Carpathian Journal of Earth and Environmental Sciences August 2023, Vol. 18, No. 2, p. 461 – 474; DOI:10.26471/cjees/2023/018/273

WEATHERING PATTERNS IN ALLUVIAL SOILS UNDER MEDITERRANEAN CLIMATIC CONDITIONS IN ALBANIA AND IMPLICATIONS FOR SOIL FERTILITY

Fran GJOKA[1], Liri MIHO[1], Avni SPAHOLLI[2], & Elian KASA[1]
[1]*Agricultural University of Tirana, Kodër Kamëz 1029, Tirana, Albania*
[2]*Fan Noli University, Bulevardi Rilindasit 11, Korçë, Albania*
*Corresponding Author: *fgjoka@ubt.edu.al*

Abstract: This study comprehensively assesses weathering and soil development in the alluvial plains of Albania's Drin and Mat rivers. By analyzing soil properties, mineralogical compositions, and weathering indices, it provides crucial insights into the intricate link between geological processes and soil fertility in these key agricultural areas. The focus is on weathering indices such as the Chemical Index of Alteration (CIA), Chemical Index of Weathering (CIW), and Plagioclase Index of Alteration (PIA), which reveal distinct weathering patterns across soil profiles and alluvial plains. Drin River alluvial soils display moderate indices, signaling relatively lower weathering, while Mat River alluvial soils exhibit higher indices, indicating more pronounced weathering. The study emphasizes the role of mineral composition on weathering and soil development, with easily weathered minerals suggesting a more conducive environment for weathering in Mat River soils compared to Drin River soils. Elemental composition differences in these soils significantly impact fertility, potentially affecting agricultural productivity. Correlation analyses highlight the influence of mineralogy and chemical composition on weathering rates. This study's insights into weathering dynamics, mineralogical, and elemental composition in alluvial soils highlight soil fertility implications, crucial for optimizing agriculture and addressing environmental concerns in these vital Albanian regions.

Keywords*:* Alluvial soils, weathering indices, Drin River, Mat River, Albania

1. INTRODUCTION

Weathering is the physicochemical process of breaking down rocks into small particles of the minerals from which they are formed, of synthesizing very fine minerals known as clays, and of releasing the chemical elements that make up the minerals. It is the initial process of soil formation from rocks at or near the Earth’s surface under the influence of environmental factors such as local climate, living organisms, parent material, local relief, and territory age. The rate and extent of the pedogenetic process depends on these five factors (Jenny, 1941). Different rocks are weathered at different rates depending on their chemical-mineralogical composition and texture, as well as climatic conditions and topography.

The main source of plant nutrients is soil minerals, while weathering is the key. This makes this complex process very important in both agricultural and environmental contexts. Weathering has a central role in controlling soil fertility status (Wilson, 2003), and in stabilizing global surface temperatures in the long term (Walker et al., 1981). On the other hand, weathering rates can be accelerated through agricultural practices. The rate of mineral weathering can be estimated using weathering indices, which can provide information on the rate of soil development and the mobility of the chemical elements that make up the minerals during this process. Therefore, the weathering has been the subject of many studies of the genesis and fertility of the soil (Wagner et al., 2007, Tunçay et al., 2019, de Mello et al., 2022).

Alluvial soils are very complex in terms of their genesis and nature, and generally are considered very productive. Their pedogenesis is regarded as synlithogenic pedogenesis (Khokhlova et al., 2001) since the formation process is associated with concurrent sedimentation. Alluvium serves as the parent material of alluvial soils. The new alluvium comes from both the eroded A horizon in the catchment's soils and from weathering and erosion of bedrock and unconsolidated sedimentary deposits. Alluvium characteristics such as texture, chemical and mineralogical composition and floodplain topography determine the nature of alluvial soils.

Despite the importance they have for Albania's ecology and economy (these soils make up 6% of the total land surface and about 12% of agricultural land), alluvial soils have not been sufficiently studied. This includes the works of several authors (Bajraktari, 1960, Bajraktari & Xinxo, 1972, Veshi & Spaho, 1988) related to the main chemical-physical characteristics of the soil.

A systematic study of the soils of the alluvial plains of the Drin and Mat rivers, including data on their chemical composition and mineralogical analyses, was carried out by Gjoka (1996). In the past decade, these soils have been extensively studied due to high levels of heavy metals. These metals originate from both natural (geological background) and human sources (agriculture and industry) (Shkurta et al., 2017, Kasa et al., 2015, Kasa et al., 2014).

Regardless of the effects of chemical weathering of rocks and human intervention on the total chemical and mineralogical composition of the soil, both of these inherent soil properties remain relatively stable. Consequently, the use of existing data of these soil properties makes sense from a scientific point of view, and their review in the light of new developments in Soil Science, as part of assessing the intensity of soil weathering, is of particular theoretical interest and practical. Moreover, such studies are missing in our country.

Therefore, this paper aims to assess the weathering and development degree of arable soils of the alluvial plains of the Drin and Mat rivers (NW Albania), which occur in similar conditions of relief, climate, natural vegetation and land use, but formed on different parent materials using the three most commonly employed indices: the Chemical Index of Alteration (CIA), Chemical Index of Weathering (CIW) and Plagioclase index of alteration (PIA). For this purpose, the chemical and mineralogical data published previously from a pedological study of soils carried out in these two alluvial plains (Gjoka, 1996) were used. According to a national expert for studies of water issues in agriculture, these soils have not been flooded by the respective rivers since 1960 when the construction of the embankments of these rivers was completed, as a result they have not received any more sediments.

2. MATERIALS AND METHODS

2.1 Description of study area

The research was conducted in the northwestern region of Albania, with a specific focus on the alluvial plains of the Drin and Mat rivers. The study area comprises two sections: the Mjede-Shelqet section in Shkodër, running along the Drin River, which extends for approximately 4.5 km. In this segment, three profiles were examined - profile 1021 (upper part), profile 1061 (middle part), and profile 1040 (lower part of the alluvial plain). Additionally, the Gajush-Tale section in Lezhë, situated along the Mat River, was investigated. This section spans about 6.5 km and encompasses three profiles: profile 4002 (upper part), profile 210 (middle part), and profile 5002 (lower part of the alluvial plain).

The alluvial plain of the Drin River primarily consists of sediments deposited by the river in the adjacent flood basin located to the south. These sediments are a mixture of detritus materials carried by its two tributaries, the Black Drin and White Drin. The Black Drin contributes Quaternary deposits, Paleogene flysch, Triassic-Jurassic-Cretaceous limestones, as well as ultrabasic rocks and limestones, while the White Drin deposits materials from ultrabasic rocks, Cretaceous limestones, and Neogene molasses. After the confluence of these tributaries, the river follows a southeast-northwest extending valley through the ophiolitic complex of Mirdita. Subsequently, the river valley extends southwestward, representing the convergence of magmatic rocks (ultrabasic, basic, medium-acid), metamorphic rocks, and effusive-sedimentary rocks of the Mirdita zone to the south-southeast, and limestone and flysch formations of the Cukali subzone to the north-northwest.

Similarly, the Mat alluvial plain was formed by sediments from the Mat River in the south and the Drin River in the north. The detrital materials in this area originate from the eastern geological terrains, mainly comprising ophiolitic rocks like peridotite, pyroxenite, gabbro, plagiogranite, and volcanic rocks. These geological formations are widespread and followed by Triassic, Jurassic, and Cretaceous limestones, as well as molassic and flyschoidal formations.

The study area is characterized by a Mediterranean climate, influenced by warm sea air from the nearby Adriatic Sea. However, there are significant climatic variations between the two alluvial plains. The alluvial plain of the Drin River experiences an average annual temperature of 15.5°C, an average annual precipitation of 1416.2 mm, and an annual evaporation of 1661 mm. In contrast, the alluvial plain of the Mat River exhibits slightly different climatic conditions, with an average annual temperature of 15.4°C and an average annual precipitation that is 17.3% higher, totaling 1660.1 mm. Additionally, the annual evaporation in this area is higher, measuring 2209.2 mm. These distinctive climatic characteristics in each alluvial plain play a significant role in influencing the rate of weathering in the soils of these respective areas. Moreover, the elevation above sea level varies across the study area, ranging from 20 m (Profile 1021), 15 m (Profile 1061), and 13 m (Profile 1040) in the upper, middle, and lower parts of the alluvial plain of the Drini River, respectively, to 9 m (Profile 4002), 6 m (Profile 210), and 2 m (Profile 5002) in the corresponding parts of the Mati River alluvial plain. These differences in elevation have a crucial impact on controlling the level of underground water in the respective subareas.

2.2 Data collection and analysis

In order to gain a comprehensive understanding of the contrasting patterns in weathering and soil formation rates between the two alluvial plains being examined, as well as within different sections of each plain, extensive data pertaining to the morphological, physical-chemical, elemental, and mineralogical properties of these soils were meticulously gathered and subjected to thorough analysis. The necessary data for the study were acquired through a combination of fieldwork and laboratory analyses conducted on soil samples extracted from the horizons of eight soil profiles, with four profiles dedicated to each of the two alluvial plains. Profiles were opened at intervals of 2 km and 3 km in the alluvial plains of Drin and Mat, respectively, in the selected sections. A profile was opened in the bed of each river, and samples were collected for analysis (Figure 1).

The soil samples were dried naturally at room temperature and subsequently sieved through a 2 mm sieve to prepare them for chemical, physical, and mineralogical analysis. The elemental composition was determined using the quantitative silicate method (Tables 2 and 3). The mineralogical composition of fractions larger than 0.05 mm (0.5, 0.25, 0.125, 0.07, and 0.05 mm) and smaller than 0.05 mm (0.01, 0.005, 0.002, and 0.001 mm) was assessed using the photometric method, while the fraction smaller than 0.001 mm was analyzed using the semi-quantitative method. The pH level was determined using the colorimetric method, organic carbon content was measured using the Tyurin method, and the presence of $CaCO_3$ was quantified using the gas volumetric method. Soil texture was determined using the pipette method. The soil analyses were conducted at multiple laboratories, including the laboratories of the Agricultural University of Tirana, the former Institute of Soil Studies, and the Tirana Geological Enterprise.

2.3. Assessment of soil development degree

To assess the extent of soil weathering and the level of soil development, weathering indices are commonly employed. These indices utilize the ratio between immobile cation oxides such as aluminum (Al) and mobile cation oxides such as magnesium (Mg), calcium (Ca), and sodium (Na) present in the soil. In this study, the variation in weathering intensity with soil depth was examined using three weathering indices specifically designed for river sediments and the soils formed from them. These indices were derived from the analysis of major elements including silicon (Si), aluminum (Al), iron (Fe), calcium (Ca), magnesium (Mg), potassium (K), sodium (Na), manganese (Mn), titanium (Ti), and phosphorus (P). The three weathering indices are calculated using the number of moles of the corresponding oxides in the following formulas:

$$CIA=[(Al_2O_3\times100)/(Al_2O_3+CaO^*+Na_2O+K_2O)]$$

(Nesbitt & Young, 1982). CaO* represents the CaO in silicate minerals only (Fedo et al., 1995). The content of CaO in silicate minerals will be calculated according to the methodology proposed by McLennan, (1993), including correction for phosphates and considering the ratios between corrected CaO and Na_2O. If the moles of corrected CaO are less than those of Na_2O, then the corrected value of CaO* is used, and if the moles are more than Na_2O, CaO* is taken equal to Na_2O.

$$CIW=[(Al_2O_3\times100)/(Al_2O_3+CaO^*+Na_2O)]$$

(Harnois, 1988). CIW is calculated similarly to CIA but does not include the contribution of K_2O (Nadłonek & Bojakowska, 2018).

$$PIA=[(Al_2O_3-K_2O)\times100]/(Al_2O_3+CaO^*+Na_2O-K_2O)$$

(Fedo et al., 1995). PIA gives values of 50 for fresh rocks and close to 100 for clay minerals such as kaolinite, illite and gibbsite, which correspond to CIA values. The number of moles of the respective oxides was used in the calculation.

2.4 Statistical analyses

The statistical calculations for data analysis were conducted utilizing the statistical software package SPSS Statistics, Version 23.

Figure. 1 Spatial distribution of soil profiles in the study area

3. RESULTS AND DISCUSSION

3.1 Morphological and chemico-physical properties of soils

According to WRB classification (WRB, 2014), the soils in the study area were Eutric Fluvisol as the main soil type, Eutric Arenosol (Profile 431) and Eutric Regosol (Profile 239) (Table 1). These soils have an A-C type profile. Soils of the middle and lower parts of the Drin alluvial plain have a buried A horizon (Ab). The alluvial soils of the Drin River show more pronounced variability in texture than those of the Mat River. Thus, passing from the upper to the lower part of the alluvial plain, the texture becomes heavier (from sandy loam to loam in the A horizon). Even more pronounced variability of soil texture was observed between the genetic horizons of all soils.

The pH(H_2O) values (7.2-7.4) were similar between the soils of the two alluvial plains and between the horizons of the profiles, suggesting a neutral to weakly alkaline reaction. The soils of the Drin alluvial plain had a higher carbonates content. Overall, organic carbon was low in the soils of the two alluvial plains (0.17-0.30%), it but was higher in the soils of the Mat alluvial plain. An increasing trend has been observed in the soils of the middle and lower part of the alluvial plains. The cation exchange capacity varies irregularly according to the soil layers. Its values of 14.5-36.25 meq/100 g, found in these soils, are typical of soils having a mixture of kaolinite and hydromica. The highest CEC values belonged to the soils of the Mat alluvial plain, which have more organic carbon. The soil exchange complex was fully saturated with bases (>94%).

3.2 Soil mineralogy

The mineralogical composition of the >0.05 mm soil fraction was similar between the soils of the middle and lower parts of the studied section of the Drin alluvial plain (Figure 2). The constituent minerals of this fraction were pyroxenes and quartz. Quartz, renowned for its resistance to weathering, can serves as a key indicator of the weathering rate. Therefore, the decrease in quartz content in the soils of the lower part of the section (in the C1 horizon of Profile 1040) in addition to changes in mineralogy, also suggests a higher intensity of weathering. This fraction in the soils of the upper part (Profile 1021) also contained limonite which must have been formed by the weathering of iron-bearing minerals such as hematite. Meanwhile, in the gravelly soils of the riverbed (Profile 239), the fraction also contained significant amounts of hematite, residual materials, and amphiboles. The presence of hematite as a highly weathering-resistant mineral suggests a low rate of weathering in these soils. Sirbu-Radasanu et al. (2022) used mineralogical composition to interpret soil development stages.

The mineralogical composition of the <0.05 mm soil fraction was similar among the soils of the three parts (upper, middle and lower) of the studied section and was presented as a mixture of hydromica and kaolinite + hydromica. Kaolinite must have "alluvial origin", which means that it was part of the alluvium. Unlike the soils of the alluvial plain of Drin, the fraction >0.05 mm in the soils of the alluvial plain of Mat is mainly presented as a mixture of quartz, micas and limonite, with the exception of the soils of the middle part of the studied segment (Profile 210) which present a more diverse mineralogy where minerals such as pyroxenes, serpentine, etc. also appear. This fraction in the sandy loam soils of the riverbed (Profile 431) appears more diverse, containing primary minerals such as amphiboles, residual materials, etc. Whereas the mineralogical composition of the soil fraction <0.05 mm differs significantly between the soils of the upper and lower parts (kaolinite + hydromica) with the soils of the middle part and those of the Mat riverbed (mixture of hydromicas and kaolinite + hydromica). The presence of easily weathering minerals such as pyroxenes and amphiboles suggests that such local factors as climate (rainfall and temperature) and hydrological conditions (water availability, etc.) are more favorable for weathering in the alluvial soils of the Mat River than in soils of the Drin River. The mineralogical composition of alluvial soils varies according to soil layers, and like the morphological and physico-chemical properties, depends on the nature of the parent material (alluvium) of soil formation.

3.3. Soil elemental composition

The elemental composition of the soils in the two alluvial plains (Tables 2 and 3) differed due to variations in mineralogy, influenced by the soil forming parent material. Compared to the alluvial soils of the Mat River, the alluvial soils of the Drin River exhibited higher average contents of SiO_2, Al_2O_3, MgO, K_2O, TiO_2/NiO and P_2O_5 by 5%, 4%, 10%, 86%, 321%, and 6%, respectively. Conversely, the alluvial soils of the Drin River had lower contents of Fe_2O_3, FeO, CaO, Na_2O, MnO, with reductions of 43%, 54%, 2%, 5%, and 36%, respectively.

The ratio between the content of oxides of elements in the surface horizon and the subsurface horizon was calculated to evaluate the pattern of

Table 1. Main morphological, physical and chemical properties of soils

Horiz.	Soil depth (cm)	Color	Texture	Structure	Root Abundance	Effervescence class	Boundary	pH $_{(H2O)}$ (1/2.5)	$CaCO_3$ (%)	C_{org} (%)	Clay (%)	CEC (meq/100g)
I. Alluvial plain of the Drin River												
Profile 1021 Eutric Fluvisol, WRB, 2014 (Upper part of the Drin alluvial plain)												
Ap	0-26	Gray to light brown	Sandy loam	Weak fine granular to single grain	Common	Moderate	Gradual	7.2	5.42	0.17	4.96	14.50
AC	26-52	Gray with light brown shades	Loamy sand	Fine granular to cemented single grain	Few	Moderate	Abrupt	7.2	6.97	0.12	3.96	18.31
C1	52-77	Gray	Sand	Single grain	Few	Moderate	Abrupt	7.4	8.06	0.11	3.88	13.79
C2	77-92	Gray	Sand	None	None	Moderate	Gradual	7.4	8.86	0.05	2.80	12.88
C3	92-132	Brown-grey	Sand	None	None	Moderate	Gradual	7.4	7.09	0.11	3.24	*
Profile 1061 Eutric Fluvisol, WRB, 2014 (Middle part of the Drin alluvial plain)												
Ap	0-18	Light brown	Loam	Fine angular blocky	Many	Moderate	Gradual	7.4	6.8	0.17	18.56	22.70
AC	18-42	Light brownish gray	Silt loam	Coarse angular blocky	Common	Moderate	Abrupt	7.4	5.79	0.25	17.00	23.36
C1	42-67	Gray brown	Silt loam	Fine angular blocky	Few	Moderate	Abrupt	7.4	7.72	0.22	19.44	24.42
Ab	67-100	Light gray with dark and brown spots	Loamy sand	Single grain	Very few	Moderate	Gradual	7.4	5.12	0.21	7.40	20.41
C2	100-140	Gray with red spots	Loamy sand	Single grain	None	Moderate	Gradual	7.4	6.63	0.14	*	18.75
Profile 1040 Eutric Fluvisols, WRB, 2014 (Lower part of the Drin alluvial plain)												
Ap	0-27	Light brownish gray	Loam	Subangular blocky nut	Common	Slight	Gradual	7.4	3.61	0.21	12.92	25.73
AC	27-50	Gray with brown and black spots	Loam	Fine angular blocky	Few	Slight	Gradual	7.4	3.82	0.12	15.48	25.08
C1	50-72	Gray with brown spots	Loamy sand	Angular blocky nut	Few	Slight	Gradual	7.4	3.52	0.09	7.96	20.72
Ab	72-105	Brown with dark gray, black spots	Loam	Angular blocky nut	Very few	Slight	Gradual	7.4	0.30	0.17	24.16	20.42
C2	105-158	Gray with brown and blue spots	Silt loam	Coarse subangular blocky	None	Slight	Gradual	7.4	2.52	*	27.60	27.70
Profile 239 Eutric Regosol, WRB, 2014 (The Drin riverbed)												
A	0-15	Grayish brown	Loamy sand	Fine angular blocky	Common	Slight	Gradual	7.4	3.94	0.11	3.84	18.21
C1	15-45	Gray	Sand	Single grain	Common	Slight	Abrupt	7.4	3.34	0.12	3.42	17.72
C2	45-55	Brown	Sandy loam	Medium sub-angular blocky	Few	Slight	Abrupt	7.4	1.37	0.14	5.92	*
C3	55-120	Gray	Gravel and sand	None	None	Slight	Gradual	7.4	4.71	0.10	5.32	*

Corg: Oganic carbon, CEC: Cation Exchange Capacity, *: No data

Table 1. Continued

Horiz.	Soil depth (cm)	Color	Texture	Structure	Root abundance	Effervescence class	Boundary	pH $_{(H2O)}$ (1/2.5)	$CaCO_3$ (%)	C_{org} (%)	Clay (%)	CEC (meq/100g)
II. Alluvial plain of the Mat River Profile 4002 Eutric Fluvisols, WRB, 2014 (Upper part of the Mat alluvial plain)												
Ap	0-28	Light brownish gray	Sandy loam	Nut-subangular blocky	Common	Slight	Gradual	7.4	0.42	0.22	*	31.75
AC	28-68	Dark gray	Sandy loam	Nut to grain	Common	Slight	Gradual	7.4	1.51	0.14	*	33.00
C1	68-98	Light brownish gray	Loamy sand	Weak nut to grain	Few	Slight	Abrupt	7.4	1.51	0.13	*	23.05
C2	98-128	Gray with brown spots	Loamy sand	Angular blocky nut	None	Slight	Gradual	7.4	1.77	0.12	*	22.93
C3	128-160	Gray	Loamy sand	Single grain	None	Slight	Gradual	7.4	1.03	0.12	*	22.60
Profile 210 Eutric Fluvisols, WRB, 2014 (Middle part of the Mat alluvial plain)												
Ap	0-30	Gray brown	Loamy sand	Fine angular blocky	Common	Slight	Abrupt	7.4	0.55	0.30	12.08	36.25
AC	30-55	Gray brown	Sandy loam	Medium subangular blocky	Few	Slight	Gradual	7.4	0.68	0.20	19.20	36.25
C1	55-67	Gray	Sandy loam	Single grain	Very few	Slight	Gradual	7.4	1.45	0.11	9.96	*
C2	67-110	Gray	Sandy loam	Single grain	None	Slight	Abrupt	7.4	1.28	0.17	8.28	*
C3	110-130	Gray	Sand	None	None	Moderate	Gradual	7.4	2.82	0.10	2.52	*
Profile 5002 Eutric Fluvisols, WRB, 2014 (Lower part of the Mat alluvial plain)												
Ap	0-35	Grayish brown	Sandy loam	Subangular blocky to nut	Common	Slight	Abrupt	7.4	0.42	0.20	17.32	34.37
AC	35-65	Light grayish brown	Loam	Nutty	Common	Slight	Gradual	7.4	0.42	0.22	18.20	31.79
C1	65-95	Gray brown	Loam	Nutty to grain	Few	Moderate	Gradual	7.4	2.10	0.16	14.72	34.26
C2	95-115	Light brown	Loam	Nutty	Very few	Moderate	Abrupt	7.4	2.02	0.12	22.76	31.11
C3	115-160	Grayish brown	Silt loam	Angular blocky to nut	None	Moderate	Gradual	7.4	2.44	0.12	9.24	31.19
Profile 431 Eutric Arenosol, WRB, 2014 (The Mat riverbed)												
Ap	0-30	Grayish brown	Sandy loam	Weak fine subangular blocky	Common	Slight	Gradual	7.4	0.60	0.30	7.88	*
AC	30-68	Light grayish brown	Sandy loam	Weak fine subangular blocky	Few	Slight	Gradual	7.4	1.71	0.16	4.72	*
C1	68-94	Gray with brown spots	Loamy sand	Single grain	None	Slight	Gradual	7.4	1.97	0.08	4.00	*
C2	94-154	Gray with brown spots	Loamy sand	Weak very fine subangular blocky	None	Slight	Abrupt	7.4	1.71	0.11	2.68	*
C3	154-164	Gray	Sand	Single grain	None	Moderate	Gradual	7.4	2.14	0.09	17.36	*

Corg: Oganic carbon, CEC: Cation Exchange Capacity, *: No data

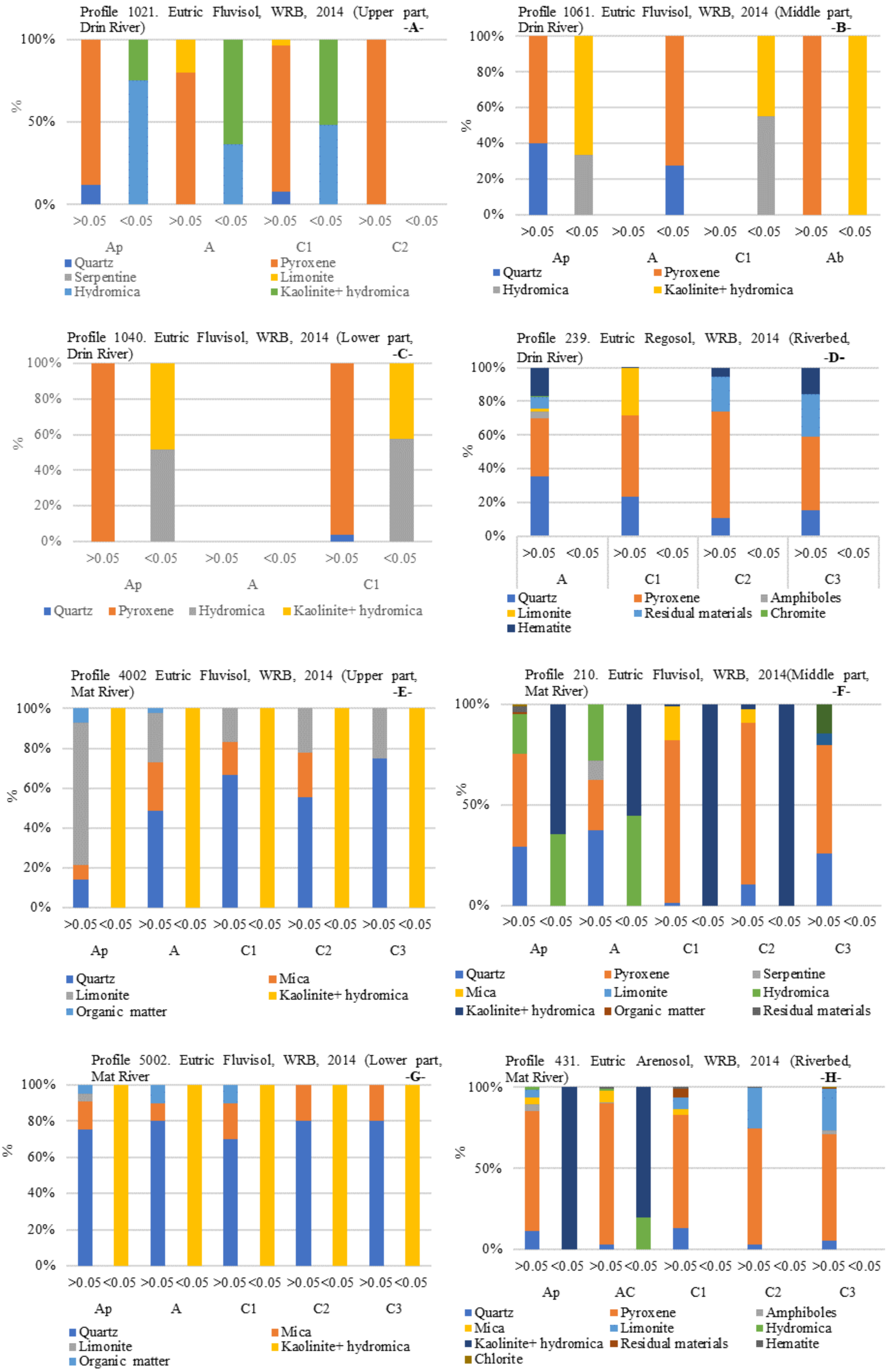

Figure 2. Mineralogical composition of soil fractions (>0,05/<0,05 mm), expressed as percentage of weight

Table 2. Major oxides contents according to depth, alluvial soils of Drin River

Profile No/ Location	Depth (cm)	SiO_2	Al_2O_3	Fe_2O_3	FeO	CaO	MgO	K_2O	Na_2O	MnO	TiO_2 /NiO†	P_2O_5	Loss on ignition	TOT
		%												
1021 Upper part, Drin alluvial plain	Eutric Fluvisol (WRB, 2014)													
	0-26	56.06	10.40	3.75	3.16	4.76	7.34	1.56	1.58	*	2.71	*	8.10	91.32
	26-52	56.56	10.40	3.50	3.16	5.32	6.69	1.69	1.56	*	2.76	*	8.36	91.64
	52-77	56.80	10.23	3.56	3.08	6.72	5.61	1.50	1.54	*	3.04	*	8.25	92.08
	77-92	59.56	7.52	1.86	3.73	7.56	4.96	1.16	1.39	*	2.64	*	7.72	90.38
	92-132	58.06	10.20	3.47	2.64	6.16	5.61	1.64	1.65	*	3.04	*	7.53	92.47
1061 Middle part, Drin alluvial plain	Eutric Fluvisol (WRB, 2014)													
	0-18	53.14	11.20	4.67	1.97	5.61	10.02	1.53	1.21	0.15	0.76	0.15	9.50	90.41
	18-42	52.74	12.40	4.39	2.69	6.34	6.78	1.63	1.31	0.10	0.72	0.38	10.30	89.48
	42-67	58.08	10.14	3.82	2.60	5.71	5.22	1.63	1.25	0.10	0.76	0.28	10.10	89.59
	67-100	52.68	12.82	4.12	2.42	5.71	10.44	1.48	1.31	0.08	0.76	0.20	7.64	92.02
1040 Lower part, Drin alluvial plain	Eutric Fluvisol (WRB, 2014)													
	0-27	53.44	10.25	2.44	1.25	5.29	14.06	1.32	1.31	0.19	0.74	0.20	9.55	90.49
	27-50	52.56	10.08	6.52	1.25	5.61	10.50	1.24	1.25	0.09	0.85	0.30	9.50	90.25
	50-72	58.24	10.38	5.92	1.16	5.39	6.64	1.42	1.31	0.10	0.79	0.22	7.60	91.57
	72-105	49.04	10.91	8.97	1.61	4.86	8.08	0.92	0.99	0.10	0.69	0.19	11.9	86.36
	105-158	52.04	12.04	7.17	1.16	4.13	11.58	2.00	1.12	0.10	0.76	0.18	8.02	92.28
239 Riverbed, Drin river	Eutric Regosol (WRB, 2014)													
	0-15	55.90	7.24	2.68	*	6.10	9.17	0.81	1.12	0.21	0.08†	0.22	4.96	88.49
	15-45	53.10	8.66	2.63	*	4.44	9.57	0.78	0.99	0.19	0.07†	0.24	7.20	87.87
	45-55	56.22	9.75	2.83	*	6.66	8.97	0.65	0.59	0.18	0.06†	0.19	5.78	91.88
	55-120	55.54	4.65	2.20	*	5.82	9.77	0.53	0.58	0.22	0.07†	0.27	6.60	86.25
Mean		54.99	9.96	4.14	2.28	5.68	8.39	1.31	0.82	0.14	1.18	0.23	8.26	90.27
SD		2.76	1.96	1.90	0.87	0.85	2.48	0.41	0.28	0.05	1.10	0.06	1.68	1.94
Minimum		49.04	4.65	1.86	1.16	4.13	4.96	0.53	0.58	0.08	0.06	0.15	4.96	86.25
Maximum		59.56	12.82	8.97	3.73	7.56	14.06	2.00	1.12	0.22	3.04	0.38	11.90	92.47
CV (%)		5.02	19.63	45.81	38.30	14.97	29.61	31.52	33.72	37.14	92.64	26.54	20.39	2.15

*No data, †NiO

Table 3. Contents of major oxides according to depth, alluvial soils of Mat River

Profile	Depth (cm)	SiO_2	Al_2O_3	Fe_2O_3	FeO	CaO	MgO	K_2O	Na_2O	MnO	TiO_2 /NiO†	P_2O_5	Loss on ignition	TOT
		%												
4002 Upper part, Mat alluvial plain	Eutric Fluvisol (WRB, 2014)													
	0-28	50.0	4.91	17.75	5.58	3.91	3.97	0.66	1.54	0.09	0.41	0.09	10.68	99.59
	28-68	51.4	9.8	9.6	4.05	4.45	8.24	0.65	1.5	0.11	0.49	0.05	9.45	99.79
	68-98	52.26	9.17	10.08	3.51	4.45	8.82	0.69	1.54	0.095	0.57	0.09	8.58	99.86
	98-128	35.4	16.26	14.39	3.51	6.07	12.5	0.73	1.41	0.12	0.70	0.04	8.70	99.83
	128-168	49.78	9.98	10.08	3.6	4.04	6.59	0.85	1.32	0.13	0.43	0.05	12.84	99.69
210 Middle part, Mat alluvial plain	Eutric Fluvisol (WRB, 2014)													
	0-30	53.6	6.78	2.29	*	7.01	5.53	0.58	0.57	0.18	0.03†	0.24	9.19	86.00
	30-55	55.6	14.7	3.25	*	7.71	7.04	0.8	1.35	0.22	0.06†	0.38	8.00	99.11
	55-67	57.98	8.35	2.58	*	8.78	7.04	0.8	1.22	0.17	0.06†	0.34	7.27	94.59
	67-110	55.7	10.31	2.62	*	8.06	8.04	0.83	1.13	0.19	0.07†	0.29	3.61	90.85
	110-130	57.48	7.07	3.23	*	8.41	8.55	0.48	1.04	0.25	0.06†	0.31	6.72	93.60
5002 Lower part, Mat alluvial plain	Eutric Fluvisol (WRB, 2014)													
	0-35	49.46	9.25	11.51	4.31	4.85	8.33	0.57	1.65	0.095	0.46	0.08	9.05	99.62
	35-65	49.66	10.78	11.04	3.33	4.04	7.75	0.8	1.5	0.11	0.53	0.04	10.8	100.38
	65-95	49.62	8.86	10.56	3.96	4.18	7.27	1.19	1.59	0.09	0.49	0.04	11.78	99.63
	95-125	47.94	9.54	9.6	3.33	4.58	8.53	0.96	1.56	0.13	0.50	0.06	12.69	99.42
	125-160	48.59	9.22	11.51	3.33	4.58	7.36	0.92	1.32	0.12	0.45	0.07	12.14	99.61

Table 3. Continued

Profile	Depth (cm)	SiO_2	Al_2O_3	Fe_2O_3	FeO	CaO	MgO	K_2O	Na_2O	MnO	TiO_2 /NiO†	P_2O_5	Loss on ignition	TOT
		%												
	Eutric Arenosol (WRB, 2014)													
431	0-30	51.52	9.28	2.93	*	7.01	7.04	0.52	1.25	0.21	0.06†	0.18	10.34	90.34
	30-68	50.6	12.53	3.13	*	7.36	6.08	0.65	1.37	0.22	0.05†	0.22	10.67	92.88
Riverbed,	68-94	60.4	7.15	2.26	*	6.3	6.79	0.47	1.12	0.16	0.06†	0.17	7.47	92.35
Mat River	94-154	58.32	8.22	2.72	*	3.33	8.38	0.39	0.72	0.2	0.04†	0.19	5.38	87.89
	154-164	58.26	10.32	3.08	*	6.66	9.17	0.51	1.29	0.23	0.05†	0.19	2.98	92.74
Mean		52.18	9.62	7.21	3.85	5.79	7.65	0.70	1.30	0.16	0.28	0.16	8.92	95.89
SD		5.51	2.60	4.86	0.70	1.73	1.69	0.20	0.28	0.05	0.24	0.11	2.78	4.68
Minimum		35.40	4.91	2.26	3.33	3.33	3.97	0.39	0.57	0.09	0.03	0.04	2.98	86.00
Maximum		60.40	16.26	17.75	5.58	8.78	12.50	1.19	1.65	0.25	0.70	0.38	12.84	100.38
CV (%)		10.56	27.02	67.37	18.08	29.89	22.03	27.91	21.60	34.06	85.46	71.12	31.18	4.88

*No data, †NiO

distribution with depth. If the ratio of an element oxide content in the surface horizon to that in the subsurface horizon is >1, it shows a decrease with soil depth; if the ratio is <1, it suggests an increase with depth; and a ratio of ≈1 indicates a mixed distribution pattern with soil depth.

The analysis of this report revealed an increasing trend with depth in CaO and TiO_2 contents in the soils of the upper part, FeO, P_2O_5, Na_2O dhe Al_2O_3 in the soils of the middle part, Fe_2O_3, K_2O and Al_2O_3 in the soils of the lower part of the Drin alluvial plain. Also an increasing trend with depth was foundfor Al_2O_3, K_2O, MnO and MgO in the soils of the upper part, Fe_2O_3, CaO, MgO, Na_2O, MnO, NiO, P_2O_5 and SiO_2 in the soils of the middle part and in K_2O and MnO in the soils of the lower part of the Mat alluvial plain. The pedological processes of formation and transformation of clay minerals and leaching of elements may have contributed to this trend. In the Drin alluvial plain, a downward trend in MgO, FeO, and Fe_2O_3 was observed in the upper section, and for MnO and Fe_2O_3 in the middle part, along with CaO, MgO, Na_2O, MnO, FeO, and P_2O_5, in the lower part. Similarly, the Mat alluvial plain exhibited a decrease in Fe_2O_3, FeO, P_2O_5, and Na_2O in the upper portion, K_2O in the middle portion, and FeO, CaO, MgO, P_2O_5,, and Na_2O in the lower portion. Irregular distribution with depth was observed for SIO_2, Al_2O_3, K_2O and Na_2O in the upper part, SiO_2, CaO, MgO, K_2O and TiO_2 in the middle part, and SiO_2 and TiO_2 in the lower part of the Drin alluvial plain. Likewise, in the Mat alluvial plain, irregular distribution was evident for SiO_2, CaO and TiO_2 in the upper part, Al_2O_3 in the middle part, and SiO_2, Al_2O_3, Fe_2O_3 and TiO_2 in the lower part. Sediment heterogeneity, weathering, pedogenic processes, and other post-depositional transformations may have contributed to this pattern of oxide distribution, Similar results have been reported by Goydaragh, et al., (2019).

3.4. Weathering rate assessment

The soils of the Mat River and Drin River alluvial plains exhibit different patterns in terms of weathering rates (Tables 4 and 5). In the Drin River alluvial soils, the CIA index varies between soil profiles, ranging from 60 in the surface soils of the upper part of the alluvial plain to 66 in the middle part, 64 in the lower part, and 61 in the riverbed. The CIW and PIA indices follow a similar trend, with values ranging from 67 and 63 in the surface soils of the upper part to 73 and 70 in the middle part, 71 and 67 in the lower part, and 66 and 63 in the riverbed. The higher values of the CIA, CIW and PIA indices indicate that the middle part of the Drin River alluvial plain tends to have the highest weathering rates. The surface soils of the upper part exhibit relatively lower weathering rates.

In the Mat River alluvial soils, the CIA index varies between soil profiles, ranging from 46 in the surface soils of the upper part to 73 in the middle part, 60 in the lower part, and 66 in the riverbed. The CIW and PIA indices also show variations, with values ranging from 49 and 45 in the surface soils of the upper part to 79 and 77 in the middle part, 63 and 61 in the lower part, and 69 and 68 in the riverbed. In this case, the middle part of the alluvial plain exhibits the highest weathering rate, as indicated by the highest values of CIA, CIW, and PIA indices. As in the case of the alluvial soils of the Drin River, the surface soils of the upper part show relatively lower rates of weathering. These data suggest that the alluvial soils of the Mat River have undergone a higher degree of weathering compared to the alluvial soils of the Drin River.

Based on the CIA index values (Nesbitt & Young, 1982), weathering can be categorized as slightly weathering (CIA 60-70) in the surface soils of the Drin River, and as very slightly (CIA 46) in

Table 4. Evaluation of the content of major oxides in Moles and weathering indices in alluvial soils of Drin

Profile	Depth (cm)	Al_2O_3	K_2O	Na_2O	[1]CaO*	CIA	CIW	PIA
		Moles						
1021 Upper part, Drin alluvial plain	Eutric Fluvisol (WRB, 2014)							
	0-26	0.102	0.017	0.025	0.025	60	67	63
	26-52	0.102	0.018	0.025	0.025	60	67	63
	52-77	0.100	0.016	0.025	0.025	60	67	63
	77-92	0.074	0.012	0.022	0.022	57	63	58
	92-132	0.100	0.017	0.027	0.027	58	65	61
1061 Middle part, Drin alluvial plain	Eutric Fluvisol (WRB, 2014)							
	0-18	0.110	0.016	0.020	0.020	66	73	70
	18-42	0.122	0.017	0.021	0.021	67	74	71
	42-67	0.099	0.017	0.020	0.020	63	71	67
	67-100	0.126	0.016	0.021	0.021	68	75	72
1040 Lower part, Drin alluvial plain	Eutric Fluvisol (WRB, 2014)							
	0-27	0.101	0.014	0.021	0.021	64	71	67
	27-50	0.099	0.013	0.020	0.020	65	71	68
	50-72	0.102	0.015	0.021	0.021	64	71	67
	72-105	0.107	0.010	0.016	0.016	72	77	75
	105-158	0.118	0.021	0.018	0.018	67	77	73
239 Riverbed, Drin river	Eutric Regosol (WRB, 2014)							
	0-15	0.071	0.009	0.018	0.018	61	66	63
	15-45	0.085	0.008	0.016	0.016	68	73	71
	45-55	0.096	0.007	0.010	0.010	78	83	82
	55-120	0.046	0.006	0.009	0.009	66	72	68
Mean Drin		0.098	0.014	0.020	0.020	65	69	67

[1]CaO* = Na_2O

Table 5. Evaluation of the content of major oxides in Moles and weathering indices in alluvial soils of Mat River

Profile	Depth (cm)	Al_2O_3	K_2O	Na_2O	[1]CaO*	CIA	CIW	PIA
		Moles						
4002 Upper part, Mat alluvial plain	Eutric Fluvisol (WRB, 2014)							
	0-28	0.048	0.007	0.025	0.025	46	49	45
	28-68	0.096	0.007	0.024	0.024	64	67	65
	68-98	0.090	0.007	0.025	0.025	61	64	62
	98-128	0.159	0.008	0.023	0.023	75	78	77
	128-168	0.098	0.009	0.021	0.021	66	70	68
210 Middle part, Mat alluvial plain	Eutric Fluvisol (WRB, 2014)							
	0-30	0.066	0.006	0.009	0.009	73	79	77
	30-55	0.144	0.008	0.022	0.022	73	77	76
	55-67	0.082	0.008	0.020	0.020	63	67	65
	67-110	0.101	0.009	0.018	0.018	69	74	72
	110-130	0.069	0.005	0.017	0.017	64	67	65
5002 Lower part, Mat alluvial plain	Eutric Fluvisol (WRB, 2014)							
	0-35	0.091	0.006	0.027	0.027	60	63	61
	35-65	0.106	0.008	0.024	0.024	65	69	67
	65-95	0.087	0.013	0.026	0.026	57	63	59
	95-125	0.094	0.010	0.025	0.025	61	65	63
	125-160	0.090	0.010	0.021	0.021	63	68	66
431 Riverbed, Mat River	Eutric Arenosol (WRB, 2014)							
	0-30	0.091	0.006	0.020	0.020	66	69	68
	30-68	0.123	0.007	0.022	0.022	71	74	73
	68-94	0.070	0.005	0.018	0.018	63	66	64
	94-154	0.081	0.004	0.012	0.012	74	77	76
	154-164	0.101	0.005	0.021	0.021	68	71	70
Mean	0.094	0.007	0.021	0.099	0.021	69	72	70

[1]CaO* = Na_2O

Table 6. Correlation coefficients (r) between the weathering indices and soil components

	$CaCO_3$	Organic C	Clay	Al_2O_3	K_2O	Na_2O
Alluvial soils of the Drin River						
CIA	-0.762**	0.346	0.385	0.211	-0.414	-0.749**
CIW	-0.717**	0.449	0.513*	0.343	-0.214	-0.676**
PIA	-0.737**	.415	.461	0.297	-0.291	-0.705**
Alluvial soils of the Mat River						
CIA	0.069	-0.014	-0.252	0.610**	-0.262	-0.556*
CIW	0.063	0.028	-0.197	0.584**	-0.160	-0.580**
PIA	0.065	0.015	-0.203	0.599**	-0.201	-0.565**

**Significant at the 0.01 level; *Significant at the 0.05 level.

the surface soils of the upper part, transitioning to moderately weathering (CIA 70-80) in the middle part of the Mat River alluvial plain.

The greater rates of chemical weathering of minerals in the alluvial soils of the Mat River, as compared to those of the Drin River, along with the soils in the middle part of the alluvial plains of the two rivers, can be attributed to shifts in soil mineralogy, precipitation levels, and groundwater levels. This is corroborated by findings from other researchers (Chojnicki, 2022).

3.5. Correlation Analysis

The correlation analysis reveals important relationships between the weathering indices (CIA, CIW, and PIA) and various soil properties (Table 6). The results indicate notable correlations between weathering indices and specific components within the alluvial soils of both the Drin River and the Mat River. In the Drin River alluvial soils, a negative correlation was observed between the weathering indices and Na_2O (CIA: $r = -0.749$, $p < 0.01$; CIW: $r = -0.676$, $p < 0.01$, PIA: $r = -0.705$, $p < 0.01$) as well as $CaCO_3$ (CIA: $r = -0.762$, $p < 0.01$; CIW: $r = -0.717$, $p < 0.01$, PIA: $r = -0.737$, $p < 0.01$). This suggests that as sodium oxides and calcium carbonates decrease, the weathering indices increase in the Drin River alluvial soils.

Conversely, in the alluvial soils of the Mat River, a positive correlation was found between the weathering indices and Al_2O_3 (CIA: $r = 0.610$, $p < 0.01$; CIW: $r = 0.584$, $p < 0.01$, PIA: $r = 0.599$, $p < 0.01$) while a negative correlation was observed with Na_2O (CIA: $r = -0.556$, $p < 0.01$; CIW: $r = -0.580$, $p < 0.01$, PIA: $r = -0.565$, $p < 0.01$). This suggests that as aluminum oxides increase, the weathering indices also increase in the alluvial soils of the Mat River, whereas higher levels of sodium oxides are associated with lower weathering indices. These findings align with previous research by Chojnicki (2022), underscoring the influence of specific mineralogical and compositional factors on the observed correlations between weathering indices and soil components in these river alluvial soils.

3.6 Implications for soil fertility

Alluvial soils of the Drin River: The presence of pyroxenes and quartz in the >0.05 mm soil fraction suggests a moderate level of weathering. The decrease in quartz content in the lower part of the section indicates a higher intensity of weathering, which can contribute to the breakdown of minerals and release of nutrients. While, the presence of limonite in the upper part indicates the weathering of iron-bearing minerals, which can contribute to the availability of iron for plant uptake. The mineralogical composition of the <0.05 mm soil fraction, containing hydromica (illite) and kaolinite + hydromica, suggests the presence of clay minerals that can contribute to soil fertility by providing cation exchange capacity and retaining nutrients.

The presence of easily weathering minerals in the soils of the Mat River such as pyroxenes, serpentine, and amphiboles suggests a higher rate of weathering compared to the Drin River alluvial soils. This indicates that the local factors such as climate and hydrological conditions in the Mat River alluvial soils are more favorable for weathering processes, which can enhance soil fertility. As in the alluvial soils of the Drin River, the mineralogical composition of the <0.05 mm soil fraction (a mixture of hydromica and kaolinite + hydromica), suggests the presence of clay minerals that may contribute to soil fertility.

Mineralogical composition and conditions of weathering determine the chemical composition of soils. Differences in the content of oxides (higher content of SiO_2, Al_2O_3, MgO, K_2O, TiO_2/NiO and P_2O5 in alluvial soils of the Drin River and lower content of Fe_2O_3, FeO, CaO, Na_2O and MnO in alluvial soils to the Mat River) can influence soil fertility by affecting nutrient availability and soil processes.

The weathering rate assessment showed that the middle parts of the two alluvial plains studied show the highest weathering rates based on the CIA, CIW and PIA indices. Higher rates of weathering can lead to increased mineral breakdown and release of nutrients, which can contribute to soil fertility. The surface soils of the upper parts show relatively lower weathering rates, suggesting potential limitations in nutrient availability.

4. CONCLUSIONS

This study provides valuable insights into the weathering and development of alluvial soils in the Drin and Mat river plains of Albania. Through a comprehensive analysis of soil properties, mineralogical composition, and weathering rates across various soil profiles and alluvial plains, a holistic understanding of the relationships between geological processes and soil fertility emerges. The mineralogical composition of the soils shows variations based on factors such as soil depth and parent material. Notably, the presence of easily weathered minerals like pyroxenes and amphiboles in the Mat River alluvial soils suggests a higher weathering rate compared to the Drin River alluvial soils. These mineralogical variations have implications for the overall weathering process. The elemental composition of the soils exhibits distinct differences between the two alluvial plains, primarily due to disparities in mineral content. These differences directly impact nutrient availability and various soil processes, subsequently influencing the overall soil fertility and agricultural productivity of the regions. Assessing weathering rates using indices such as CIA, CIW, and PIA reveals significant variations. The middle sections of both alluvial plains show higher weathering rates, potentially leading to increased nutrient release and improved soil fertility. In contrast, the surface soils in the upper regions display relatively lower weathering rates. Correlation analyses unveil interesting relationships between weathering indices and specific soil components. The Drin River alluvial soils exhibit negative correlations between weathering indices and elements like Na_2O and $CaCO_3$. On the other hand, the Mat River alluvial soils demonstrate positive correlations of the weathering indicies with Al_2O_3 and negative correlations with Na_2O. In conclusion, this study contributes to a comprehensive understanding of the intricate connections between weathering, mineralogical composition, elemental content, and soil fertility in the context of alluvial plains. The findings underscore the importance of weathering processes in shaping soil development and fertility, providing valuable insights that have implications for agriculture and environmental management in these critical regions.

Acknowledgment

This research was supported by the Agricultural University of Tirana. The map of the study area where the sampling points are given was prepared by Ing. Elson Salihaj.

REFERENCES

Bajraktari, F., 1960. *The Soils of Albania and the ways for their fertile growth*, Ministry of Agriculture, Tirana, 252 pp,

Bajraktari, F. & Xinxo, M., 1972. The belt of gray cinnamon soils and alluvial soils of Lushnja district and ways to increase their fertility, Bulletin of Agricultural Sciences, 3: 89-107,

Chojnicki, J., 2022. *Chemical weathering of the middle Vistula and Żuławy (Vistula delta) alluvial soils*, Soil Science Annual, 73(3), 157349. https://doi.org/10.37501/soilsa/157349

Fedo, C.M., Nesbitt, H.W. & Young, G.M., 1995. *Unraveling the effects of potassium metasomatism in sedimentary rocks and paleosols, with implications for paleoweathering conditions and provenance, Geology, 23(10): 921–924. https://doi.org/10.1130/0091-7613(1995)023<0921:UTEOPM>2.3.CO;2*

Gjoka, F., 1994. *Problems of genetic and production characterization and of improvement of the alluvial soil fertility*. Ph.D. Thesis. Agricultural University of Tirana.

Gjoka, F., 1996. *Data on genesis and fertility of the alluvial soils of northwest Albania*, Bulletin of Agricultural Sciences, Nr, 1, 25-30, Tirana, Albania.

Gjoka, F., 1999. *Available micronutrients in two Fluvisols of humid zone of northwest Albania*, Bulletin of Agricultural Sciences, Nr, 4: 27-34, Tirana, Albania.

Gjoka, F., 2000. *Available micronutrients in two Fluvisols in the humid zone of northwest Albania*, Bulletin of Agricultural Sciences, Nr, 4, 27-34, Tirana, Albania.

Gjoka, F., Luli, F. & Sulioti, V., 1994. *Data on composition of alluvial soils of Mat and Drin rivers*, Albanian agriculture, Nr, 4, 26-28, Tirana, Albania.

Goydaragh, M.G., Jafarzadeh, A.A., Shahbazi, F., Oustan, Sh., Taghizadeh-Mehrjardi, R. & Lado, M., 2019. *Estimation of elemental composition of agricultural soils from West Azerbaijan, Iran, using mid-infrared spectral models*. R, Bras, Eng, Agríc, Ambiental, 23(6): 460-466. https://doi.org/10.1590/1807-1929/agriambi.v23n6p460-466

Harnois, L., 1988. *The CIW index: a new Chemical Index of Weathering*, Sedimentary Geology 55: 319–322.

https://doi.org/10.1016/0037-0738(88)90137-6
Jenny, H., 1941. *Factors of Soil Formation*, McGraw-Hill, New York. https://netedu.xauat.edu.cn/sykc/hjx/content/ckzl/
Kasa, E., Contin, M. & Gjoka, F., 2015. *Accumulation of Heavy Metals in Vegetables from Agricultural Soils*. Albanian Journal of Agricultural Sciences. 2015, Vol. 14 Issue 2, p169-175.
Kasa, E., Felix-Henningsen, F., Duering, R-A, Gjoka, F. & Shkurta, E., 2014. *Mobility of heavy metals in arable soils from Bregu i Matit Plain, NW Albania*. Carpathian Journal of Earth and Environmental Sciences, August 2014, Vol. 9, No. 3, p. 61 – 68
Khokhlova, O.S., Voronin, K.V., Malashev, V.Yu ., Golyeva, A.A. & Khokhlov, A.A., 2001. *Soil evolution and accumulation of loess-like material in the Chechen depression, Northern Caucasus, Russia*, Quaternary International, Volumes 76–77, 103-112. https://doi.org/10.1016/S1040-6182(00)00094-X**.**
McLennan, S.M., 1993. *Weathering and global denudation*, J, Geol,, 101, pp, 295-303. https://www.jstor.org/stable/30081153
Mello, D.C.D., Ferreira, T.O., Veloso, G.V., Lana, M.G.D., Mello, F.A.D.O., Di Raimo, L.A.D. L., Cabrero, D.R.O., Souza, J.J.L. L.D., Fernandes-Filho, E.I., Francelino, M.R., Schaefer, C.E.G.R. & Demattê, J.A.M., 2022. *Weathering intensities in tropical soils evaluated by machine learning, clusterization and geophysical sensors*, SOIL Discuss. [preprint], https://doi.org/10.5194/soil-2022-17.
Nadłonek, W. & Bojakowska, I., 2018. *Variability of chemical weathering indices in modern sediments of the Vistula and Odra Rivers (Poland)*, Applied Ecology and Environmental Research, 16(3), 2453–2473, DOI: http://dx,doi,org/10,15666/aeer/1603_24532473
Nesbitt, H. & Young, G., 1982. *Early Proterozoic climates and plate motions inferred from major element chemistry of lutites*. Nature 299, 715–717 (1982). https://doi.org/10.1038/299715a0
Shkurta, E., Gjoka, F., Contin, M. & Kasa, E., 2017. *Heavy metals in vegetables from soils contaminated by various sources*. Fresenius Environmental Bulletin. Volume 26 – No. 2a/2017, pages 1771-1777
Sirbu-Radasanu, D.S., Huzum, R., Dumitraş, D.-G., & Stan, C.O., 2022. *Mineralogical and Geochemical Implications of Weathering Processes Responsible for Soil Generation in Mănăila Alpine Area (Tulgheş 3 Unit—Eastern* Carpathians). Minerals, 12, 1161. https://doi.org/10.3390/min12091161
Tunçay, T., Dengiz, O., Bayramin, I., Kilic, S. & Baskan, O., 2019. *Chemical weathering indices applied to soils developed on old lake sediments in a semi-arid region of Turkey*, Eurasian J Soil Sci, 8 (1) 60 – 72. https://doi.org/10.18393/ejss.499122
Veshi, L. & Spaho, Sh., 1988. *Pedology*, Publication of the Agricultural University of Tirana, 574 pp, Tirana, Albania.
Wagner, S., Costantini, E.A.C., Sauer, D. & Stahr, K. 2007. *Soil genesis with time in a marine terrace sequence of Sicily*, Revista Mexicana de Ciencias Geologicas, 24, 247–260. https://repositorio.unam.mx/contenidos/4120432
Walker J.C.G., Hays P.B. & Kasting, J.F., 1981. *A negative feedback mechanism for the long-term stabilisation of the Earth's surface temperature*. Journal of Geophysical Research, 86, 97769782 https://doi.org/10.1029/JC086iC10p09776
Wilson, M.J., 2003. *Weathering of the Primary Rock-Forming Minerals: Processes, Products and Rates*, Clay Minerals, Vol, 39, No, 3, 2004, pp, 233-266, http://dx,doi,org/10,1180/0009855043930133
WRB. 2014., *World reference base for soil resources*. World soil resources report no. 106. 181 p. ISBN 978-92—5-108369-7. http://www.fao.org/3/a-i3794e.pdf

Received at: 13. 07. 2023
Revised at: 26. 08. 2023
Accepted for publication at: 29. 08. 2023
Published online at: 30. 08. 2023