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Geospatial Variation of Rainfall Erosivity factor in Muvattupuzha River Basin

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Abstract - Soil erosion is a critical issue in India where 58% of the population depends on agriculture and allied sectors for their livelihoods. Rainfall erosivity is one of the main factors affecting soil erosion. The erosive power of rainfall is quantified by rainfall erosivity factor. It is the product of kinetic energy of rainfall and rainfall intensity. Continuous rainfall data is a prerequisite to obtain rainfall erosivity factor accurately. High temporal resolution data is required for the determination of these parameters. At places where high temporal resolution data is not available, rainfall erosivity index can be obtained using various relations connecting erosivity index and average annual precipitation. Such available relations are used to obtain the erosivity index of Muvattupuzha river basin. The average sediment discharge of Muvatupuzha River is 167408 MT with an erosion rate of 0.042 mm/year. The results of these equations show a percentage variation of 85% in the results. Region specific equations show better average results. The effect of latitude, longitude and elevation on the index is also analysed.

Key Words: precipitation, rainfall erosivity index, erosion, sediment, storm intensity.

1. INTRODUCTION

Soil erosion is the separation of soil particles and its transportation which is a global problem that drastically effects agricultural activities [6]. Though a natural process caused by erosive agents like wind or water, soil erosion is also triggered and increased by human activities like agriculture, construction, mining and forestry [10].

Rainfall characteristics are major factors that directly effects rainfall of which the major role played by erosive factor of rainfall. There has been large difference in rainfall characteristics in Kerala in the past 30 years. No particular trend is observed in the rainfall pattern through these years. Unexcepted flood and landslide are repeatedly effecting the state.

Soil conservation practices have to be undertaken to control the depletion of quality and quantity of available soil resources. Regional-specific quantitative erosion assessment is needed to infer efficient erosion control and soil conservation strategies to prevent soil erosion and locate critical areas for its implementation. Conventional methods to determine quantitative soil erosion at a spatial scale are expensive and time-consuming [4]. Substantial efforts have been spent developing soil erosion models [6]. To include the erosive effect of soil, these models have included a factor called rainfall erosivity factor.

2. RAINFALL EROSIVITY INDEX

Rainfall erosivity is the measure of erosive force of a specific rainfall and is defined as the aggressiveness of rain to cause erosion [8]. Rainfall erosivity index is an important factor in Revised Universal Soil Loss Equation used for the calculation of sediment loss from an area. This index is directly proportional to the soil loss. More the rainfall erosivity value, more will be the soil loss due to erosion.

Several approaches have been developed to determine the rainfall erosivity factor (R factor). But lack of accurate data has always been a hurdle. Various equations are proposed for the determination of R value, which in turn depends on storm energy for a storm of minimum thirty minutes duration. Many equations for the determination of R value using storm energy requires high temporal resolution data which is not available in most countries including India.

In cases where high temporal resolution data is unavailable, R value is obtained from precipitation data. Many relations are available for R value and average annual precipitation. In Indian conditions where hourly precipitation data is not available, R value can be determined more effectively with Fourier Index and Modified Fourier Index (MFI).

Most relations between precipitation and rainfall erosivity are developed in USA, Spain, Germany etc. where average annual rainfall is only half of that of Kerala. Such relations are included in Table 1 and Table 2. As an exception of these equations, the relation developed by Arnoldus in1977 [1] considers conditions of both USA and West Africa. West Africa has rainfall conditions more intense than that of Kerala. The equations developed in Indian scenario for similar area are included in Table 3.

Table 1. Equations for the calculation of R value with MFI.

Author (Year)	Equation	Developed in
Wischmeier & Smith (1978)	$R = \sum_{1}^{12} 1.735 \times 10^{(1.5 \log_{10}(P_i/P) - 0.08188)}$	USA
Arnoldus (1977)	$0.264 MFI^{1.5}$	USA and West Africa
Renard and Freimund (1994)	$0.07397\, MFI^{1.847}$ (MFI<55mm) $95.77 - 6.081\, MFI + 0.477 MFI^2$ (MFI>55mm)	USA
Hernado and Romana (2015)	$1.28\, MFI$	Spain

Table 2. Equations for the calculation of R value with average annual precipitation (P)

Author (Year)	Equation	Developed in
Schwertmann et al. (1987)	$(0.083P - 1.77) \times 10$	Germany
Renard and Freimund (1994)	$0.0483P^{1.61}$ $(for\ P < 850\ mm)$ $587.8 - 121P + 0.004105\ P^2$ $(for\ P > 850\ mm)$	USA
Hernado and Romana (2015)	$0.18P$	Spain
Bonilla and Vidal (2011)	$0.015P^{1.617}$	Chile
Loureiro and Coutinho (2001)	$(0.0337P + 39.093) \times 10$	Portugal
Fiener et al. (2020)	$0.833P + 1.73$	Czech Republic
Lo et al. (1985)	$3.48P + 38.46$	USA

Table 3. Developed in Indian scenario

Author	Equation	Developed in
Singh G. (1981)	$79 + 0.363P$	Entire India
Babu et al (2004)	$81.5 + 0.38P$	Damodar Valley
Rambabu et al. (1979)	$22.8 + 0.64P$	Dehradun, India

3. MUVATTUPUZHA RIVER BASIN

Muvattupuzha river basin is a river basin in Kerala formed by the joining of three rivers namely Kaliyar, Kothamangalam and Thodupuzha. With an area of 1554 km^2 the basin extends between latitude 9°45' to 10 0 05'N and longitude 76°22' to 76°50'E (as shown in figure 1) getting rainfall with an average annual rainfall of the from minimum of 2779 mm to maximum of 4526 mm.

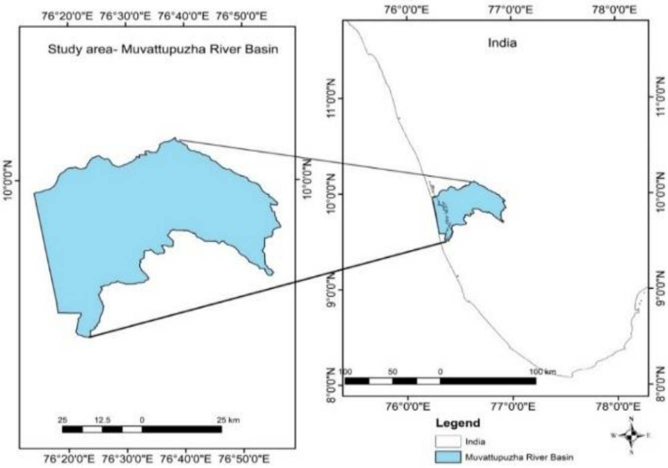

Figure 1. Muvattupuzha River Basin

4. DATA AND COMPUTATION OF R VALUE

The monthly rainfall of different locations from 1981 to 2021 is obtained from NASA MERRA. From this monthly rainfall data, the annual average rainfall for twenty years is received, and using the above equation, the rainfall erosivity index is calculated at different stations using the above mentioned equations.

4.1. Comparison of various equations

R value for Muvattupuzha river basin is obtained using the above thirteen equations and it is graphically represented in figure 2. The highest value and smallest values are obtained using equations developed by Babu [2] and Hernado and Romana [7] respectively. The variation in value is 85%. Equations Singh H. [15] and Babu [2] which are developed in Indian scenario is giving an average comparing all equations. This shows the important of usage of location specific equations for the determination of R value.

On comparison of equations developed using MFI, no similarity in value is obtained for R values developed in same countries. But the equations connecting R value and precipitation are giving similar values. The value obtained with Wischmeier and Smith [17] and these equations is similar.

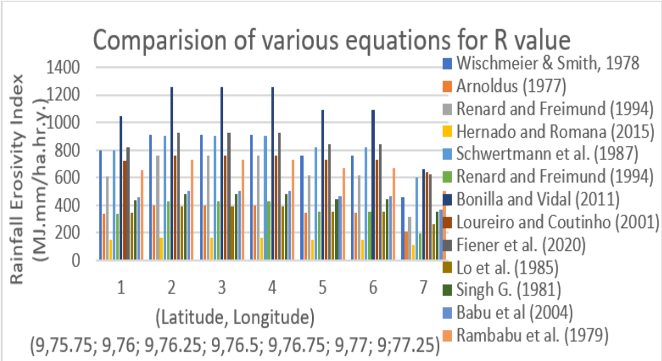

Figure 2. Comparison of various equations for R value

In most of the papers that access soil erosion, the equation used is [17] which in this gives a safer value. This relation is used in Nethravathi [4] and Pamba [16] River basins, which have similar precipitation as that of Muvattupuzha river basin. The R value distribution in river basin obtained using Wischmeier & Smith equation [17] and interpolated using Inverse distance weighted (IDW) interpolation. For all equations, the highest is obtained at Kannamppadi town near Idukki Wildlife Sanctuary. The variation of the Rainfall erosivity factor is depicted in figure 3. Specific erosion control measures needed to be adopted in rainfall.

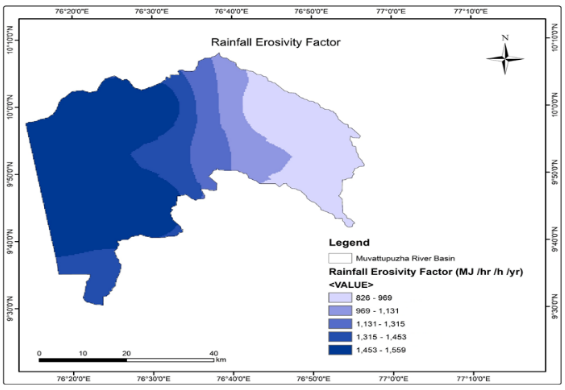

Figure 3. Rainfall erosivity factor of Muvattupuzha River basin using Wischmeier & Smith (1978)

4.2. Effect of longitude

Change in rainfall erosivity with longitude was analysed for three different latitudes and is graphically shown in figures 4 to 5. The rainfall intensity slightly increased and decreased on increasing longitude for all latitudes. All equations showed the same kind of variation.

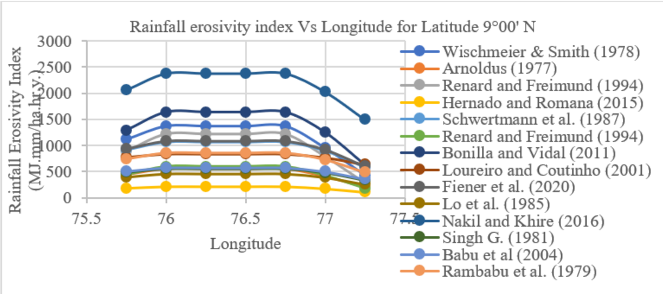

Figure 4. Rainfall erosivity index Vs Longitude for Latitude 9°00' N

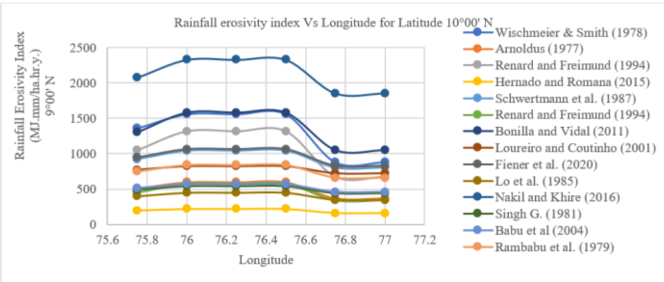

Figure 5. Rainfall erosivity index Vs Longitude for Latitude 10°00' N

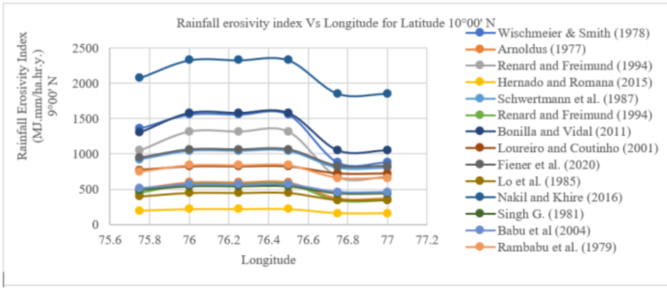

Figure 6. Rainfall erosivity index Vs Longitude for Latitude 9°30' N

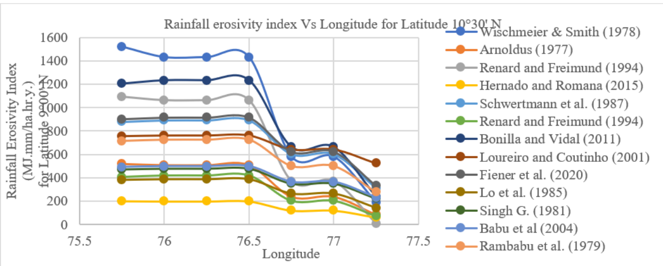

Figure 7. Rainfall erosivity index Vs Longitude for Latitude 10°30' N

4.3. Effect of latitude

Variation of rainfall erosivity with longitude for three different longitudes were analysed and is illustrated in figures 7 to 8. There was an increase in R value initially but then decreased from 10°N. The variation is similar to that for longitude and the pattern was same as that of longitude.

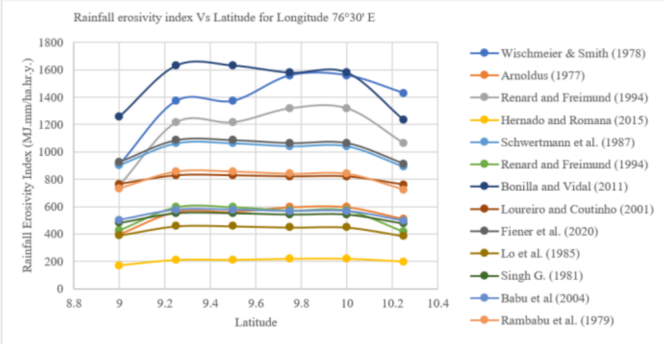

Figure 8. Rainfall erosivity index Vs Latitude for Longitude 76°30' E

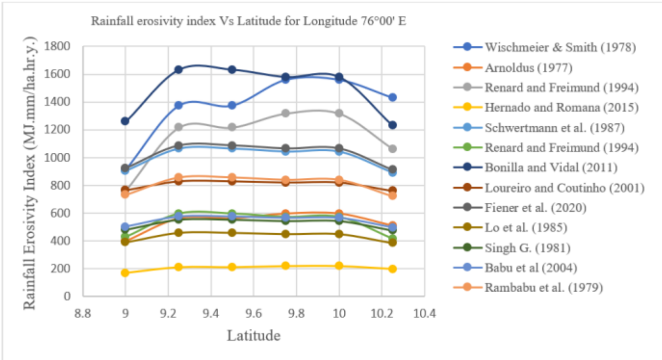

Figure 9. Rainfall erosivity index Vs Latitude for Longitude 76°0' E

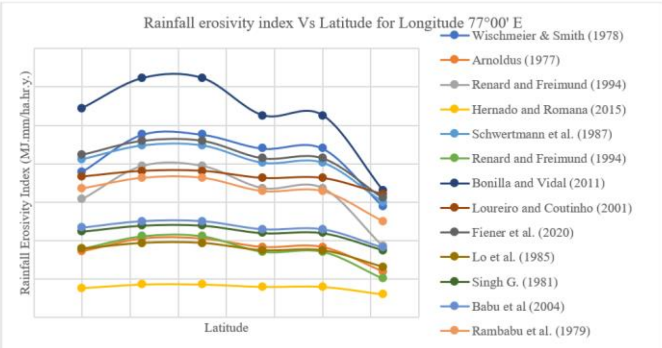

Figure 10. Rainfall erosivity index Vs Latitude for Longitude 77°00' E

4.4. Effect of Elevation

A plot of rainfall erosivity with elevation was prepared for values of R obtained using different relations. The variation pattern was same for all equations. To analyse the variation, average annual precipitation with elevation was plotted and the same pattern of variation was obtained. This proves that rainfall erosivity is not effected by elevation but the precipitation in the area.

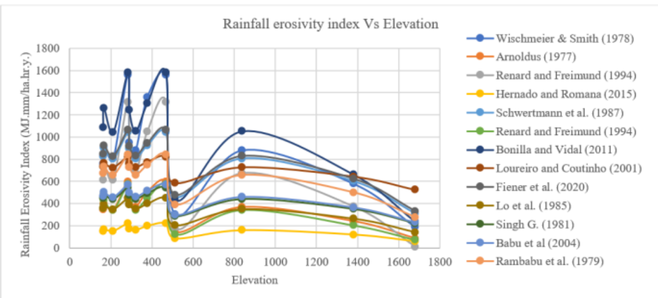

Figure 11. Rainfall erosivity index Vs Elevation

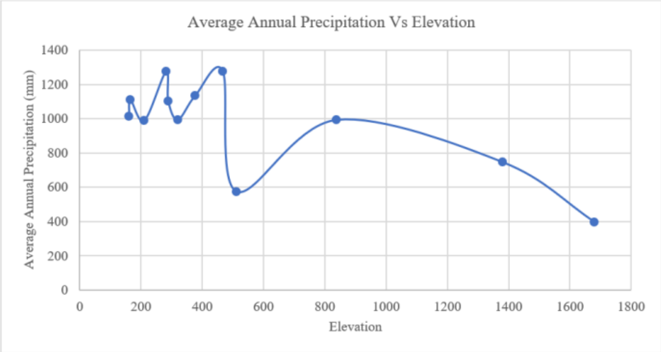

Figure 12. Average Annual Precipitation Vs Elevation

5. CONCLUSION

Rainfall erosivity of Muvattupuzha River basin was obtained using thirteen different equations. The was significant change in the values obtained with a percentage variation of 85%. Equations developed for nearby localities in India showed similar values falling to average value of other equations depicting the importance of region specific equations for determination of R value. The effect of latitude, longitude and elevation on rainfall intensity was analysed. But the effect was not noteworthy. This is because rainfall intensity mainly depends on various rainfall characteristics and landuse pattern of the area. When the rainfall intensity is larger, the soil loss due to erosion will be also larger and vise versa. For Muvattupuzha river basin with precipitation more than 2000mm per year, the erosion and soil loss caused by water will be higher and hence erosion control measures like controlled tillage, bunds, intercropping, addition of organic compound to soil, vegetation growth over soil can be adopted.

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