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THE STUDY OF EROSION PROCESSES IN THE HILLY AREA OF BUZĂU COUNTY (ROMANIA) IN THE SPECIFIC CLIMATIC CONDITIONS OF YEAR 2022

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Abstract

The research was carried out in 2022 in the Valea with Drum hydrographic basin, located on the Buzău county, in the area of Aldeni - Romania. The Station for the Study of Soil Erosion, established in 1971, operates in this perimeter. Starting from the fact that the intensity of the erosion phenomenon is determined by: precipitation, the slope and length of the slopes, the degree of erodibility of the soil and the agricultural practices used, research in the field of erosion has become very important in this area. The research carried out within this stationary follows a complex range of processes such as: quantifying runoff and erosion processes on sloping land produced by torrential rains, the influence of crops and cultivation technologies on erosion processes, on the Chernozem subtype argic. The main objectives of this study were to present and interpret the data regarding the annual rainfall regime and the vegetation period, the study of the rains that produced runoff and erosion, respectively the surface runoff determined by these rains and the annual amount of soil washed from the plots control, differentially cultivated. The analysis of the experimental results shows that the year 2022 was dry, the recorded temperatures exceeded 22.6 ^{0}C in the May-September period, out of 46 rains recorded at the station during the summer period, 60.9 % were less than 5 mm. Quantitative and qualitative study of the erosion process allowed the assessment of the amount of material washed from the soil surface (this being 26 t ha^{-1} on a 15% slope and 28.1 t ha^{-1} on a 20 % slope recorded in uncultivated plots) by the runoff produced by the rains that fell during the summer.

Key words: *watershed, chernozem, erosivity, slope, turbidity*

INTRODUCTION

The phenomenon of erosion, as a natural process, has occurred since the emergence of land and continues to occur, being one of the main shaping agents of the earth's crust. The deleterious influence of accelerated soil erosion on agricultural societies was recognized by Plato and Aristotle, and several classical studies attributed the bare rocky slopes of the classical world to ancient soil erosion [1].

Degraded soil means less food. As a result of soil degradation, an estimated 11.9–13.4% of global agricultural capacity has been lost over the past five decades [8]. Knowing the particularities of the erosion process, the consequences on soil degradation and the reduction of agricultural productivity, as well as the rational use of sloping soils, determined the intensification and expansion of extensive research in the field [2].

Globally, soil erosion has been addressed as one of the most destructive processes of soil degradation. It was found that almost 12% of the European territory (115 million hectares) is subject to erosion, while the impact of erosion in terms of financial cost has been calculated at several billion euros [3].

The rate of water erosion on a mollisol in China was 1.24–2.41 mm/year, and soil loss in farmland with 1°, 5°, and 15° slopes was 3 t/ha/year, 78 t/ha/year and 220.5 t/ha/year respectively [9]. The loss of soil from a landscape located on a slope through erosion depends to a great extent on the intensity and duration of the precipitation that occurs in that place. The detachment force of raindrops striking the land surface and its contribution to runoff is primarily responsible for soil loss through rain or subsequent water erosion [11]. Recent studies [14] have shown that human activities and climate change are increasing the risk of soil erosion worldwide and that global Environmental Science &Policy services are facing serious challenges.

Montgomery (2007), looks like geological erosion rates increase from gently sloping lowland landscapes on continents (from <10−4 to 0.01 mm/year), to steep hills (from 0.001 to 1 mm/year) and on steep alpine ridges they reach values between 0.1 and >10 mm /year [10].

Soil and water conservation practices are widely used to prevent erosion and protect soil and water resources, which is significant for ecological restoration and food security [4].

In general, decreasing tillage depth and plowing along contour lines substantially reduce soil erosion rates and can be considered effective soil conservation strategies. The erosivities caused by agricultural machinery, characterized by the soil transport coefficient, are very consistent and vary between 400–800 kg $m^{-1}year^{-1}$ for mechanized agriculture and 70–260 kg $m^{-1}year^{-1}$ for non-mechanized agriculture [19].

The result of soil erosion estimation is affected by several factors such as climate, vegetation and human activities that can cause fluctuations in water erosion. Therefore, changes in soil erosion allow the establishment of thresholds, which are based on the standard for classification and grading of soil erosion. According to a study, the levels of soil water erosion in China are divided according to the following thresholds. For Water Erosion <200 t x km^{-2} x a^{-1} we find the level 1 classification, between 200 – 2,500 t x km^{-2} x a^{-1} we have level 2, between 2,500 – 5,000 t x km^{-2} x a^{-1} we have level 3, between 5,000 – 8,000 t x km^{-2} x a^{-1} we have level 4, and at >15,000 t x km^{-2} x a^{-1}, water erosion is the strongest, being classified at level 6 [8].

In the Soil Thematic Strategy (COM (2006) 231) of the European Commission, the EU Biodiversity Strategy for 2030 within the European Green Pact has as objectives: erosion reduction; restoration of degraded soils; protecting soil fertility; increasing soil organic matter; defining what constitutes "good ecological status" for soil. The basis of this strategy was the data obtained from the studies conducted and centralized at the EU level. Thus, the share of soil losses (as a general average): erosion E (t h^{-1} $year^{-1}$) is 7.43 in Slovenia, 7.9 in Austria, 8.46 in Italy, 6.0 in Malta, 4.13 in Greece, 2.84 in Romania, 1.25 in Germany, 0.31 in Poland, 0.5 in Denmark, 0.06 in Finland, etc. [17].

In Romania, out of a total agricultural area of 14.8 million ha, over 6 million ha are located on land with a slope greater than 5 %, being affected by various degradation processes through erosion and landslides. The total annual soil loss in the entire country is about 126 million tons of eroded solid material, with an average of 16.3 t ha^{-1} [6].

The zonal distribution of erosion on the territory of our country is differentiated, the highest values of this damaging process are those in the area of the Subcarpathians of Curvature, in the Moldavian Plateau and in Transylvania, Thus, in the Hilly area of Buzau county, the specific erosion has a value of 41.5 t ha^{-1} $year^{-1}$ against the allowed specific erosion value of 3-6 t ha^{-1} $year^{-1}$ [12].

In this context, the aim of the paper is to present the negative effects of the climatic features of the year 2022 on soil erosion and the productivity of agricultural ecosystems in the hilly area of Buzău [15].

MATERIALS AND METHODS

Study Area

The agricultural lands located on the slope in the hilly area of Buzău county are susceptible to degradation through the erosion produced by the torrential rains that fell in the area, the intensity and pace of manifestation depending on the climate conditions. The research undertaken in 2022 was carried out in the Valea with Drum hydrographic basin, located on the left slope of Slănicu de Buzău in the area of Aldeni, at the Soil Erosion Study Station, with an area of 840 m^2.

The station for the Soil Erosion Study is located on the left side of the Valea with Drum hydrographic basin, with geographical coordinates 45°19'38'N and 26°44'15'E.

The researched area falls into the continental climate sector, with an average annual temperature of 10.5 ^{0}C and an average precipitation of 512 mm. As for the wind regime, Crivățul (from the northeast) predominates, followed by those from the southwest [16]. From a geological point of view, the formations encountered in this region belong to the Paleo-Neogene period, the predominant ones being the Neogene deposits made up of conglomerates, sandstones, gypsum and clay deposits.

In the Sarmatian, limestones, marls, sandstones and conglomerates were formed, and in the Quaternary, clays and loessoid deposits were formed [18]. The Valea with Drum hydrographic basin (HB) has an area of 83.87 ha, with a length of 1,375 m, the density of the hydrographic network of 4.63 km/km^2, the length of the left slope of 375 m, and of the right slope of 450 m, the hydrographic basin being strongly elongated [13].

Soil study

The environmental factors specific to the hydrographic basin led to the formation of a soil cover made up of: Chernozem subtype argic in the stationary area, Phaeozom subtype pelic on the right slope and Antrosol subtype argic in the upper third of the watershed [7].

Morphological description of the chernozem argic profile

Horizon Am (0-20 cm). Clay, color 10YR 2/2 when wet and 10 YR when dry, soft, moderately developed glomerular structure, friable when wet, moderately plastic, adhesive and compact, frequent cervotocins and larval nests, frequent thin root, straight net passage.

Horizon A/B (20-30 cm). Clay, color 10YR 2/3 in the wet state and 10YR 4/3 in the dry state, moderately developed columnoid-prismatic structure, discontinuous clay films, moderately cohesive, moderately plastic, adhesive and compact, rare cracks, straight transition.

Horizon Bt_1 (30-67 cm). Clay, color 10YR 3/3 wet and 10YR 4/4 dry, soft, columnoid-prismatic structure, continuous clay films, hard wet, hard dry, plastic adhesive and compact, frequent fine cracks, straight transition.

Horizon Bt_2 (67-120 cm). Clay loam, color 10YR 3/4 wet and 10YR 4/6 dry, soft, columnoid-prismatic structure well developed, continuous clay films, hard dry, plastic, adhesive and compact, straight gradation.

Cni horizon (>120cm). Clay loam, color 10YR 4/4 in the wet state and 10YR 6/6 in the dry state, unstructured, hard in the wet state, hard in the dry state, plastic, adhesive and compact, discontinuous ferric clay laminae are found.

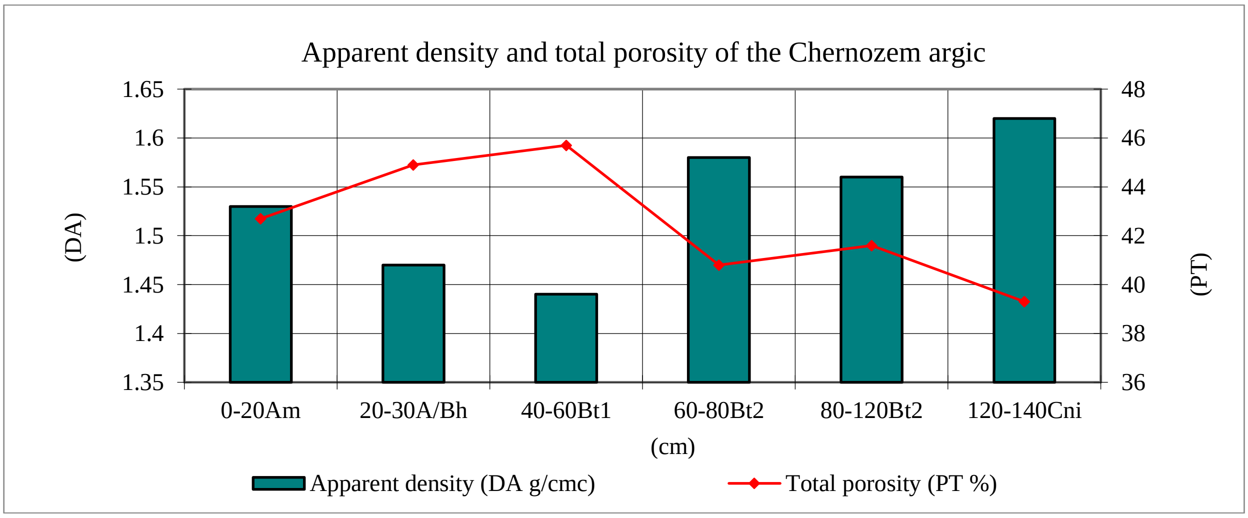

Fig. 1. The aparent density and total porosity values to Chernozem argic
Source: own research.

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Deep very strongly argic subtype chernozem, moderately water-eroded, on clay shales, medium loam/medium clay loam, on arable and belongs to the class Chernisols. It occupies an area of 27 ha on the right side of the Valea with Drum hydrographic basin where the Station for the Study of Soil Erosion is located, whose operation scheme is presented in point 2.3.

The ratio between the total porosity and the apparent density (Figure 1) highlights a moderate subsidence in the upper part and a strong subsidence starting from 60 cm, corresponding to the argic horizon [15]. The factors with a determining role in triggering or intensifying the erosion process are: climate, soil, relief, vegetation and applied technology.

Experimental scheme

The 840 m^2 area of this Soil Erosion Study Station is divided into 12 plots for erosion control, of which 6 plots (4 x 25 m) on a 20 % slope and 6 plots (4 x 10 m) on a 15% slope (Photo 1) [20].

To highlight the role of agricultural crops in reducing runoff and erosion, in 2022, the control plots located on the terrane with a slope of 15 % and 20 % were cultivated as follows:

V1 - maize,
V2 – sugar beet,
V3 - cultivated sugar beet in strips,
V4 – uncultivated land,
V5 – alfalfa,
V6 – wheat.

The plots are equipped downstream with capture devices in order to determine the volume of runoff and soil loss recorded after each rain event. After each runoff rain, the volume of the water + soil mixture collected at each runoff collection facility was determined.

To determine the amount of washed soil, from the well-homogenized mixture collected in the facility, samples of one liter are taken, in three repetitions, which are dried and weighed for quantitative determinations [22].

Methods of estimating erosion

Estimation of surface erosion is done by indirect and direct methods.

V3 - cultivated sugar beet in strips,
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Photo 1. Plots for erosion control. The Aldeni-Buzău Soil Erosion Study Station, Data, 2023 [20].
Source: original photo.

Estimation of surface erosion is done by indirect and direct methods.

(a) Indirect methods are used in the quantitative assessment of erosion by different models for estimating the amount of soil washed away annually by torrential rains. Such a model was adapted for the conditions of Romania through the universal erosion formula [12].

$E = Ka \times S \times L^m \times I^n \times C \times Cs$ (t ha^{-1}year^{-1})……………………………………….(1)

where:

E-refers to the average surface erosion; Ka-coefficient of climatic aggressiveness determined according to rain erosivity and the amount of washed soil from the standard plot; L^m- the correction coefficient according to the runoff length measured in the direction of the greatest slope; I^n-correction coefficient according to the slope of the land in the drainage direction; S-correction coefficient for soil erodibility; C-correction coefficient for crop uses and structure; Cs = correction coefficient for soil erosion control measures and works ;m and n represent the constants, which for Romanian conditions have values of: m = 0.3 and n = 1.5

The allowed erosion for chernozem-argic soil and arable use is 6 - 8 t ha^{-1} year^{-1}.

(b) Direct methods of drain plots is the most effective method of determination of the volume of surface runoff and the amount of washed soil. The study includes the analysis of the climatic parameters in the premises of the station compared to the data from the meteorological station Buzău [5].

The calculation methods are as follows:

$As = h/S$ l m^{-2} ....(2)

where:

As refers to the Surface leaks; h refers to the amount of water drained (l) and S refers to the surface of the plot (m^2):

$Cs = As/P$ ....(3)

where:

Cs refers to the runoff coefficient determined by the rainfall and P refers to the total rainfall (l/m^2):

$T = As \times Mp$ g l^{-1}...................................... (4)

where:

T refers to the turbidity; As refers to the surface runoff and Mp refers to the mass of solid material transported:

$E = T \times As$ kg m^{-2} .... (5)

where:

E refers to the Erosion on the control plots cultivated differently; T refers to the turbidity; As refers to the Surface leaks. The determination model is based on the result obtained in the field and is derived from the Universal Soil Loss Equation (USLE), introduced by Ene (1987), through long-term experimental [5].

RESULTS AND DISCUSSIONS

Climatic conditions

Analyzing the dynamics of the air temperature during the vegetation period and presented in Figure 2, it is found that the values recorded at Aldeni are lower than those at the Buzău weather station.

The lowest temperatures were recorded in April at both recording stations, 7.8 ^{0}C in Aldeni (lower than the normal 10.7 ^{0}C) and 13 ^{0}C in Buzau (Figure 3).

The highest air temperature values were recorded in May, 24.8 ^{0}C in Aldeni and 25.3 ^{0}C in Buzau. The dynamics of air temperatures characterize a period of warm weather.

In the year 2022, the climatic parameters, such as precipitation and temperatures, had a different dynamic compared to previous periods, presenting numerous particularities, radically differentiating them from previous conditions. The total annual amount of precipitation recorded at stationary was 352.4 mm, 274.2 mm less than 2021 and 429.5 mm less than the climatically normal year 2014. The dynamics of precipitation during the months of the vegetation period (April-September) are shown in Figure 3.

The values recorded at Aldeni are higher compared to those at the Buzău weather station. In April, the difference is the largest, 62.2 mm, and in June the values are close. The decreasing trend of monthly precipitation values starting from June at both recording points is noted. The reduced amounts of precipitation in 2022 are highlighted by comparison with those recorded in 2014.

A special feature of the summer precipitation, which fell this year at the station, is the large number of rains smaller than 5 mm.

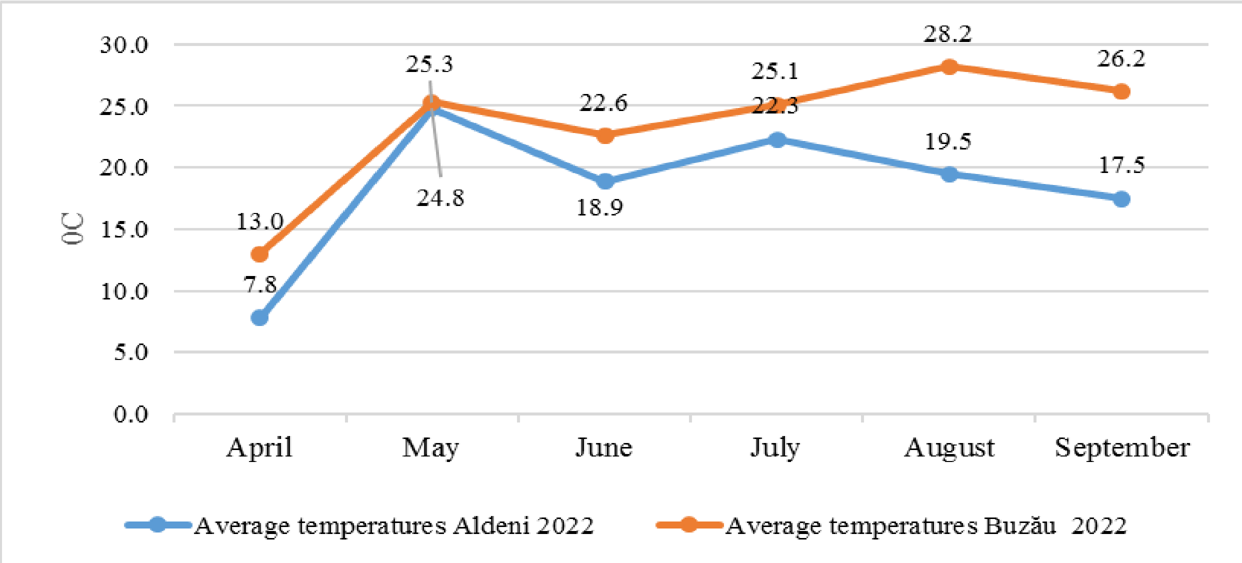

Fig. 2. Air temperature dynamics during the vegetation period in 2022 at the Aldeni-Buzău Soil Erosion Study Station (^{0}C) (recorded data)
Source: data, collected from the Study Station for Soil Erosion, Aldeni-Buzău.

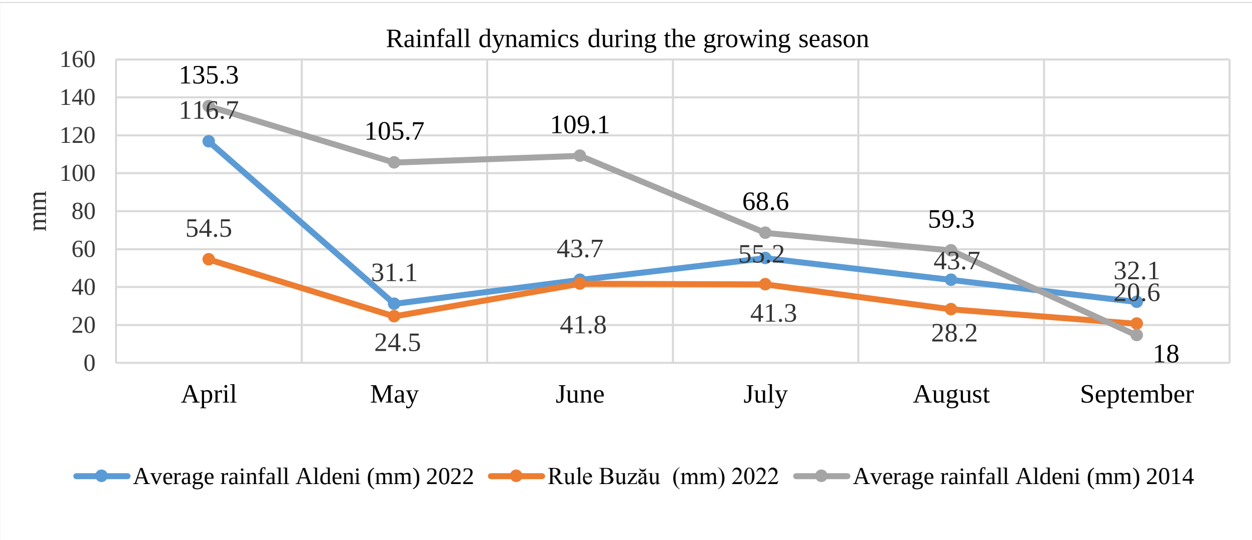

Fig. 3. Rainfall dynamics during the vegetation period (April-September) in 2022 at the Aldeni-Buzău Soil Erosion. Study Station (mm) (recorded data)
Source: data, collected from the Study Station for Soil Erosion, Aldeni-Buzău.

Following the data in Table 1, which includes the grouping of rains according to the amount of water, we find that 60.9 % of their number are smaller than 5 mm, i.e. 46 rains.

There were 7 rains with an amount of water between 5.1 mm and 10 mm and as many with an amount between 10 mm and 20 mm. Of the 46 rains, only 4 produced leaks (Figure 4) (none of them were torrential).

They were concentrated in the first part of the vegetation period, from April to June, which shows the climatic particularity of this year.

Table 1. Grouping of rain during the growing season (April-September) according to the amount of water - Aldeni Buzău (mm) (recorded data)

Month	Grouping of rain during the vegetation period (April-September) 2022, according to the amount of water						Total	%
	Under 5 mm	5.1-10 mm	10.1-20 mm	20.1-30 mm	30.1-40 mm	Over 40.1mm		
April	5	1	1	2	1	-	10	21.7
May	5	1	1		-	-	7	15.2
Getting	6	1	-	1	-	-	8	17.5
July	3	2	2	-	-	-	7	15.2
August	4	1	2	-	-	-	7	15.2
September	5	1	1	-	-	-	7	15.2
Total	28	7	7	3	1		46	100
%	60.9	15.2	15.2	6.5	2.2	-		

Source: data, collected from the Study Station for Soil Erosion, Aldeni-Buzău.

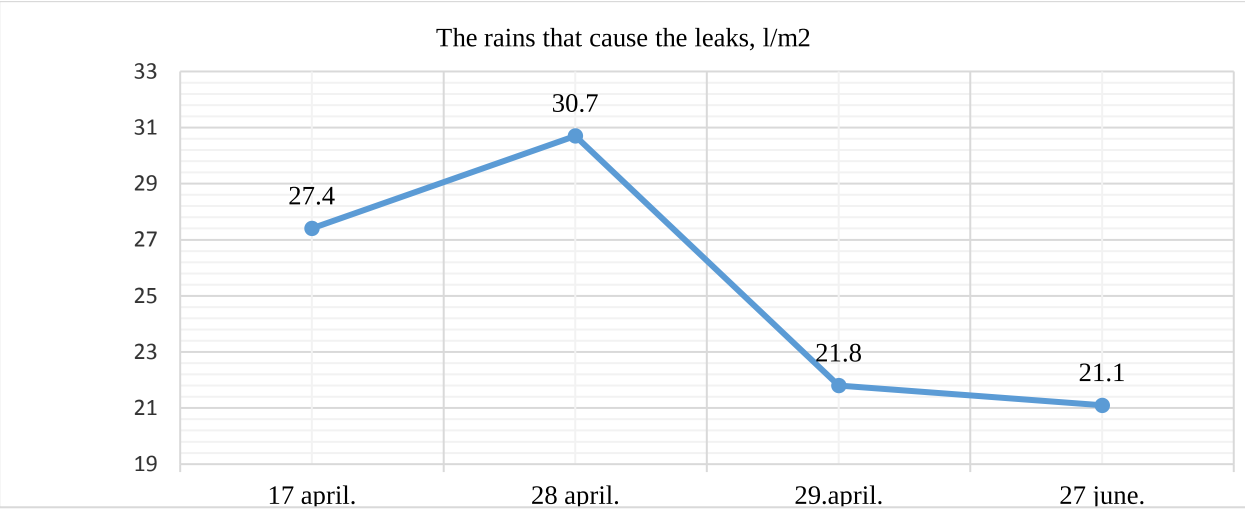

Fig. 4. The rains that produced runoff (l m^{-2}) (recorded data)
Source: data, collected from the Study Station for Soil Erosion, Aldeni-Buzău.

Analysis of surface runoff

The experimental data obtained, regarding the amount of water spilled on the control plots, are presented in Figure 5. Runoff amounts from the control plots have low values for all crops.

The highest amount of runoff water was recorded in the fields cultivated with alfalfa, 10.56 l m^{-2} in the plot with a 15 % slope and 10.4 l/ m^{-2} in the plot with a 20 % slope.

High values of surface runoff were recorded in the maize crop of 7.75 l m^{-2} and 7.73 l m^{-2} respectively and in beet 7.8 l m^{-2} and 8.78 % respectively. For the two cultures, the amounts of runoff water are similar on both slope categories.

In the field, the highest amount of runoff water was recorded on the plot with a 20 % slope, 8.1 l m^{-2}. The lowest runoff values were recorded on the plots with a slope of 15 % beet grown in strips and the wheat crop 1.66 l m^{-2} and 1.31 l m^{-2}, respectively.

The differences recorded in the amounts of runoff from the control plots are due to the specific climate of this year, three of the rains that produced runoff were in April, at the beginning of the vegetation period, and only one at the end of June.

The same conclusions can be drawn from the analysis of the leakage coefficient values presented in Figure 6.

In the alfalfa crop the runoff coefficient is 0.1 and in the beet crop sown in strips on a 15 % slope it is 0.02 (Figure 6).

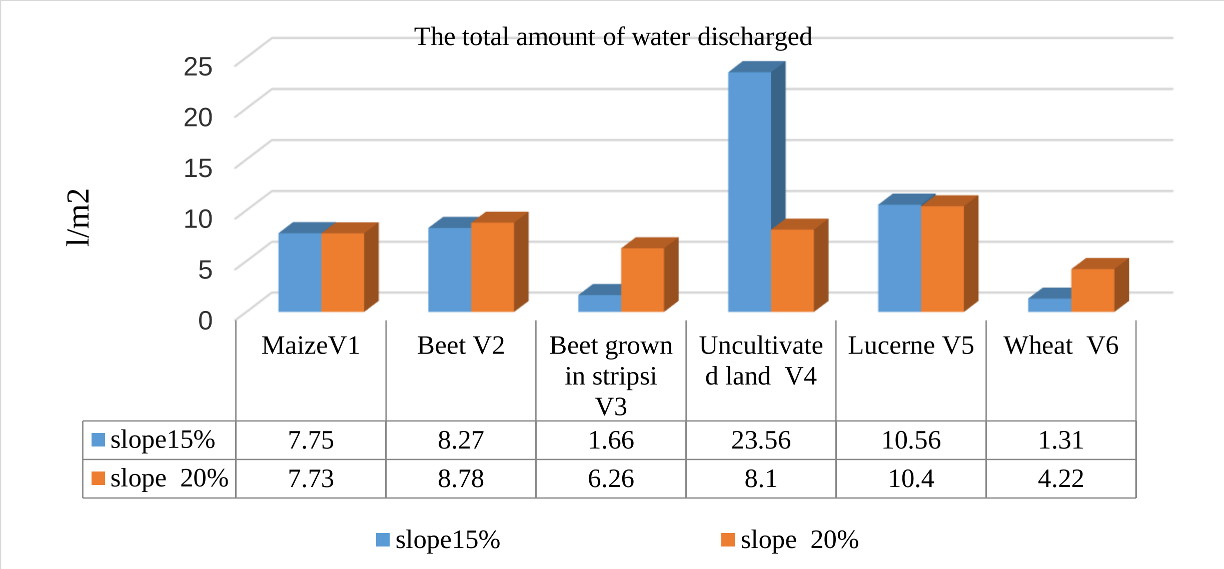

Fig. 5. The total amount of water drained from the control plots depending on the slope and culture, in the year 2022 – Aldeni- Buzău (l m^{-2}) (calculated with formula 2)
Source: Own calculation.

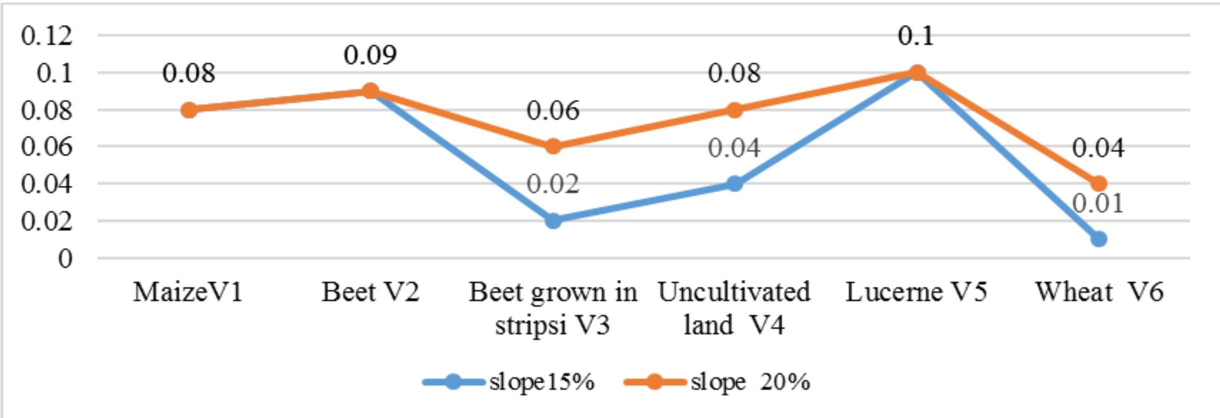

Fig. 6. The variation of the runoff coefficient on the control plots depending on the slope and crop, in the year 2022 Aldeni, Buzău (calculated with formula 3)
Source: Own calculation.

Soil loss analysis

The data on the amount of soil washed by the 4 rains that fell in the first part of the vegetation period are presented in Figure 7. Under this year's conditions when most of the rains that produced runoff were of short duration and quantitatively reduced, the soil losses recorded from the control plots located on the 15 % and 20 % slope land were different compared to the records of the past years.

In the green field, the highest amount of washed soil was recorded this year, 26.8 t ha^{-1} on the plot with a 15 % slope and 28.1 t ha^{-1} on the one with a 20% slope, compared to 2014 when the amount of washed soil was 58 t ha^{-1}.

In the beet crop, the amount of soil washed from the 15 % plot was 17.6 % and 21.7 t ha^{-1} from the 20 % slope.

In the maize crop, the amount of washed soil was 4.7 t ha^{-1} from the plots with a 15 % slope and 10.3 t ha^{-1} from the 20 % slope.

In the alfalfa crop, the amount of washed soil was greater in the case of the plot with a slope of 15 % 6.9 t ha^{-1} compared to 5.1 t ha^{-1} on the plot with a slope of 20 %. In strip-grown beet and maize the amount of washed soil was insignificant, 0.4 t ha^{-1} from the plot with 20% slope and in wheat 0.003 t ha^{-1} from the plot with the same slope.

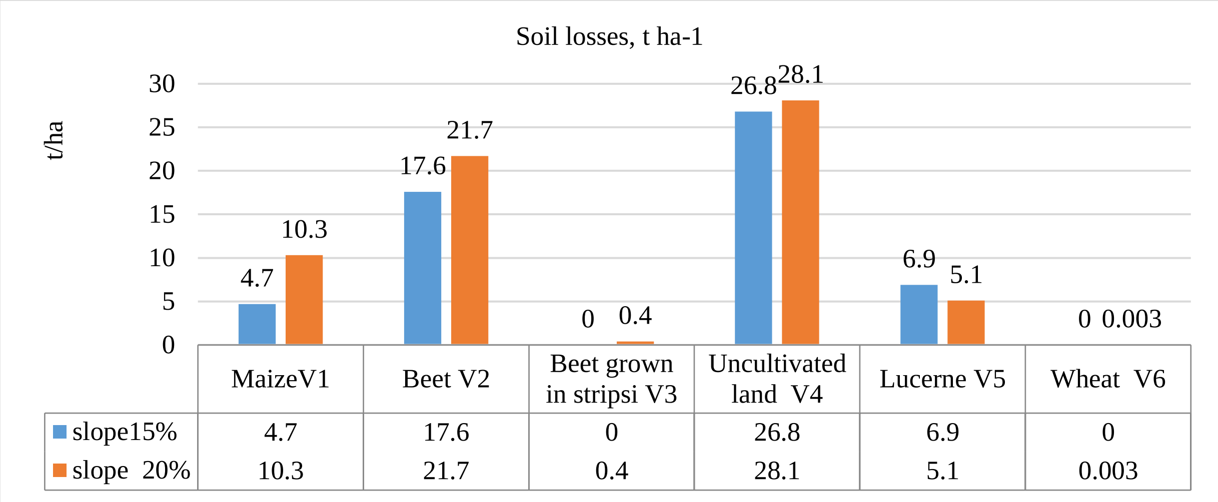

Fig. 7. Soil losses from control plots caused by torrential rains depending on slope and crop, in 2022 - Aldeni, Buzău, (t ha^{-1}) (calculated with formula 5)
Source: Own calculation.

The estimated erosion values, for 2022 by the indirect method (a) and those calculated by direct methods (b) in the parcels located on the 15 % slope cultivated differently, are presented in Figure 8.
The estimated erosion compared to that determined by direct methods in the case of the plots located on the 15 % slope, shows significant positive differences in the case of the plot kept fallow and significantly negative in the case of the plot cultivated with beet sown in strips.
Note the close values of the two values, in the plot cultivated with normal culture beet.

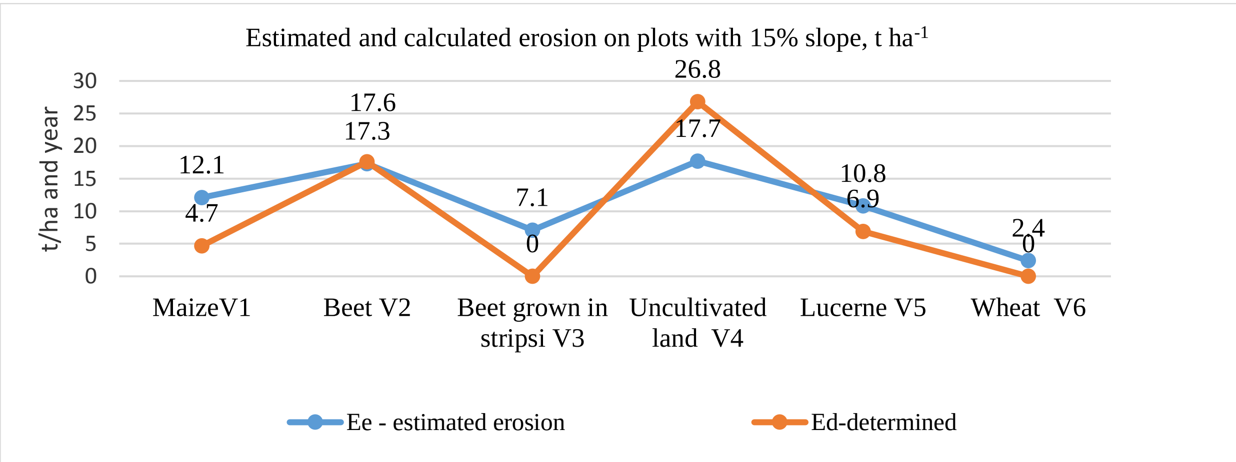

Fig. 8. Estimated erosion [1] and calculated erosion [5] at plots with a 15% slope (t ha^{-1} and year^{-1}) (calculated values)
Source: Own calculation.

The estimated erosion values, for 2022 by the indirect method (a) and those calculated by direct methods (b) for plots located on a 20 % slope, are % presented in Figure 9.
In the case of the control plots located on the 20 % slope, the estimated erosion has, in most cases, values below those determined by direct methods, only in the field plot the values are close.

Although this year's rainfall was reduced in quantity, it was a dry and hot year, but there were still 4 rains that produced runoff. In these climatic conditions, the plots cultivated with beet in strips and with wheat had the least amounts of water runoff and the least amounts of washed soil (they were insignificant).

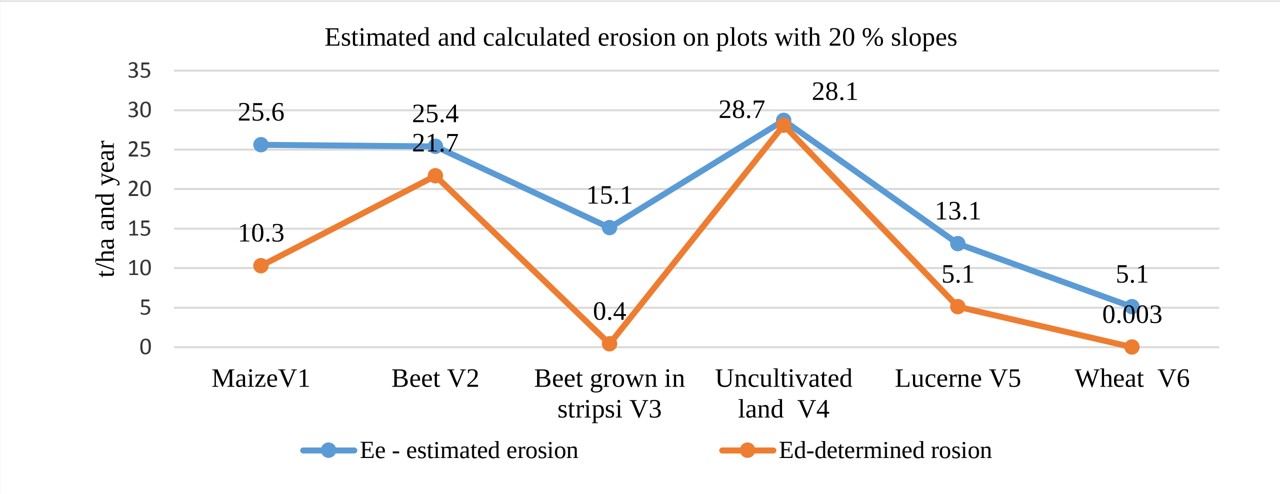

Fig. 9. Estimated erosion [1] and calculated erosion [5] at plots with a 20 % slope (t ha^{-1} and $year^{-1}$) (calculated values)
Source: Own calculation.

Table 2. The economic impact of soil erosion on the productions obtained from the agricultural crops on the control plots – Aldeni-Buzău Soil Erosion Study Station, recorded data)

Crop / Indicator	Maize	Sugar beet	Cultivated sugar beet in strips	Alfalfa	Wheat
Calculated average erosion (t ha^{-1})	7.5	19.7	0.2	6.0	0.0002
Average degree of coverage (%)	18.8	23.2	61.1	20,5	73.5
Production losses (kg ha^{-1})	370	420	27	300	18
The value of production losses (RON t^{-1})	448	630	41	900	22

Source: data, collected from a The Aldeni-Buzău Soil Erosion Study Station and own calculations.

The economic impact of soil erosion is significant. Soil erosion reduces the productivity of sloping lands, the recorded production losses vary depending on the crop and the anti-erosion variant of cultivation. The data obtained in 2022 (Table 2) shows that the biggest loss of production was recorded in sugar beet (420 kg ha^{-1}) followed by maize (370 kg ha^{-1}) and alfalfa (300 kg ha^{-1}). The highest value of this production is in alfalfa, where production losses were of 900 RON t^{-1}.

CONCLUSIONS

The research undertaken in 2022 was carried out in the Valea with Drum hydrographic basin, located on the left side of the Slănic river basin in Buzău county in the area of Aldeni.

In 2022, during the vegetation period, 46 rains were recorded, of which 28 had an amount less than 5 mm and only 4 produced leaks, none of them were torrential.

The total amount of water drained from the control plots was below 10.5 l m^{-2}, the highest values, under the given conditions, were recorded in the plots cultivated with alfalfa (on both slope categories) and in the plot kept fallow on the 20 % slope.

For alfalfa the runoff coefficient is 0.1 and for beet sown in strips the plot with a 15 % slope is 0.02.

The highest amount of washed soil in 2022 was recorded on the land kept uncultivated of 26.8 t ha^{-1} on the plot with a 15 % slope and

28.1 t ha^{-1} on the one with a 20 % slope, with 30 t ha^{-1} less than the same values recorded 10 years ago.

In the case of plots cultivated with beet, the soil losses exceeded the values allowed for the studied area of 6-8 t ha^{-1} year-1, by 9 t ha^{-1} year^{-1} on the plots located on the 15 % slope and by 13 t ha^{-1} year-1 in plots located on a 20 % slope.

The sugar beet culture, cultivated in strips, as an anti-erosion measure, provided much better protection, by comparison with the version of the beet culture in normal culture.

The specific climatic conditions of 2022, the concentration of precipitation at the beginning of the vegetation period, determined lower soil losses than the allowed average, in the maize crop (slope 15 %) and the alfalfa crop, and in the wheat crop and the beet crop grown in strips, soil losses were insignificant.

The estimated erosion, compared to that determined by direct methods in the case of plots located on a 15 % slope, shows significant positive differences, in the case of the plot maintained with arable land, and significantly negative in the case of the plot cultivated with beet sown in strips. Note the close values of the two values, in the plot cultivated with beets.

The estimated erosion has, in most cases, values below those determined by direct methods, in plots located on a 20 % slope, only in the arable plot the values are close. For the correct estimation of the amount of soil washed away annually (erosion), in difficult climatic conditions, studies and research are necessary for periods of 5 or 10 year.

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