ASSESSING THE RAIN EROSIVITY AND RAIN DISTRIBUTION IN DIFFERENT AGRO-CLIMATOLOGICAL ZONES IN VENEZUELA

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ABSTRACT

Evaluating runoff and field soil losses by either empirical or physically based erosion models, requires an understanding and assessment of rainfall characteristics affecting the erosion (sub)processes.

In spite of shortcomings and many criticisms on the worldwide use and applicability of RUSLE (Revised Soil Loss Equation), this empirical model still gains worldwide popularity for estimating erosion on a farmfield or micro-catchment scale.

One of the limits of the model is the assessment of its climate factor in terms of rain energy and maximum storm intensity, both factors combined in the erosivity factor R, although they not easily available nor easily determinable. Therefore attempts are made to look for more easily determinable rain characteristics such as the monthly precipitation for evaluating the rain aggressiveness (or rain erosivity) on a monthly or yearly basis.

As agro-climatological zones have typical rain distributions and rain concentrations, the Modified Fournier Index (MFI) and the Precipitation Concentration Index (PCI), both calculated from monthly precipitation values over a number of successive years, will be used to characterize zones in Venezuela.

Monthly rainfall data were collected for at least 10 successive years from nine stations in Venezuela: three stations in the Llanos Centrales, four stations in the Llanos Occidentales and two stations in the semiarid zone of Lara State.

According to the available data sets, two different procedures were used to calculate (MFI):

- In the first procedure the monthly rainfall amounts are averaged over a number of years. The (MFI) is then calculated from this averaged rainfall data set and reported as (MFI)1.
- In the second procedure the (MFI) is calculated from the monthly rainfall amounts of each individual year and the (MFI) averaged over a number of years. Those long term average values are reported as (MFI)2.

Temporal aspects of the rainfall distribution within a year was defined by the *Precipitation Concentration Index* (PCI) also based on monthly rainfall amounts and calculated following the two procedures as for determining the (MFI).

From those stations of which R = EI_{30} was available an attempt was made to relate R to (MFI).

INTRODUCTION

In Latin America and hence also in Venezuela sufficient rainfall records, especially rain intensity, from automatic rain recorders, are not available to calculate countrywide the rainerosivity index R =E_{30} as defined in the Universal Soil Loss Equation (USLE) (Wischmeier and Smith, 1978) with E the kinetic energy and I30 the maximum intensity during 30 minutes of the individual rainstorms.

For a number of experimental sites in Venezuela the R values were calculated on the basis of the relationship between kinetic energy E and intensity I as proposed by Wischmeier and Smith (1978) and by Renard et al (1993).

Attempts were already made in Venezuela to derive the erosivity factor R from more easily determinable rainfall parameters .

Guarisma et al (1981) developed a model to determine EI_{30} for the tropical zone of Bosque Seco in Venezuela on the basis of daily rainfall amounts P_d (mm) :

$$R = EI_{30}\ (MJ.mm.ha^{-1}.h^{-1}) = -231.7 + 19.3\ P_d\ (mm)$$

Paez and Aguero (1986) found a similar realtion for La Paragua (Estado Bolivar, Venezuela) :

$$R=EI_{30}\ (MJ.mm.ha^{-1}.h^{-1}) = -237.9 + 8.7\ P_d\ (mm)$$

Fournier (1960) developed an index (FI) *(Fournier Index)* to be correlated to sediment loads in rivers (FI) = p^2max/P, with pmax the mean monthly rainfall amount of the wettest month of the year and P being the mean annual rainfall amount.

However this (FI)-index has shortcomings as estimator of the rain erosivity index within the USLE. As also low amounts of monthly rainfall can have erosive power, an increase in total rainfall amount should result in an increase of erosivity. It is also not logic that if the maximum monthly rainfall pmax remains the same with the mean annual rainfall increasing, the (FI) is decreasing.

Therefore Arnoldus(1980) modified the (FI) index into a *Modified Fournier Index* (MFI) considering the rainfall amounts of all months in the year.

$$(MFI) = \Sigma\ p^2/P$$

with p: the monthly rainfall amount and P: the annual rainfall amount

In an attempt to define temporal aspects of the rainfall distribution within a year, Oliver (1980) proposed the *Precipitation Concentration Index (PCI),* derived from the Index of Employment Diversification (Gibbs and Martin, 1962)

$$PCI = 100 \times \Sigma\ p^2/P^2$$

Where p stands for the rainfall amount of each month of the year and P for the yearly rainfall amount.

The theoretical limits of the (PCI) are obtained as follows:

- when the rainfall in each month of the year is the same, the (PCI) equals 8.3
- when all the rainfall of the year occurs in one single month, the (PCI) equals 100

The (PCI) permits grouping of data sets according to the derived value. Oliver (1980) came to the conclusion that a (PCI) of less than 10 suggests a uniform distribution; a value from 11 to 15 denotes a moderate seasonal distribution, a value from 16 to 20 denotes a seasonal distribution. An index above 20 represents strong seasonal effects, with increasing values indicating increasing monthly rainfall concentration.

Meteorological stations and methodologies: Three important agricultural areas in Venezuela were selected for the study: the 'Llanos Centrales', the 'Llanos Occidentales' and a semiarid zone in Lara State. In this study we include three the meteorological stations in the Llanos Centrales': 'Valle de la Pascua' and 'Los Arbolitos' and 'San Antonio Tama', four stations in the Llanos Occidentales: 'Mesa de Cavacas', 'Santa Bárbara de Barinas', 'Colonia Agricola Turén' and 'Banco de los Cedros', and two stations in the semiarid zone of Lara State: 'Carora Granja' y 'Bobare', of which the coordinates and number of years of data are presented in table 1.

Table 1. Meteorological stations

Station	**State**	**Institute**	**Latitude**	**Longitude**	**Elevation**	**Years**
Valle de la Pascua	Guárico	MARN	9º 13'	66º 00'	168	1969 – 1990
Los Arbolitos	Guárico	MARN	9º 22'	66º 23'	161	1969 – 1986
San Antonio Tama	Guárico	MARN	9º 41'	66º 02'	175	1978 – 1998
Colonia Turén	Portuguesa	MAC	9° 15'	69° 06'	275	1960 – 1982
Santa Bárbara	Barinas	MARN	7° 50'	71° 09'	224	1970 – 1980
Mesa de Cavacas	Portuguesa	UNELLEZ	9º 04'	68º 48'	300	1980 – 1991
Banco de LosCedros	Portuguesa	MARN	8° 57'	69° 43'	125	1980 – 1991
Carora Granja	Lara	MARN	10º 16'	70º 08'	413	1978 – 1998
Bobare	Lara	MARN	10º 29'	69º 46'	660	1978 – 1997

MARN: Ministerio del Ambiente y de los Recursos Naturales (Ministry of Environment and Natural Resources)
MAC: Ministerio de Agricultura y Cría (Ministry of Agriculture and Development)
UNELLEZ: Universidad de Los Llanos

For the different stations and for the years mentioned in table 1 the following indices were calculated:
- the *Modified Fournier Index (MFI),* using the two procedures as mentioned above resulting in *(MFI)1 en (MFI)2*
The *(MFI)* ranges proposed by CORINE (1992) (cited by Jordán and Bellinfante, 2000), are presented in table 2.

Table 2 : The *(MFI)* is classified as follows:

***(MFI)* range**	**description**	**class**
<60	very low	1
60 - 90	low	2
90-120	moderate	3
120-160	high	4
>160	very high	5

- the *Precipitation Concentration Index (CPI), is* also calculated using the same two procedures as for calculating *(MFI).*
In the first procedure, the mean monthly rainfall amount is estimated by averaging the monthly rainfall data over a number of years. Afterwards, the *(PCI)* is calculated from the estimated mean rainfall data set. Those values will be reported as *(PCI)1*. In the second procedure, the *(PCI)* values are averaged over a number of years. Those values are reported as *(PCI)2*.
The first procedure results in *(PCI)1* if an average year if the series of years is long enough. The second procedure will yield long term average *(PCI)2* values of individual years.

The theoretical limits of the *(PCI)* are obtained as follows:

- when the rainfall in each month of the year is the same, the *(PCI)* equals 8.3
- when all the rainfall of the year occurs in one single month, the *(PCI)* equals 100

The *(PCI)* permits grouping of data sets according to the derived value. Oliver (1980) came to the conclusion that a *(PCI)* of less than 10 suggests a uniform distribution; a value from 11 to 15 denotes a moderate seasonal distribution ; a value from 16 to 20 denotes a seasonal distribution. An index above 20 represents strong seasonal effects, with increasing values indicating increasing monthly rainfall concentration

The rainerosivity factor R = EI_{30} is calculated from the relationships developed by Páez et al.(1983) for Valle de La Pascua (Llanos Centrales) and for Guanare (Llanos Occidentales) and Yaritagua (semiarid zone)

EI_{30} = -21.69 + 1.04 p (Valle de La Pascua)
EI_{30} = -15.82 + 0.93 p (Guanare)
EI_{30} = - 8.27 + 0.65p (Yaritagua)

In which p is the mean monthly rainfall amount.

RESULTS AND DISCUSSION

Figures 1, 2 and 3 illustrate the *(MFI)* values for the individual years for respectively the stations of the Llanos Centrales, of the Llanos Occidentales, and semiarid zone of Lara State

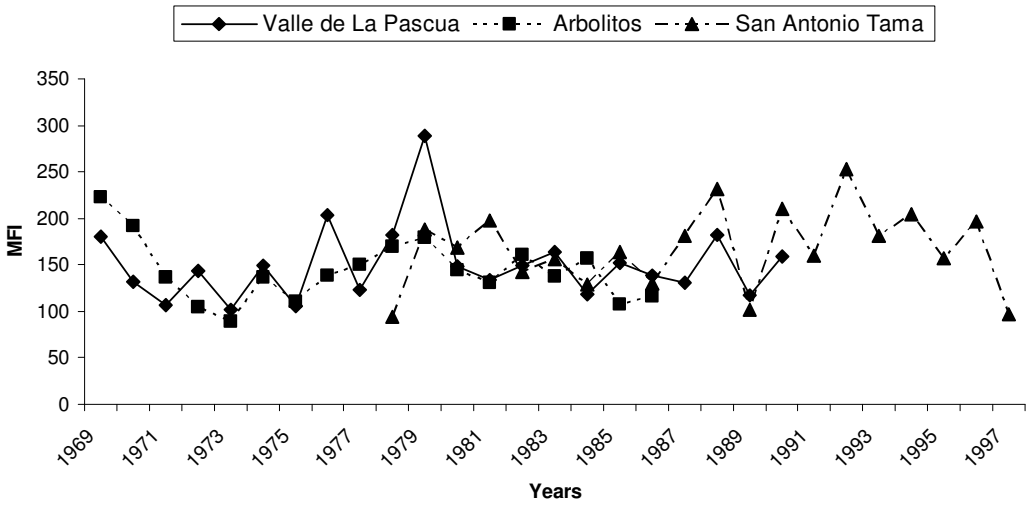

Figure 1: The Modified Fournier Index *(MFI)* for each individual year of the three stations of the Llanos Centrales.

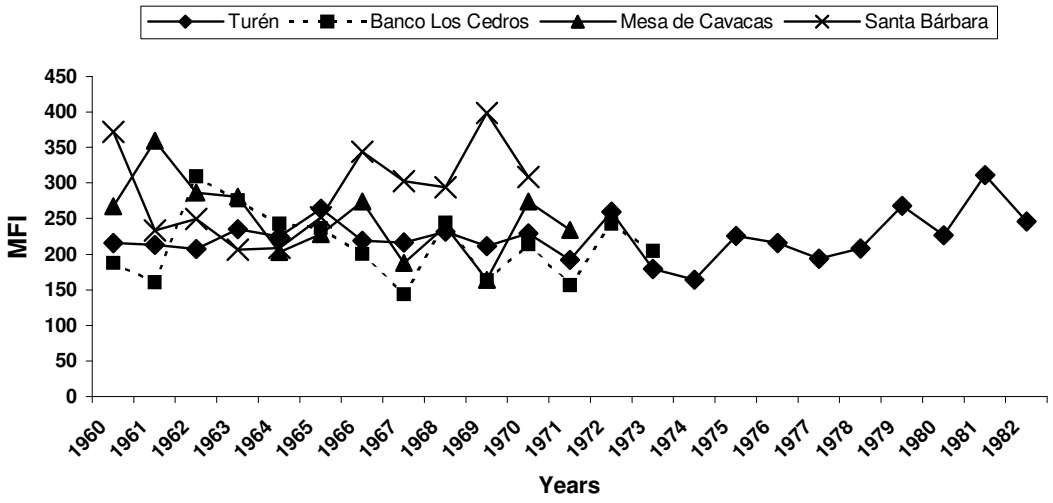

Figure 2**:** The Modified Fournier Index *(MFI)* for each individual year of the four stations of the Llanos Occidentales.

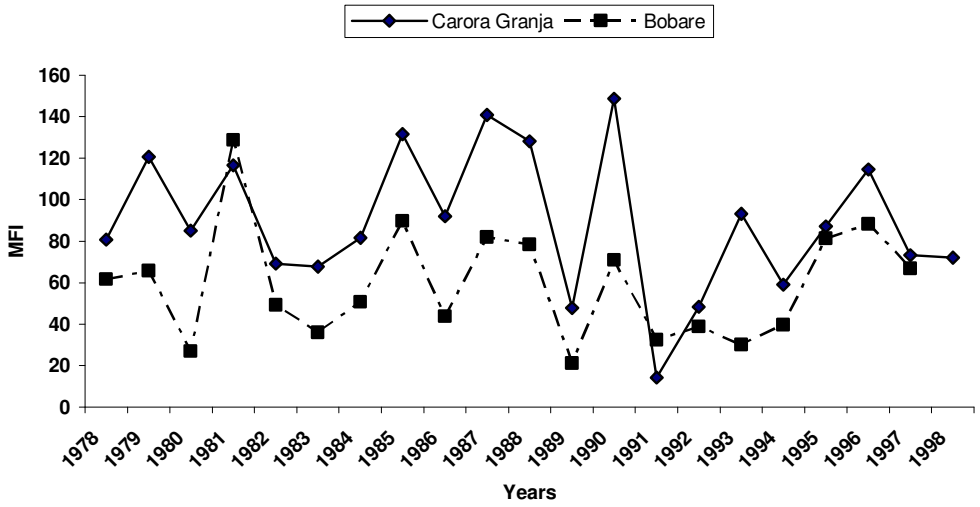

Figure 3: The Modified Fournier Index *(MFI)* for each individual year of the two stations of the semiarid zone in Lara State

Figures 4, 5 and 6 illustrate the *(PCI)* values for the individual years for respectively the stations of the Llanos Centrales, of the Llanos Occidentales, and of semiarid zone of Lara State

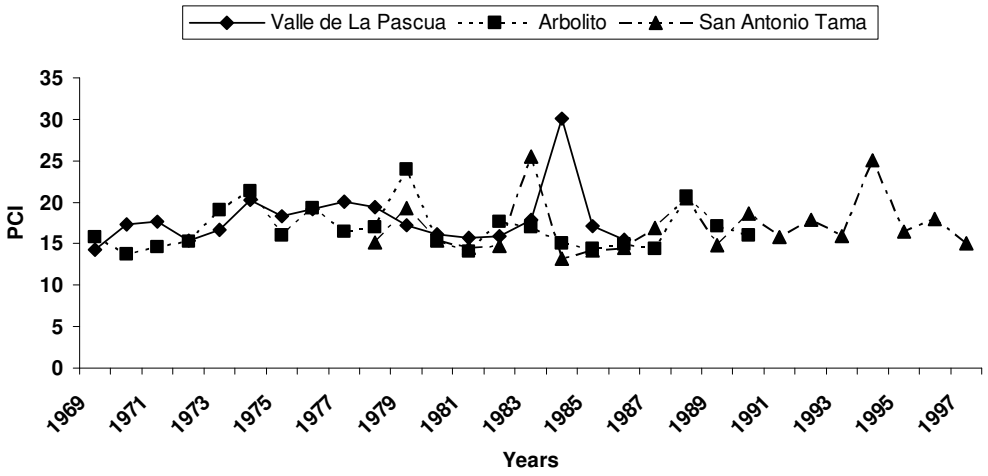

Figure 4. The Precipitation Concentration Index *(PCI)* for each individual year of the three stations of the Llanos Centrales.

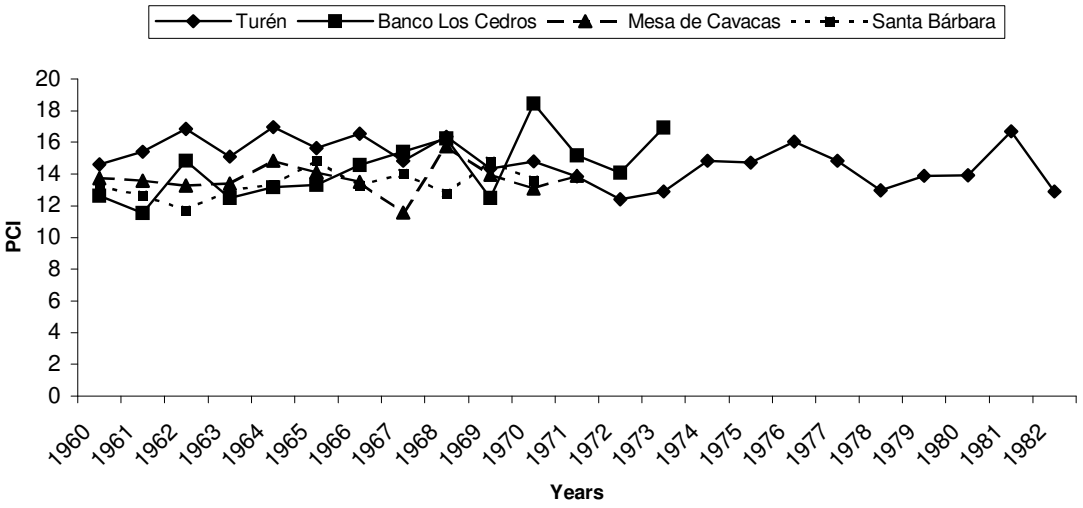

Figure 5. The Precipitation Concentration Index *(PCI)* for each individual year of the four stations of the Llanos Occidentales.

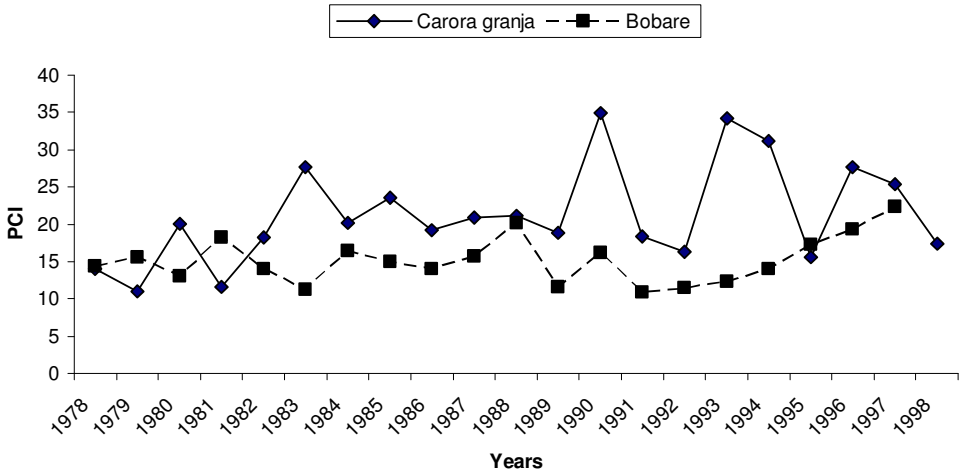

Figure 6. The Precipitation Concentration Index *(PCI)* for each individual year of the two stations of the semiarid zone in Lara State

Table 3 reports the mean $EI_{30,}$ the mean *(MFI)* and the *(PCI)* for the nine meteorological stations

Table 3. The mean annual *(MFI),(PCI)* and EI_{30} values for nine meteorological stations in Venezuela

Station	**Number of years**	**Mean annual precipiation (mm)**	***(PCI)1* mean**	***(PCI)2* mean**	***(MFI) 1* (mm) mean**	***(MFI)2* (mm) mean**	**EI_{30} MJ.mm.ha**
Valle de La Pascua	21	896	14	16	128	151	6762
Los Arbolitos	17	820	15	18	122	144	5922
San Antonio Tama	21	988	13	17	127	167	7700
Colonia Turén	23	1521	12	14	182	213	11100
Santa Bárbara	11	2051	12	14	220	250	17606
Mesa de Cavacas	12	1830	13	15	198	224	13822
Banco de Los Cedros	12	1503	12	13	263	288	10939
Carora Granja	21	458	12	21	55	89	2897
Bobare	20	378	10	15	38	59	2375

The *(PCI)2-* values for the three stations of the Llanos Centrales indicate a seasonal distribution of the rainfall within the year and a moderate seasonal distribution for the four stations of the Llanos Occidentales, whereas for the stations of semiarid zone indicate a moderate seasonal distribution in one of those and irregular distribution in the other one.

When considering the Modidified Fournier Index *(MFI)* as an indication of rainerosivity, then the rain in the Llanos Occidentales is much more agressive than in the Llanos Centrales and semiarid zone. This is also reflected in the EI_{30} values which are very high for the Llanos Occidentales. It is also worth to observe the higher values of *(PCI)2* and *(MFI)2* values as compard to *(PCI)1* and *(MFI)1*.

In view of estimating the rain erosivity in the three agricultural zones by means of rain characteristics more easily to determine than those required for the R-factor of the USLE, a linear relationship between *(MFI)2* and $R = EI_{30}$ was found as well as for the Llanos Centrales (figure 7) as for the Llanos Occidentales (figure 8).

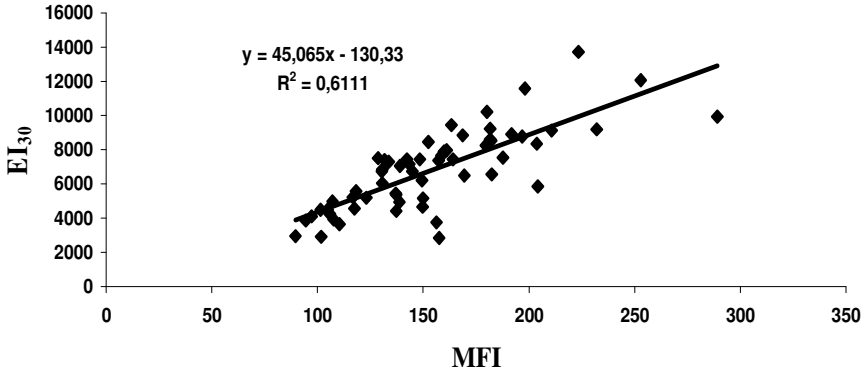

Figure 7. Relationship between the Modified Fournier Index *(MFI)2* and the USLE erosivity factor $R=EI_{30}$ for the two stations of the Llanos Centrales.

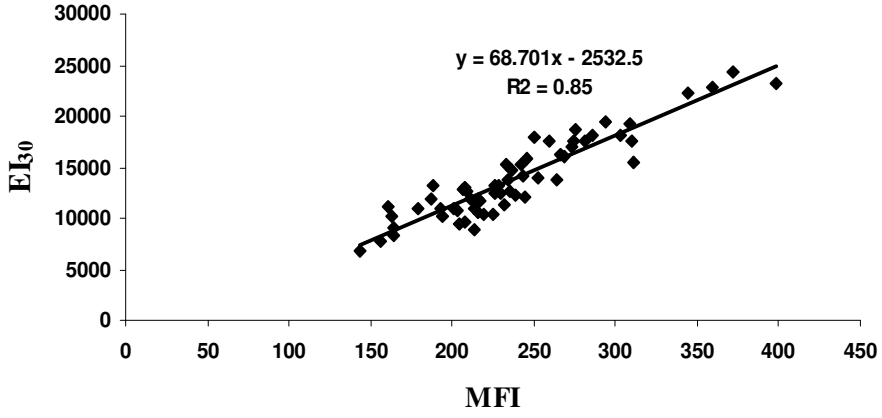

Figure 8. Relationship between the Modified Fournier Index *(MFI)2* and the USLE erosivity factor $R=EI_{30}$ for the four stations of the Llanos Occidentales

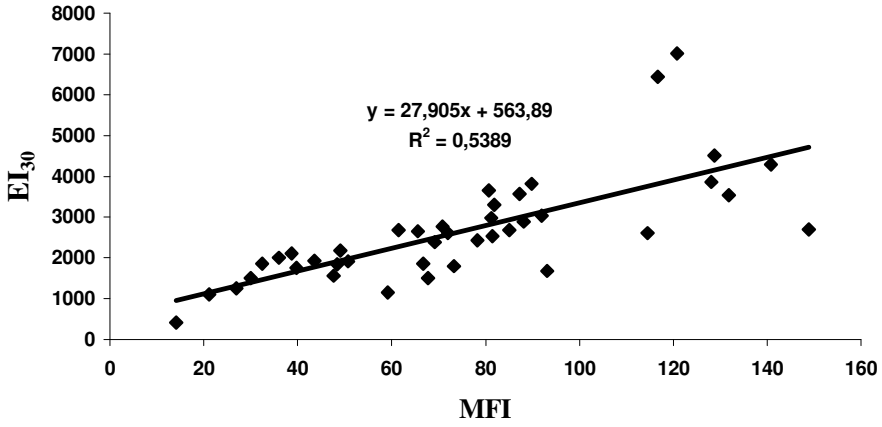

Figure 9. Relationship between the Modified Fournier Index *(MFI)2* and the USLE erosivity factor $R=EI_{30}$ for the two stations of the semiarid zone in Lara State

CONCLUSIONS

In view of assessing the rain erosivity in three agricultural zones of Venezuela (the Llanos Centrales and the Llanos Occidentales and a semiarid zone in Lara State), the Modified Fournier Index *(MFI)* was calculated on the basis of monthly precipitation amounts. In the Llanos Occidentales the rain is more aggressive than in the Llanos Centrals, with the lowest aggressiveness in the semiarid zone of Lara State

The Precipitation Concentration Index *(PCI)2* for the two stations of the Llanos Centrals indicate a seasonal distribution of the rainfall within the year and a moderate seasonal distribution for the four stations of the Llanos Occidentales. In the semiarid zone, these values indicate a moderate seasonal distribution in one of the stations and irregular distribution in the other one.

In view of using the *(MFI)* as the erosivity index in the USLE a relationship has to be established between *(MFI)* and $R=EI_{30}$. Different relationships exist for the stations of the

Llanos Centrales and for the stations of the Llanos Occidentales and for the two stations of the semiarid zone of Lara State.

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