Rainfall variability indices for the assessment of rainfall erosivity in arid and semi-arid zones of Venezuela

Deyanira Lobo L.[(1)]; Francisco Ovalles V.[(2)]; Donald Gabriels[(3)]; Naghely Mendoza[(1)]
[(1)] Universidad Central de Venezuela, Maracay, Venezuela; [(2)] Instituto Nacional de Investigaciones Agrícolas, Maracay, Venezuela;[(3)] Ghent University, Ghent, Belgium. lobod@agr.ucv.ve

1. Introduction

In ecologically marginal zones, the variability of the rainfall amounts and the distribution of rainfall evoke periods of drought or periods of rainfall excess. Spatial and temporal variability of rainfall patterns and the rainfall concentration are essential in assessing soil erosion, land degradation, desertification and soil and water conservation.
As agro-climatological zones have typical rain distributions and rain concentrations, the Modified Fournier Index (MFI) (Arnoldus, 1980) and the Precipitation Concentration Index (PCI) (Oliver, 1980), both calculated from monthly precipitation values over a number of successive years, could be used to characterize zones of rainfall aggressiveness in Venezuela.
In Venezuela sufficient rainfall records, especially rain intensity from automatic rain recorders, are not available to calculate countrywide the rain erosivity index $R = E_{30}$ as defined in the Universal Soil Loss Equation (USLE) (Wischmeier and Smith, 1978) with E the kinetic energy and I_{30} the maximum intensity during 30 minutes of the individual rainstorms.
For a few 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 as daily rainfall amounts (Guarisma et al, 1981) and mean monthly rainfall amounts (Páez and Agüero ,1986; Páez et al,1989)

2. Meteorological stations and methodologies:

Precipitation data were collected from nine meteorological stations in four states in the semi-arid regions of Venezuela. Their coordinates and the number of years of observation are shown in table 1.

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.

Table 1. Meteorological stations

Station	State	Latitude	Longitude	Elevation masl	Years
Clarines	Anzoategui	9º 96'	65º 16'	12	1979 – 1997
Barcelona	Anzoategui	10º 12'	64º 68'	7	1970 – 1991
Coro -aeropuerto	Falcon	11º 41'	69º 67'	21	1970 – 1998
Carora Granja	Lara	10º 16'	70º 08'	413	1978 – 1998
Bobare	Lara	10º 29'	69º 46'	660	1978 – 1997
Barquisimeto	Lara	10º 07'	69º 32'	614	1970 – 1990
Quibor	Lara	9º 9'	69º 42'	500	1969 – 1989
Quisiro	Zulia	10 º 88'	71º 29'	20	1970 – 1998
Maracaibo	Zulia	10 º 57'	71º 73'	65	1970 – 1990

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).
The limits of (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%

A low index value indicates a uniform distribution of the rainfall, while a higher index value indicates a higher concentration of the rainfall.
The EI_{30} values are calculated according to the relationship developed by Páez et al, (1989) for semi-arid regions and based on a linear relationship [EI_{30} = (- 8.27 + 0.65p)*10] with p the monthly precipitation.

3. Results and discussion

For the different stations and for the years mentioned in table 1 the *Modified Fournier Index (MFI)* and *Precipitation Concentration Index (CPI),* are calculated based on two different procedures (Michiels et al.1992). If the *(MFI)* and *(PCI)* are calculated from the estimated mean rainfall data set, they are reported as *(MFI)1* and *(PCI)1*. If the *(MFI)* and *(PCI)* values are averaged over a number of years they are reported as *(MFI)2* and *(PCI)2* (table 2). Those values are hence higher than *(MFI)1* and *(MFI)2.*

According to the *(MFI)* ranges proposed by CORINE (1992) the rain aggressiveness in the semiarid zones of Venezuela can be described as *low* with *(MFI)2* between 60-90 mm and *moderate* with *(MFI)2* values between 90-120 mm.
With a *(PCI)2* value of 21 the rainfall in Carora Granja is strong seasonally distributed While the stations with *(PCI)2* values between 16-20 are seasonally distributed and those with *(PCI)2* values between 11-15 have moderate seasonally distributed rainfalls

Table 2. The mean annual *(MFI),(PCI)* and EI_{30} values for meteorological stations in semiarid zones in Venezuela

Station	**Number of years**	**Mean annual precipitation (mm)**	***(PCI)1* mean**	***(PCI)2* mean**	***(MFI)1* (mm) mean**	***(MFI)2* (mm) mean**	**EI_{30} $MJ.mm.ha^{-1}.h^{-}$**
Clarines	19	679	15	17	99	117	3419
Barcelona	22	616	14	17	87	104	3010
Coro - aeropuerto	29	349	10	20	35	70	1276
Carora Granja	21	458	12	21	55	89	2897
Barquisimeto	21	552	11	14	58	77	2596
Bobare	20	378	10	15	38	59	2375
Quibor	21	510	11	13	55	75	2322
Quisiro	29	448	14	19	64	84	1921
Maracaibo	21	589	14	18	80	105	2833

As one of the objectives of the study is to find alternative indices for EI_{30} to be applied in USLE for prediction of field soil losses from water erosion, relationships were sought between EI_{30} and the Modified Fournier Index (MFI). The regressions showing the highest determination coefficient (r^2) for each meteorological station are reported in table 3.

Table 3. Relationship between MFI and EI_{30}

Station	**Regressions**
Clarines	$y = 3836,3\ Ln(x) - 14704$ ($r^2 = 0,75$)
Barcelona	$y = 0,1891x^2 + 69,833x - 2114,2$ ($r^2 = 0,64$)
Coro - aeropuerto	$y = 20,95x - 139,25$ ($r^2 = 0,64$)
Carora Granja	$y = 30,054x^{1,0049}$ ($r^2 = 0,72$)
Bobare	$y = 143,23x^{0,6916}$ ($r^2 = 0,86$)
Quibor	$y = 17,084x^{1,1332}$ ($r^2 = 0,79$)
Barquisimeto	$y = 0,265x^2 + 74,631x - 1406,9$ ($r^2 = 0,68$)
Quisiro	$y = 5,6674x^{1,3013}$ ($r^2 = 0,69$)
Maracaibo	$y = 0,1472x^2 + 5,311x + 1569,6$ ($r^2 = 0,84$)

y: EI_{30} = R
x: MFI

4. Conclusions

Although the Modified Fournier Index *(MFI)* is low to moderate in the semi-arid regions of Venezuela, this index can be used to describe the rainfall aggressiveness and to relate *(MFI)* with $R = EI_{30}$ to be used in USLE.
The Precipitation Concentration Index *(PCI)* shows that the rainfall in the semi-arid regions of Venezuela is moderate seasonally to strong seasonally distributed.

4. References

Arnoldus, H.M.J. (1980). *An approximation of the rainfall factor in the universal soil loss equation.* In: De Boodt, M. and Gabriels, D. (Eds) Assessment of Erosion. John Wiley and Sons, Chichester, 127-132

CORINE (1992): *Soil erosion risk and important land resources in the southern regions of the European Community*. Brussels, Commission of the European Community EUR 13233 EN, Luxemburg, Office for official Publications of the European Community, pp 97

Guarisma, R., Paez, M.L. and Rodriguez, O.S. (1981): *Rainfall erosion indices estimated from daily precipitation amount.* Winter meeting ASAE. December 15-81, 1981, Chicago, Illinois

Michiels, P., Gabriels, D. and Hartmann, R. (1992). *Using the seasonal and temporal precipitation concentration index for characterizing the monthly rainfall distribution in Spain.* Catena, 19:43-58.

Oliver, J.E. (1980): *Monthly precipitation distribution: a comparative index.* Professional Geographer, 32, 300 - 309

Páez, M.L., Rodríguez, O.S. and Lizaso,J. (1989). *Potencial erosivo de la precipitación en tierras agrícolas de Venezuela.* Rev. Fac. Agron (Maracay) Alcance 37:45-58

Páez, M.L., and Aguero, H. (1986): *Classificación de la tierra y recomendaciones de uso y manejo con fines de prevención y control de erosión íidrica en un área adyacente al embalse del Guri (La Paragua - El Cristo- San Pedro de las Bocas, Edo. Bolivar).* Informe de Avance. Proyecto Facultad de Agronomia, UCV - EDELCA. 79p Mimeografiado

Wischmeier, W.H., and Smith, D.D. (1978): *Predicting rainfall erosion losses. A guide to conservation planning. U*SDA Agric. Manual, N° 537