Journal of Sustainability Science and Management
Volume 18 Number 8, August 2023: 74-86
eISSN: 2672-7226

PHYSICOCHEMICAL PROPERTIES OF A SALT LICK AT SUNGAI BETIS FOREST RESERVE, KELANTAN, MALAYSIA

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Submitted final draft: 31 March 2023 *Accepted: 15 May 2023* http://doi.org/10.46754/jssm.2023.08.005

Abstract: Salt licks, locally known as '*jenut*', are areas with accumulated minerals such as sodium (Na), magnesium (Mg), potassium (K) and calcium (Ca). The characterisation of physicochemical properties is crucial to be done as it links to the wildlife ecosystem and needs to be protected from destruction. The objectives of this study are to characterise the physicochemical properties of soils from natural mineral salt licks at Sg. Betis Forest Reserve, Gua Musang, Kelantan and to study the relationship between soil physicochemical properties and its elevation as well as to determine the correlation between measured soil physicochemical properties. The overall finding shows that the soil is sandy loam with acidic pH (4.39 - 6.52). It has high Organic Matter % (> 80) and Gravimetric Water Content % (104.43). The minerals concentration is high (Na = 2506.67 mg/L, Mg = 29.085 mg/L, K = 63.43 mg/L, and Ca = 21.54 mg/L). There is no significant difference between each subplot except for Water Filled Pore Space % with P value = 0.039. The result indicates that the salt lick area at Sg. Betis Forest Reserve have a high mineral concentration as the other previous salt lick studies where areas like this need to be managed sustainably for wildlife conservation.

Keywords: Salt licks, physicochemical properties, sustainable management, wildlife conservation.
Abbreviations: Na, Mg, K, Ca.

Introduction

Salt lick, locally known as *jenut* is referred to as an area that has been accumulated by high amounts of minerals such as sodium (Na), magnesium (Mg), calcium (Ca), and potassium (K). In the wildlife ecosystem, salt lick is a dynamic key to the wildlife communities where animals exhibit geophagical behaviour to supplement their diet with minerals (Molina *et al*., 2013). The soil is being actively ingested by wildlife such as birds, insects and especially ungulate species like deer, gaur and tapir (Simpson *et al*., 2020). This behaviour is a common practice and has been associated with herbivores since they do not manage to obtain minerals sufficiently from plants. This is because in tropical rainforests, the soils are known to have depleted major cations, thus plants in this ecosystem have intrinsically low sodium content compared to the plants in temperate ecosystems (Matsubayashi *et al*., 2006).

In the tropical ecosystem, herbivores and frugivores visit the salt licks more often than carnivores and it is expected that their preference is mineral licks with richer sodium concentration (Matsubayashi *et al*., 2006). The pattern of salt licking has always been studied by camera traps and this behaviour varies depending on many reasons such as diet, reproductive status, season, geographical features of area, and environment (King *et al*., 2016). According to Ayotte *et al*. (2006), each salt lick has a different chemical composition and has multiple benefits for different species and sexes at different times in that year. For instance, more female white-tailed deer (*Odocoileus virginianus*) went to licks with richer magnesium, calcium and phosphorus during the late gestation and early lactation. Apart from benefitting the animals for reproductive system, these minerals also soothe gastrointestinal issues by neutralising gastric acidity, buffering the dietary effect toxins, and acting as an agent for antidiarrheal (King *et al*., 2016). Considering the importance of mineral licks in the wildlife communities, it has been gazetted to be a buffer protection zone where hunting is illegal within 500 m of the area (Siong *et al*., 2020).

Generally, there are two types of salt licks which are wet and dry licks. Wet licks are reservoirs that are associated with groundwater springs meanwhile dry licks usually can be found along streams or riverbeds where erosion has exposed the impervious layers of concentrated soluble elements (Ayotte *et al*., 2006; Razali *et al*., 2020; Siong *et al*., 2020). Rainforest salt lick is one of the examples to portray the dry lick's characteristics as it is usually located near the river banks. For example, in Ulu Muda Forest Reserve, more than 12 salt licks along the stretch of Sungai Muda to Kuala Labua base camp are to be recorded (Chew *et al*., 2014).

Salt lick sources can be natural, artificial and there is even commercialised one. Natural licks are formed by the weathering of rock forming minerals into mineral soil fraction. The concentration of common minerals like Na, Mg, K, and Ca are depends on the weathering rate and leaching rate of the weathered resulting products (Jakovljeviã *et al*., 2003). As for artificial salt licks area, it has been developed in some areas of the wild ecosystem to enhance the supplementation of these minerals for the animal's dietary needs. The Department of Wildlife and National Park (DWNP) has established more than 30 artificial licks in Peninsular Malaysia to support these minerals enhancing efforts. In developing the salt licks area, an appropriate and strategic location has been chosen in the forest and several shallow pits will be dug. These pits typically will be 2-3 m long, 1.5-2 m wide and 30-50 cm deep. However, the size and depth will vary depending on the erosion rate (Simpson *et al*., 2020). As for artificial commercialised salt licks, it is the concentrated minerals that have been compacted into a block form. This mineral salt block has been commercialised widely in husbandry industries as farmers need these minerals to supplement the dietary needs of the livestock such as cattle, and swine (Lameed & Adetol, 2012).

The effort of establishing the artificial salt lick is great to help the minerals supplementation for the wildlife. However, the natural licks have become a concern as these areas are facing the threat of destruction by the increasing rate of deforestation in recent years. According to the International Timber Organization (ITTO), the deforestation is estimated to rise by 12.9 million ha per year (Wan Mohd Jaafar *et al*., 2020) and in Malaysia itself, it is recorded that the deforestation rate from the year of 1990-2005 is up to 77% (Aisyah *et al*., 2015). To protect the wildlife, it is important to understand the mineral lick's characteristics and identify the essential minerals supplementing wildlife's diet.

Hence the objectives of the study are: (1) to characterise the overall physicochemical properties of soils; (2) to study the difference of soil physicochemical properties at different elevation and (3) to determine the correlation between essential minerals and soil physicochemical properties in the natural mineral salt licks at Sg. Betis Forest Reserve, Gua Musang, Kelantan.

Materials and Methods

Study Area

The study area is located at Sungai Betis Forest Reserve, Gua Musang Kelantan at 4.7487 Lat 101.634919 Lon (Figure 1). The sampling site is located near a creek of the Sungai Betis river basin. This location is susceptible to continuous urbanisation process. This forest reserve is located within a patch of fragmented forest and surrounded by developing road networks, oil palm plantation and within the proximity of

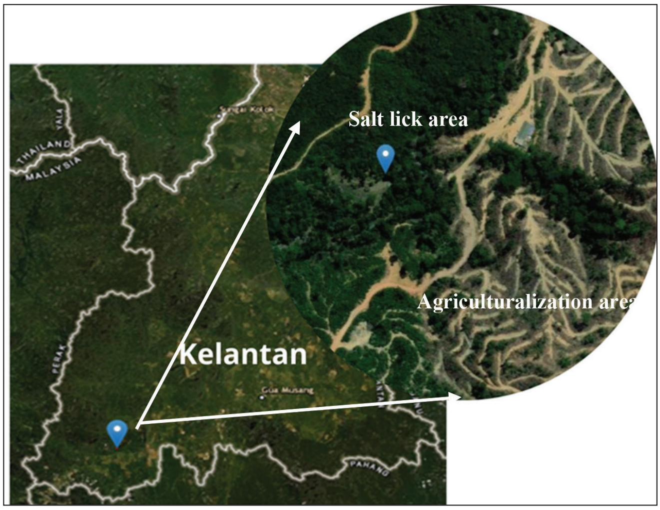

Figure 1: Map of Kelantan and location of study which is in Sungai Betis Forest Reserve (USGS EarthExplorer)

durian plantation. This place is an open semi bare land with low vegetative cover (i.e mostly Pteridophyte phyla) and a pool of muddy soil in the pan resulting from elephant trampling and wallowing. Surrounding the muddy soil pool, evidence of wildlife pounding was observed on the soil and most likely caused by elephant digging and licking behaviour. During site observation, suspended element and a rotten egg smell was discovered in the air near pond at lower section area. Not just that, there was elephant dung accumulation observed within the sampling sites.

Experimental Design

Three subplots were established within a 20 m width x 40 m height plot along 50 meters transect representing the lower, middle and upper section of the plot according to their elevation. Then, eleven sampling points were established, constituting four points within upper section, three points within the middle section and four points within the lower section (Table 1). The sampling points were randomly decided with consistent scattering pattern. The random sampling done was stratified by grouping the sampling points to the same shared characteristics because this type of sampling is more accurate and unbiased (Braidek *et al*., 2006). The coordinate of each point was taken, and the GPS waypoint was generated.

Soil Sampling

The soils were sampled in two replicates (11 samples x 2) following the composite sampling approach using hammered core ring. Soil core rings with 2.5 cm radius and 15 cm length were hammered on surface soils at range of 2.9 to 9 cm depth until the rings hit the impermeable rocky topsoil layer. Sampled soils were put into labeled zipper bags meanwhile soil slurry from the stagnant pond's surface was sampled using a 500 ml polyethylene bottle. All the samples were stored temporarily in an icebox during the transportation before being stored in the chiller (4^{o}C) in the laboratory.

Field Measurement

Four parameters were measured at the sites which are soil temperature, air temperature, air humidity, and lux measurement. Soil temperature parameter is important to be measured as it plays a role in all physical, hydrological, and biogeochemical processes in the soil (He *et al*., 2018). To measure the soil temperature, a Hanna soil temperature probe (Hanna Instrument,

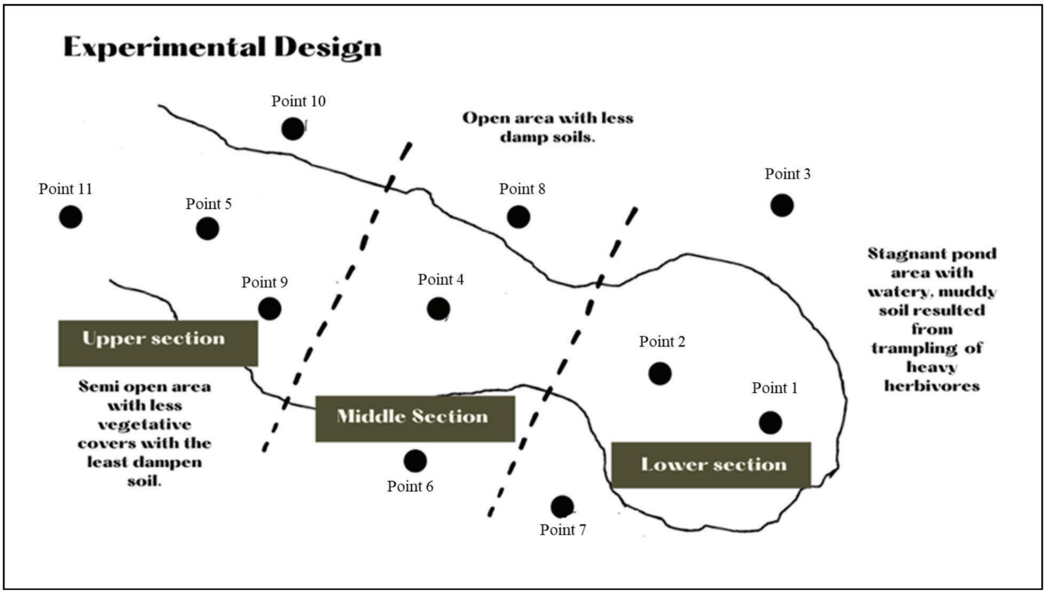

Figure 2: Sketch of transect plot sketch with sampling points

Table 1: General observation and sampling points coordinate of three subplots

Subplot Sections	Sampling Points	Latitude	Longitude	General Observation
Upper	Point 1 Point 2 Point 3	4.7487	101.634919	Stagnant pond area with watery, muddy soil resulted from trampling's of heavy herbivores.
	Point 7	4.748856	101.63497	
Middle	Point 4	4.74854	101.634889	Open area with less damp soils.
	Point 6	4.748517	101.634908	
	Point 8	4.748588	101.634917	
Lower	Point 5	4.748441	101.63495	Semi open area with less vegetative covers with the least dampen soil.
	Point 9	4.748452	101.634926	
	Point 10	748486	101.634834	
	Point 11	4.748367	101.634882	

Inc., USA) has been used. It has been planted into the soil and the reading was taken. The measurements for air temperature and air humidity were done using the digital OEM (China) Thermometer and Hygrometer.

The range and average readings of these parameters were recorded. These physical parameters were recorded as they do affect the other parameters such as soil moisture as it will alter the terrestrial water cycle (Feng & Liu, 2015). The light intensity was recorded to observe the openness of the sampling site, represented by the lux reading using a UNI-T lux meter [UNI-TREND TECHNOLOGY (CHINA) CO., LTD]. Higher lux readings indicate higher light intensity, and it is associated with the openness and vegetative cover at the sampling site. The light intensity is also having a close relation to soil temperature and moisture as bare soil can absorb heat quickly in a hot season and become cold easily in cold season (Onwuka, 2018).

Soil Analysis

Gravimetric Water Content (GWC)

Reaching the laboratory, the samples were transferred into aluminium foils and their fresh weight was taken by using three and two decimal weighing scales. The samples then were oven dried overnight at 105°C and the weight of the oven dried soils was taken again. To maintain the sample's condition, the dry samples were put into the desiccator to avoid any moisture absorption from the air. According to Bilkkie (2001), the soil gravimetric water content (GWC) percentage was calculated by using this formula:

$$\text{Gravimetric water content, GWC (\%)} = \frac{100 \times \text{wet mass-oven dried mass(g)}}{\text{oven dried mass (g)}} \quad (1)$$

Bulk Density (BD), Porosity (Ps) and Water-filled Pore Space (WFPS)

After that, bulk density of the soil was estimated by using this formula:

$$\text{Bulk density, BD (g/cm3)} = \frac{\text{Mass of oven dried soil (g)}}{\text{Volume of soil in cylinder ring (cm3)}} \quad (2)$$

The cylinder ring used was 15 cm height with radius 2.5 cm. By calculating bulk density (BD) both porosity (Ps) and water filled pore space (WFPS) can be estimated. As for porosity, the formula used was:

$$\text{Soil porosity, Ps} = \frac{\text{1- BD (g/cm3)}}{\text{PD (g/cm3)}} \quad (3)$$

PD = 2.65 g/cm^3

From that, WFPS was calculated by formula:

$$\text{WFPS\%} = \frac{\text{volumetric water content(g/cm3)}}{\text{soil porosity}} \quad (4)$$

Soil Texture

After that, the samples were ground and sieved by using 1 mm sieve. Then, the soil texture was determined by using hydrometer test (Abella & Zimmer, 2007). Then, 100 ml of 5% sodium hexametaphosphate, $Na_6(PO_3)_6$ (dispersing solution) and 880 ml deionized water were mixed in 1000 ml measuring cylinder to make a blank solution.

For sample solution, approximately 30 g of sieved soil samples were weighed and transferred into dispersing cup and 100 ml of 5% percent of $Na_6(PO_3)_6$ was added. The samples were mixed and been transferred into 1000 ml measuring cylinder and deionized water was added until the calibration mark. At the very beginning of each set, the initial temperature and hydrometer reading were taken including for blank.

As for sample sets, the solution will be mixed again by using plunger and after 40 second, the readings were taken. After 6 hours and 52 minutes, the readings were taken again. The reading of the hydrometer was corrected according to the temperature. 0.2 unit was added for temperature above 67°F (19.4°C) and the 0.2 unit was subtracted for temperature below 67°F (19.4°C). The percentage of soil texture was determined by the percentage of sand, silt, and clay (Hristov, 2013). The percentage was calculated by using this formula:

$$\% \text{ clay} = \frac{100 \text{ x corrected hydrometer reading after 6 hours 52 minutes}}{\text{weight of sample}} \quad (5)$$

$$\% \text{ silt} = \frac{100 \text{ x (corrected hydrometer reading after 40 seconds - \% clay)}}{\text{weight of sample}} \quad (6)$$

$$\% \text{ sand} = 100 - \% \text{ silt} - \% \text{ clay} \quad (7)$$

After that, the type of soil can be determined by using USDA textural triangle.

pH

For pH, it has been measured by using a pH meter (Abebe & Deressa, 2017). The same method was used by Liu *et al*. (2010) where 10 g of dried and sieved samples were added into falcon tubes and 20 ml of distilled water was added. These mixtures with 1:2 ratios were mixed well and left for 1 hour. After that, by using calibrated Hanna pH probe (Hanna Instrument, Inc., USA), the pH readings were taken.

Organic Matter (OM)

To estimate Organic Matter (OM)%, the Loss of Ignition method (LOI) was used. A total of 3 g dried and desiccated soil samples were weighed in the crucible and combusted at 550°C in a muffle furnace for 2 hours. After that, the combusted soils were cooled again in a desiccator and weighed for the second time. Salehi *et al.* (2011) estimate Soil Organic Matter (SOM)% by the equation:

$$\text{SOMLOI} = 100 \text{ x } [(\text{soil weight after combustion} - \text{oven-dry soil weight})/\text{oven-dry soil weight}] \quad (8)$$

Mineral Na, Mg, K and Ca

As for Na, Mg, K and Ca concentration determination, Atomic Absorption Spectrophotometry (AAS) was used. In sample preparation, extracting solution (0.05N hydrochloric acid, HCl + 0.025N sulphuric acid, H_2SO_4) is the important material needed. The solution was prepared where 37% (12M) of HCl and 98% (18.4M) of H_2SO_4 have been diluted with distilled water to 1500 ml solution. As the extracting solution has been prepared, the 5 g of soil samples were put into Erlenmeyer flask and 20 ml of extracting solution was added.

The flasks were shaken by a mechanical shaker for 15 minutes and the samples were then filtered with filter paper followed by 0.45 µm of the sample transferred by syringe into a 50 ml flask and the extracting solution was added up to the 50 ml calibration mark to make a stock solution. From that, 15 ml stock solution was transferred into a 15 ml falcon tube and diluted to 10^{-1}, 10^{-2},10^{-3}, and 10^{-4}. To run the AAS, the instrument will be calibrated by running the blank (distilled water), standard solutions 1, 2, and 3. These readings of four solutions formed a calibration curve. Then, all 11 samples were analysed using dilution 10^{-1}. The reading was switched to another dilution solution when the reading exceeded the calibration mark.

Statistical Analysis

All data was analysed statistically using Minitab 19.1 version software (Minitab Inc, United States). Descriptive statistics such as mean, standard error, standard deviation, maximum value, minimum value as well as the value range were used in achieving the objective (1) which is to characterise the overall soil physicochemical properties for the plot and subplot sections.

As for objective (2), the effect of elevation on soil physicochemical properties were tested using one-way analysis of variance (ANOVA). A normality test was performed on all data prior to further statistical analysis. In performing the normality test, Ryan Jonner test that equivalent to the Shapiro Wilk test has been used as it suits the nearest sample size (n) sensitivity. Shapiro Wilk test is sensitive for sample size, $n < 40$ (Ahad *et al*., 2011). The datasets following a non-normal distribution was transformed using Johnson Transformation in quality tools to meet the assumption of normal distribution. These transformation tools have been used as it works well for many natures of data, and the values do not require to be strictly in positive value. Not just that, the transformation by Johnson can make the distribution more symmetric. After all the data followed by the normal distribution, only then the one-way ANOVA test was run using Tukey Pairwise Comparison at 95% Confidence Levels.

Lastly, for objective (3), the relationship between measured soil physicochemical properties were tested using Pairwise Pearson correlation. The mean value and standard error were presented at 0.05 significance level to determine significant differences and correlation**.**

Results and Discussion

Overall Soil Physicochemical Properties of Mineral Salt Licks

At the time of our visit, the air humidity, air temperature, and light intensity at the study area were 58%, 34.7°C and 102384 lux respectively (Table 2).

The soil is classified as sandy loam soil which constitutes of 63.61% sand, 11.39% silt and 25.0% clays with 0.71 g/cm^3 bulk density and 0.73 g/cm^3 porosity which indicates that the soil is highly porous (Table 3). The average soil temperature was 31.3°C and saturated with water (i.e., 104.43% GWC, 110.95% WFPS).

From this study, the soil was acidic with the pH range between 4.39 to 6.52. Previous studies have reported that soils from mineral salt licks are usually basic (Matsubayashi *et al*., 2006; Molina *et al*., 2013). The basic reading is due to the higher concentration of Na. However, although the Na concentration for this study is very high, all pH readings for the samples give the value below 7 which indicates a higher concentration of H^+ ions. Higher concentrations of sulfur and higher microbial activities may lead to these results. According to Panahi *et al*. (2016), sulfur oxidising bacteria such as *Thiobacillus* may convert elemental sulfur to sulfuric acid which can cause soil pH to be more acidic. Additionally, our observation at the study area also suggests the presence of suplhur element suspended in the air which produce a rotten egg odor. Beside the sulphur, the other possibility of acidic soil may be due to hydrolysis where the pH of the Kelantan's River sediments has been lowered after the great flood in December 2014 (Shamshuddin *et al*., 2016).

The soil organic matter OM% content is depicted as high (Table 3), exceeding 80% as compared to previous studies. For example, Elyau *et al*. (2012) reported that the OM% from natural salt lick soils in Lake Mburo National Park, Uganda ranged between 0.6% to 3.87%, despite of having similar soil texture as this study. This contrasting finding may be caused by two reasons: (1) Accumulation of elephant

Table 2: The overall value of air humidity, air temperature, light intensity, and elevation at different sections of the salt licks in Sg. Betis Forest Reserve

	Sub section Plot			
Soil Properties (units)	**Down Section**	**Middle Section**	**Upper Section**	**Average Total**
Air humidity (%)**	-	-	-	58
Air temperature (°C)**	-	-	-	34.7
Light intensity (lux)**	116137	104761	86255	102384
Elevation (m), above sea level	265.30	268.83	274.16	269.43

**Single values were recorded from portable data logger.

Table 3: The overall mean total and mean value of physicochemical properties s at different sections of the salt licks in Sg. Betis Forest Reserve

	Sub Section Plot			
Soil Properties	**Down Section**	**Middle Section**	**Upper Section**	**Average Total**
Texture				
Sand%	48.7(19.3)$_A$	68.43(7.12)$_A$	73.70(3.54)$_A$	63.6
Silt%	15.93(4.65)$_A$	10.57(5.06)$_A$	7.67(2.51)$_A$	11.4
Clay%	35.4(15.0)$_A$	21.00(2.10)$_A$	18.63(1.28)$_A$	25.0
USDA Classification	Sandy clay	Sandy clay loam	Sandy loam	Sandy loam
Bulk density (g/cm^3)	0.70(0.07)$_A$	0.70(0.05)$_A$	0.78(0.14)$_A$	0.7
Porosity (g/cm^3)	0.75(0.03)$_A$	0.74(0.02)$_A$	0.71(0.05)$_A$	0.7
Temperature (^{o}C)	31.14(2.09)$_A$	30.83(2.63)$_A$	31.94(2.02)$_A$	31.3
Gravimetric water content (%)	143.8(43.1)$_A$	91.5(12.6)$_A$	78.0(15.9)$_A$	104.4
WFPS (%)*	167.2(39.0)$_A$	87.06(9.56)$_{AB}$	78.6(13.6)$_B$	111.0
pH, 1:2	5.43$_A$	4.67$_A$	4.73$_A$	4.9
pH, 1:5	5.60$_A$	4.90$_A$	4.96$_A$	5.2
Organic matter (%)	82.35$_A$	86.48$_A$	87.67$_A$	85.5
Na (mg/L)	2872)$_A$	$_A$	1075(331)$_A$	2506.7
Mg (mg/L)	$_A$	19.75$_A$	14.92$_A$	29.1
K (mg/L)	117.5(71.7)$_A$	33.6$_A$	39.2$_A$	63.4
Ca (mg/L)	15.37$_A$	25.66$_A$	23.59$_A$	21.5

Means with different alphabets (A and B) are significantly different ($P < 0.05$*) between the location of subplots using one-way ANOVA at 95% confidence interval. Values in parentheses are standard error of mean (S.E.M)

dung in the stagnant pool in the studied site at Sg. Betis or (2) methodological difference when analysing OM%. Elyau *et al*. (2012) used the Walkley Black method to estimate the OM% while LOI method was used in this study. According to Wood (2015), LOI method can be overestimating or underestimating the organic carbon depending on the overlapping combustion and dewatering temperatures. In addition, soil samples were sieved through a < 1 mm sieve instead of the commonly used < 2 mm sieve in this study. This would likely increase the total surface area for combustion of organic matter.

As for mineral's concentration, the soil Na, Mg, K and Ca concentrations are 2506.67, 29.085, 63.43 and 21.54 mg/L, respectively (Table 3). This is common for mineral salt licks since these minerals are common to supplement the wildlife dietary needs. However, in this study, the concentration of Na is much higher compared to the concentration of Mg, K and Ca. This was most probably due to the prevalence of Na^+ to be the dominant cations in licks (Holdo *et al*., 2002). So, these minerals (Mg, Ca, and K) might have been replaced by Na cations since all four are base cations (Peterson *et al*., 2015).

Soil Physicochemical Properties within Site Variation

The soil physicochemical properties were mostly similar at different heights across the site profile, except for WFPS% (*P value = 0.039*) (Figure 3). The soil WFPS% for the lower section subplot is the highest which is 167.2 as compared to the middle and upper sections with 87.06 and 78.6 respectively. WFPS% of the down part is significantly different with the upper part ($P < 0.05$, using one-way ANOVA and Tukey's b comparison). This is because down section's elevation is the lowest (265.30 m) and the water from the highest elevation in the upper part (274.16 m) is moving as seepage drains into the down part.

In addition, the lower part is where large herbivores wallow and trample, and in doing so they form a drainage basin. Thus, seepage from the upper part is accumulated at the lower part and forms a stagnant pond. In addition, higher soil WFPS% was also related to soil texture. Soils from the lower section is sandy clay as compared to the sandy loam soils from the upper section. Clay has the smallest particle size (< 0.002 mm) as compared to silt (0.002 - 0.05 mm) and sand (0.05 - 2 mm) (Abd-Elmabod *et al*., 2017). Soils with finer texture such as clay has higher porosity, thus increasing the water filled pore space and water holding capacity. Bilkkie (2001) pointed out that more finely textured soil has a broader distribution of pore size and larger particle surface area. Greater surface area means that more water can be adsorbed through electrostatic forces. Thus, a larger change in water potential is needed in removing the same amount of water.

Correlation Between Soil Physicochemical Properties

The concentration of soil minerals was significantly correlated with OM%, H^+ concentration, bulk density and gravimetric water content but the strength and direction varied between type of minerals (Table 4). The concentration of K and Mg are strongly correlated with OM%, GWC% and bulk density. Both K and Mg are positively correlated with GWC% and negatively correlated with bulk density. According to Siczek *et al*. (2008), cations are more available in water saturated soils than structured soils. Similarly, lower section with water saturated soil has high concentration of Mg and K as the section has high GWC% and WFPS%. Thus, the concentration of the soil minerals is related to the water content and bulk density.

As for the correlation between K and OM%, these two variables showed a strong negative correlation with $r = -0.859$. According to Wang and Huang (2001), organic matter is the most important contributor of Cation Exchange Capacity (CEC) in soil. This study suggested that OM% can increase the adsorption rate of K by soils.

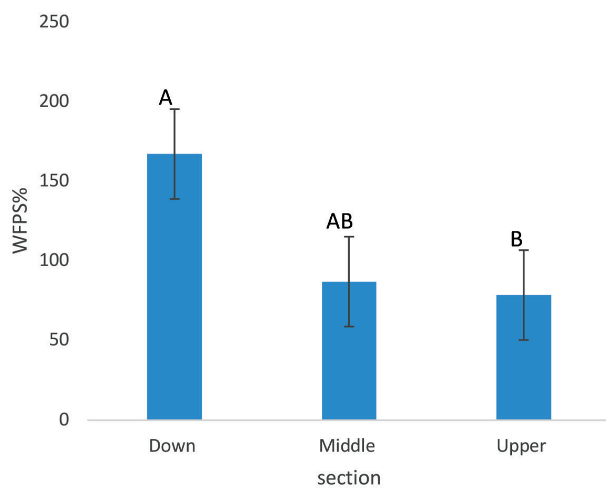

Figure 3: The histogram graph of WFPS% means across the section plot at mineral salt lick in Sg. Betis Forest Reserve, Gua Musang, Kelantan. Different alphabets (A and B) indicates significantly different ($P < 0.05$) between the location of subplots using one-way ANOVA at 95% confidence interval

Table 4: Shows a significant correlation between soil physicochemical properties in mineral salt licks at Sg. Betis Forest Reserve

	Ca	Na	K	Mg	Bulk Density
Ca		0.047	-0.086	0.317	-0.07
Na			-0.501	-0.514	0.363
K				0.823	-0.906
Mg	0.317				-0.841
GWC	0.284	-0.536	0.789	0.818	-0.686
OM%	0.302	0.500	-0.859	-0.782	0.649
H^+ concentration	-0.287	0.430	-0.389	-0.322	0.457

significant Pearson correlation, *r* at 95% confidence level

Comparison Between Soil Na, Mg, K, Ca Concentration with Other Studies

In Table 5, the range of mineral concentrations of soils in Sg. Betis Forest Reserve is compared with some previous studies in the Amazon Basin, South America and Sabah and Sarawak, Malaysia. These study locations are all located in tropical rain forest.

The range of Na concentrations was higher, but the Mg, Ca and K concentrations were lower in this study as compared to other studies by Molina *et al*. (2013), Matsubayashi and Lagan (2014), and Siong *et al*. (2020). High concentration of Na from this study site might be due to the accumulation of elephant dung that was observed. In Holdo *et al*. (2002), elephant dung was also related to high sodium concentrations ranging from 60 to 3850 mg/kg. The accumulation of elephant dung in salt licks may therefore affect Na concentrations where elephants are major users of the sites.

Conclusion

The objectives outline for this study have been accomplished. Firstly, the soil physicochemical properties of mineral salt licks at the studied site in Sg. Betis Forest Reserve have been characterised. The salt lick is categorised as loose sandy loam topsoil (63.61% sand, 11.39 silt and 25% clay) with acidic pH (4.94), and highly porous. The salt lick also has high GWC% (104.43), OM% (88.5), and mineral salts 2506.67 (Na), 29.085 (Mg), 63.43 (K) and 21.54 (Ca) mg/L. There is also a significant difference in WFPS% ($P < 0.05$) between subplots in different parts of the site because

Table 5: Comparison of mineral content between the present study and some previous studies at salt licks in tropical rain forest

Soil Parameters Concentration mg/kg	This study: Sg. Betis Forest Reserve, Kelantan, Malaysia	[a]Deramakot Forest Reserve, Sabah, Malaysia	[b]Amazon Basin, South America	[c]Sarawak, Malaysia
Na	625 - 49160	200 - 600	29 - 1361	nd - 136
Mg	16.4 - 208	1200 - 8600	93 - 978	450 - 3627
K	47.2 - 1308.4	1300 - 10060	101 - 3823	454 - 1834
Ca	21.16 - 166	700 - 4400	92 - 4240	nd - 1017

nd: Not detected

[a]Matsubayashi and Lagan (2014); [b]Molina *et al*. (2013); [c]Siong *et al*. (2020)

of the soil texture and the terrain. Finally, significant correlations were flagged between the concentration of soil minerals (i.e., Na, K, Mg, Ca) with bulk density, GWC%, OM% and pH. OM% correlates with K concentration as it plays a role in K adsorption in the soil while GWC% and bulk density determine the availability of cations in the soil. Porosity and bulk density have the strongest negative correlation (r = -1.00) while potassium, K concentration and porosity has the strongest positive correlation (r = 0.906). This is due to direct linear relationship between the soil porosity and bulk density since bulk density value is needed in porosity calculation. To conclude, the studied salt lick has the same theoretical physicochemical characteristics as in previous studies (Molina *et al*., 2013; Matsubayashi & Lagan, 2014; Siong *et al*., 2020) except for pH. However, the mean values vary as each salt lick's natural ecosystem is not the same.

Acknowledgements

The authors thank to the Department of Wildlife and National Parks (DWNP) for providing the research permit. Not to forget the Faculty of Earth Science, Universiti Malaysia Kelantan for the support in terms of materials and apparatus to conduct this study.

References

Abd-Elmabod, S. K., Jordán, A., Fleskens, L., Phillips, J. D., Muñoz-Rojas, M., van der Ploeg, M., Anaya-Romero, M., El-Ashry, S., & de la Rosa, D. (2017). Modeling agricultural suitability along soil transects under current conditions and improved scenario of soil factors. *Soil Mapping and Process Modeling for Sustainable Land Use Management*, 193–219. https://doi.org/10.1016/b978-0-12-805200-6.00007-4

Abebe, Z., & Deressa, H. (2017). The effect of organic and inorganic fertilizers on the yield of two contrasting soybean varieties and residual nutrient effects on a subsequent finger millet crop. *Agronomy*, *7*(2), 42. https://doi.org/10.3390/agronomy7020042

Abella, S. R., & Zimmer, B. W. (2007). Estimating organic carbon from loss-on-ignition in Northern Arizona Forest Soils. *Soil Science Society of America Journal*, *71*(2), 545–550. https://doi.org/10.2136/sssaj2006.0136

Aisyah, A. S., Shahrul, A., Zulfahmie, M. Z., Mastura, S., & Mokhtar, J. J. (2015). Deforestation analysis in Selangor, Malaysia between 1989 and 2011. *Journal of Tropical Forest Science, 27,* 3-12.

Ayotte, J. B., Parker, K. L., Arocena, J. M., & Gillingham, M. P. (2006). Chemical composition of lick soils: Functions of soil ingestion by four ungulate species. *Journal of Mammalogy*, *87*(5), 878–888. https://doi.org/10.1644/06-mamm-a-055r1.1

Bilkkie, J. (2001). *Soil water status: Content and potential*. Campbell Scientific, Inc. https://s.campbellsci.com/documents/fr/technical-papers/soilh20c.pdf

Braidek, J. Pennock, T., & Yates, T. (2006). Chapter 1: Soil sampling design. In M. R. Carter, & E. G. Gregorich (Eds.) *Soil sampling and methods of analysis* (2nd ed.). CRC Press Taylor & Francis Group.

Chew, M. Y., Hymeir, K., & Shahfiz, M. A. (2014). Relation between grasses and large herbivores at the Ulu Muda Salt Licks, Peninsular Malaysia. *Journal of Tropical Forest Science, 26*(4), 554-559.

Elyau, A., Siefer, L., & Ocaido, M. (2012). Physical and chemical characteristics of animal natural salt lick soils in Lake Mburo National Park, Uganda. *Africa Journal of Animal and Biomedical Sciences, 7*(2), 60–72.

Feng, H., & Liu, Y. (2015). Combined effects of precipitation and air temperature on soil moisture in different land covers in a humid basin. *Journal of Hydrology*, *531*, 1129–1140. https://doi.org/10.1016/j.jhydrol.2015.11.016

He, H., Dyck, M. F., Horton, R., Li, M., Jin, H., & Si, B. (2018). Distributed temperature sensing for soil physical measurements and its similarity to heat pulse method. *Advances in Agronomy*, 173–230. https://doi.org/10.1016/bs.agron.2017.11.003

Holdo, R. M., Dudley, J. P., & McDowell L. R. (2002). Geophagy in the African elephant in relation to availability of dietary sodium. *Journal of Mammalogy, 83*(3), 652–664.

Hristov, B. (2013). The importance of soil texture in soil classification system. *Journal of Balkan Ecology, 6*(2), 137-139.

Jakovljeviã, M. D., Kostiã, N. M., & Antiã-Mladenoviã, S. B. (2003). The availability of base elements (*Ca, Mg, Na, K*) in some important soil types in Serbia. *Proceedings for Natural Sciences, Matica Srpska Novi Sad, 104*, 11-21.

King, A., Behie, A. M., Hon, N., & Rawson, B. M. (2016). Patterns of salt lick use by mammals and birds in northeastern Cambodia. *Cambodian Journal of Natural History, 2016*(1), 40-50.

Lameed, G., A., & Adetol, J.-O. (2012). Species-diversity utilization of salt lick sites at Borgu Sector of Kainji Lake National Park, Nigeria. In Lameed, G. A. (Ed.). *Biodiversity Enrichment in a Diverse World*. InTech. https://doi.org/10.5772/51089

Liu, E., Yan, C., Mei, X., He, W., Bing, S. H., Ding, L., Liu, Q., Liu, S., & Fan, T. (2010). Long-term effect of chemical fertilizer, straw, and manure on soil chemical and biological properties in northwest China. *Geoderma*, *158*(3-4), 173–180. https://doi.org/10.1016/j.geoderma.2010.04.029

Matsubayashi, H., & Lagan, P. (2014). *Natural salt licks and mammals in Deramakot: Their importance and why they should be conserved*. Sabah Forestry Department.

Matsubayashi, H., Lagan, P., Majalap, N., Tangah, J., Sukor, J. R., & Kitayama, K. (2006). Importance of natural licks for the mammals in Bornean inland tropical rain forests. *Ecological Research*, *22*(5), 742–748. https://doi.org/10.1007/s11284-006-0313-4

Molina, E., León, T. E., & Armenteras, D. (2013). Characteristics of natural salt licks located in the Colombian Amazon foothills. *Environmental Geochemistry and Health*, *36*(1), 117–129. https://doi.org/10.1007/s10653-013-9523-1

Onwuka, B. (2018). Effects of soil temperature on some soil properties and plant growth. *Advances in Plants & Agriculture Research*, *8*(1). https://doi.org/10.15406/apar.2018.08.00288

Panahi, S. V. S. P., Moshiri F., & Ardakani, M. R. (2016). Sulfur application effect on pH measurement of wheat rhizosphere in calcareous soils. *Biological Forum – An International Journal, 8*(1), 199-203.

Peterson, B. C., Koupal, K. D., Schissel, A. K., & Siegel, C. M. (2015). Longevity of mineral supplements within the soil and associated use by white-tailed deer. *Transactions of the Nebraska Academy of Sciences and Affiliated Societies, 35,* 61–67.

Razali, N. B., Shafie, M. S., Mohd Jobran, R. A., Abdul Karim, N. H., Khamis, S., Mohd-Taib, F. S., Md Nor, S., Ngadi, E., Atiqah Razali, S. H., Husin, S. M., & Redza Hussein, M. S. (2020). Physical factors at salt licks influenced the frequency of wildlife visitation in the Malaysian tropical rainforest. *Tropical Zoology*, *33*(3). https://doi.org/10.4081/tz.2020.69

Salehi, M. H., Beni, O. H., Harchegani, H. B., Borujeni, I. E., & Mortaghian, H. R. (2011). Refining soil organic matter determination by loss-on-ignition. *Pedosphere, 21*(4), 473–482.

Shamshuddin, J., Panhwar, Q. A., Othman, R., Ismail, R., Jol, H., & Yusoff, M. A. (2016). Effects of December 2014 great flood on the physico-chemical properties of the soils in the Kelantan Plains, Malaysia. *Journal of Water Resource and Protection*, *8*(2), 263–276. https://doi.org/10.4236/jwarp.2016.82023

Siczek, A., Kotowska, U., Lipiec, J., & Nosalewicz, A. (2008). Leaching of potassium, magnesium, manganese, and iron in relation to porosity of tilled and orchard loamy soil. *Acta Agriculturae Scandinavica, Section B - Plant Soil Science*, *58*(1), 60–65. https://doi.org/10.1080/09064710701214346

Simpson, B. K., Nasaruddin, N., Traeholt, C., & Nor, S. M. (2020). Mammal diversity at artificial saltlicks in Malaysia: A targeted use. *Frontiers in Environmental Science*, *8*, 1-8. https://doi.org/10.3389/fenvs.2020.556877

Siong, F. S., Mohd Azlan, J., Mior Abdul Rahman, N. A. H., Lihan, S., & Pei, L. K., (2020). Mineral characteristics of tropical salt licks in Sarawak, the Northwest of Borneo Island. *Journal of Sustainability Science and Management, 15*(8), 53-62.

Wan Mohd Jaafar, W. S., Abdul Maulud, K. N., Muhmad Kamarulzaman, A. M., Raihan, A., Md Sah, S., Ahmad, A., Saad, S. N., Mohd Azmi, A. T., Jusoh Syukri, N. K., & Razzaq Khan, W. (2020). The influence of deforestation on land surface temperature—A case study of Perak and Kedah, Malaysia. *Forests*, *11*(6), 670. https://doi.org/10.3390/f11060670

Wang, F. L., & Huang, P. M. (2001). Effects of organic matter on the rate of potassium adsorption by soils. *Canadian Journal of Soil Science, 81,* 325–330.

Wood, J. C. (2015). Determination of moisture content and total carbon within basin environment: Loss-on-ignition. In *Geomorphological Techniques*.