

The effect of soil burning on the chemical and physical properties of soil and potassium status in northern Iraq

Naba'a Marwan Alsultan¹, Muhamad Ali Jamal AL-Obaidi²

^{1,2}University of Mosul College of Agriculture and Forestry, Department of Soil Science and Water Resources, Mosul, Nineveh, Iraq.

Corresponding Author: Naba'a Marwan Alsultan; E-mail: abdulsalam.faisal@uomosul.edu.iq

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ABSTRACT

Two sites were chosen in northern Iraq, the first was from Baweza(Aridisols) village in the city of Mosul famous for its cultivation of wheat, and the other was from Zawita (Mollisols) forests in Dohuk governorate that were exposed to fires, Samples of surface soils were collected with a depth of (0.30) m to study the effect of Burning on some physical ,chemical properties and potassium status. The results indicated that burning caused an increase in the bulk density from (1.64to1.69)and (1.45to1.54) Mg.m-3 and decrease in the total porosity from (38 to36 and (45-42)% in Ba'wiza and Zawita soils respectively, the soil particle size distribution were changed from (355-160),(395-520), (250-320)and (310-360, (400-350) (190-390) gm.Kg for clay silt and sand separates for Ba'wiza and Zawita soils. pH (7.1 - 7.9) and (7.0 - 7.4) electrical conductivity (0.40-0.90) and (0.40-0.80) dS.m-1 CEC from (33.75-25), and (43.75-33.75) C.molc.Kg-1 for Ba'wiza and Zawita soils respectively., a slight increase in of the organic matter content in Ba'wiza soil from (21.32- 29.2) and a sharp decrease (22.33-11.69) gm.Kg-1 in the Zawita soil, a clear increasing in of calcium carbonate content (160.36-261.82) and (28.63-141.54) gm.Kg-1.

1. Introduction

Burning is one of the wrong practices followed on the local and global scales, as fire is an important physical factor that affects many environmental processes and is used in agricultural operations as one of the practices of soil management (Santín, 2016), and although it is banned in many countries, burning the remains of Cropping is a common activity for some farmers during the annual preparation of the land for cultivation and the eradication of weeds and harmful bush seeds and pathogens in the world in general and in northern Iraq (Ninawa Governorate) in particular. Controlled fire is defined as the burning of plant residues in low quantities to achieve completely different objectives due to specific weather conditions, quantity of plant residues, and topographical conditions (Fernandes et al., 2013 ; Pereira, 2014). It is seen as an essential and integrated vegetation management option to mitigate wildfire activity, thereby reducing carbon emissions from uncontrolled natural fires (Bennet et al., 2014).

As fires affect the physical, chemical, and biological properties and the accumulation of dry matter. It also controls the main processes and properties of the ecosystem, such as the cycle of nutrients. The burning of plant residues increases the surface temperature of the soil up to 500°C. The heat generated during combustion can change the physical, chemical, biological and mineral properties of the soil (Thomaz et al., 2014).

Artificial fire depends on the amount of plant residues available for combustion, while the effect of the intensity of combustion on soil properties is determined by the temperature gradient that occurs in it. To 300° C, it tends to decrease in the capacity of positive ion exchange (CEC) and increase in soil salinity and calcium carbonate content (Inbar et al., 2014) (Najafi-Ghiri, 2020). In this regard, it was confirmed by (Alcañiz et al., 2018) and (Akhzari, 2022) Specific fires affect soil properties but vary greatly depending on the initial properties of the soil, vegetation cover or the type of fire. It can also be noted that the physical and biological properties the accessibility of the soil is more strongly affected by the described fires than its chemical properties.

Finally, we conclude that the described fires clearly constitute a disturbance to the environment (positive, neutral or negative depending on the characteristic of the studied soil). Since most of the agricultural fields spread in Nineveh Governorate and nearby areas are famous for the cultivation of wheat and barley crops, the practice of burning became common in these fields, especially after Harvest Potassium is one of the major important elements in plant nutrition, and its

readiness and liberation from the soil is an important matter in agricultural strategies (Wakeel, 2022) (Nguyen et al., 2020) and due to the lack of in-depth studies of the impact of fires on soil, so we believe that our current study is the first in Iraq Which aims to study the effect of burning on the physical and chemical properties of soil, including potassium and its adsorption formulas for burnt soils.

3. Methodology (New Times Roman (Body), Font Size 10)

Two sites were chosen in northern Iraq, the first from the village of Ba'wiza in the city of Mosul in northern Iraq, famous for its cultivation of wheat, and the other from Zawita forests in the province of Dohuk, whose location and nature of agricultural exploitation are proven in Table (1), whose fires are shown in the picture (1).

Table 1 Geographical data and morphological description of the locations of the study soil samples

Siteand rating	Geographical location (GPS)	Agricultural exploitation
1- Mosul (Aridsol)	36°25'59.52"N43°08'21.55"E	Cereal Crops
2- Dhok (Mollisols)	36°54'46.3"N 43°08'14.2"E	Forests



Figure 1 the areas that were burned in the two study sites

The physical and chemical analyzes below were carried out according to the methods mentioned in Spark, (2017) on soil samples obtained from burning and non burning , as follows: Particles size distribution of soil separations was used by the hydrometer method according to (Gee, 2002). The bulk density was estimated by the paraffin wax method.

Soil chemical properties

Electrical conductivity and pH were measured in 1:1 extract. Calcium and magnesium ions were estimated with EDTA (0.01N), while sodium and potassium were determined by a flame photometer. The CEC is extracted in 250 ml using 1 M NH_4Cl with the process repeated twice and all the extracts are collected and analyzed as exchangeable ions (Na^+ , K^+ , Mg^{+2} , Ca^{+2}) for replaceable ions (Rayment and Lyons, 2011). While calcium carbonate CaCO_3 was estimated by a calcimeter method. The soil organic matter was estimated by wet oxidation method using potassium dichromate as an oxidant with concentrated sulfuric acid and then treated with ammonium ferrous sulfate in the presence of ferroin indicator.

Forms of potassium

1-Soluble potassium (Soluble-K):- The soluble K was determined from the soil saturation extract by using (Flame photometer) as mentioned before.

2-Exchangeable potassium:- Exchangeable potassium was extracted from the soil by three different methods including 1M ammonium acetate solution (NH_4OAc pH 8.1) as mentioned before, 1M (NH_4Cl), as the extraction solution according to Suarez (1996), and 1M CaCl_2 solution as described by Pratt (1982).

3-Non-Exchangeable potassium (non-exchangeable-K):- Non-exchangeable K was extracted from the soil by using 1M boiling HNO_3 according to Page et al. (1982), the non-exchangeable K was calculated from the difference between the amount of K which was extracted by boiling HNO_3 and the amount which was extracted by 1M CaCl_2 .

4- Total potassium (T.K):- The total K was determined from the soil sample by digestion the soil with concentrated HNO_3 and 60% perchloric acid and digests the mixture until dense white fumes of acid appear.

5- Mineral potassium (Min-K):- The mineral K was calculated according to the suggested mathematical formula by (Martin and Sparks, 1983) as follows:

$$\text{Min-K} = \text{T.K} - (\text{CaCl}_2\text{-K} + \text{HNO}_3\text{-K}) \dots\dots\dots (1).$$

Where:

Min-K= mineral potassium. T.K= total potassium. $\text{CaCl}_2\text{-K}$ = extracted potassium by 1M CaCl_2 . $\text{HNO}_3\text{-K}$ = extracted potassium by 1M boiling nitric acid.

6-Potassium adsorption:- Potassium adsorption was studied according to 6-2- Thermodynamic approaches.

Effect of added K on K adsorption

Potassium adsorption study was performed according to procedure described by Beckett (1964 a, b). (2.5.00 gm) duplicate samples of the soils were equilibrated in 100 ml polypropylene tubes containing 50 ml of solution containing from (0, 0.25, 0.5, 1, 2, 4 and 8 mmol K^+ L^{-1} as KCl in 0.01M CaCl_2 . suspensions were shaken for one hour at 298K (Isotherm reaction) and let to equilibrate for 48 hours and then centrifuged. The supernatant were analyzed for K .

The adsorbed quantity is calculated according to the following equation:

$$\text{K.ad} = (\text{K}_{\text{in}} - \text{K}_{\text{fin}}) \times \text{V/S} \dots\dots\dots (2).$$

Where:

K.ad : Adsorbed potassium (mmol.Kg^{-1}).

K_{in} : Added primary potassium (mmol.L^{-1}).

K_{fin} : Final potassium in equilibrium solution (mmol.L^{-1}).

V : equilibrium volume liter .

X : Soil mass kg.

The criteria for potassium ion exchange) are calculated as follows:

The Langmuir and Freundlich equations

$$1/X = 1/K_{bc} + 1/b \dots\dots\dots (3).$$

$$\text{Log X} = \text{Log K} + b \text{Log C} \dots\dots\dots (4).$$

Amount of adsorbed potassium (mmole.kg^{-1}).

and C: the ion concentration in the equilibrium solution (mmole.L^{-1}).

K: a constant representing the binding energy (mmole.L^{-1}).

a,b : constants.

Then the statistical analysis of the correlation coefficient is performed according to the Exel (2010) program.

The adsorption criteria (adsorption capacity and binding energy) are determined by adopting the linear formula of the above equations.

4. Results and Discussion

Burned soil properties

Effect of burning on physical properties

Table (2) shows some of the studied physical properties of the studied soils, as we note from the results that the burning processes led to a change in the values of the bulk density in the soil of Ba'wiza, which is famous for the cultivation of wheat and barley crops, as it ranged from (1.64) to (1.69) Mgm^{-3} Which led to a decrease in the porosity values from (38)% to (36)%, while the forest fire in Zawitah led to a change in the value of the bulk density from (1.45) to (1.54) Mgm^{-3} .

Which was reflected on the values of the total porosity as it changed from (45%) to (42) and the reason for this is due to the fact that the fires that occur in wheat fields are less severe than forest fires, because crop residues of low quantities do not affect the change in bulk density compared to forest trees It was noted by Shakesby et al., (2006) that after a low density fire, the bulk density of the soil increased significantly with a corresponding decrease in the porosity as it was concluded that the destruction of the soil aggregates contributed to the increase in the bulk density.

Hence it appears that many factors determine the bulk density of soil (including, fire density and intensity, soil texture, and moisture) and these factors need to be carefully monitored if we hope to gain greater knowledge of this soil property (Lopes et al., 2020).

As shown in the table. (2) that the burning operations led to a change in the soil separations in Baouizah, as it changed from (355) to (160) for separated clay ,(395) to (520) for silt, and (250) to (320) gmkg^{-1} for sand fraction, while The forest fire in Zawita led to a change in the joints from (310) to (360) for clay separated, from (400) to (350) for silt separated, and from (290) to (390) kg.Kg^{-1} for sand separated, and this is consistent with what was found.

Both (Afif and Oliveira, 2006) and Granged et al., 2011) showed significant changes in the sandy clay soil in Spain and Australia after a specific fire, as the sand content increased due to the formation of unstable soil aggregates, but they noticed after seven days that the sand content had increased It returned to its pre-burning levels, so these ephemeral changes resulted in a 39% reduction in clay content in the clayey soils.

Rough due to the accumulation of fine particles in larger particles of silt. In contrast, Pierson et al. (2008) showed a slight decrease in clay content and greater values of sand content in coarse soils found in the western United States after a wildfire.

Table 2 Some physical properties of the two study soils before and after burning

Land use , soil classification			
Mollisols		Aridsol	
43°08'14.2"E	36°54'46.3"N	43°08'21.55"E	36°25'59.52"N

Burned		un Burned		Burned		un Burned	
Bulk desity Mg m ⁻³							
1.54		1.45		1.69		1.64	
%Porosity							
42		45		36		38	
Soil Separates gm.Kg ⁻¹							
Clay	260	310		160		355	
Silt	350	400		520		390	
Sand	390	290		320		250	
Texture							
Loam		Clay loam		Silt loam		Clay loam	

Effect of burning on chemical properties

Table (3) shows the effects of burning heat and its interactions on some soil properties and the dynamics of potassium. The pH of the soil increase from (7.1) to (7.9) (slightly basic) due to its calcifying nature, as the increase in the pH value was slight (Fernandez et al., 2019). Because the selected soil contains a low content of organic matter (few cations are released after combustion).) and a large carbonate content that may prevent any change in soil pH. The electrical conductivity of the studied soil was affected by heating. All soils were non-saline. The heating temperature and the burning reaction significantly affected the soil EC, as the soil EC values increased from (0.6) to (0.9) dSm. Which indicates that our results agree with what was obtained (Hueso et al., 2018). Also, the CEC value of the soil significantly decreased after heating from (33.75) to (25) CmolcKg⁻¹ because it was affected by the heating temperature. Changes in soil CEC after heating may be due to combustion of organic matter, breakdown of minerals and conversion of smectite to illite (with a value lower than CEC) after stabilization of K ions (released by organic matter and K-bearing mineral decomposition) within the interlayer space (Ulery et al., 2017). It agrees with what the researcher pointed out about an 80% decrease in CEC in soil after burning and concluded that this is due to the combustion of organic matter and changes in soil minerals, but the role of organic matter combustion is more important. In fact, soil humus can be converted to coal (black carbon) with lower CEC after heating at low temperature (250-500°C) (Bodi et al., 2014). Inbar et al. (2014) reported a 50% loss. of CEC for soil due to soil heating to 250°C.

Table 3 Some chemical properties of the two study soils before and after burning

Property	Mollisol			
	Burned	un Burned	Burned	un Burned
EC dS.m ⁻¹	0.80	0.40	0.90	0.40

pH	7.40	7.00	7.90	7.10
O.M gm.Kg ⁻¹	11.69	22.33	29.23	21.23
CaCO ₃ gm.Kg ⁻¹	141.54	28.63	261.82	160.36
CECC.molc.Kg ⁻¹	33.75	43.75	25.00	33.75

potassium forms

The results shown in Table (4) refer to the amounts of water soluble potassium in the study soil solution, which amounted to (0.018), which increased to 0.100 Cmolc.Kg⁻¹ after adding charcoal with an increase of (4.55)%. These two values express the Potassium is soluble in the soil solution and is not adsorbed on the surface of the colloids, which is subject to leaching and is strongly affected in the root zone (Calvaruso et al., 2014 and according to the International Potash Institute IPI, 2016). The values we obtained in the study soil are below The critical limit of potassium amounting to (0.05) Cmolc.Kg⁻¹, which is sufficient to meet the needs of the plant. As Table (4) shows, the exchangeable potassium amounts, which amounted to (0.20) Cmolc.Kg⁻¹, extracted with a solution of 1 molar calcium chloride CaCl₂, while it reached after adding burning 0.72 Cmolc.Kg⁻¹, while the exchanged potassium was extracted with 1 molar of ammonium chloride NH₄Cl, which amounted to (1.53) before burning and 5.11 Cmolc.Kg⁻¹ after burning and with reference to the assessment of the International Potash Institute (2016)), which determined the critical limit for potassium The soil under study is above the critical limit, which indicates the need to monitor the potassium status in these soils to obtain an optimal production. Table (4) also shows the quantities of nonexchangeable potassium, which amounted to (2.55) Cmolc.Kg⁻¹ for Baoza site before burning and it increased to 8.43 Cmolc.Kg⁻¹ after burning. The values we obtained express the potassium present between the layers of minerals and held by electrostatic forces - Van der Waals forces - resulting from the presence of negative charges of the inner layers of minerals, as expressed by potassium located within the inner pathways of its exit from the mica minerals (Wedge zone Joycyely) et al., (2018), which is attached to the core region of the mica core. There are non-exchanged potassium ions at different dimensions from the exit holes at the mineral edges. And that its dimensions depend on the size of the metal particles, the intensity of weathering, and the equilibrium state of potassium ions in this phase with potassium ions of the liquid soil phase. It is classified as medium to difficult to prepare, and in the long term represents the reserve responsible for the preparation of potassium for the soil solution. It is controlled by the stabilization and release interactions (Jalali et al., 2007), which are typical for semi-humid soils. It has a high supply of non-exchanged potassium according to the critical limit of non-exchanged potassium (1.00) Cmolc.Kg⁻¹ proposed by Al-Zubaidi and Pagel, (1979). It has a high ability to release from the non-exchangeable phase to the alternating and dissolved phases according to the critical limit of potassium release threshold proposed by Datta and Sastery, (1988), which is (1.08) Cmolc.Kg⁻¹.

Table4 The different Potassium formulas before and after burning

Potassium form Cmol.kg ⁻¹	Mollisol		Aridisol	
	Burned	un Burned	Burned	un Burned
Soluble	0.025	0.022	0.100	0.018
Exchangeable-CaCl	0.410	0.026	0.720	0.200
Exchangeable-NH ₄ Cl	3.060	2.550	5.110	1.530
Non- Exchangeable	4.090	3.060	8.430	2.550
Mineral ¹	5.630	3.580	0.770	5.360

Total	7.720	6.640	9.200	7.910
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Table (4) shows the amounts of mineral potassium in the soil-solid phase ($5.36 \text{ Cmolc.Kg}^{-1}$) for Ba'wiza site unburned and $0.77 \text{ Cmolc.Kg}^{-1}$ in burned soil. The high values of potassium for the form The three mentioned above are due to the role of burning and its decomposition by high heating, which work on weathering and destroying potassium-bearing minerals, including mica, and thus facilitating the process of its release into the liquid phase of the soil (Christophe et al., 2014), our results obtained in soils are in agreement with the findings of (James et al. 2018) (Najafi et al., 2021) This increase in different potassium forms is due to the partial destruction of potassium-bearing minerals such as mica and feldspar, then releasing potassium ions to soil solution. Due to the balance between the different forms of potassium, its dissolved ions may be diffused to exchange over the sites and its stabilization may occur in the interlayer space of the clay and increase both its exchangeable and non-exchangeable forms on the clay surfaces as shown in Table (4) As it is noted from Figure (1) that the burned soil led to the movement of the solubility-controlled phase (Illite mineral) away from its original position, making it more ready for the plant.

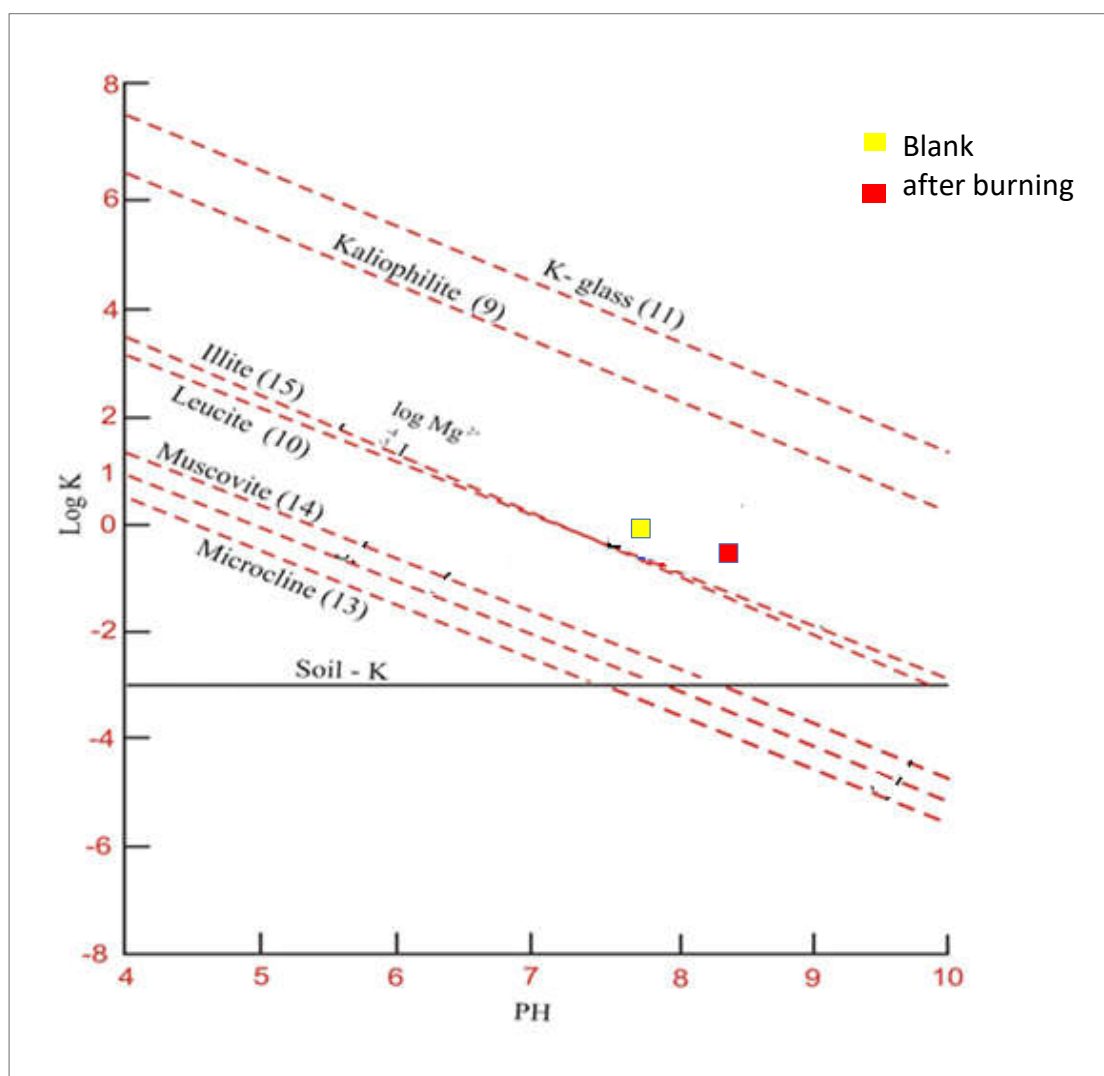


Figure 2 The graph for determining the minerals controlling the solubility of potassium for the study soil.

Ion exchange equations: Langmuir equation

The results shown in Table (5) indicated the validity of the linear formula for each of the one-surface Langmuir and Freundlich equations in the mathematical description of potassium exchange and adsorption. Franklech from the lowest value (0.961) to the highest value (0.996), which gives a clear indication of the validity of the two equations in the mathematical description

due to the high values of the coefficient of determination. and that the superiority of the two equations in the mathematical description of the adsorption

process in the study soils leads us to conclude the high validity of these equations with the possibility of their application in other soils. And to reveal the course of the potassium adsorption process. Which showed that there is one surface for the adsorption process, and then the value of the obtained binding energy, as well as the maximum adsorption capacity, will give a realistic evidence for the nature of the real interaction between the added ion and the adsorption surface (Das and Mondal, 2011) that the thermally symmetric Langmuir adsorption assumes that the adsorption sites have an equal slope (affinity).) for adsorption on the surface, but adsorption on the surface does not affect the rest of the adsorbed molecules in the corresponding sites (Dada et al., 2012)(Joycely et al., 2018).

The maximum adsorption capacity and binding energy

The results shown in Table (5) showed that the greatest coverage of potassium ions as an adsorption monolayer appeared in the unburned soils, as it reached (8.53) and (2.28) mgKg^{-1} for the sites of Baweza and Zawiya, respectively, before burning, and that the burning operations that affected the two sites led to This constant was reduced, which amounted to (2.97) and (0.59) mg kg^{-1} for Baweza and Zawiya sites, respectively, after burning, which indicates that the adsorption capacity decreased sharply in both sites after burning, and this may be due to the loss of organic matter as one of the effective surfaces for adsorption. In addition to the modifications that may occur on the surface of the clay, as it is the party responsible for adsorption in the soil, and this is consistent with what was included in (Najafi-Ghiri and Boostani, 2020). Which showed that heating the soil to (225) and (350) degrees Celsius had A significant role in reducing the potassium adsorption capacity of limestone soils in Iran, as heating the soil to a high temperature leads to the breakdown of some clay minerals such as smectites and reduces the diffusion of K in the interlayer area and adsorption (Ulery et al., 2017). However, this process may lead to a partial breakdown of smectite, but complete dehydration of the expanded minerals may occur at temperatures above 500 °C (Sarıkaya et al., 2000). On the other hand, heating to high temperatures may cause dehydration of some cations such as Ca, Mg and Na. These cations may enter the interlayer space and limit K fixation in metals (Morodome and Kawamura, 2011) (Bangroo et al., 2021). Smectites may also fix K ions that are released after combustion of organic matter and their ability to adsorption of K may be limited by the conversion to Illite. Roberson and Lahann , (1981) indicated that some parts of smectite may turn into illite after several hours of heating in the presence of potassium ions. This conversion reduces the K adsorption capacity of the soil. Li diffusion into the smectite octahedral plate and heating to 300 °C may reduce the expansive nature of smectite and fixate the potassium (Komadel et al., 2003)

The maximum regulatory capacity (MBC)

This value is expressed mathematically by the product of multiplying the maximum surface adsorption capacity (X_m) by the binding energy (K) of Langmuir equation, which is a characteristic of ion adsorption in the soil as it reflects the strength of the capacity factor of the adsorbed ion on the total surfaces of the soil. Table (5) shows the values of the regulatory capacity The maximum levels of potassium ranged from (13.76 and (5.61) in Ba'wiza and Zaweta soils, respectively, unburning, and decreased to (3.06) and (0.78) in Ba'wiza and Zawiya soils, respectively, after burning. The dominant clay mineral and its transformation into another formula significantly reduced the ability of the regulatory soil to cope with changes in potassium as a result of its addition to the soil. Li et al., (2013) see that the values of (MBC) are an important criterion in the characterization of adsorption and that the high values of them (un burning) explain The ionic type of the adsorbed potassium is characterized by a low binding energy and thus ease of movement and migration towards the depths of the soil, and then makes these soils with a high capacity and organizing capacity to counteract the potassium leaching, unlike what happens to the soil after burning, which makes the potassium more adsorbed and more difficult to be released. from the soil before burning.

	Mollisol		Aridisol	
	Burned	un Burned	Burned	un Burned
Equation	$y = 1.2831x - 1.6953$	$y = 0.1702x - 0.4381$	$y = 0.3269x - 0.3366$	$y = 0.0727x - 0.1172$
R^2	0.945	0.988	0.995	0.997
K_L	3.06	2.55	5.11	1.53
X_M	4.09	3.06	8.43	2.55

MBC	5.36	3.58	0.77	5.36
RL	7.72	6.46	9.20	7.91

Figure 3 The linear form of Langmuir equation for studied soils

Frendlich equation (linear adsorption model)

This model expresses the linear form of Frendlech's equation on the basis that $n = 1$, where K_d expresses the percentage of the potassium adsorbed concentration on the soil particles relative to its concentration in the soil solution at equilibrium called the distribution coefficient (or Distribution Coefficient Partition) (K_d) and this value It reflects the ability of the soil to retain potassium, which is related to its movement in the soil solution (Kabata and Pendias, 2011) (Alloway, 2013).

Which ranged from 33.58 in unburned Ba'wiza sit reduced to 13.10 $L.Kg^{-1}$ in burned Ba'wiza sit and were ranged from 34.40 in unburned Zaweta sit reduced to 15.75 $L.Kg^{-1}$ in burned Zaweta sit as shown in Table (6). It is also noted that the burning process led to an increase in the diffusivity of potassium. And release it to the soil compared to the two soils that have not been burned, according to sparks, 2003) that adding potassium to the soil encourages the release and release of original potassium from the soil.

	Mollisol		Aridisol	
	Burned	un Burned	Burned	un Burned
Equation	$y=0.3313x-1.2754$	$y=0.4865x-2.2759$	$y=0.1651x-0.6956$	$y=0.3365x-1.8876$
R^2	0.97	0.99	0.96	0.95
K_f	1.2754	2.2759	0.6956	1.8876
K_d	15.75	34.40	13.10	33.58
$1/n$	0.3313	0.4865	0.1651	0.3365

Figure 4 Linear forms of Frendlich's equation for the two study soils unburned and burned soil

As for Figure (2 a,b), it represents the path of the diffusion process for the adsorption and release reactions, if the diffusion efficiency decreases with the increase in the amount of the added ion. Due to the complexity in the components of the soil and the competition between different ions, the diffusion coefficient (K_d) cannot be estimated as a slope of the straight line (Gao et al., 1997) because adsorption or What the soil retains of ions is usually at low concentrations. The high values of the diffusion coefficient (K_d) are related to the high ability of the sites to adsorb potassium, as they have a high binding energy, and the adsorption becomes non-specific at high concentrations, as the adsorption sites become occupied by the adsorbed ion (Mouhamed et al., 2016) (Kassa et al., 2019).

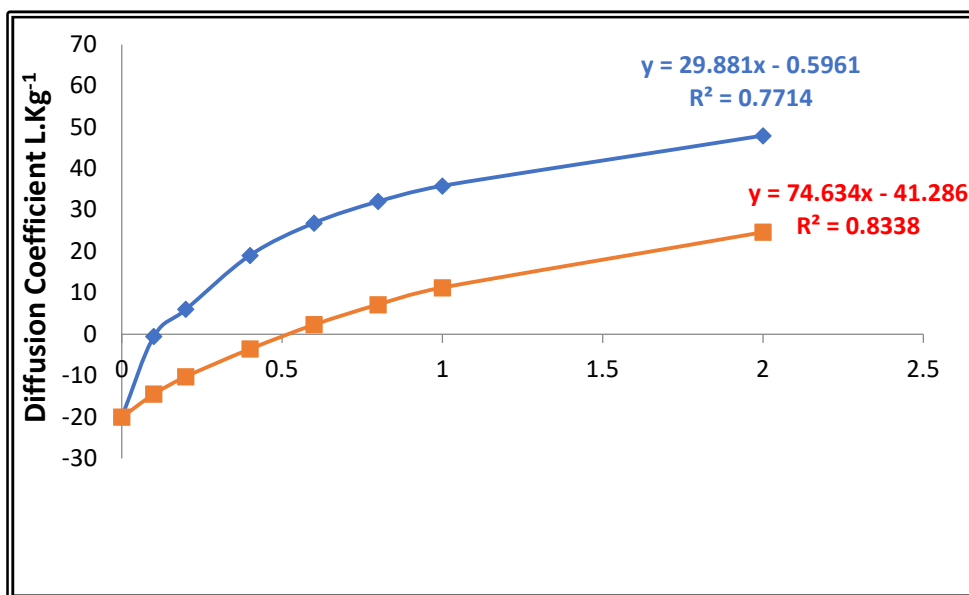


Figure 5 (a): Added potassium (mmol.L-1)

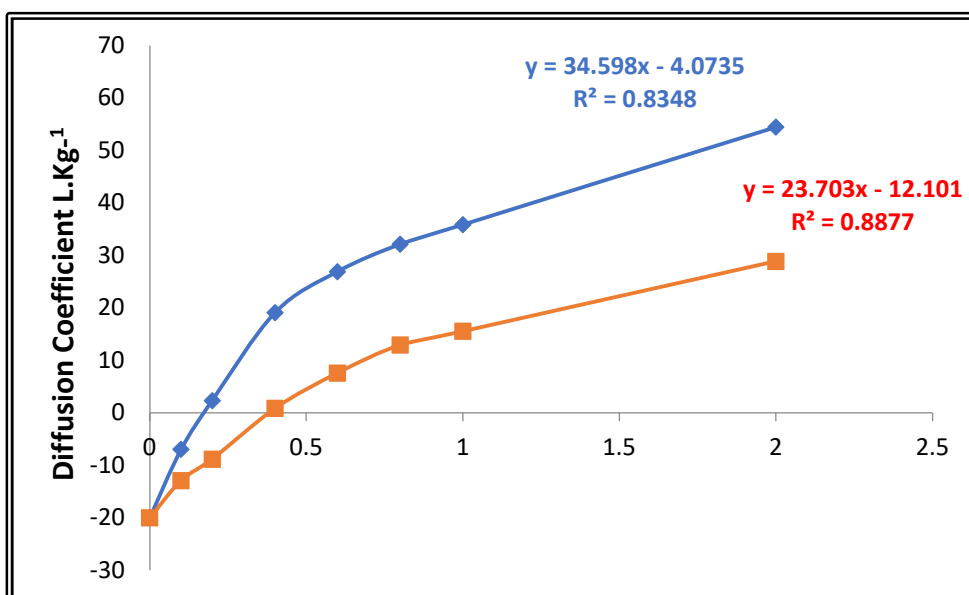


Figure 6 (2 - b) Added potassium (mmol.L-1).

Figure (2): The statistical relationship between the rate of diffusion coefficient and the initial concentration of potassium added to the two study burned and unburned soils.

The difference in the tendency of the element to bind to the soil components is attributed to the hydrolysis constant of the element (PKH), electronegativity, acidity, charge density and solubility (Ksp) of the sediment (Sparks, 2003). It is clear from the high values of Kd values the role of mineral and organic colloids in soils, especially crystallized and amorphous iron oxides and calcium carbonate, which may cause ion adsorption and stabilization within those colloids.

References

- Afif, E., Oliveira, P., (2006). Efectos del fuego prescrito sobre el matorral en las propiedades del suelo. *Investig. Agrar. Sist. Recur. For.* 15 (3), 262–270 .
- Akhzari, D., Mohammadi, E., and Saedi, K. (2022). Studying the effect of fire on some vegetation and soil properties in a semi-arid shrubland (Case study: Kachaleh Rangelands, Kamyaran Region). *ECOPERSIA*, 10(1), 27-35.
- Alcañiz, m. , L. Outeiro, M. Francos , and, X. Úbeda (2018) Effects of prescribed fires on soil properties: A review/ *Science of the Total Environment* 613–614 .
- Alloway, B. J. (2013). *Heavy Metals in Soils*. Third Edition ,Blackie Academic and Professional. London, Springer Science +Business Media Dordrecht.
- Al-Zubaidi, A.H., and H. Pagel, (1979). Content of different potassium forms in some Iraqi soils. *Second Sci. Con. Scientific Research Foundation*, Baghdad, Iraq.
- Bangroo, S. A., Kirmani, N. A., Bhat, M. A., Wani, J. A., Iqbal, A. M., Dar, Z. A., ... and Malik, A. A. (2021). Potassium isotherm partitioning based on modified quantity-intensity relation and potassium buffering characterization of soils of North India. *Journal of Plant Nutrition and Soil Science*, 184(1), 112-122.
- Bennet, L., Aponte, C., Baker, T., Tolhurst, K., (2014). Evaluating long-term effects of prescribed fire regimes on carbon stocks in a temperate eucalypt forest. *For. Ecol. Manag.* 328, 219–228.
- Bodi, M. B., Martin, D. A., Balfour, V. N., Santin, C., Doerr, S. H., Pereira, P., ... Mataix-Solera, J. (2014). Wildland fire ash: production, composition and eco-hydro- geomorphic effects. *Earth-Science Reviews*, 130, 103–127.
- Calvaruso, Ch., C. Christelle, K. Antoine, T. Marie-Pierre (2014). Seasonal Evolution of the Rhizosphere Effect on Major and Trace Elements in Soil Solutions of Norway Spruce (*Picea abies* Karst) and Beech (*Fagus sylvatica*) in an Acidic Forest Soil. *Journal of Soil Science*, 2014, 4, 323-336.
- Christophe C , Christelle C , Antoine K, Marie-Pierre T .(2014). Seasonal Evolution of the Rhizosphere Effect on Major and Trace Elements in Soil Solutions of Norway Spruce (*Picea abies* Karst) and Beech (*Fagus sylvatica*) in an Acidic Forest Soil. *Journal of Soil Science*, 2014, 4 , 323-336.
- Dada, AO., AP. Olalekan, AM. Olatunya, O. Dada (2012). Langmuir, Freundlich, Temkin and Dubinin – Radushkevich Isotherms studies of equilibrium sorption of zn unto phosphoric acid modified rice husk. *IOSR J. Appl. Chem. (IOSR-JAC)* 3(1) : 38 - 45.
- Das, B. and N.K. Mondal (2011). Calcareous Soil as a New adsorption to Remove Lead from aqueous Solution : Equilibrium Kinetic and Thermodynamic Study. *Universal Journal of Environmental Research and Technology*. Vol.1, Issue 4 : 515-530.
- Datta, S. C., and T. G. Sastry (1988). Determination of threshold levels for potassium release in three soils. *Journal of the Indian Society of Soil Science* 36:676–681.
- Fernandes, P., Matt Davies, G., Fernández, C., Moreira, F., Rigolot, E., Stoof, C., Vega, J.A., Molina,D., (2013). Prescribed burning in southern Europe: developing firemanagement in a dynamic landscape. *Front. Ecol. Environ.* 11, 4–14.
- Fernandez-Garcia, V., Miesel, J., Baeza, M. J., Marcos, E., and Calvo, L. (2019). Wildfire effects on soil properties in fire-prone pine ecosystems: Indicators of burn severity legacy over the medium term after fire. *Applied Soil Ecology*, 135, 147–156.
- Gao,S.;W.J.Walker;R.A.Dahlgren and J. Bold (1997). Simultaneous sorption of Cd, Cu, Ni, Zn, Pb and Cr on soils treated with sewage sludge supernatant. *Water Air Soil Pollut.*, 93: 331-345.
- Gee, G. W., and Or, D. (2002). 2.4 Particle-size analysis. *Methods of soil analysis*. Part, 4(598), 255-293.
- Granged, A.J.P., Jordán, A., Zavala, L.M., Muñoz-Rojas, M., Mataix-Solera, J., (2011). Short-term effects of experimental fire for a soil under eucalyptus forest (SE Australia). *Geoderma* 167–168, 125–134.

- Hueso-Gonzalez, P., Martinez-Murillo, J. F., and Ruiz-Sinoga, J. D. (2018). Prescribed fire impacts on soil properties, overland flow and sediment transport in a Mediterranean forest: A 5 year study. *Science of the Total Environment*, 636, 1480–1489.
- Inbar, A., Lado, M., Sternberg, M., Tenau, H., and Ben-Hur, M. (2014). Forest fire effects on soil chemical and physicochemical properties, infiltration, runoff, and erosion in a semiarid Mediterranean region. *Geoderma*, 221, 131–138.
- International Potash Institute (IPI) (2016). Potassium in plant production. Basel/Switzerland. 1- 44.
- Jalali, M., (2007). A study of the quantity/intensity relationships of potassium in some calcareous soils of Iran. *Arid Land Res. Manag.* 21, 133–141.
- James, J. A., Kern, C. C., and Miesel, J. R. (2018). Legacy effects of prescribed fire season and frequency on soil properties in a *Pinusresinosa* forest in northern Minnesota. *Forest ecology and management*, 415, 47–57.
- Joycyely, M.A., S. Freitas, A. M. Netto, M. M. Correa, B.T.L. Xavier, and F. X. DE Assis (2018). Potassium adsorption in soil cultivated with sugarcane. *Annals of the Brazilian Academy of Sciences*. Printed version ISSN 0001-3765.
- Kassa, M., Haile, W., and Kebede, F. (2019). Evaluation of adsorption isotherm models for potassium adsorption under different soil types in Wolaita of Southern Ethiopia. *Communications in soil science and plant analysis*, 50(4), 388–401.
- Komadel, P., Madejova, J., Hrobarikova, J., Janek, M., and Bujdak, J. (2003). Fixation of Li⁺ cations in montmorillonite upon heating. *Solid State Phenomena*, 90, 497–502.
- Li, J.-S.; P.Wang and L.Liu (2013). Environmental PredictionModel for dynamic release of Leadin contaminated soil under washingRemediation . *EJGE*.Vol. 18,pp.:55-70 .
- Lopes. A. R. , S.A. Prats, F. C. Silva, J.J. Keizer (2020). Effects of ploughing and mulching on soil and organic matter losses after a wildfire in central portugal *Cuadernos de Investigación Geográfica* 46 (1), 2020, pp. 303-318
- Martin , H.W. and D.L. Sparks (1983) . Kinetics of non exchangeable potassium release from two coastal plain soils. *Soil Sci. Soc. Am. J.* 47 : 883 - 887.
- Mataix-Solera, J., Cerdà, A., Arcenegui, V., Jordán, A., Zavala, L.M., (2011). Fire effects on soil aggregation: a review. *Earth Sci. Rev.* 109, 44–60.
- Morodome, S., and Kawamura, K. (2011). In situ X-ray diffraction study of the swelling of montmorillonite as affected by exchangeable cations and temperature. *Clays and Clay Minerals*, 59, 165–175.
- Nguyen BT, Phan BT, Nguyen TX, Nguyen VN, Tran TV, Bach QV (2020) Contrastive nutrient leaching from two differently textured paddy soils as influenced by biochar addition. *J Soils Sedim* 20:297–307.
- Pereira, P., Úbeda, X., Martin, D., Mataix-Solera, J., Cerdà, A., Burguet, M., (2014) . Wildfire effects on extractable elements in ash from a *Pinus pinaster* forest in Portugal. *Hydrol. Process.* 28, 3681–3690.
- Pierson, F.B., Robichaud, P.R., Moffet, C.A., Spaeth, K.E., Williams, C.J., Hardegree, S.P., Clark, P.E., (2008). Soil water repellency and infiltration in coarse-textured soils of burned and unburned sagebrush ecosystems. *Catena* 74 (2), 98–108.
- Rayment, G. E., and Lyons, D. J. (2011). *Soil chemical methods: Australasia (Vol.3)*. CSIRO publishing.
- Roberson, H. E., and Lahann, R. W. (1981). Smectite to illite conversion rates: effects of solution chemistry. *Clays and Clay Minerals*, 29, 129–135.
- Santín, C., Doerr, S.H., (2016). Fire effects on soils: the human dimension. *Phyl. Trans. R. Soc. B*.371, 20150171.

- Sarikaya, Y., Onal, M., Baran, B., and Alemdaroğlu, T. (2000). The effect of thermal treatment on some of the physicochemical properties of a bentonite. *Clays and Clay Minerals*, 48, 557–562.
- Shakesby, R.A., Doerr, S.H. (2006) . Wildfire as a hydrological and geomorphological agent. *Earth- Science Reviews* 74, 269-307.
- Sparks , D.L (2003). *Environmental Chemistry of Soils* .AcademicPres, Inc ., England .
- Sparks , D.L. , (2017) . *Methods of soil analysis . soil science society of america* . 5585 Guilfords Rd., Madison , WI 537 Vol . 2.
- Thomaz, E. L., Antoneli, V., and Doerr, S. H. (2014). Effects of fire on the physicochemical properties of soil in a slash-and-burn agriculture. *Catena*, 122, 209–215.
- Ulery, A. L., Graham, R. C., Goforth, B. R., and Hubbert, K. R. (2017). Fire effects on cation exchange capacity of California forest and woodland soils. *Geoderma*, 286, 125–130.