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A CASE STUDY

Estimation of spatial rainfall distribution using inverse distance weighting (IDW) in Parambikulam Aliyar sub-basin, Tamil Nadu

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ABSTRACT : The inverse distance weighting (IDW) method integrated with GIS was used to estimate the rainfall distribution in the Parambikulam-Aliyar sub-basin. The study was carried out based on 31 years of the monthly rainfall data from 8 rain gauge stations. Average annual rainfall of the region was found to be 1841.08 mm. The average annual rainfall of southwest, northeast, winter and summer monsoon was recorded as 1188.94, 430.89, 20.04 and 201.21 mm, respectively. The Chinnakallar rain-gauge station received the highest rainfall of 4750.25 mm whereas, Vettaikaranpudur recorded the lowest rainfall of 741.54 mm. The mean annual variability of rainfall was varied from 20 to 57 per cent. The south and south east part of the region experienced the heavy rainfall. East and north east received moderate rainfall, whereas the north, west and central part of the region experienced the lowest rainfall.

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Key Words : Geographic information systems (GIS), Inverse distance weighting (IDW), Spatial interpolation, Annual and seasonal rainfall, Rainfall variability

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India is a tropical country, agricultural planning and utilization water is depends on monsoon. More than 75 per cent of rainfall occurs during the monsoon season; rainfall is uneven due to both time and space, so this is an important factor to analysis the rainfall pattern (Ishappa and Aruchamy, 2010). Rainfall is a highly significant for hydrologic data. Rainfall is recorded as observational data through comprehensively designed rainfall stations. Rainfall is the important parameter for the agricultural activities and ground water recharge for potential ground water (Ishappa and Aruchamy, 2010). The rainfall is known to exhibits a high degree of variability due to both in space and time. Rainfall analysis can be estimated through spatial interpolation techniques.

Various spatial interpolation techniques have been employed to assess the rainfall pattern. These techniques are divided into geographical statistics and non-geographical statistics. In non-geographical statistics, following techniques are used *viz.*, nearest neighbor (NN), Thiessen polygons, splines and local trend surfaces, global polynomial (GP), local polynomial (LP), trend surface analysis (TSA), radial basic function (RBF), inverse distance weighting (IDW) and geographically weighted regression proposed by (Fotheringham *et al.*, 2002). Naoum and Tsanis (2004) developed a Geographical Information System (GIS) based spatial

interpolation module, by adopting a multiple linear regression (MLR) technique and this method can be compared with other methods, such as spline regularized, spline tension, IDW, kriging and second-order polynomial. Li *et al.* (2006) used the annual precipitation, from 2114 meteorological stations of China, for a period of 30 years between 1961 and 1990, to estimate the spatial distribution. The data were compared with its respective adjacent regions and analyzed through spline, ordinary kriging (OK) and IDW and showed a good and accurate output. A similar study was carried out by Chu *et al.* (2008) and reported a similar trend. Further, if indicates that the IDW method is the good method for interpolations using spatially dense networks. IDW is based on the concept of Tobler's first law (the first law of geography) proposed in 1970. It was defined as everything is related to everything else, but near things are more related than distant things. The IDW was developed by the U.S. National Weather Service in 1972 and is classified as a deterministic method. This is due to the lack of requirement in the calculation to meet specific statistical assumptions, thus, IDW is different from stochastic methods (e.g., Kriging and TRA). With this background, the IDW method is used to interpolate the spatial rainfall distribution in the Aliyar sub basin.

EXPERIMENTAL METHODOLOGY

Study area :

Parambikulam-Aliyar basin is located in the south western part of the Peninsular India and covering areas of both Kerala and Tamil Nadu states. This basin area lies within the co-ordinates of north latitude between 10° 10'00" to 10°57'20" and east longitudes 76°43'00" to 77°12'30". The basin is source for eight west flowing rivers *viz.*, Valaiyar, Koduvadiaru, Uppar, Aliyar and Palar (tributaries of Bharathappuzha river) and Parambikulam, Solaiyar and Nirar (tributaries of Chalakudy river). The Aliyar river has its source in the Anamalai hills. It flows in a north-westerly direction for about 37 km in Tamil Nadu and enters into Kerala and finally confluence in Bharathappuzha. Total area of sub basin is 574.75 km^2 and command area of 20,536 ha which covers Pollachi (north), Pollachi (south) and Anamalai block of Coimbatore district. Crops grown in this sub basin area are coconut, sugarcane, banana, sapota, mango and fodder. Besides that, annual crops, such as paddy, groundnut, cotton, vegetables, pulses, fodder, tomato, gourds, maize as 1st crop and paddy and groundnut as 2nd crop.

Aliyar sub-basin is considered as the study area for this research, since, the management of water resources in this basin is important to downstream user for their water requirements and environmental flow. Eight rain-gauge (Anamalai, Aliyar Nagar, Attakatti, Chinnakallar, Pollachi, Topslip, Vettaikaranpudur and Weaverly) stations were selected to study the spatial rainfall distribution in the Aliyar sub-basin.

Data collection and analysis :

The base map of Aliyar sub-basin has been prepared from Survey of India Toposheet on 1:250000 scale. Monthly rainfall data for the period of 31 years from 1982 to 2012 was collected from the office of state Surface and Ground Water Data Centre of Public works Department, Chennai. Data from 8 rainguage station from the study area (Fig. A) were analysed for seasonal and annual rainfall pattern for 31 years. The collected data had processed and analysed by preparing various charts, maps and diagrams using GIS software by using IDW approach.

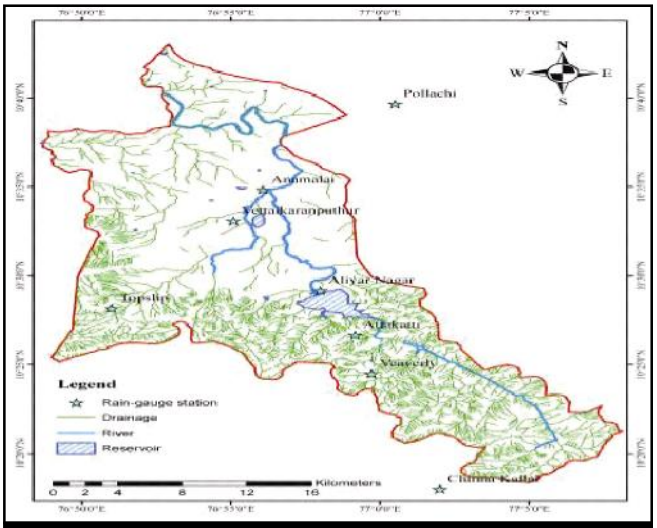

Fig. A : Location of rain guage station

Inverse distance weighting (IDW) :

The IDW method is also used for interpolation of multivariate data. It is based on the assumption of attribute value for un-sampled point by weighted average of known values within the neighborhood. This involves the process of assigning values to unknown points by using values

from a scattered set of known points. The value of the unknown point is a weighted sum of the values of N known points. In this study, the IDW method is used to interpolate spatial data based on the concept of distance weighting. It can be used to estimate the unknown spatial rainfall data from the known data of sites that are adjacent to the unknown site Li and Heap (2008). The general form of IDW approach Rase (2001) and Shepard (1968) is given in the equation :

$$zn_i = \frac{\sum_{j=1}^{m} z_j * d_j^{-p}}{\sum_{j=1}^{m} d_j^{-p}} \quad (1)$$

zn_i is the new value for grid i; z_j value of m nearest neighbours; d_j distance to m nearest neighbours; p exponent of distance. A higher *p* value assigns more weight to closer points, creating a less smooth gridded surface, while a lower *p* value assigns a relatively lower weight to closer points, resulting in a smoother surface (Irmak *et al.*, 2010). In the present study, the exponent of distance is taken as 2 to spatial interpolate the rainfall in the basin. Generally it assumed as two as used by Zhu and Jia (2004) and Lin and Yu (2008).

EXPERIMENTAL FINDINGS AND DISCUSSION

The results obtained from the present investigation as well as relevant discussion have been summarized under following heads :

Mean annual rainfall :

The mean annual rainfall of the region was about 1841.08 mm of which the southwest, northeast, winter and summer monsoon contributes 64.6, 23.4, 1.09 and 10.93 per cent, respectively. The study area was characterized by sharp areal differences of the quantum of rainfall due to the varying nature of topography. It is due to orientation and configuration of western Ghats. It is observed that, Chinnakallar recorded the maximum rainfall of 4750.25 mm, whereas, the minimum rainfall of 741.54 mm at Vettaikaranpudur. Spatial difference in the rainfall distribution was too large in the shorter distance while comparing the mean annual rainfall of the study area. This is due to the sporadic elevation at Vettaikaranpudur due to the influence of orographic effect in rainfall distribution.

Spatial distribution of mean annual rainfall was analysed by IDW technique (Fig. 2). It shows that, the Southern region received the highest rainfall and the rainfall was decreased spatially towards Northern region as elevation decreases. It is observed that, Pollachi and Vettaikaranpudur received 828.66 mm and 741.54 mm of rainfall, respectively. There was a sudden increasing rainfall towards southeast, northeast and southern region of the study area and spell about 839.51 mm at Aliyar Nagar station within the short range of distance. Further, it is substantiated with the rainfall as well as elevation of other stations. At Aliyar nagar, the elevation decreases (Fig. 1) towards northeast successively, Vettaikaranpudur and Pollachi were recorded 741.54 mm and 828.66 mm, respectively, which is located in the northern region. As elevation increases, further increased in rainfall towards southeast were observed at Attakatti and Weaverly, received an amount of 1110.32 mm and 1760.5 mm of rainfall.

Mean seasonal rainfall and variability :

The mean annual and seasonal (winter, summer, SWM and NEM) rainfall and their variability are presented in Table 1. The co-efficient of variability was calculated for 31 years. The co-efficient variability explains the stability of rainfall in the sub basin. Co-efficient of variability is calculated using equation (2) :

$$\text{Co - efficient of variability} = \frac{SD}{\text{Mean}} \times 100 \quad (2)$$

where, SD = Standard deviation = $\sqrt{\Sigma d^2/n}$.

Mean annual variability :

The annual variability (Table 1 and Fig. 7) varied from 19 to 57 per cent in the watershed. The lowest variability was 19.5 per cent at Anamalai station where the maximum rainfall was found 3564.7 mm. Topslip, Pollachi and Aliyar Nagar shows the lowest variability of 24.56, 27.27 and 27.33 per cent, respectively and if shows the high dependability of rainfall. The stations located at the Anamalai hills and Nilgris hills were under moderate-high variability. For example, Vettaikaranpudur and Attakatti had the variability of 30.61 and 34.77 per cent. From Vettaikaranpudur the variability decreased towards north east and increased towards south east of the study area.

South east monsoon :

The study area received 64.6 per cent of rainfall during this season. During the season, rainfall of different

stations (Table 1 and Fig. 3) within the sub-basin was recorded as lowest of 285 mm at Aliyar Nagar, 301.08 mm at Vettaikaranpudur and 357.37 mm at Pollachi. The highest rainfall was recorded at Chinnakallar. Data among the eight raingauge stations the variability (Table 1 and Fig. 8) was relatively low in Anamalai (23.19 %). It is located at northern portion of the study area whereas, the high is at Weaverly (65.7 %), located at the southern hills (western Ghats).

North east monsoon :

The north east monsoon is important rainy season in the district. Total rainfall in this season was low as compared to the south west monsoon. The basin received 23.4 per cent of the total annual rainfall during this season. The highest rainfall occurred during this season (Table 1 and Fig. 4) was highly densed at Chinnakallar and Anamalai vicinity of north east and south boundary of the sub-basin, and received more than 450 mm of rainfall. From Anamalai, the rainfall increased towards north east and south of the sub-basin area. Since. the watershed is covered by the western Ghats, Anamalai reserve forest and Nilagiri hills, received the highest rainfall in the southern boundary of the study area. However, the interior part receives relatively very low amount of rainfall as the area lies in the rain-shadow region of the western Ghats. It is inferred that the spatial distribution of rainfall pattern was controlled by elevation of the terrain during all seasons except winter. From this zone, the variability (Table 1 and Fig. 9) increases towards north east and decreased towards South along the lower valley portion of the Aliyar Dam. During this season, the rainfall variability lies within 35.92-64.42 per cent.

Winter :

During the winter season, the region had low rainfall and it was dry compared to other seasons. The winter rainfall contributed to the annual rainfall was only 1.09 per cent. During winter season (Table 1 and Fig. 5), Anamalai received the highest rainfall of 25.32 mm within the watershed. The lowest rainfall of 12.51 mm was recorded at Vettaikaranpudur. The spatial pattern of winter rainfall was unique and totally different from other seasons. During this season, the variability (Table 1 and Fig. 10) was triple fold than summer, southwest and northeast monsoon.

Summer :

During weather season, the amount of rainfall was gradually increased. This was due to convection process. During the summer rainfall (Table 1 and Fig. 6) contributes 10.93 per cent to the watershed. During this season, Chinnakallar received the highest rainfall of 384.59 mm within the watershed. The lowest rainfall of 120.59 mm was recorded at Vettaikaranpudur. The variability of the rainfall during this season (Table 1 and Fig. 11) was varied between 46.15-70.69 per cent. It shows a large variation in spatial distribution.

Conclusion :

Aliyar sub-basin bounded by western Ghats, in the west and Nilagiri hills in the north, Anaimalai and Palani hills in the south. Study area stretches in the rain shadow region of western Ghats. The rainfall trends and variability of the rainfall for the Aliyar sub-basin was analysed using IDW technique of GIS. The mean annual rainfall of the region was about 1841.08 mm of which the southwest, northeast, winter and summer monsoon contributes 64.6, 23.4, 1.09 and 10.93 per cent of the annual rainfall, respectively. Among 8 rainfall stations, the maximum and minimum rainfall was recorded as 4750.25 mm at Chinnakallar and 741.54 mm at Vettaikaranpudur,

Table 1 : The mean annual and seasonal rainfall (in mm) and its variability

Sr. No.	Raingauge station	Annual	Cv	Swm	Cv	Nem	Cv	Winter	Cv	Summer	Cv
1.	Aliyar Nagar	839.51	27.33	285	44.23	387.68	44.85	19.9	139.33	146.92	69.58
2.	Anamalai	3564.75	19.57	2631.5	23.19	567.14	35.92	25.32	132.12	340.79	61.35
3.	Attakatti	1110.32	34.77	486.18	55.86	454.49	45.45	21.72	142.33	147.93	50.53
4.	Chinnakallar	4750.25	33.02	3639.37	35.7	704.81	42.34	21.48	143.98	384.59	70.16
5.	Pollachi	828.66	27.23	357.37	36.01	310.04	51.63	15.76	165.45	145.49	47.45
6.	Topslip	1328.2	24.56	756.45	28.98	386.4	54.68	24.6	156.9	160.75	63.66
7.	Vettaikaranpudur	741.54	30.61	301.08	34.22	307.36	62.65	12.51	170.24	120.59	46.15
8.	Weaverly	1565.4	57.16	1054.6	65.7	329.2	64.42	19	255.82	162.6	70.69
	Mean	1841.08		1188.94		430.89		20.04		201.21	

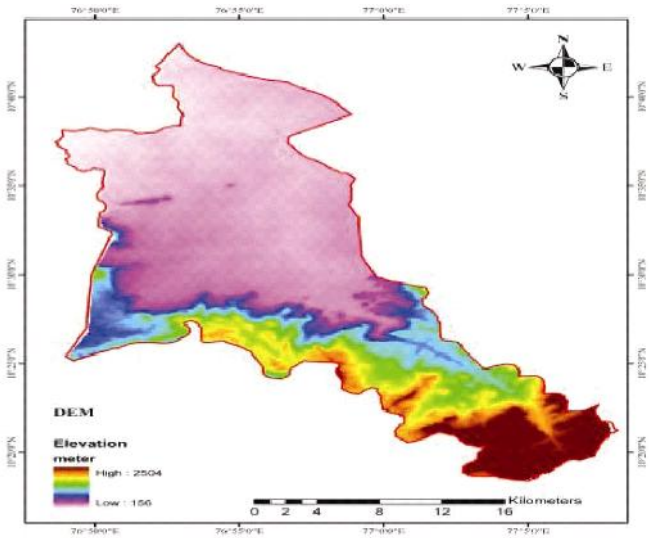

Fig. 1 : Digital elevation map

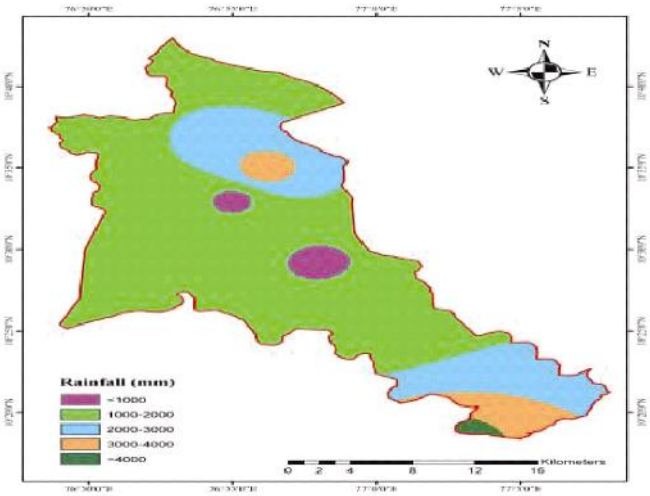

Fig. 2 : Mean annual rainfall

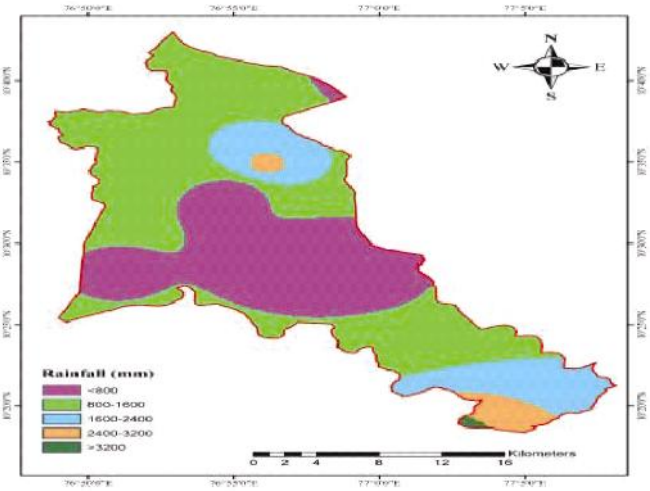

Fig. 3 : South west monsoon

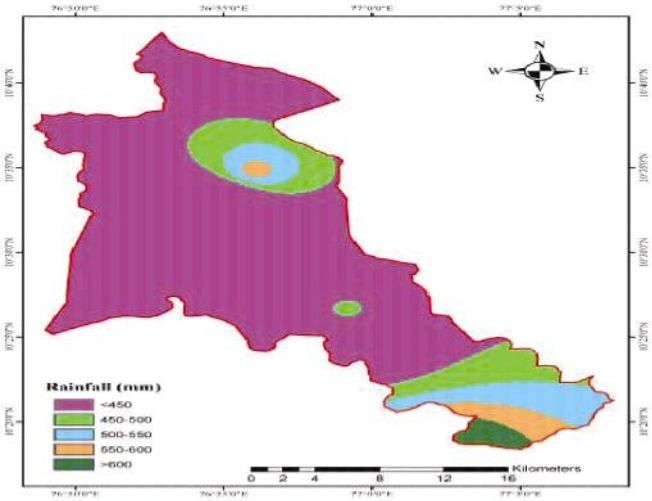

Fig. 4 : North east monsoon

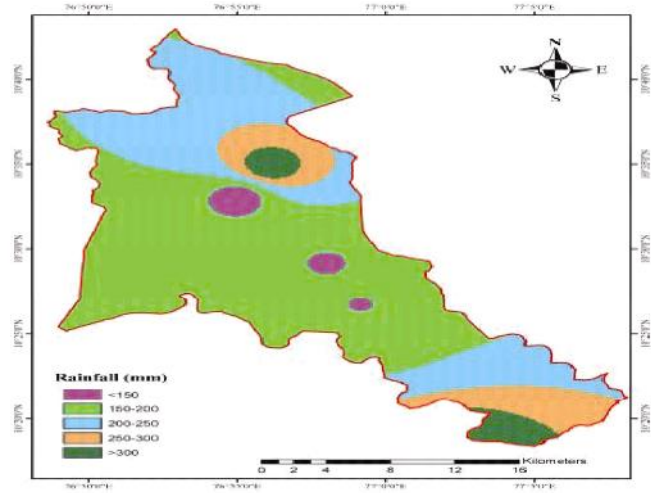

Fig. 5 : Winter rainfall

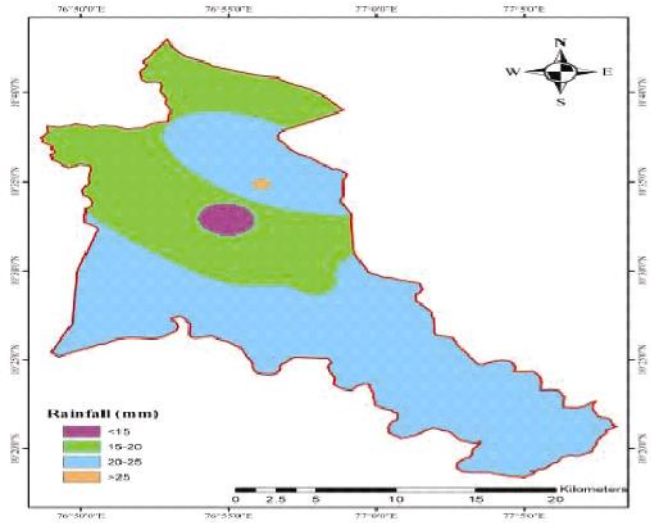

Fig. 6 : Summer rainfall

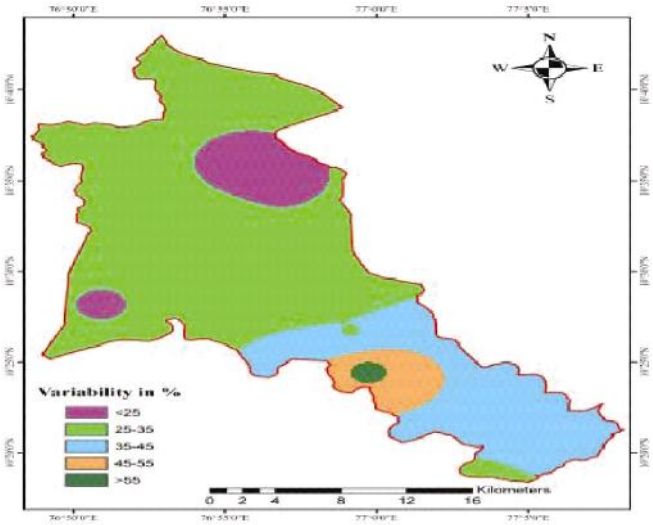

Fig. 7 : Co-efficient variability (%) of mean annual rainfall

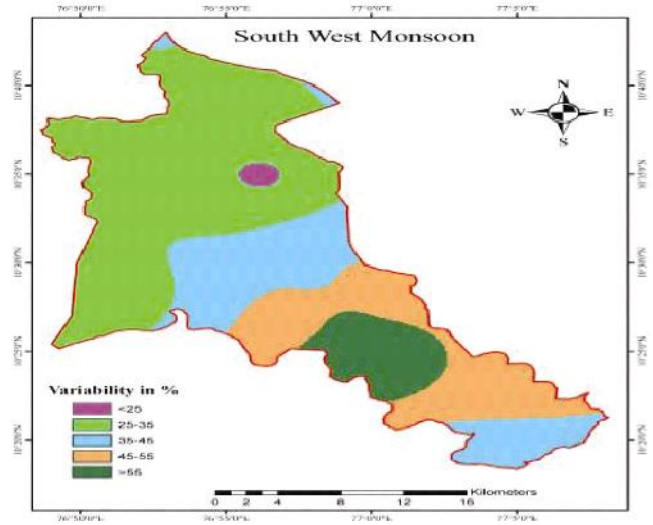

Fig. 8 : Co-efficient variability (%) of SWM

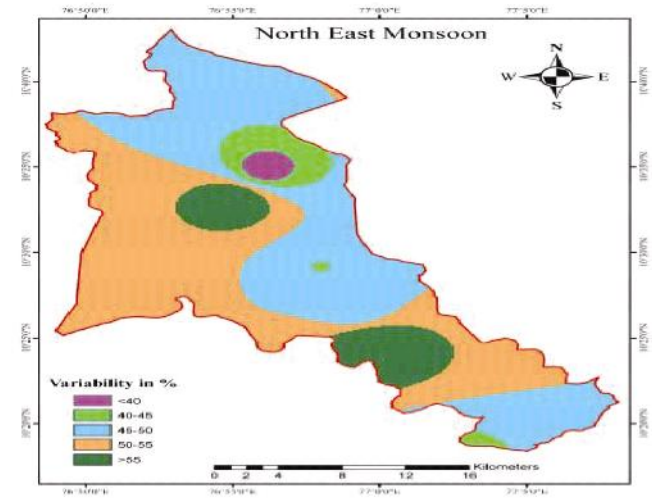

Fig. 9 : Co-efficient variability (%) of NEM

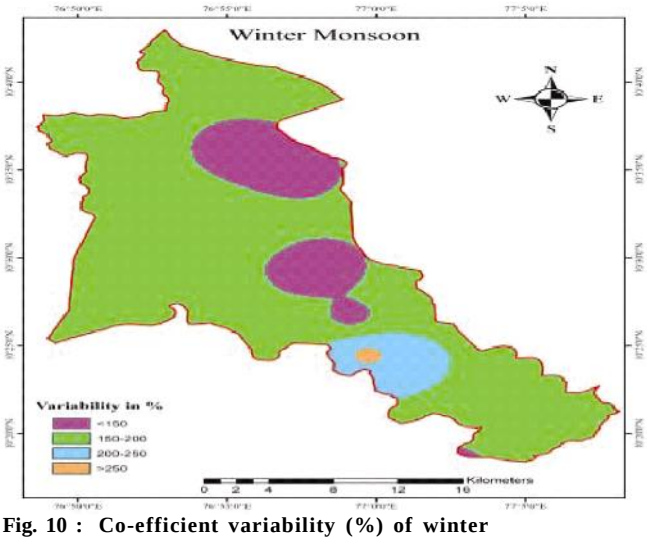

Fig. 10 : Co-efficient variability (%) of winter

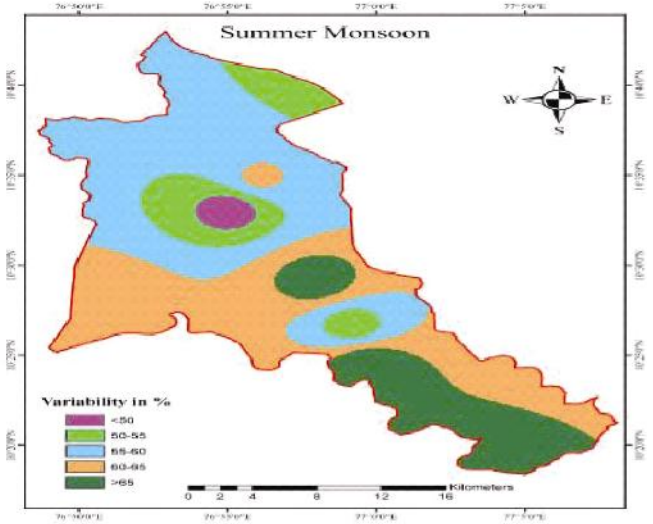

Fig. 11 : Co-efficient variability (%) of summer

respectively. The spatial distribution of mean annual rainfall the south east portion received the maximum rainfall. This study proved that the south west and north east monsoon are paramount dominating but the south west monsoon is stabilized in western Ghats. Anamalai reserve forest were permanent dominating every monsoon season, however, the south west monsoon paramount dominant to the upland region. The wind ward of the western Ghats region was at high intensity during monsoon season at Aliyar Nagar, Attakatti and Weaverly. Chinnakallar is being considered as the wettest point in the region and it is located in the western Ghats. The northern region experienced the highly deficits rainfall. The co-efficient of variation (CV) of the annual rainfall varied between 20 per cent (Anamalai) and 57 per cent

(Weaverly) indicates that, there is large variation in the total amount of rainfall between the locations. The south west monsoon gives complete stabilized rainfall for the entire region which helps to take place for the agricultural activities in the region.

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