# New forms and directions in mathematical modeling of pluvial erosion

PETRU CARDEI
C Department
INMA Bucharest
No 6, Bd. Ion Ionescu de la Brad, Bucharest
ROMANIA
petru_cardei@yahoo.com http://www.inma.ro

*Abstract:* - This paper presents theoretical results obtained under research contract about the pluvial soil erosion and landslide prognosis. The presented results refer to a reformulation of the USLE model in the spirit of theoretical physics, in order to modeling the pluvial soil erosion phenomenon as dynamic process. There are many problems to be solved in the direction of the USLE model formulation in the language of the modern physics: USLE formula must be express in variables which depends by space and time; the replacement of the particular physical quantities characteristic of this model with universal physics quantities (for example, like the hydraulic models for soil pluvial erosion); the application of the general principles of physics to modeling the transformation of the geometry of the eroded surface; introduction of the random elements in the model. Another research direction is currently redrafting USLE model in terms of vectors. This model divides the year into time units. The issue presented here is not exhaustive. In this paper is addressed only the first two problems. To check the results obtained, is used experimental data obtained using a mobile installation to estimate the risk of pluvial soil erosion. In aim to replacement the particular USLE model variables with universal (not particular) physical variables, is used the tool of the dimensional analysis. The results and their verification, show that the proposed formulation for USLE is plausible.

With this material I hope to attract in this direction other researchers in the same category of phenomena. The new formulation can be a start to much new research.

*Key-Words:* - Soil, Erosion, Pluvial, USLE, model, physics, theory

## 1 Introduction

The Universal Soil Loss Equation, USLE is a mathematical model used to describe soil erosion processes caused by the water action on the hill slope. Erosion models play critical roles in soil and water resource conservation and nonpoint source pollution assessments, including: sediment load assessment and inventory, conservation planning and design for sediment control, and for the advancement of scientific understanding. The USLE or one of its derivatives is the most widely used models.

The USLE was developed in the United States based on soil erosion data collected beginning in the 1930s by the USDA Soil Conservation Service (now the USDA Natural Resources Conservation Service). The model has been used for decades for purposes of conservation planning both in the United States where it originated and around the world, and has been used to help implement the United States' multi-billion dollar conservation program. The Revised Universal Soil Loss Equation, RUSLE continues to be used for similar purposes. Under the direction of W. H. Wischmeier, the National Runoff and Soil Loss Data Center was established in 1954 at Purdue University with the goal of developing an erosion prediction equation compatible with data from all over the United States. What they would come up with would change the face of soil conservation. USLE stands for Universal Soil Loss Equation. The USLE is the most comprehensive technique available for field use in estimating cropland erosion. It involves six major factors that affect upland soil erosion in terms of water: rainfall erosiveness, soil erodibility, and slope length, slope steepness, cropping management techniques, and supporting conservation practices. The USLE model was created to provide a convenient working tool for conservationists.

## 2 Problem Formulation

The main objectives of the researches are the next:

O1-set out a formula of the USLE to estimate soil loss for pluvial isolated events;

O2-in this model, annual soil loss will be obtained by brief loss of soil corresponding to each pluvial event held during a year in agriculture;

O3-variables that occur in the proposed formula will be expressed only in SI units of measurement;

O4-will replace some particular variables of the USLE model with the usual physical quantities;

O5-mathematical expressions derived from experimental data for topographic factors (length and tilt), will take over from the scientific literature is now satisfactory express. However, a subsequent trial is recommended to obtain expressions of these factors starting from the physical and mathematical principles;

O6-is preserved from the classical model USLE factors influence addicted management;

O7-is consider that the future formulation of the pluvial erosion phenomenon like a dynamical process require a functional frame (already tried in the hydraulic formulations, [10]), starting from the general frame of the continuum mechanics.

### 2.1 USLE Classic Model, Short Presentation

Mathematical model of pluvial erosion of hill slope, USLE, is described by the universal equation of soil erosion:

$$A = R \cdot K \cdot L \cdot S \cdot C \cdot P,\ C = C_1 C_2 \qquad (1)$$

where the meaning and dimension of the factors is given in Table 1. This presentation is made in spirit of the objective O3.

Table 1 Notations, meanings, and dimensions of the USLE model variables.

| Factor | Signification | Dimension |
|---|---|---|
| $A$ | long-term average annual soil loss | $ML^{-2}T^{-1}$ |
| $R$ | rainfall erosivity factor | $MLT^{-4}$ |
| $K$ | the soil erodibility factor | $L^{-3}T^{3}$ |
| $L$ | topographic factor of length | $M^0L^0T^0$ |
| $S$ | topographic factor of slope | $M^0L^0T^0$ |
| $C_1$ | cropping management factor of vegetal cover | $M^0L^0T^0$ |
| $C_2$ | cropping management factor of tillage | $M^0L^0T^0$ |
| $P$ | conservation practices factor | $M^0L^0T^0$ |

Equation (1) contains global factors, usually features for a year and a certain land area. Unlike the original formulation, which uses imperial system of units of measure, we used units of measurement system international (SI). To complete the definition, must be explained the factors of the right member of equation (1). We will not reproduce tables or formulas for these factors, we only made references.

For each factor of the right member of the universal soil erosion equation (1), there are tables, maps and diagram, which giving the values of this factors in the most common situations. For example see [1] and [2]. For the calculation of rain erosivity, $R$ is given by the experimental formula, for example, in [1], [2], [4], [5] or [6]. Also, in [4], is given a relationship for calculating soil erodibillity, $K$, proposed by Romkes in 1986 and reviewed by Renard and others in 1997. Another formula for the soil erodibility appears in [6].

The authors of [4] give a relationship for calculating the factor $C$, keeping the index of the normalized difference vegetation.

Are very well known a series of formulas for calculating topographical factors, $L$ and $S$, for example, [4] or [7].

In recent decades, much of the data are obtained by digital processing of aerial images (airplane, satellite), see for example [15].

### 2.2 Defining a New USLE Model

To find possible links between variables that occur in the universal equation of soil erosion (1) and physical characteristics of precipitation, soil and hill slope geometry is necessary to introduce a rigorous dimensional and functional framework (O7).

First, in the universal equation of soil erosion, (1), will replace the global variables with spatial - temporal density (function) of the same variables.

Initial goal was to produce this change only for rain erosivity $R$ and soil erodibility, $K$, thus avoiding the use of particular physical quantities, which are difficult to measure or determine.

In the proposed formulation, the new variables of the universal soil erosion equation, will be fields depending on the spatial and temporal variable $\boldsymbol{x}$, $t$. Thus, the proposed equation is the next:

$$\begin{aligned} & a(\boldsymbol{x},t) = r(\boldsymbol{x},t)k(\boldsymbol{x},t)l(\boldsymbol{x},t)s(\boldsymbol{x},t)c(\boldsymbol{x},t)p(\boldsymbol{x},t), \\ & c(\boldsymbol{x},t) = c_1(\boldsymbol{x},t) \cdot c_2(\boldsymbol{x},t) \end{aligned} \qquad (2)$$

This formulation reveals that the erosion phenomenon is a process developed in time and space. The geometry of the soil surface subject of the pluvial erosion is described by the equation:

$$\boldsymbol{x} = \boldsymbol{x}(t) \tag{3}$$

For each erosion event, there is a reference configuration, an initial surface, described in the coordinates ***X***, independent of time. The link between the two types of coordinates is given by the equation:

$$\boldsymbol{x} = \chi(\boldsymbol{X}, \boldsymbol{t}) \tag{4}$$

where $\chi$ is a mapping of the initial configuration onto the current configuration.

For $t = 0$ we find the initial surface soil subject to erosion pluvial. Equation (4) express the connection between the material coordinates, ***X***, and the spatial coordinates, ***x***, as in the continuum mechanics (see for example, [11]). Taking into account these observations, the equation of the initial surface shape can be written in the implicit form:

$$\boldsymbol{F}(\boldsymbol{X}) = \boldsymbol{F}(X_1, X_2, X_3) = 0 \tag{5}$$

where $X_1$, $X_2$, $X_3$ are components of the vector $\boldsymbol{X}$ on the initial configuration of surface. The current form of the surface (at time $t$) can be written in the implicit form:

$$\boldsymbol{f}(\boldsymbol{x}) = \boldsymbol{f}(x_1, x_2, x_3) = 0 \tag{6}$$

where $x_1$, $x_2$, $x_3$ are the coordinates of the vector $\boldsymbol{x}$ (eroded) the deformed configuration of the surface. In many cases the surface, at least locally, can be described as parametric surface.

To describe the entire process of deformation of the surface by erosion, equation (1) is not enough. Additional assumptions and principles of physics are necessary for modeling the complex phenomenon of pluvial erosion. The erosion is much more complex than a plastic deformation and than the flow of a fluid with a variable concentration on vessel variable walls. I have not profoundly discussed this idea. Without success, tried before a model that would provide the final form of the material surface subjected to erosion phenomenon.

This formulation satisfies the objective O7.

After (2), the amount of lost ground on a surface $S$, subject to erosion, in a time interval of length $T$, will be calculated using the formula:

$$A(T) = \iint_{\boldsymbol{S}} \int_0^T a(\boldsymbol{s}, \tau) d\tau d\boldsymbol{s} \tag{7}$$

where $d\boldsymbol{s}$ is the variable of integration on the current configuration surface $\boldsymbol{S}$, and $d\tau$ is the time variable of integration. Then, taking $T$ = 1 year = 365 (or 366) x 24 x 3600 seconds, annual soil loss per hectare (in tons per hectare and year) will be given by the formula:

$$A = \frac{\iint_{\Sigma} \int_0^T a(\boldsymbol{\Sigma}, \tau) d\tau d\boldsymbol{\Sigma}}{\iint_{\Sigma} d\boldsymbol{\Sigma}} \cdot 10 \tag{8}$$

where $d\boldsymbol{\Sigma}$ is the variable of integration on the initial configuration, surface $\Sigma$. The formula (2) satisfies the objective O1. The formulas (7) and (8) satisfy the objective O2.

Such a formulation would be appropriate to address issues of dynamic of the pluvial erosion, for example [14].

## 3 Problem Solution

In this chapter will make the transition from originating factors of USLE model at the quantities of all common areas of the physics. I mean replacing the rain erosivity factor and the soil erodibility factor, as I showed the objective O4. For this stage of development, the remaining factors are kept in original or modified form in various papers in the field. A list of variables that appear in the new formula (2), containing the notations, significance, and physical dimensions, is given in Table 2, according with objective O3.

Table 2 Significance of the variables that appear in the new formula USLE, (2) and dimension.

| **Factor** | **Signification** | **Dimension** |
|---|---|---|
| $a$ | Soil loss | $ML^{-2}T^{-1}$ |
| $r$ | Rainfall erosivity | $MLT^{-4}$ |
| $k$ | Soil erodibility | $L^{-3}T^{3}$ |
| $l$ | topographic factor of length | $M^0L^0T^0$ |

| | | |
|---|---|---|
| $s$ | topographic factor of slope | $M^0L^0T^0$ |
| $c_1$ | cropping management factor of vegetal cover | $M^0L^0T^0$ |
| $c_2$ | cropping management factor of tillage | $M^0L^0T^0$ |
| $p$ | conservation practices factor | $M^0L^0T^0$ |

Among the factors of the right member of the equation (2), only $r$ and $k$ have physical dimension. Rainfall erosivity, $k$, and soil erodibility $r$, are physical quantity used only in this type of physical phenomena. These are reasons why I tried to replace the two factors with physical quantities, largely implied in the describe of the natural phenomena. Topographic factors are already fairly well quantified under experimental formulas, so I don't change their structure. Changing topographic factors formulas, involve complicated researches located at the border between the solid mechanics and fluid mechanics. Until now we have not obtained positive results in this direction. Finally, the cropping management factors, $c_1$, $c_2$ and $p$, will keep that in the original form of USLE model, because for them we have no alternative now.

Using some very plausible assumptions, equation (2) may be simplified enough. Generally, for regular pluvial events, can be considered that the factors $k$, $c_1$, $c_2$, $p$, are independent of time, but values should be chosen according to the stage of development of vegetation and distribution works in the soil.

Also, taking into account the areas sizes for which is made an assessment of the risk of erosion, is can accept the hypothesis that the same factors are independent of the spatial variable.

If that assumption that the eroded surface is approximately flat portion of width $b$ (often used in the original USLE model calculations) is permitted, then space is reduced to two dimensions, properly to two coordinates: $x$ - horizontal distance from the top of slopes and $y$ height (elevation).

For the usual pluvial events and for surfaces without appreciable convexity, it can be the assumption that the topographic factors do not depend on time.

In these conditions the equation (2), became:

$$a(\boldsymbol{x},t) = r(t)\cdot k\cdot l(\boldsymbol{x})\cdot s(\boldsymbol{x})\cdot c_1\cdot c_2\cdot p \qquad (9)$$

In the model given by equation (9), the function $r$ plays the role of command for the erosion process, and the other factors on the right member are factors of influence for the dynamic process.

For the purpose of finding rainfall erosivity and soil erodibility dependence by the physical quantities widely used, is used tools of dimensional analysis (Buckingam π theorem).

### 3.1 Investigations on the Possible Factorial Structure of the Rainfall Erosivity

Using dimensional analysis can lead to different formulas depending on the type and number of physical quantities considered. For the rainfall erosivity, a possible variant is the next:

$$U(r, I, i, \rho_w, w, \phi_w) = 0 \qquad (10)$$

where $U$ is a function, yet does. Physical quantities which appear in formula (10) and have not been specified so far are given in Table 3.

Table 3 Physical size of which depends rainfall erosivity.

| notation | Denomination | Dimension |
|---|---|---|
| $I$ | precipitation amount | L |
| $i$ | speed variation of precipitation amount | $LT^{-1}$ |
| $\rho_w$ | rain water density | $ML^{-3}$ |
| $w$ | average speed of a falling drop of water to impact with the ground | $LT^{-1}$ |
| □*w* | average diameter of the rain drop | L |

Speed variation of the precipitation amount is defined by the formula:

$$i = \frac{dI}{dt} \qquad (11)$$

Applying Buckingam π theorem of dimensional analysis, are obtained, for the rainfall erosivity, the following three dimensionless combinations:

$$\pi_4 = \frac{r}{\rho_w \cdot i^4},\ \pi_5 = \frac{\phi_w}{I},\ \pi_6 = \frac{w}{i} \qquad (12)$$

According to theorem π, between the four dimensionless combinations there is the next relationship:

$$r = \rho_{\mathbf{w}} \cdot i^4 \Phi\left(\frac{\phi_w}{I}, \frac{w}{i}\right), \qquad (13)$$

where $\Phi$ is a function whose form is determined experimentally.

It can still get an interesting and simple form for the rain erosivity, $r$, starting from the relationship:

$$U(r, I, i, e) = 0 \qquad (14)$$

where $e$ is the volume density of the kinetic energy of rain:

$$e = \rho_w w^2 \qquad (15)$$

In this case there is one dimensionless combination:

$$\pi_4^{'} = \frac{r}{i^2 \rho_w w^2} \quad . \qquad (16)$$

For this case, is obtaining the following formula of rain erosivity:

$$r = \psi\left(\rho_w i^2 w^2\right), \qquad (17)$$

where $\Psi$ is a function whose form is experimentally determined.

### 3.2 Investigations on the Possible Factorial Structure of the Soil Erodibility

For soil erodibility density, $k$, a similar calculus to that for $r$ starts from the relationship:

$$V(k, \rho_S, \sigma, v) = 0 \qquad (18)$$

where $V$ is a function, yet does. The dimensions of the physical quantities involved are given in Table 4.

Table 4 Physical sizes of which the soil erodibility depend.

| **notation** | **denomination** | **dimension** |
|---|---|---|
| $\rho_s$ | soil density | $ML^{-3}$ |
| $\sigma$ | stress resistance to detachment in the superficial layer of the soil | $ML^{-1}T^{-2}$ |
| $v$ | infiltration rate | $LT^{-1}$ |

In this case the dependence is simpler:

$$k = const. \cdot \left(\frac{\rho_S}{\sigma}\right)^{\frac{3}{2}} \; , \qquad (19)$$

where the constant will be experimentally establish.

## 4 Final Forms for the new USLE Formula

If rain erosivity is the form (13) and $\Phi$ function is the identity function is, then the formula (2) becomes:

$$a = c \cdot \rho_W \left(\frac{dI}{dt}\right)^3 w \frac{\phi_W}{I} \left(\frac{\rho_S}{\sigma}\right)^{\frac{3}{2}} l(x) s(\theta) c_1 c_2 p \qquad (20)$$

where $c$ is a constant. If the rain erosivity is the form (17) and $\Psi$ function is identity function, then the formula (2) becomes:

$$a = c \cdot \rho_W \left(\frac{dI}{dt}\right)^2 w^2 \left(\frac{\rho_S}{\sigma}\right)^{\frac{3}{2}} l(x) s(\theta) c_1 c_2 p \qquad (21)$$

Generally, the derivative of the precipitation amount in report to time, which is called the speed variation of precipitation amount, will be replaced in checking calculations with the ratio of the precipitation amount and the rain duration. Experimental data used for verification were obtained in experiments with constant flow.

## 5 Experimental Verifications

Dimensional analysis recommends using experimental data to determine the arbitrary functions or constants which has obtained by applying of the dimensional calculus. In this work, is verify the formula (21) considering that the constant value is unity and adjusting the theoretical results with experimental data using the soil stress resistance $\sigma$, which appears in the formula for calculating soil erodibility (19). The test will be passed if the soil stress resistance $\sigma$ has admissible values and if they can be explained relative to the time of year in which experiences were made. The tested formula is the next:

$$a = \rho_w i^2 w^2 \left( \frac{\rho_s}{\sigma} \right)^{\frac{3}{2}} LSC_1C_2P \qquad (22)$$

Experimental data used were obtained using a mobile installation to estimate the risk of erosion on the territory of the Research Institute for Vine and Viticulture Valea Calugareasca [8], [9]. The conditions and results of the experiences and results of verifications, appear in Table 5. Basically, is calculating the soil stress resistance σ, so that the theoretical density of sediment yields to better estimate the experimental density of sediment yields.

Is important for the result verification the time of experiences were held. The soil stress resistance must be correlated with the initial soil moisture and with the distance in time at the last plowing. Crop technologies used in the plantation where the experiences are developed, recommends four or five plowing, around of the data: April 1, May 15, July 1, August 15 (optional), and October 15.

The experience A was held on April 03, 2008 immediately after the first spring plowing. Therefore superficial layer of soil was very loose, the tension of the resistance being negligible. This explains the very short time until the starting to flow sediments.

The experience B, was held on May 13, 2008, was performed two days before a new plow, the soil is more compacted, due to maintenance works plantation. At that time was recorded and the smallest amount of moisture in the superficial soil layer. These conditions justify the higher stress resistance of the soil in the experiences B and E than the experience A. Experiences developed in the area of lysimeter station, E, the soil stress resistance was higher than the values recorded in the experiences A and B because the moment of experience E is before the one last autumn plowing and after the traffic caused by the treatments and collect the harvest.

Experience C, took place in June 25, 2008, also with a few days before a new plow, but the superficial layer of soil had a little more moisture than in the cases of the experience D, is held in the same location, farm no 4. These conditions explain stress resistance higher in the superficial layer of soil in C experience in report to the experience D.

## 6 Reflections on the rain erosion problem meshing time

Rain erosion problem is a spatial-temporal problem. Generally, the temporal period or quasi period of the phenomenon, is not less than one year. This time is very long to effectively address the problem of rain erosion taking the time unit the second. This statement is valid in a mathematical model type USLE, but also for the mathematical model sketched in 2.2. Temporal unity of the original USLE model is the year. All factors that influence storm erosion are global factors (see (1) and Table 1), valid for a period of one year. Experimental research of storm erosion, using the experience of short duration, with the control system of watering, required adaptation USLE model storm events, in aim to verify the results. The pluvial erosion events durations are by the order of minutes or hours. It was therefore necessary to refine the annual time period divisions: months, days, hours, etc. Refining the time mesh lead at least two advantages. The first is to increase the accuracy of risk prediction of storm erosion. The second advantage is to use directly in the calculus, the weather observations (rainfall intensity), which permit the calculus of the rainfall erosivity factor.

### 6.1 Meshing the year in days

If the basic unit of time is considered the day when the annual amount of soil lost by erosion will be calculated by summing up the losses of soil corresponding daily rain events. It starts from the diagram of daily precipitation amounts (Fig.1) and the corresponding durations thereof, or information on their average duration.

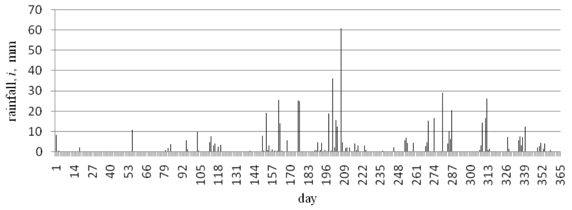

Fig. 1 Weather observations – the daily rainfall, which is the component of the rainfall vector.

An example of such precise estimates appears in [16]. The formulation of the universal equation of soil erosion is, in this vision:

$$a_j = r_j \cdot k_j \cdot l_j \cdot s_j \cdot c_{1j} \cdot c_{2j} \cdot p_j,\ j = 1,\dots,N, \qquad (23)$$

where

$$\begin{aligned} &\boldsymbol{a} = \{a_j\}_{j=1,\dots,N},\ \boldsymbol{r} = \{r_j\}_{j=1,\dots,N},\ \boldsymbol{k} = \{k_j\}_{j=1,\dots,N},\\ &\boldsymbol{l} = \{l_j\}_{j=1,\dots,N}, \boldsymbol{s} = \{s_j\}_{j=1,\dots,N},\\ &\boldsymbol{c}_1 = \{c_{1j}\}_{j=1,\dots,N},\ \boldsymbol{c}_2 = \{c_{2j}\}_{j=1,\dots,N},\ \boldsymbol{p} = \{p_j\}_{j=1,\dots,N},\\ &\boldsymbol{i} = \{i_j\}_{j=1,\dots,N},\ \boldsymbol{t} = \{t_j\}_{j=1,\dots,N} \end{aligned}, \qquad (24)$$

are the vector form of the factors of the erosion influence and *j* are the components indices.

For the new formulation is important the way that divides the period of one year: months, weeks, days, hours, minutes or seconds. The length of the vectors (vectors dimension) depend on the unit of year divide: 12 for the monthly divide, 52 for the weekly divide, 365 or 366 for daily divide, etc. I note *N* the number of divisions of the year. In these conditions, the factors of the USLE are shown in the table 7.

Table 7 The USLE factors in the vector formulation

| Vector factor | Physical dimension |
|---|---|
| The vector of the soil loss, *a* | $M L^{-2} T^{-1}$ |
| The vector of rainfall erosivity, *r* | $M L T^{-5}$ |
| The vector of the soil erodibility, *k* | $L^{-3} T^{2}$ |
| The vector of the topographic factor of slope length, *l* | - |
| The vector of the topographic factor of slope angle, *s* | - |
| The vector of the of the vegetation cover, $c_1$ | - |
| The vector of the soil disturbation management, $c_2$ | - |
| The vector of the conservative practices, *p* | - |
| The vector of the rainfall intensity, *I* | L |
| The vector of the of the duration of the pluvial events, *t* | T |

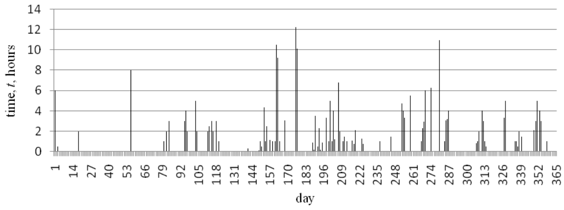

Fig. 2 The daily distribution of the rainfall – the component of the time rainfall during, ***t***.

The vector ***r*** will be calculated using the vectors ***i*** and ***t*** (whose distributions are shown in the figure 1 and 2), by the formulae for the calculus of the rainfall erosivity, [4] and [5]. If the vector of the kinetic energy is note ***e***, then, after [4] or [5], is possible to use the next variants:

$$e_j = 0.29\left[1 - 0.72\exp(-0.05\frac{i_j}{t_j})\right], t_j \neq 0, \qquad (25)$$

$$e_j = 0.283\left[1 - 0.52\exp(-0.042\frac{i_j}{t_j})\right], t_j \neq 0, \qquad (26)$$

and

$$e_j = \begin{cases} 0.119 + 0.0873 \cdot \log_{10}\frac{i_j}{t_j}, & \frac{i_j}{t_j} \leq 76\text{mm/h} \\ 0.283, & \frac{i_j}{t_j} > 76\text{mm/h} \end{cases}, \qquad (27)$$

for all $t_j \neq 0$. For the vector, ***r*** component calculus is use the next formula:

$$r_i = e_j \cdot \frac{i_j}{t_j},\ t_j \neq 0. \qquad (28)$$

Using the distribution of the ***i*** and ***t*** factors, which are shown in Fig. 1 and 2 (year 2002 in Valea Calugareasca), is calculate the vector ***r***, which is shown in the Fig. 3.

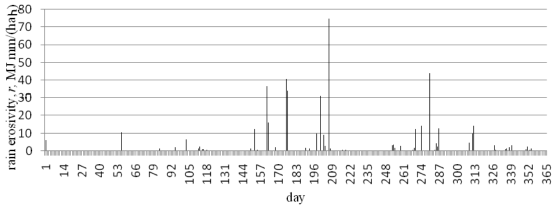

Fig. 3 The daily distribution of the rainfall erosivity factor – the components of the vector ***r***.

The soil erodibility vector can be determined experimentally or using the calculation formula as in [12], for example. The erodibility factor depends on the soil structure and texture. Although you cannot exclude these factors change during the year, it can be assumed that, for a domain space sufficiently small the erodibility factor varies little. This factor can be calculated using the formulae given in [12], knowing the soil structure and texture, or can be experimentally determined. For example, is consider that the soil erodibility vector (factor), is constant, $k_j=k_0$, for all $j$ = 1,…, 365 or 366.

The topographical factors (vectors) can be presumed constant during the year also. Rarely, these factors can vary appreciably during the year (even possible due to erosion or landslides, irreversible changes, or, in case of redevelopment, changes remediative). Therefore it is considered: $l_j=l_0$, $s_j=s_0$ for all $j$ = 1,…, 365 or 366. Vectors $\boldsymbol{l}$ and $\boldsymbol{s}$ are presumed constant and can be calculated with the classical formula in [4] or [5].

Coverage factor (vector) depends on the type of cultivation and management, describing the extent to which plant cover protects the soil against the water. The example described in this paper refers to a vineyard, so that the spectrum of variation of annual coverage factor $\boldsymbol{c_1}$, as shown in Figure 4.

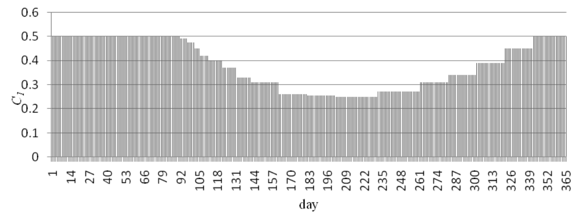

Fig. 4 The distribution of the coverage factor (vector) during the year.

Cover management factor that depends on the technology of the culture, especially mechanized work and, within them, particularly the work of the soil, $\boldsymbol{c_2}$, has a variable during the annual cycle of cultivation of vines. Various types of works causing disturbance of the soil more or less sensitive to the water erozional action. For this example we built a distribution corresponding to a plantation of vines located on the direction of the hill - valley (up – down) with the distance of 3 m between rows, which are the subject of a plow, four times on the year, this is the only mechanized work which affects the soil For this example we built a distribution of a plantation of vines on the direction of the hill - valley with the distance of 3 m between rows, which are the subject of a plow, four times a year, this is only a mechanized work affects. Therefore, the distribution of cover management factor that depends on the technology of the culture, $\boldsymbol{c_2}$**,** is shown in Fig. 5.

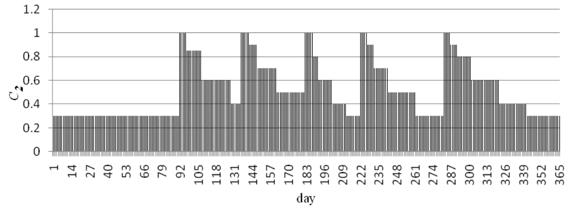

Fig. 5 The distribution of the cover management factor that depends on the technology of the culture.

Assume that the (vector) factor $\boldsymbol{p}$, which depends on the arrangement of crops in the field, is constant during a year and for the vineyard with more. Therefore, $p_j=p_0$, $j$= 1,…, 365 or 366. With these data can pass to calculate the vector of daily soil loss, using the formula (23).

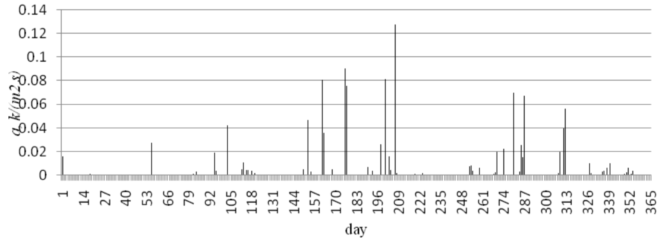

Fig. 6 Soil loss vector time distribution, $\boldsymbol{a}$.

By summation, is calculating annual soil loss per hectare:

$$A = \sum_{j=1}^{N} a_j , \tag{9}$$

where $A_a$ is the annual soil loss per hectare, $N$ is the number of days of the year, and $j$ is variable summary (summation indices).

For verification, we chose an area that has experienced an artificially pluvial event, by the following data: = 0.03, $l_0$= 0.795, $s_0$= 0.716, $p_0$= 1, slope 7.1 %, slope length 14 m, and parcel width 6 m. The manager communicated carrying four plowing, around data 01.04, 15.05, 01.07 and 15.10. Sometimes, optionally, may be an additional plow around the 15.08. Pluvial regime, whose spectrum appears in Fig. 1, corresponds to the registered Valea Calugareasca in 2002. Is obtain $A$= 1.19 t/ha. The average daily quantity of soil lost per hectare in 2002 is 3.26 kg. Soil loss per hectare for 2002, estimated with this algorithm, fits very well in European maps erosion, [13].

## 6.2 Meshing the year in months

Another example of the meshing of the year it is split into monthly periods. The twelve components of the monthly vector ***R*** are obtained by monthly sum of daily meshing components. The monthly distribution of the erosivity factor is show in the figure 7 (year 2002). The monthly vector factors $C_1$ and $C_2$ are obtain by averaging the daily distribution by each month. These distribution factors is show in the figure 8 and 9. Performing the same operations as in the case of daily mesh, we obtain the distribution of annual soil loss / ha. This distribution is given in the figure 10. By summing up, resulting annual soil loss per hectare: 1.435 t/ha per year. Calculation of soil loss by erosion during the annual undivided classic method, the same year, 2002, leading to value 1.491 t/ha. These values show that the estimation of erosion risk decreases with increasing the number of divisions or low their length.

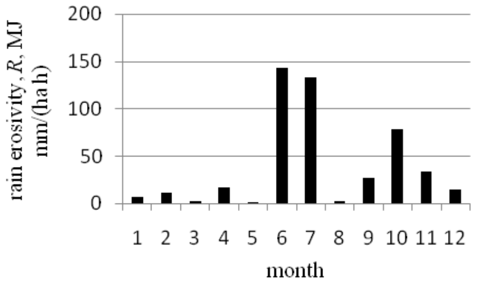

Fig. 7 The monthly distribution of the rainfall erosivity factor – the components of the vector ***r***.

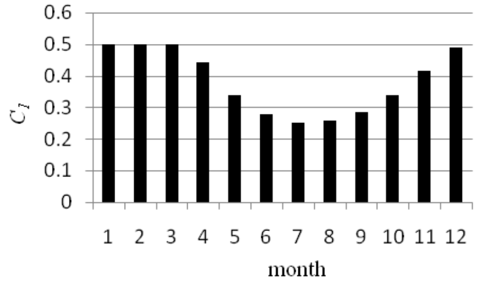

Fig. 8 The distribution of the coverage factor (vector) during the year.

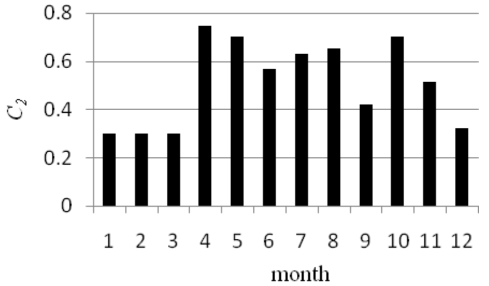

Fig. 9 The distribution of the cover management factor that depends on the technology of the culture.

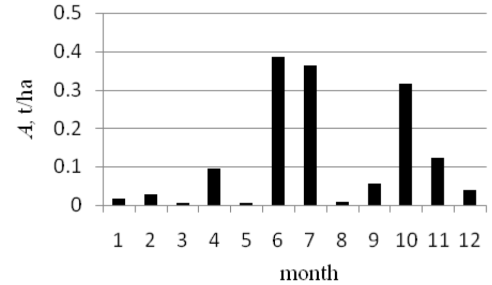

Fig. 10 Soil loss vector time distribution, ***a***.

Refining the mesh annual period could continue, reaching the hours, minutes, seconds. Using the division of the second, rain can be described very well by the amount, duration, and intensity. Number of divisions will then be very large: 31536000 – 31622400 s. This will be the size of the vector of influence factors described in this chapter. Even for basic calculations of the method described in this chapter, common software has difficulty for two reasons: large size of vectors and methods for data input. When data on rainfall regime cannot be collected for every second, interpolation and extrapolation are necessary to realize complex refining data per second.

The difficulties are greater for the application time erosion problem that in Chapter 3, which would require solving differential equations with partial derivatives (maybe integral-differential), for this great range of time.

We have not any detail of these developments.

## 7 Conclusions

The values of soil stress resistance in shallow layer of soil resulting from the requirement that the formula (22) to estimate how much better experimental results are perfectly plausible. Variations are in accordance with the schedule of works on planting of vines. Result that the formula (22) satisfies a minimum check.

To enhance the formulas precision, are necessary further experimental verification, in which the constants can be replaced with correction coefficients in formulas (20) and (21). Research will continue to finalize a model derived from the USLE, which contain only common (universal) physical quantities. Remain unsolved for now the objective O5.

USLE model reformulation, in the spirit of the objectives O1 – O7, may lead to the natural unification of the two traditional ways of addressing the pluvial erosion: the experimental model USLE, and the hydraulic modeling.

Vector representation method for estimating the risk of erosion, facilitating users to work directly with meteorological observations. In addition, using this method, spectra may be mold coatings management. These features allow a personal contribution limit users to selecting the parameters that appear in the universal equation of erosion. Thus, the result obtained by a more pronounced objectivity.

Sometimes, weather observations do not give rain duration, and then the user must complete the rain duration vector. Vector of terms filling rain is not arbitrarily, but taking into account: maps to the average intensity of pluvial zone of interest, number and distribution very intense pluvial events, data that are contained in various sources.

Correlation between rain and the high-intensity erosion is very strong. Between the vectors of the annual soil loss per hectare and the quantity of rainfall, the correlation has a very high value, 0.976.

Starting from this representation of the classic calculation of erosion risk estimation can develop a simple program for calculating the risk of erosion. Input data (vectors), $\boldsymbol{t}$ and $\boldsymbol{i}$, are exactly the meteorological observations. After the basis calculus, may be a computer optimization of the management works, which perturb the soil. This calculation will achieve optimal allocation of mechanized works, which disturb soil depending on the amount of rain vector or on the rain erosivity vector.

If the test of this method will be satisfactory, then I want to develop the theory of the functional USLE formula, where the factors are function on the time and space.

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Table 5 Conditions of the experiments.

| **Experiences** | **A** | **B** | **C** | **D** | **E** |
|---|---|---|---|---|---|
| Parcell | Lysimeter Station | Lysimeter Station | Farm no 4 | Farm no 4 | Lysimeter Station |
| Time experiences | 03.04.2008 | 13.05.2008 | 25.06.2008 | 26.06.2008 | 16.10.2008 |
| Land slope, % | 7.10 | 7.10 | 10.13 | 10.13 | 7.40 |
| Rows orientation | up -down | up -down | up -down | up -down | up -down |
| Distance between the rows, m | 3.00 | 3.00 | 2.00 | 2.00 | 3.00 |
| Parcell width, m | 6.00 | 6.00 | 6.00 | 6.00 | 6.00 |
| Parcell length, m | 14.00 | 14.00 | 9.00 | 9.00 | 13.00 |
| Parcell area, m$^2$ | 84.00 | 84.00 | 54.00 | 54.00 | 78.00 |
| Initial humidity in the layer 0 – 20 cm, % | 15.01 | 14.72 | 17.74 | 27.77 | 15.00 |
| amount of water down, m | 0.007464 | 0.040283 | 0.112276 | 0.025965 | 0.127141 |
| Time to flow, s | 1464 | 8292 | 13980 | 3120 | 22920 |
| Time to collect sediment, s | 480 | 972 | 429 | 410 | 955 |
| The average rain intensity, m s$^{-1}$ | 0.0000051 | 0.00000486 | 0.00000779 | 0.00000736 | 0.00000533 |
| Density of water fallen, kg m$^{-3}$ | 1000 | 1000 | 1000 | 1000 | 1000 |
| Average speed of rain drops, m s$^{-1}$ | 8 | 8 | 8 | 8 | 8 |
| Average soil density, kg m$^{-3}$ | 1050 | 1050 | 1050 | 1050 | 1050 |
| Soil stress resistance, N m$^{-2}$ | 83.0 | 13000 | 5050 | 3800 | 24280 |
| $L$ | 0.795 | 0.795 | 0.638 | 0.638 | 0.766 |
| $S$ | 0.716 | 0.716 | 1.189 | 1.189 | 0.758 |
| $C_1$ | 0.46 | 0.36 | 0.27 | 0.27 | 0.31 |
| $C_2$ | 1 | 0.6 | 0.5 | 0.5 | 0.9 |
| $P$ | 1 | 1 | 1 | 1 | 1 |
| a, theoretical value, kg m$^{-2}$s$^{-1}$ | 0.01900 | 0.0000041 | 0.00001619 | 0.00002112 | 0.00000253 |
| a, experimental value, m$^{-2}$s$^{-1}$ | 0.01955 | 0.0000041 | 0.00001608 | 0.00002178 | 0.00000256 |

Table 6 Synthesis of the experimental data.

| **Experience** | **A** | **B** | **C** | **D** | **E** |
|---|---|---|---|---|---|
| Time | 03.04.2008 | 13.05.2008 | 25.04.2008 | 26.06.2008 | 16.10.2008 |
| Initial humidity, % | 15.10 | 14.72 | 17.74 | 27.77 | 15.00 |
| Resistance stress in the superficial layer, Pa | 83.00 | 13000.00 | 5050.00 | 3800.00 | 24280.00 |
| Time until the sediment flow, s | 480 | 972 | 429 | 410 | 955 |