow over the state from 1951 to 2013.

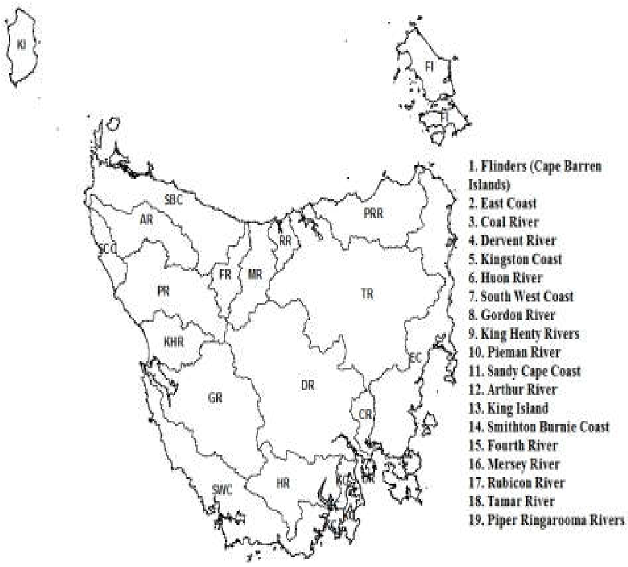

Fig 1 The geographical locations of drainage divisions of Tasmania

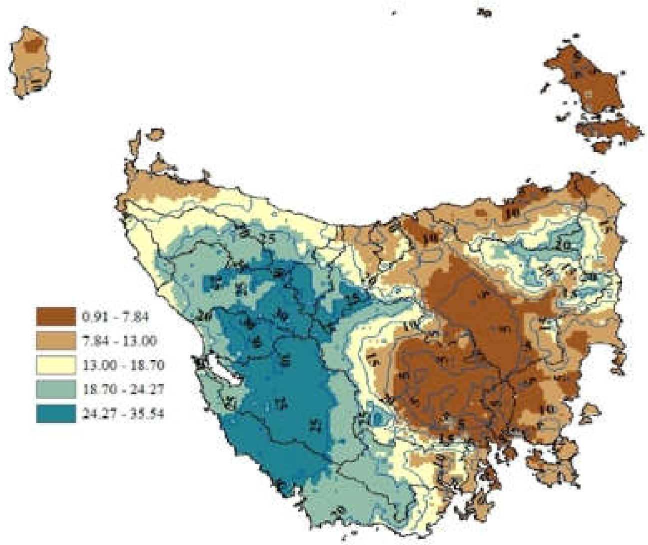

Fig 2 Annual standard deviation of stream flow (mm) over Tasmania (1951-2013)

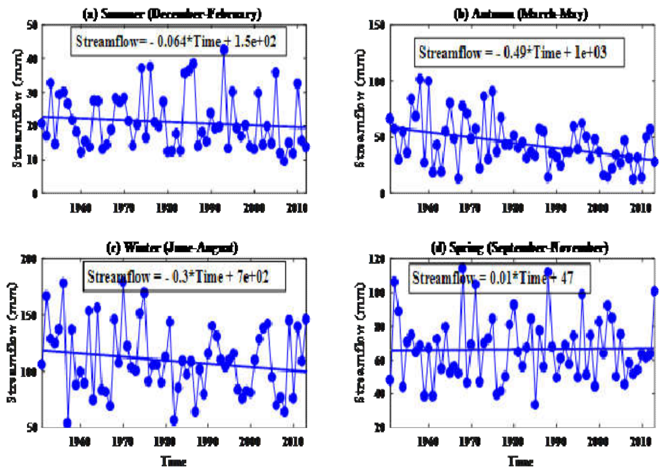

Fig 3 Seasonal stream flow analysis over Tasmania (1951-2013) for (a) Summer (December-February), (b) Autumn (March-May), (c) Winter (June-August) and (d) Spring (September-November)

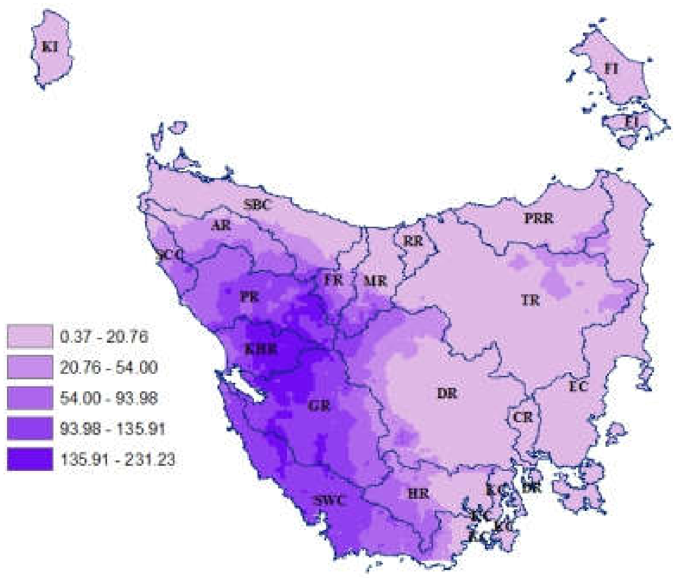

Fig 4 Average autumn (March-May) Stream flow distribution over Tasmania (1951-2013)

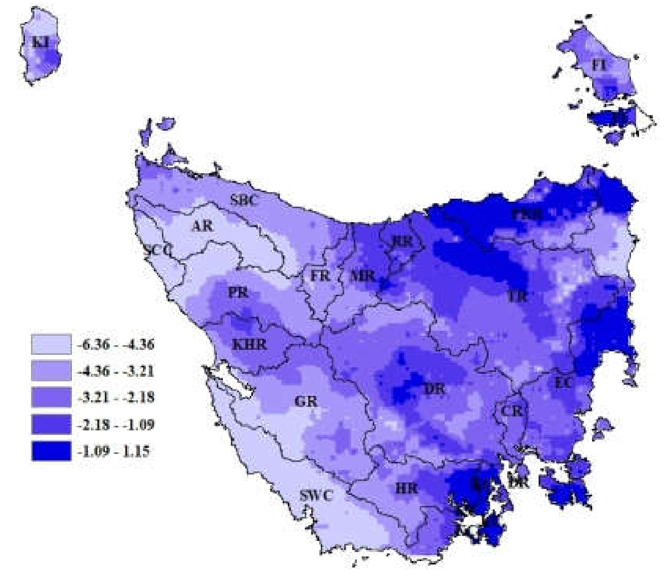

Fig 5 Depicts the Mann-Kendall trend test results for autumn stream flow, areas bounded by values below-1.96 are significant at 0.05 level of significance from 1951-2013

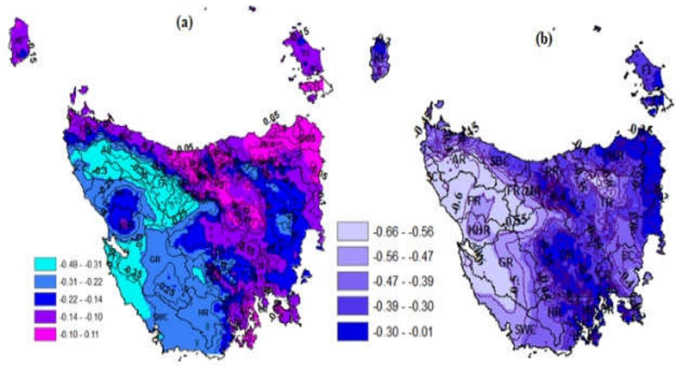

Fig 6 (a) The spatial distribution of correlation between Tasmanian autumn time stream flow and autumn time Indian Ocean High Pressure (IOH_P) from 1951 to 2013; (b) the same for Indian Ocean High Longitude (IOH_LN)

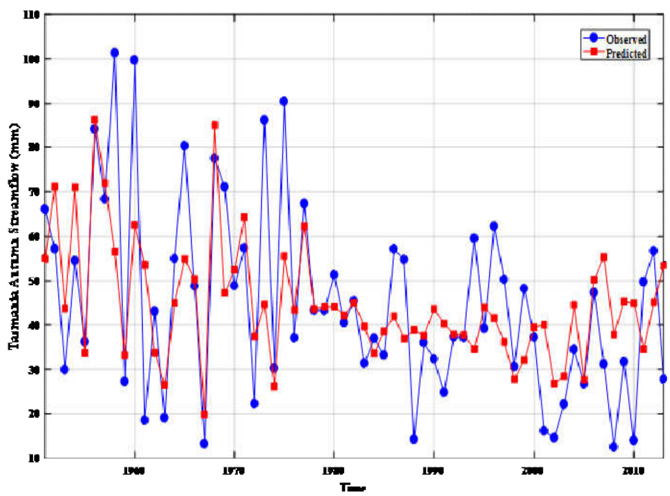

Fig 7 The comparison between observed autumn time stream flow (mm) and predicted autumn time stream flow (mm), obtained from the multi-linear regression model with IOH_P and IOH_LN as predictors from 1951 to 2013.

Table 1 The correlations of Tasmania autumn stream flow among the autumn time climate variables (1951–2013). The values significant at 95% statistical levels are shown in bold

Predictors	Tasmania stream flow
Time	**-0.42**
Nino3	-0.13
Nino3.4	-0.05
Nino4	-0.07
MEI	-0.09
SOI	0.12
SAM (1951-2011)	-0.13
IOD	-0.19
IOH_P	**-0.32**
IOH_LN	**-0.61**
IOH_LT	**0.38**
IOH_P and IOH_LN	**0.62**

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