ISSN: 1475-7192

CHEMICAL PROPERTIES OF FIVE SOIL TYPES IN THE INDONESIAN SOIL CLASSIFICATION SYSTEM AT KRUENG MEUEH SUB-WATERSHED, ACEH PROVINCE

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ABSTRACT--*The operation of soil forming factors could simultaneously be formed into different or similar soil properties. Soil types are grouped based on the soil classification system. This research aims to study the soil chemical characteristics and soil development in several types of soil (The Indonesian Soil Classification System) in the Krueng Meueh sub-watershed. The research was conducted by using descriptive survey methods and based on the soil type map. In the study area, there were found five soil types, namely Alluvial, Latosol, Mediterranean, Brown Podsolic (BP) and Red Yellow Podsolic (RYP). In each soil type had one minipit, every a minipit consists are three layers (0-25, 25-50, 50-75 cm), and fifteen soil samples were taken from five minipits. The soil samples were air-dried and sieved 2 mm to analysis purpose of soil chemical properties in the laboratory. The results showed that value of pH H_2O range 3.6-6.0, pH KCl 3.0-5.8, Organic-C 0.34-1.78%, exchangeable-Ca 6.7-8.9 cmol/kg, exchangeable-Mg 0.3-0.41 cmol/kg, exchangeable-K 0.16-0.62 cmol/kg, exchangeable-Na 0.12-0.15 cmol/kg, cation exchange capacity (CEC) 7.7-19.05 cmol/kg, base saturation (BS) 42.26 – 98.25%, exchangeable-Al 0-9.2 cmol/kg, exchangeable-H 0.16–2.44 cmol/kg and aluminum saturation (Al-sat.) 0-48%. Based on the Ca/Mg ratio, ∆pH and CEC, RYP and BP were classified as further development soils. Statistically, there were a correlation inter-soil characteristic, soil pH was significantly negatively correlated with exchangeable-H, -Al and Al-sat., and significantly positively correlated with CEC, BS. Duncan Multiple Range Test (DMRT) showed that the soil chemical characteristics were variated among inter-soil types, except the content of organic-C and exchangeable-K.*

Key words--*soil chemical properties, soil forming processes, soil types, weathering degree.*

I. INTRODUCTION

Soil chemical properties are one of indicators for soil quality and become one of important parts in agricultural development efforts (Zamalea et al., 2016). Soil chemical characteristics as well as physical and biological properties are formed due to the influence of materials and energy input, output, translocation and transformation in the soil system (Buol et al., 2011) . The properties of the soil can differ laterally or vertically

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ISSN: 1475-7192

due to the influence of the soil forming factors themselves. The soil is different in nature if one of its constituent factors is different even though the other factors are at the same nature, and vice versa- the nature of the soil will be different even if the other factors are the same. The basic parent material will form alkaline soil under its climatic conditions, organisms, reliefs and its uniformity of time. However, the base parent material will develop into different types of soil due to differences in climate, organisms, relief and time. Soil formed from base parent material will become acidic soils if they form in areas of high temperature and rainfall (Buol et al. 2011; Zamalea et al., 2016). The same type of soil can be different in its properties in different environment (Balasubramanian, 2017).

Soil types are formed through soil classification which sorts the soil, according to its characteristics, therefore, it can be distinguished between one type of soil and another. The uniqueness of soil properties is also seen in different types of soil- but it is possible for them to have the same properties (Medinski, 2007). This fact shows that several types of soil are different but have more or less are at the same characteristics. RYP (Ultisol) and Mediterranean or Latosol (Alfisol) are different types of soil, but both have argillic or clay horizons (Soil Survey Staff, 2014). Therefore, understanding the characteristics of each type of soil is important, especially for agricultural use plans.

Krueng Meueh sub-watershed is part of the Krueng Peusangan watershed. The extent of about 12,255.47 ha, spreading over three districts, namely North Aceh, Bener Meriah and Bireuen. According to BAPPEDA Aceh (2018), in this sub-watershed, there are five types of soil (Indonesian soil classification system) which are relatively broad, with Alluvial at 1,942.65 ha, Mediterranean at 3,729.29 ha, RYP at 1,502.69 ha, Latosol at 4,552,13 ha, and BP at 528.71. The condition of the slope and land use type in this region are also different.The 0-3% slope is about 9,717.00 ha, the 3-8% is 296.80 ha, and the 8-15% covering an area of 2,241.10 ha. Land use types were found in the form of 5,578.69 ha shrubs, 4,138.27 ha secondary forest, and 2,258.51 ha mixed gardens. The difference in slope and land use type will affect the properties of various types of soil in this region. Information on the soil chemical properties of the five soil types in the Kreung Meueh Sub-watershed is not yet widely known.

II. MATERIALS AND METHODS

This research examined five types of soil according to the Indonesian soil classification system, namely Alluvial, Latosol, Mediterranean, BP and RYP at the Krueng Meueh sub-watershed (Figure 1). The research was conducted from February to April 2019. The study area was spread in three districts namely North Aceh, Bener Meriah and Bireuen with an area of 12,255.48 ha. Geographically, the Krueng Meueh sub-watershed is located at coordinates 4°56'0 "- 5°6'0" N and 96°42'0 "- 96°52'0" E. The northern border is the Ulee Glee sub-watershed, the south is the Timang Gajah sub-watershed, the west is the Krueng Simpo sub-watershed and the east is the Krueng Mane sub-watershed.

The material used in this study are soil samples and other chemicals used in analyzing soils such as $K_2Cr_2O_7$, aquades, indifenil indicators, H_2SO_4, H_3PO_7, $FeSO_4$, NH_4OAc, NaOH, KCl 1N, NaOH 1N, NaF 4%, PP (phenolphthalein) indicator, conway indicator, and Nessler reagent. The tools used in this study were hoes, plastic ropes, plastic bags, gauges, maches, label paper, stationery, cameras, 2 mm sieves, Erlenmeyers, analytical scales, shakers, measuring cups, shake bottles, beaker glass, measuring flasks, pH meters, centrifuge tubes, test tubes, spatulas, gloves, masks, rubber bands, label paper, cover paper, stationery, and cameras.

This research was conducted applying descriptive survey method, where the soil sampling was taken using minipit with the size 50 x 50 x 75 cm. One minipit was created for each soil type Alluvial, Latosol, Mediterranean, BP and RYP. The information of soil types in the location can be seen in the map of soil types (Figure 1), whereas to minipit positions on each soil type was applied in the field with GPS (Global Positioning System) software. Each minipit was divided into three layers at intervals of 25 cm (0-25, 25-50 and 50-75 cm). One soil sample of 1 kg was taken from each layer to analized purpose of soil chemical properties in the laboratory. Prior the analysis, each soil sample was air-dried and sieved with a 2 mm sieve. Air-dried soil was then analyzed to find its chemical properties which including pH in water (H_2O) (1:5) and KCl 1N (1:1) (glass electrode pH meters), Organic-C (Walkley & Black), base cations (Extraction NH_4OAc 1N pH 7.0), CEC (Extraction NH_4OAc 1N pH 7.0), BS (Extraction NH_4OAc 1N pH 7.0). The Ca and Mg elements were measured using Atomic Adsorption Spectrophotometry (AAS), while the K element using Flamephotometry (Tadesse et al., 1991), exchangeable-Al (KCl 1N extraction), exchangeable-H (KCl 1N extraction), and Al-sat. (KCl 1N extraction). To see the relationship between those soil properties, the researcher used statistics of SPSS software version 22, while to see the differences in soil chemical properties among soil types, the DMRT advanced test is used at the 5% level.

III. RESULTS AND DISCUSSION

Soil pH and organic-C

The results of pH soil measusurement of pH H_2O, pH KCl and –organic-C soil content were presented in Table 1. The table shows that pH H_2O values are ranged from 3.6-6.0 (very acid-neutral), pH KCl ranges from 3.0-5.8 (acid-neutral), while organic-C levels range from 0.34-1.78 (very low).

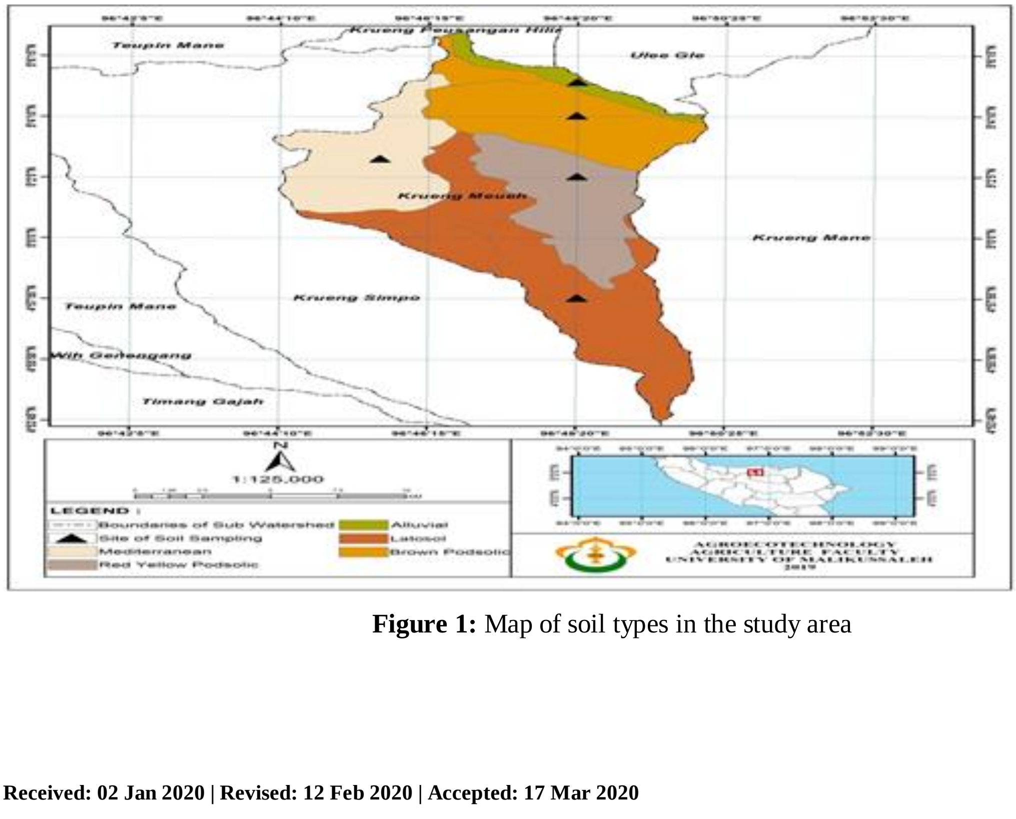

Figure 1: Map of soil types in the study area

ISSN: 1475-7192

Table 1: Soil pH (H_2O dan KCl) value and organic-C content

No	Soil Types	Soil Depth (cm)	pH H_2O	Criteria*	pH KCl	Criteria*	Org-C (%)	Criteria*
1	Alluvial	0-25	6,3	SA	5,1	NU	0,40	VL
		25-50	6,3	SA	5,0	NU	0,35	VL
		50-75	6,2	SA	4,3	NU	0,90	VL
2	Latosol	0-25	6,5	SA	5,8	NU	0,96	VL
		25-50	6,6	NU	4,9	NU	1,78	LO
		50-75	5,5	AD	4,5	NU	0,78	VL
3	Mediterranean	0-25	5,7	SA	4,7	NU	1,77	LO
		25-50	5,7	SA	3,7	AD	1,04	LO
		50-75	5,7	SA	3,5	AD	0,51	VL
4	BP	0-25	5,5	AD	4,8	NU	1,47	LO
		25-50	5,3	AD	3,4	AD	0,48	VL
		50-75	5,0	AD	3,2	AD	0,34	VL
5	RYP	0-25	5,5	AD	3,6	AD	0,37	VL
		25-50	5,2	AD	3,5	AD	0,49	VL
		50-75	3,6	SA	3,0	AD	1,27	LO

Notes : SA (slightli acid); AD (acid); NU (neutral); VL (very low); LO (low); BP (brown podsolic); RYP (red yellow podsolic)

*) Criteria by Staff of The Indonesian Soil Reseacrh Center (Hardjowigeno, 2015)

The highest soil pH values for both pH H_2O (6.6) and KCl (5.8) were found in Latosol, while the lowest pH values i.e pH H_2O (3.6) and KCl (3.0) were in RYP soils. The pH value of RYP soils is due to these soils, including old soils, where weathering and leaching processes are very intensive, which results in the loss of many basic elements (Tan, 2010; Buol et al., 2011). Vertically, all soil types in the study area show that the pH of the upper layer (topsoil) is higher than the bottom layer (subsoil), this is closely related to the parent material and the presence of soil organic acids. Soil in the study area is generally formed from rock/sediment parent material (Subagyo et al., 2000), while organic acids from the decaying of soil organic matter (OM) move to the lower layers along with soil water movement (Aziz et al. ., 2016). This condition is also in line with organic-C content in the study area where the upper layer is generally lower than the lower layer (Table 1), except in Mediterranean soil. Low levels of organic-C in the upper soil layer are associated with higher temperatures in the upper layer than the lower layer (Araya et al., 2016). The highest organic-C content was found in Mediterranean (1.23%) and Latosol (1.17%), while the lowest was seen in RYP (0.71%) and Alluvial (0.55%) soils. RYP soils are low MO-characterized soils, as are Alluvial soils whose MO content is dependent on these soil-forming sediments, but are often low (Medinski, 2007; Aziz et al., 2016). The pH values of H_2O and KCl were found to be negatively correlated with organic-C even though it was not significant which were the correlation values (r = 0.06) and (r=0.02). It's as an illustration when the MO increases the pH value of the soils will be decreased.

ISSN: 1475-7192

Exchangeable cations, CEC and BS, exchangeable-H and Al, Al-sat.

The results of determining the exchangeable cations value, CEC and BS were presented in Table 2. The exchangeable-Ca values range from moderate, exchangeable-Mg from very low to low, exchangeable-K ranges from low to moderate, and all of exchangeable-Na were low. The highest average exchangeable-Ca value (7.90 cmol/kg) was seen in Alluvial soils, while the lowest (6.80 cmol/kg) was found in Latosol. The highest mean exchangeable-Mg (0.41 cmol/kg) was found in RYP, while the lowest mean value (0.33 cmol/kg) was seen in Latosol. The highest mean exchangeable-K value (5.68 cmol/kg) was found in Alluvial soils, while the lowest value (0.27 cmol/kg) was found in Latosol soils. The highest mean exchangeable-Na value (0.15 cmol/kg) was seen in RYP soil, while the lowest value (0.13 cmol/kg) was found in Latosol. The lowest average value for all cations were found in Latosol. This is possible because Latosol is one of the further weathered soils with a complete profile development which later became known as old soil with relatively low fertility values (Hardjowigeno, 2015).

Tabel 2: Exchangeable cations, CEC, BS, exchangeable-H, Al and Al-sat.

No	Soil Types	Soil depth (cm)	Exc-Ca (cmol/kg)	Exc-Mg (cmol/kg)	Exc-K (cmol/kg)	Exc-Na (cmol/kg)	CEC (cmol/kg)	BS (cmol/kg)	Exc-H (cmol/kg)	Exc-Al (cmol/kg)	Al-Sat. (%)
1	Alluvial	0-25	8,49	0,38	0,16	0,15	9,42	97,45	0.24	tr	tr
		25-50	7,72	0,38	0,41	0,13	8,80	98,18	0.16	tr	tr
		50-75	7,85	0,36	0,62	0,13	9,12	98,25	0.16	tr	tr
2	Latosol	0-25	6,70	0,33	0,30	0,13	7,86	94,91	0.40	tr	tr
		25-50	6,92	0,30	0,26	0,14	7,82	97,44	0.20	tr	tr
		50-75	6,78	0,35	0,25	0,12	7,70	97,40	0.20	tr	tr
3	Mediterranean	0-25	7,89	0,39	0,25	0,14	10,39	83,45	0.76	0.96	9
		25-50	7,48	0,39	0,29	0,15	11,51	72,20	0.80	2.40	21
		50-75	7,46	0,40	0,32	0,14	10,32	80,62	0.80	1.20	12
4	BP	0-25	7,66	0,39	0,38	0,13	9,04	94,69	0.48	tr	tr
		25-50	7,59	0,40	0,34	0,14	15,67	54,05	1.60	5.60	36

Received: 02 Jan 2020 | Revised: 12 Feb 2020 | Accepted: 17 Mar 2020

		50-75	7,12	0,41	0,37	0,15	19,05	42,26	1.80	9.20	48
5	RYP	0-25	7,21	0,41	0,31	0,15	17,68	45,70	1.60	8.00	45
		25-50	7,99	0,41	0,42	0,15	18,37	48,83	2.44	6.96	38
		50-75	7,20	0,41	0,41	0,15	12,77	63,98	1.32	3.28	26

Noot : tr (trace); CEC (cation exchange capacity); BS (base saturation); Al-Sat (Al-saturation); BP (brown podsolic); RYP (red yellow podsolic)

The mean value of CEC is generally of a low category, BS medium to very high, whereas Al-sat. from unmeasured, moderate to very high (Table 2). The highest average CEC value (16.27 cmol /kg) was found in RYP soil, while the lowest mean value (7.79 cmol/kg) was found in Latosol soil. The highest mean BS (97.96%) was seen in alluvial soils, while the lowest values (52.84%) were found in RYP soils. The mean CEC value of RYP soil is higher than that of Alluvial, Latosol, Mediterranean and BP soils, this is allegedly because the RYP soil in the study area besides having high clay fraction, also the amount of type 1:1 clay minerals are more dominant than hydrous-oxide minerals. The magnitude of the ability of CEC clay minerals is 1:1 higher than oxide minerals (Tan, 2010). Soil organic matter (SOM) can also affect the height of soil CEC, this can be seen from the correlation between the two which are significantly positive (= 0.53*). On the other hand the BS value of RYP soil is the lowest compared to other types of soil, this is different from the CEC value of RYP soil which is higher than other soils. This phenomenon can be understood because exchangeable base cations (Ca, Mg, K and Na) in RYP soils more easily due to leaching than other soils so the amount is low. The low value of exchangeable cations on RYP soil will cause a low BS value. The highest BS values were seen in Alluvial and Latosol soils, while the lowest values were found in RYP soils (Table 2). BS value is inversely proportional to exchangeable-Al and Al-sat., this is in line with the results of the study of Lourenzi et al. (2011) which revealed that when BS increases exchangeable-Al levels and Al-sat. decreases.

In addition to base cations, acid cations consisting of H and Al were also analyzed in this study, where the highest average exchangeable-H value (1.79 cmol/kg) was found in RYP soils, while the lowest values (0.19 cmol/kg) were found in Alluvial soil. The highest exchangeable-Al values and highest Al-sat. (5.08 cmol/kg and 36.3%) were seen in RYP soil, the lowest values (1.52 cmol/kg and 14.0%) were found in Mediterranean soils, even in Alluvial and Latosol soils not measured. High concentrations of exchangeable-H, -Al and Al-saturation in RYP soils caused low pH values of RYP soils. High exchangeable-H concentrations can also be caused by high exchangeable-Al and Al-sat. levels, where hydrolysis of Al ions will produce H ions (Sanchez, 2018). This condition can be seen from the very significant positive correlation between exchangeable-Al and exchangeable-H (r = 0.92 **) and Al-sat. and exchangeable-H (r = 0.98 **).

The results of the DMRT different test analysis at the 5% level of the chemical properties of the soil in various types of soil according to the Indonesian soil classification system were presented in Table 3. In Table 3,

ISSN: 1475-7192

almost all of the chemical properties of the soil measured differ between types of soil, except organic-C content and exchangeable-K soil.

Weathering degree and soil development

The process of soil formation is the process of weathering rocks or parent material into a soil body, and the process of soil development in which the soil body experiences a differentiation of horizons due to differences in its properties. On this basis, soils can be identified with different levels of weathering and development. The degree of weathering of a soil can be seen from the mineralogical composition, the ratio of fine/coarse soil fractions, the ratio of Ca/Mg, ΔpH and CEC. In this study the degree of weathering is only seen from the ratio of Ca/Mg, ΔpH and soil CEC values.

Based on the data in Table 4, the average Ca/Mg ratio, ΔpH and CEC of the study area were relatively diverse. The average Ca/Mg ratio ranged from 18.20 to 21.48, ΔpH -1.13 to -1.73, and soil CEC ranged from 7.79 to 16.27 cmol / kg. The lowest average Ca/Mg ratio and the highest average CEC value were found in BP and RYP so that these two types of soil can be categorized as soils that have undergone further development and old (Buol et al., 2011). The lower the Ca/Mg ratio the further the weathering of a soil, as well as the soil CEC which is also used as an indicator of the degree of weathering, where young soils CEC are low and increase with increasing weathering, and if weathering continues to increase then the CEC value will decreased again (Buol, et al., 2011; Sanchez, 2018).

Table 3: Average value of the Ca/Mg ratio, ΔpH and CEC of study area soils

No.	Soil types	Depth (cm)	Ca/Mg ratio	average	ΔpH	averag e	CEC	average
		0-25	22.34		-1.2		9.42	
1	Alluvial	25-50	20.31	21.48	-1.3	-1.46	8.80	9.11
		50-75	21.80		-1.9		9.12	
		0-25	20.30		-0.7		7.86	
2	Latosol	25-50	23.06	20.91	-1.7	-1.13	7.82	7.79
		50-75	19.37		-1.0		7.70	
		0-25	20.23		-1.0		10.39	
3	Mediterranean	25-50	19.17	19.36	-2.0	-1.73	11.51	10.74
		50-75	18.70		-2.2		10.32	
		0-25	19.64		-0.7		9.04	
4	BP	25-50	18.97	18.65	-1.9	-1.46	15.67	14.58
		50-75	17.36		-1.8		19.05	
		0-25	17.58		-1.9			

Received: 02 Jan 2020 | Revised: 12 Feb 2020 | Accepted: 17 Mar 2020

							17.68	
5	RYP	25-50	19.48	18.20	-1.7	-1.40		16.27
							18.37	
		50-75	17.56		-0.6			
							12.77	

Noot : CEC (cation exchange capacity); BP (brown podsolic); RYP (red yellow podsolic)

Table 4: DMRT test of soil chemical characteristics of five soil types in study area

	Soil Types	Soil Chemical Characteristics											
		Soil pH		Organic-C	Exc-Ca	Exc-Mg	Exc-K	Exc-Na	CEC	BS	Exc-Al	Exc-H	Al-sat.
		H_2O	KCl										
1.	Alluvial	6,27 a	4,80 a	0,55 a	8,02 a	0,37 b	0,39 a	0,14 ab	9,11 c	97,96 a	0,00 c	0,16 c	0,00 b
2.	Latosol	6,20 a	5,07 a	1,18 a	6,80 b	0,33 c	0,27 a	0,13 b	7,79 c	96,58 a	0,00 c	0,26 c	0,00 b
3.	Mediterranean	5,70 ab	3,47 b	1,10 a	7,61 a	0,39 ab	0,29 a	0,14 ab	10,74 bc	78,78 ab	1,52 ab	0,78 bc	0,14 ab
4.	BP	5,26 ab	3,80 b	0,76 a	7,46 a	0,40 a	0,36 a	0,14 ab	14,58 ab	63,67 bc	4,93 ab	1,29 ab	0,28 a
5.	RYP	4,77 b	3,37 b	0,68 a	7,47 a	0,41 a	0,38 a	0,15 a	16,27 a	52,84 b	6,08 a	1,78 a	0,36 a

Note: Value followed by different letters in the same column are significantly different at 5% DMRT test

IV. CONCLUCIONS AND RECOMMENDATIONS

1. Soil pH values are generally categorized as acidic to neutral, while soil organic-C content is from very low to low.

2. Concentrations of exchangeable base cations such as exchangeable-Ca in the moderate range, exchangeable-Mg from very low to low, exchangeable-K in the low to moderate range, and exchangeable-Na in all are low.

3. CEC is generally categorized as low, BS medium to very high, while Al-sat. is not measurable, moderate to very high.

4. Soil chemical properties differ between types of soil, except organic-C and exchangeable-K-. The lowest soil pH and BS values are found in RYP and BP. The highest levels of exchangeable-Al, Al-sat., and exchangeable-H were also found in RYP and BP.

5. Based on the ratio of Ca/Mg, ∆pH and CEC, the weathered soils are RYP and BP.

Received: 02 Jan 2020 | Revised: 12 Feb 2020 | Accepted: 17 Mar 2020

6. To assess the weathering degree more precisely, additional data are needed, namely the mineralogical composition of the soil and the ratio of fine and coarse fractions (through analysis of seven soil fractions)

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