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Rainfall Trend Analysis and Adaptation Strategies to Manage Climate-Induced Crisis in Coastal Zone of Karnataka, India

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Authors' contributions

This work was carried out in collaboration between all authors. All authors read and approved the final manuscript.

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ABSTRACT

Analysis of deviation of precipitation in space, time and quantities, and its associated effect on the ecology is vital in coastal environments where the resource is highly variable and unpredictable. The present study is mainly concerned with the changing trend of rainfall and adaptation in a coastal region of Karnataka. This study is an effort to analyse one of the most important climatic factors i.e. rainfall, for analysing the trend for the area. Weekly rainfall data of 34 years from 1980 to 2013 has been processed in the study to find the seasonal and annual rainfall pattern using Mann-Kendall (MK) Test and Sen's Slope estimation. Decreasing trend in annual rainfall was observed in Dakshina Kannada (-3.2 mm/yr.), whereas increasing trend was found in Udupi (4.9 mm/yr.) and Uttara Kannada (13.0 mm/yr.). In seasonal trend analysis of rainfall, a non-significant increasing trend is observed for winter, summer, and post-monsoon in all the three districts. While decreasing trends in monsoon rainfall are noticed in Dakshina Kannada (-7.1 mm/yr.) and Udupi

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(-1.8 mm/yr.). Its need to adapt to changing rainfall patterns brought about because of climate change, as water is the most vital element for farming. Adaptation strategies of farmers to agricultural crop production, soil and water conservation and flood management were analysed. The majority of the big farmers have adopted best coping mechanisms than small and marginal farmers as they have comparative advantages.

Keywords: Adaptation; climate change; crop; Mann-Kendall; rainfall; trend.

1. INTRODUCTION

Climate variability is a key element influencing the agricultural and fishery productivity in a coastal area. The amount, spreading and intensity of rainfall mainly decide the choice of any particular crop practices and fishing activity. The relevant study of the quantum and distribution of precipitation if made would enable the farming community to adjust or adapt the cropping system as well as the cultural operations for cost-effective and sustainable crop production. Precipitation is a massively dynamic phenomenon and changing its intensity, occurrence, and interval with an effect of geographical parameters such as altitude, flora-fauna, land-use cover, and several factors. In west shoreline, coastal region of Karnataka is one of the foremost centers of action of all-pervading precipitation [1]. The coastal Karnataka exhibits a high longitudinal and temporal erraticism of rainfall, which is on the upwind side of the mount range and dense forest (flora) of Western Ghats. Typically, this region receives heavy precipitation due to orographic effect [2]. More than ninety percent of the rain drains the coastal area by dropping moisture content carried from the Arabian Sea through the southwest monsoon. In, Whole, the interface of zone receives intense precipitation, and it decreases significantly as moves towards the inland area. The amount of high altitude is well spread in the coastal area of Karnataka. In the rainy season from June to September, an intra-seasonal trend of precipitation over coastline fluctuates between active spells with dense rain and weak spells with little or no rainfall. Daily rainfall exceeding 150 mm over coast is one of the main challenges for regular activity [3].

Near future, it is expected to reduce the efficiency of paddy production by 4 percent in most of the areas in the coastal regions. However, irrigated paddy in portions of south Karnataka and north-most districts of Kerala is likely to increase. On rain-fed paddy production, all areas in the region are likely to drop yields by 9-10 percent. The results thus indicate that irrigated paddy production may benefit due to carbon dioxide fertilization consequence as related to the rain-fed paddy production, which is provided with a low quantity of fertilizers [4].

The western coast projection indicates that in 2030’s the annual precipitation will diverge from 935± 185.33 mm to 1794±247.1 mm. The tendency of precipitation in 2030’s is an increase on the 1970’s in the coastal region as well. The intensification in precipitation is nearly 6 to 8 percent, an increase that is stretching from 69 to 109 mm. However, June, July, and August show an average increase of 8 mm precipitation in 2030’s on 1970’s. However, the wintertime precipitation is expected to shrinkage by on an average by 19 mm during the period January and February in 2030’s concerning to 1970’s. The period March, April, and May also show a reduction in rainfall on 1970’s [5].

Climate change will have adverse effects on the ecology, on socio-economic and other related sectors, comprising marine resources, farming, fishery, food and nutrient security, human health, ecosystems, biodiversity and coastal zones. Variations in precipitation pattern are likely to lead to severe water shortages and flooding. Melting of glaciers can affect flooding and soil erosion. Adaptation is managed through which societies make themselves enhanced to cope with an uncertain forthcoming [6]. Adjusting to climate change involves taking the right actions to reduce the adversarial effects of climate change by building the suitable modifications [7]. There is a large diversity of farming practices because of the range of climate and other ecological factors; social, cultural, psychological, traditional, institutional, economic factors; and their connections. Means there is a congruently extensive collection of possible adaptation options. With this background, the objectives of this paper are first to analyse the change in rainfall pattern over the years and adaptation strategies adopted by the different categories of farmers on agricultural practices, soil and water conservation, and flood management.

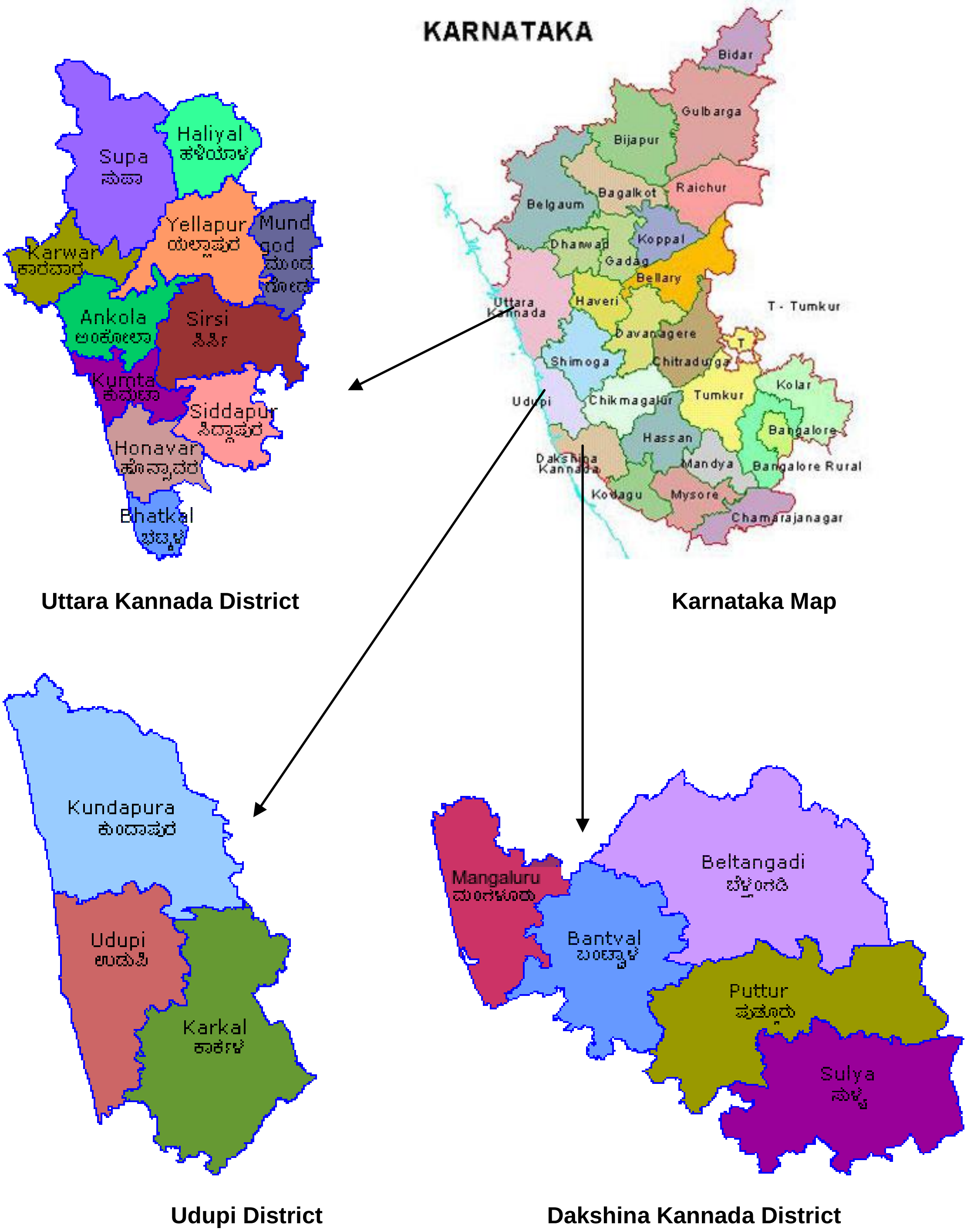

Fig. 1. Selected districts and taluks for the study

2. MATERIALS AND METHODS

2.1 Study Area

The investigation was conducted for Dakshina Kannada (12.87°N 74.88°E), Udupi (13.3389°N 74.7451°E) and Uttara Kannada (14.6°N 74.7°E) districts of Coastal (Zone-10) Karnataka (Fig. 1). The study region is characterized by high and erratic rainfall and warm temperature (Table-1), with low to average productivity in both Agriculture and fishery. The districts were purposively selected to represent coastal zone. The coast stretches for 320 km along the three districts. Of these Uttara Kannada has 160 km spread coastline while 98 km is in Udupi district and the rest *in Dakshina Kannada. Three diverse agro-climatic zones are ranging from coastal flatlands in the west with* undulating hills in the middle, and high hill kinds in the east that separate from the peninsula.

2.2 Survey Data

2.2.1 Adaptation

Two coastal taluks were selected from each district, four villages were randomly chosen from each of the selected taluks, and ten fisheries based marginal, small and big farmers were selected from each of the villages by applying proportionate random sampling technique. Thus, totally 240 fisheries based farmers from 24 villages have been selected for the survey. Ex-post-facto research design was followed for the study. Data were collected during January-February 2015 through farmer interviews using structured household questionnaires. The household interviews were held with the key decision-maker within the family, especially on crop production, soil and water conservation and flood management.

2.2.2 Rainfall

The data used in this study are weekly averages during 1980-2013. The seasonal and annual averages were calculated from the weekly readings, which are provided by the Department of Agricultural Meteorology, University of Agricultural Sciences, Bangalore.

The method applied in this study is trend analysis using the non-parametric statistical tests i.e. the Mann-Kendall test and Sen's Slope estimator on the seasonal and yearly rainfall data of the coastal region for 34 years. Usually, non-parametric tests are preferred over parametric tests because; non-parametric ones can evade the problems aroused due to data skew. The Mann-Kendall test is universally used test for trend analysis of any hydro-climatic series for testing spatial variation and temporal deviance.

Both Mann and Kendall developed this formula i.e [8] formulated it as a non-parametric test to notice trend whereas Kendall [9] gave the test statistic distribution to test non-linear pattern and turning point. Sen's Slope estimator is also used to regulate the magnitude of the trend. Sen [10], in which slope of data pairs are to be utilized to detect the pattern, formulated this.

2.2.3 The mann-kendall test

In Mann-Kendall statistic S is

$$S_0 = \sum_{k=1}^{N-1} \sum_{j=k+1}^{N} sign(x_j - x_k) \tag{1}$$

The presentation of trend test is prepared to a time series x_k is ranked from k=1, 2,……, n-1 & x_j, which is ranked from j = k+1,2, …… n. Every of the data point x_k is taken as a benchmark, which is, compared to the rest of the data point's x_j,

$$\operatorname{sgn}(x) = \begin{cases} +1, & x > 0 \\ 0, & x = 0 \\ -1, & x < 0 \end{cases} \tag{2}$$

For n > 8, S follows nearly Normal distribution with mean i.e.

$$E(S) = 0, \tag{3}$$

The variance statistic is known by,

$$\operatorname{Var}[S] = \frac{\left\{ n(n-1)(2n+5) - \sum_{j=1}^{p} t_j(t_j - 1)(2t_j + 5) \right\}}{18} \tag{4}$$

Where t_i is measured as the number of ties up to sample i

The test statistics Z (Mann-Kendall Coefficient) is computed as,

$$Z = \begin{cases} \dfrac{S-1}{[\operatorname{Var}(S)]^{\frac{1}{2}}} & \text{if } S > 0 \\ & \text{if } S = 0 \\ \dfrac{S+1}{[\operatorname{Var}(S)]^{\frac{1}{2}}} & \text{if } S < 0 \end{cases} \tag{5}$$

Z follows a standard normal distribution. A positive and negative value of Z specifies an upward trend and downward trend, respectively.

2.2.4 Sen's slope estimation

For precipitation trend analysis, this approach is most accepted than least square method. If a linear trend is present in a time series, then the true slope can be estimated by using a simple non-parametric process developed by Sen [10]. The Sen's estimator predicts the magnitude of the trend.

$$Q_i = \frac{x_i - x_k}{i - k} \tag{6}$$

Where X_i and X_k are conforming data values at time i and k and i >k. The median of the N values of T_i is represented as a Sen's estimator of the slope, which is given as:

$$Q_i = \begin{cases} Q_{\left[\frac{n+1}{2}\right]}; & If\ N\ is\ odd \\ \frac{1}{2}\left(Q_{\left(\frac{N}{2}\right)} + Q_{\left(\frac{n+2}{2}\right)}\right); & If\ N\ is\ Even \end{cases} \tag{7}$$

A positive value of Q_i indicates an increasing trend whereas a negative value indicates a decreasing trend in the rainfall data.

3. RESULTS AND DISCUSSION

3.1 Trends in Annual Rainfall

The study area lies west to the Western Ghats having per-humid climate according to Thornthwaite's climatic classification. About 85-90%, rainfall occurs in monsoon season. Fig. 2. represents the annual rainfall of Dakshina Kannada, Udupi, and Uttara Kannada districts of coastal Karnataka for 34 years with maximum rainfall occurrence in the year 1994, 1994 and 1990 with the total precipitation of 5167 mm 5318 mm and 4223 mm, respectively. Minimum rainfall has occurred in the year 1987, 1987 and 1986 with the around 2889 mm, 3498 mm and 2556 mm, correspondingly. Average rainfall for these 34 years is 3879 mm, 4388 mm and 3417 mm, respectively. The Sen's slope (Q) for 34 years showing rising slope in Udupi (4.9 mm/yr.) and Uttara Kannada (13.0 mm/yr.), although a non-significant one. In Dakshina Kannada (-3.2 mm/yr.) shows the non-significant decreasing trend (Fig. 2). From this, it may be determined that mean annual rainfall has reduced from 1980 to 2013 for the two districts and is expected to follow the same trend in the future. As all three districts are of coastal landscape with few water storage facilities, water availability for agriculture is a major concern as it floods in some places and droughts in another area of the same districts. Various studies have attempted to determine the trend for different spatiotemporal scales and reported similar results. Sarangi and Kumar [11] in New Delhi and Soman [12,13] also observed decreasing trend in the mean annual rainfall for stations in the Kerala.

3.2 Trends in Seasonal Rainfall

Table 2 depicts the trends in seasonal rainfall patterns for winter, summer, monsoon and post monsoon seasons. The non-significant increasing trend is observed in winter, summer and post-monsoon of all the three districts, while monsoon rainfall shows an increasing trend in Uttara Kannada district (8.6 mm/yr.) of the coastal region. A non-significant decreasing trend in monsoon rainfall of Dakshina Kannada (-7.1 mm/yr.) and Udupi district (-1.9 mm/yr.) over the period 1980 to 2013 (Fig. 3, Fig. 4 and Fig. 5). Maximum monsoon rainfall received at Udupi district (4728 mm) during 1994. In post-monsoon season, determined precipitation has been observed in Dakshina Kannada (784) for the period of 2010. Highest winter and summer precipitation was noticed in Dakshina Kannada (78.1 mm and 533 mm) for the period of 1997 and 2004, respectively. The variation in rainfall is a maximum for Dakshina Kannada district in monsoon season. In the coastal region, the majority of precipitation (84.4% in Dakshina Kannada, 89.1% in Udupi and 91.0% in Uttara Kannada) occurs between June-September (Monsoon). Winter rainfall (December–February) is quite low and accounts for 0.58%, 0.36% and 0.23% of the rainfall in the Dakshina Kannada, Udupi and Uttara Kannada, respectively. Krishnakumar [14] studied the temporal variability of seasonal and annual rainfall over Kerala for 1871–2005 and reported a significant decrease in southwest monsoon rainfall and an increase in the post-monsoon season, however, in our study significant reduction in post-monsoon rainfall is observed. Rainfall during the post-monsoon season plays a vital role in crop intensification.

3.3 Adaptation Pattern Related to Crops Production among Farmers

With the above said inconsistent rainfall pattern both in seasonal and annual, farmers need to achieve sustainable yield by the enchanting advantage of limited soil moisture in summer and to reduce the losses incurred in the cultivation of seasonal crops during irregular rainfall period. The farmers had resorted to several adaptive strategies. These adaptation patterns are presented in the Fig. 6. An overall 60% of the marginal, small and big farmers had selected of appropriate crops/varieties. About 81% of big farmers, 51% of small farmers and 35% of marginal farmers had replaced their traditional crops with short duration varieties. Around 86 per cent of big farmers adopted cash crops under assured irrigation/water supply. Interestingly in overall, 55% of farmers had adopted intercropping due to changes in climatic factors.

These practices were more prevalent among big farmers than marginal and small farmers'. Further, the adaptive strategies like alteration in sowing dates, reducing the plant population and intensified rabi crop cultivation were majorly adopted by big farmers than small and marginal

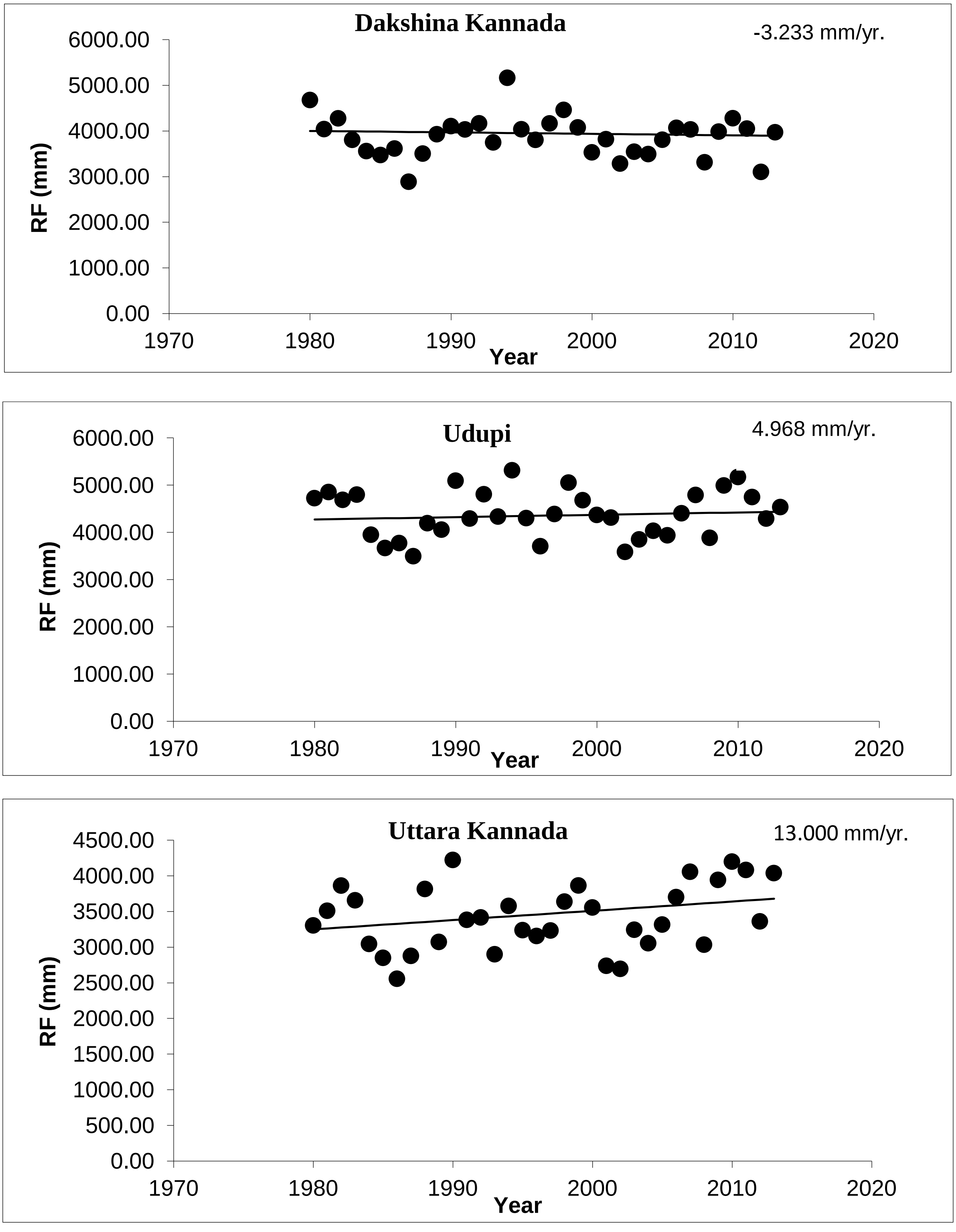

Fig. 2. Annual rainfall trend of 34 years in coastal region of Karnataka

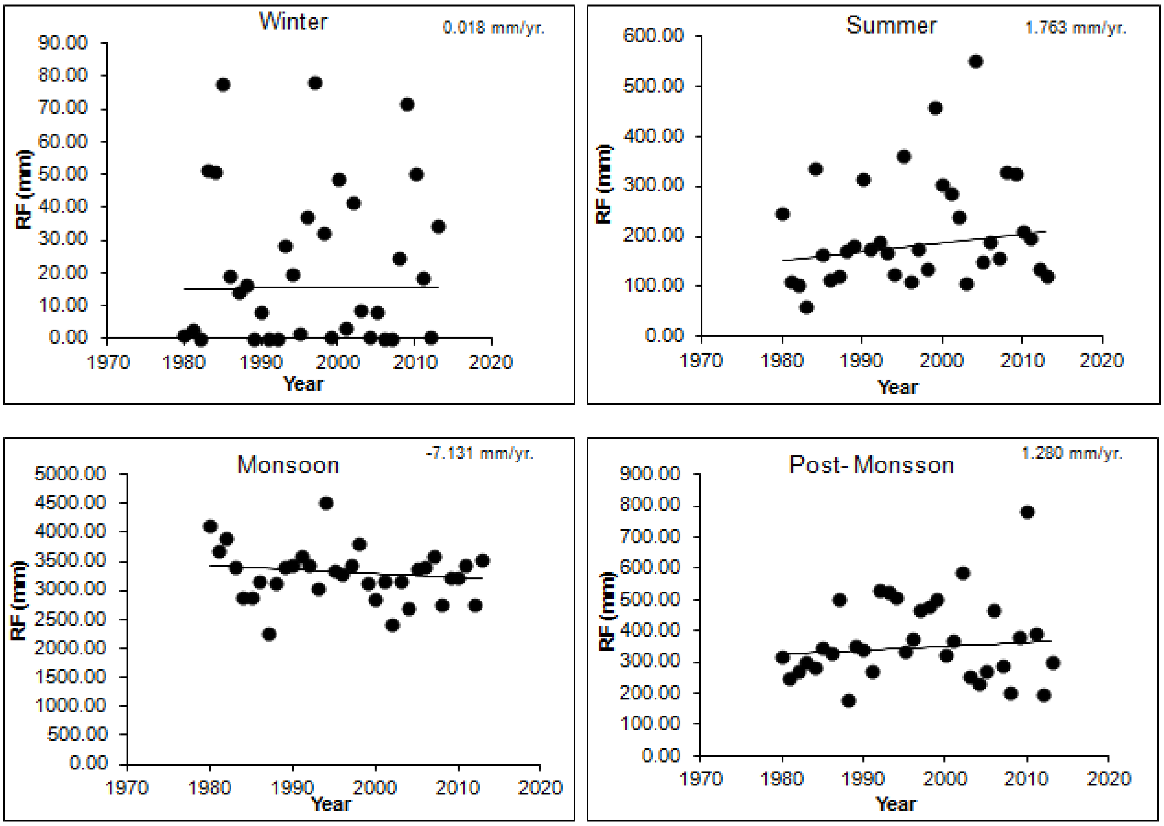

Fig. 3. Seasonal rainfall trend analysis of dakshina kannada district of coastal Karnataka (34 years)

farmers for manage the erratic rainfall. Nevertheless, surprisingly field observations revealed that many of marginal and small farmers', there was a complete replacement of food grain crops by oilseeds crop. The crops further affected by drought. The adoption of drought tolerant crop varieties is an encouraging trend. Further, when the Kharif crop failed, farmers gave more attention to rabi crop and pre-pone sowing of rabi crops. These practices were adopted by a good number of farmers might be due to make up the loss incurred during the Kharif. The practices of increasing area under cash crops, adoption of short duration crop and mixed cropping were some of the other adaptive strategies.

3.4 Adaptation Pattern Related to Soil and Water Conservation for Field Crops among Farmers

As shown in Fig. 2 we could able to observe the fluctuation in rainfall trend over a period, in this situation a variety of adaptation measures initiated by farmers to conserve soil and water are summarized in the Fig. 7. It was observed that as high as 91% of big farmers had adopted leveling of land and maintained the bunds. However, much of bunding work was done under the government sponsored soil conservation programme in addition to individual efforts. Ploughing and sowing across the slope, marginal, small and big farmers' representation were approximately 35 percent, 45%, and 61%, respectively. Only 30% of marginal farmers resorted to contour farming. Big farmers in compare with marginal and small farmers adapted construction of bunds, an adoption of drip/sprinkler irrigation, gully plugging and construction of farm pond more. Farmers had maintained these bunds because of firm conviction that bunds conserve soil moisture. Fall ploughing was also one of the significant moisture conservation adaptive strategies. Traditional practice meant to increase the infiltration and in situ conservation of rainwater. The fact that majority of the big and small farmers change their sowing direction every year on the assumption that sowing on the same line leads to depletion of soil fertility thus reducing crop yields. It was also observed that low percentage of marginal farmers attributed the reason that they do not access to improved farm implements.

3.5 Adaptation Pattern Related to Flood Management among Fishery Based Farmers

In a seasonal analysis of precipitation (Figs. 3, 4 and 5), we can notice that large percentage of the total rainfall is contributed from monsoon period, during this period high intensity of rainfall can be observed. In this region, to avoid the flood effect, the farmers were adopted some adaptive strategies are depicted in Fig. 8, which provides a fascinating insight, overall, 63% of farmers adopted indigenous technology such as the wall of wood and stone or coconut leaf to avoid flood effects. Small and marginal farmers followed this strategy to the tune of 77.50 per cent and 66.25 per cent respectively. Approximately, 79% of big farmers, 26 and 48 per cent of marginal and small farmers had reported that they used sandbags to avoid flood effect. Also, a considerable percentage of big farmers (58.75) as compared to the negligible percentage of small (15.0) and marginal farmers (5.0) practicing new agricultural practices like cultivating salt resistant varieties. Another pattern associated mainly with the big farmer to the extent of 63 per cent was improved drainage facilities, hazard insurance, and wetland restoration system. However, big farmers to a certain extent fared better by investing on flood management than the small and marginal farmers. Technological solutions have been adapted as instruments for reducing the vulnerability by coastal communities to coastal hazards. This was done in three simple ways: safeguard (decrease the probability of damage from a climate-related disaster), retreat (limit possible effects) and accommodate. Protective strategies involve measures to protect coastal zones against the impacts of natural disasters such as flooding and salinity intrusion. Protective plans can include a combination of both hard and soft knowledge.

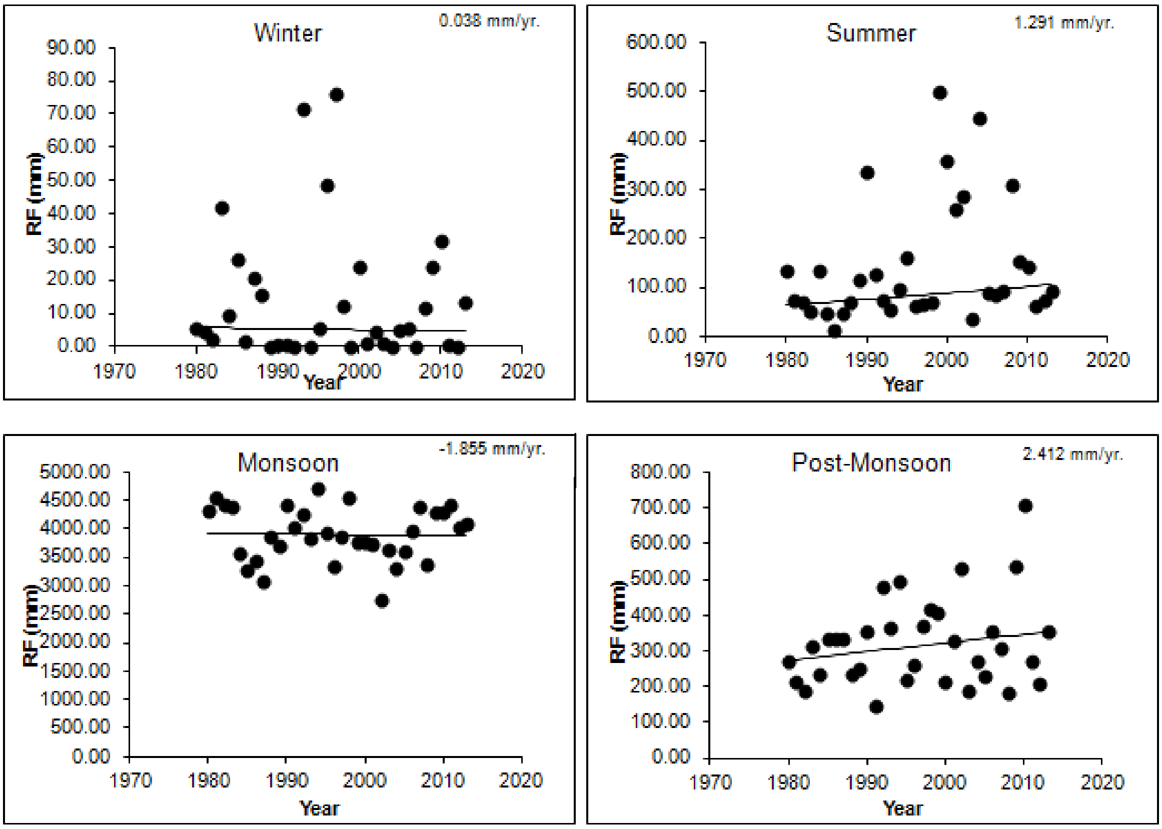

Fig. 4. Seasonal rainfall trend analysis of Udupi district of coastal Karnataka (34 years)

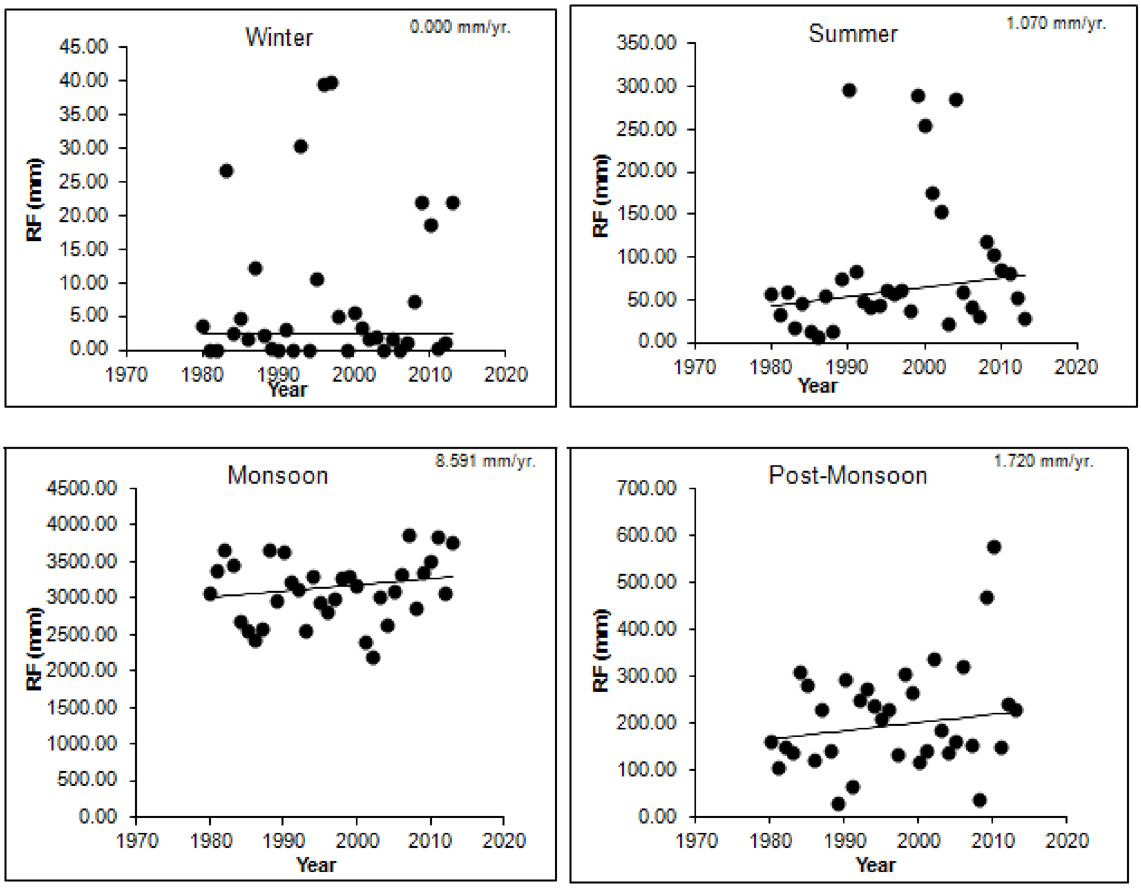

Fig. 5. Seasonal rainfall trend analysis of Uttara Kannada district of coastal Karnataka (34 years)

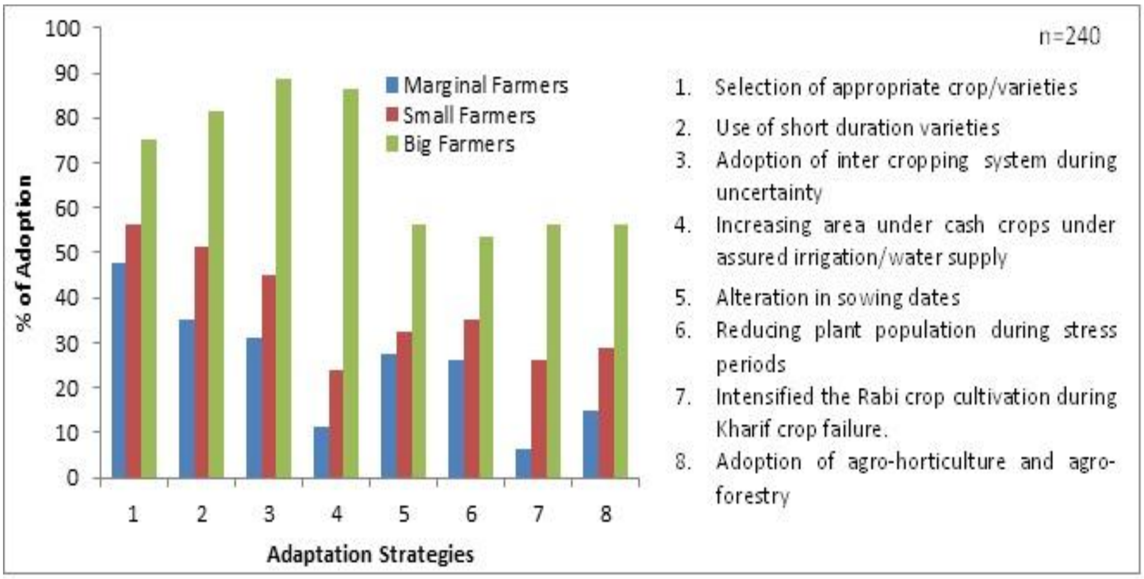

Fig. 6. Adaptation pattern of farmers related to crops production

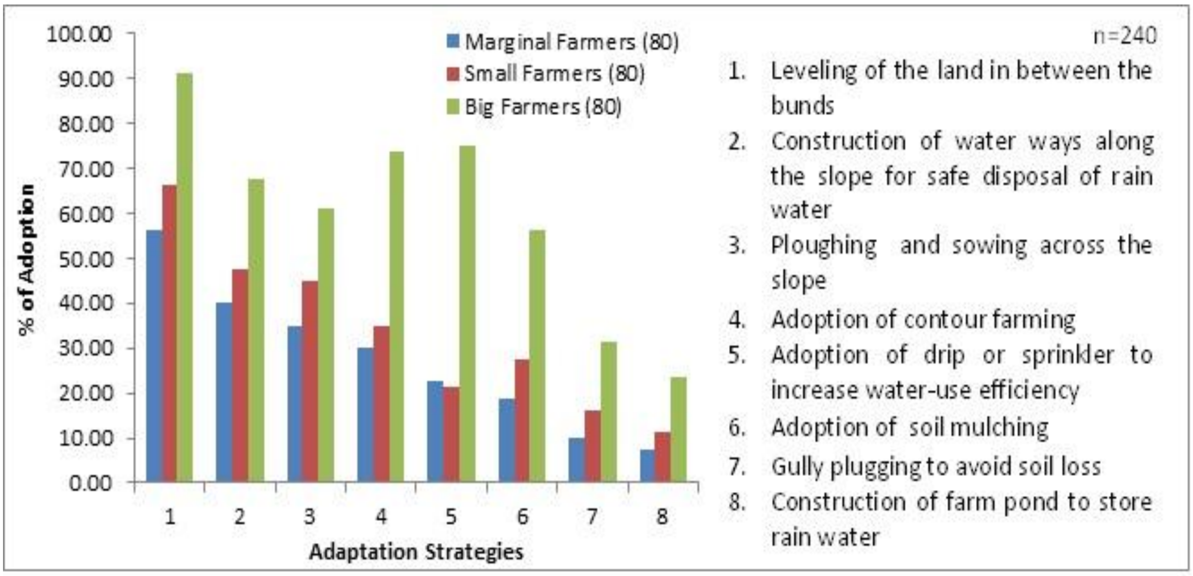

Fig. 7. Adaptation pattern of farmers related to soil and water conservation for field crops

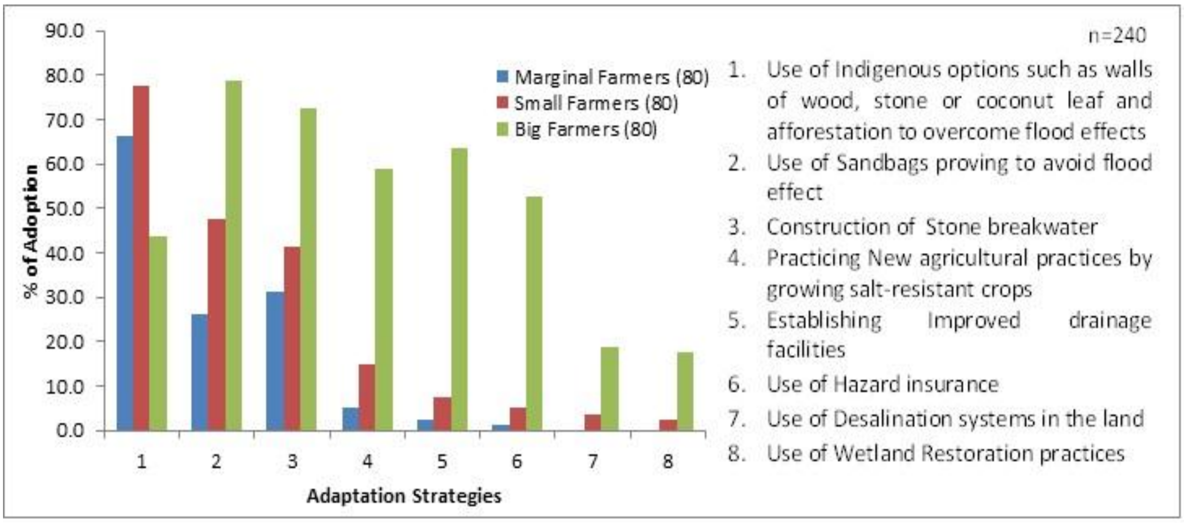

Fig. 8. Adaptation pattern of farmers related to flood management

4. CONCLUSION

Climatic changeability is the most significant occurrence affecting almost all economy sectors of the coastal region of a state. Unpredictability also postures difficulties before agriculturalists to adopt specific adaptation actions as they may become unserviceable after a time-period. As altitudinal erraticism, there is also time-based variability in climatic factors. Precipitation in the region is concentrated in only four months (June-September) of raining season and unpredictability leads to the farmers to take wrong measures. For surviving, it is important to evaluate in advance the tendency of future climatic variability based on experiences (time-series data). The precipitation has a declining trend in Udupi, and Dakshina Kannada districts whereas as in Uttara Kannada district has experienced an increase in rainfall. In connection with adaptation strategies, big farmers are more advantages than marginal and small farmers are, as they are gaining with better resources.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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