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Physical-Chemical Characteristics and Soil Classification of Lowland Alluvial Land Using Three Soil Classification Systems

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ABSTRACT

The total area of irrigated rice fields on the slopes of Mount Argopura is 21,420.02 hectares. Soil that experiences flooding will change the characteristics of the physical, chemical, and soil classification properties. The aim of the study was to examine the soil characteristics and classification system of paddy fields on the slopes of Mount Argpura. The research was conducted in July–September 2022 in paddy fields on the slopes of Mount Raung. Soil analysis in the laboratory of the Faculty of Agriculture, University of Jember This research uses a descriptive exploratory method through field surveys. Parameter research on the chemical-physical characteristics of soil and soil classification The research shows that the average rainfall of paddy fields at the foot of Mount Argopura is 2,275 mm per year with a standard deviation of 514 mm and a coefficient of variance of 23%. The morphological horizons of the genesis results in paddy fields are generally Apg, Adg, Bwg, and Cg. The USDA's classification of soil Hydraquentic Humaquepts (pedon 1), Typic Epiaquepts (pedon 2), Aeric Epiaquepts (pedon 3), Indonesian soil classification Gleisol molik (pedon 1), Gleisol eutric (pedon 2), and Gleisol eutric (pedon 3), according to WRB/ FAO Molic epireductic Gleisol (Aphihumic) (pedon 1), ochric reductive gleysol (ochric, clayic) (pedon 2), and ochric siltic reductive gleysol (pedon 3).

1. INTRODUCTION

Indonesia is an archipelagic country with a farmer's livelihood (Hidayati *et al*., 2019; Soetriono *et al*., 2023). Agricultural land is spread from the highlands to the lowlands with food crops, horticulture, and plantation commodities. Food crops are mostly in the lowlands and in the form of paddy fields. The Central Statistics Agency in 2019 recorded a total area of agricultural land with the use of irrigated rice fields of 10,903,834 ha (BPS, 2021). The land area has decreased by 3% from the previous year (Al-Mukmin *et al*., 2016). The decline in the area of agricultural land in Indonesia is difficult to avoid due to the influence of population growth and development (Basuki *et al*., 2022a). In the 1990s, Indonesia was self-sufficient in rice, which has declined until now (Mulyani *et al*., 2020; Mulyani & Nursyamsi, 2017; Pujiharti, 2017).

Rice self-sufficiency will not be achieved if these conditions are not matched by an increase in the quality of cultivated land. Government programs have been launched to support rice self-sufficiency, including intensification, diversification, and extensification programs (Mulyani & Agus, 2018). The success of cultivating irrigated lowland rice plants depends on many influential factors, including sunlight conditions, irrigation water conditions, and soil characteristics (Basuki et al., 2021). Irrigated paddy fields are located in various land typologies with different soil characteristics. Soil with various physical, chemical, and biological characteristics directly affects the growth of plants that grow on it. Variations in soil characteristics for each region have an impact on the soil's ability to provide different nutrients (Prasetyo & Setyorini, 2008; Suryani, 2013).

Paddy fields are an irrigated rice planting medium in which cultivation activities are carried out by flooding (Mulyani & Nursyamsi, 2017). The inundation process will cause the soil to become muddy and disperse. The process of dispersion of stagnant and muddy soil forms a new horizon layer arrangement according to the specific gravity of the soil textural fraction, so that it will form different soil characteristics compared to the soil from dry land. The reduction process is one of the conditions for soil chemical properties that are created when the soil is inundated (Suryana, 2016). The inundation process will form new soil morphology and soil characteristics (Ferdeanty *et al*., 2020). Soil morphology and soil characteristics that change affect the change in soil classification from the original soil. The USDA classification system published in 2015 and the national soil classification published in 2014 have not yet provided information regarding steps and methods for classifying paddy fields (IUSS Working Group WRB, 2014; Subardja *et al*., 2014; Soil Survey Staff, 2015).

Jember is a district in the Tapalkuda region of East Java that is affected by volcanic and marine activities. Volcanoes that affect the level of soil characteristics, including paddy fields, include Mount Raung and Argopura (Basuki *et al*., 2022b). The river flows upstream from some of these mountains and flows into the lowlands towards the south coast of Java, where it previously watered the irrigated rice fields in this district. The water that flows from the mountains will carry and color the characteristics of the soil in the paddy fields. Soil that is continuously cultivated will change the horizon arrangement and, at the same time, change the chemical and physical composition of the soil profile (Lubis *et al*., 2017). This factor will affect the variability of the morphology of the soil profile and soil classification in the paddy fields on the slopes of Mount Argopura. Information on morphology, chemical-physical characteristics of paddy fields, and soil classification on the slopes of Mount Argopura is still limited, and this information, if complete, will be useful for farmers in managing soil and crops more easily and in a more directed manner. Based on the description above, the research objective is to study the soil characteristics and the classification system of paddy fields on the slopes of Mount Argpura, Jember Regency, as the basis for soil management.

2. MATERIALS AND METHODS

The research was carried out in July–September 2022, with data collection locations and soil samples in the paddy fields on the slopes of Mount Argopura. Data collection points and samples were divided into 3 locations, namely the pedon 1 location with coordinates 113.338 East Longitude, -8.243 South Latitude; the pedon 2 location point with coordinates 113.408 East Longitude, -8.32 South Latitude; and the pedon 3 location with coordinates 113.469 East Longitude, -8.286 South Latitude (Figure 1). Laboratory analysis was done in the laboratory of land resources, soil physics, soil chemistry, and soil fertility, Faculty of Agriculture, University of Jember. Research activities were divided into 4 categories: pre-survey activities including secondary data collection; field survey activities by collecting soil characteristic parameters, the environment, and soil samples; and post-survey activities analyzing chemical and physical characteristics in the laboratory.

The tools used in the study included field equipment including hoes, rice field drills, tape measures, daggers, GPS, clinometers, aquadest bottles, soil taxonomy books, and laboratory analysis tools including block destruction, spectrophotometers, flamephotometers, AAS, pH meters, and other laboratory equipment that supports analysis in the laboratory. Materials used to support research activities included field activity materials including rainfall and climate data, plastic samples, markers, rubber covers, and laboratory analysis materials such as label paper, distilled water, H_2O_2 10%, HCL 10%, alcohol, K_2CrO_7, H_2SO_4, NH_4OAc pH 7, NaCL, KCL, and ammonium oxylate. Rainfall and climate data are obtained from LAPAN.

This research uses the descriptive-exploratory method through field surveys. The study began with observing the morphology of the soil profile and the physical and chemical properties of the soil at each point of the soil sampling pedon. Parameters observed at each pedon in the field included soil solum depth, horizon arrangement, texture consistency, structure, soil color, epipedon, endopedon, and soil temperature. Soil samples analyzed in the laboratory were taken with a homogeneous weight of 1 kg and dried for 1-2 weeks. The dried soil was pounded and sieved to a size of 0.5 mm and 2.0 mm. filtered soil was analyzed in the laboratory with parameters including the clay fraction of the soil using the pipette method (Basuki *et al*., 2022b), soil pH by the allorimeter and electrometer method with a ratio of 1:5 (Basuki & Sari, 2020), the base can be exchanged (Ca, Mg, Na, K) with NH4Oac extract pH 7 1M (Basuki & Winarso, 2021), the base saturation of NH_4Oac pH 7 1M (Basuki *et al*., 2015), NH4Oac pH 7 1M cation exchange capacity, and redox potential (Cyio, 2008).

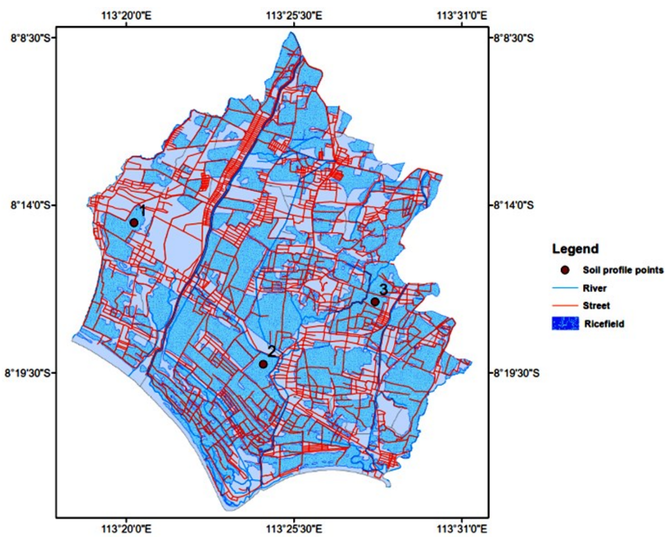

Figure 1. Paddy soil sampling point

The nomenclature for soil classification uses three systems of soil classification methods, including USDA classification, national classification, and FAO/WRB classification. The USDA soil classification is divided into 5 levels, including orders, suborders, groups, subgroups, and families. National soil classification has two levels of soil type. WRB/FAO land classification levels include principal qualifiers and supplementary qualifiers.

3. RESULTS AND DISCUSSION

3.1. Climatic Characteristics

Climatic characteristics that affect the productivity of paddy rice fields include rainfall, air humidity, solar radiation, and air temperature. The southern foot of Mount Argopura is mostly planted with rice, with an area of 21,420.02 hectares supported by suitable environmental conditions. Water that comes from rain will affect the availability of water for irrigated rice fields. Rainfall is used to determine the water potential of rice cultivation. Table 1 shows the intensity of rainfall in 2010–2019 at the foot of Mount Argopura. The total amount of average rainfall at the foot of Mount Argopura is 2,275 mm/year, with a standard deviation of 514 mm and a coefficient of variation of 23%.

Table 1. Rainfall in 2010-2019 on the slopes of Mount Argopura

Year	Month												Sum
	1	2	3	4	5	6	7	8	9	10	11	12	
2010	394	368	319	302	331	105	128	51	182	266	248	387	3082
2011	317	216	304	318	186	22	1	9	0	132	293	391	2190
2012	455	246	348	158	145	35	59	4	21	100	207	379	2158
2013	526	289	305	225	211	204	125	3	2	78	282	426	2677
2014	308	258	237	251	85	8	19	35	1	14	254	384	1855
2015	312	291	314	265	136	32	1	1	35	1	117	305	1809
2016	232	429	231	221	273	167	147	104	147	339	393	373	3055
2017	353	258	262	229	138	136	8	3	43	108	413	390	2342
2018	522	371	272	111	41	47	2	13	12	5	301	278	1975
2019	366	282	360	230	35	27	12	3	4	16	46	227	1609
Sum	3785	3009	2951	2310	1581	782	502	227	448	1061	2556	3540	22750
Average	378	301	295	231	158	78	50	23	45	106	256	354	2275
SD	96	67	44	62	95	69	60	33	65	115	112	63	514
CV	25	22	15	27	60	89	120	145	146	108	44	18	23

Note: Month 1=January, 2=February, 3=March, 4=April, 5=May, 6=June, 7=July, 8=August, 9=September, 10=October, 11=November, 12=December

The average rainfall per month or year at the foot of Mount Argopuran is 134–257 mm. The peak of rainfall at the foot of Mount Argopura with a value of 378±96 mm/month occurred in January, and the second peak of rainfall with a value of 354±63mm/month occurred in December (Table 1). The lowest rainfall, with a value of 158±95 mm/month, occurs in May and October, with a value of 106 ± 115 mm/month. Rainfall begins to decrease after May until a dry season occurs, with the peak point of the dry month in August (23±33 mm/month). The rainfall diagram at the foot of Mount Argopura can be described as Figure 2. Rainfall is influenced by the location and geographical position of the sun (Nasution & Nuh, 2018). The location of the sun, which is in the equator region, causes the sea surface to warm and causes clouds and rain (Kusumo & Septiadi, 2016).

The Oldeman climate classification divides areas based on the commodity of rice plants, which are determined based on wet months (BB) and dry months (BK). The wet month of the Oldeman climate has an average monthly rainfall of at least 200 mm, and the dry month's rainfall is below 100 mm (Sasminto *et al*., 2014; Fadholi & Supriatin, 2016; Nasution & Nuh, 2018; Wunangkolu *et al*., 2019). The analysis shows that the foot of Mount Argopura, based on Oldeman climate analysis, is classified as a C2 climate type. The C2 climate indicates that the research location has six consecutive wet months starting in November and ending in April and three consecutive dry months starting in July and ending in September.

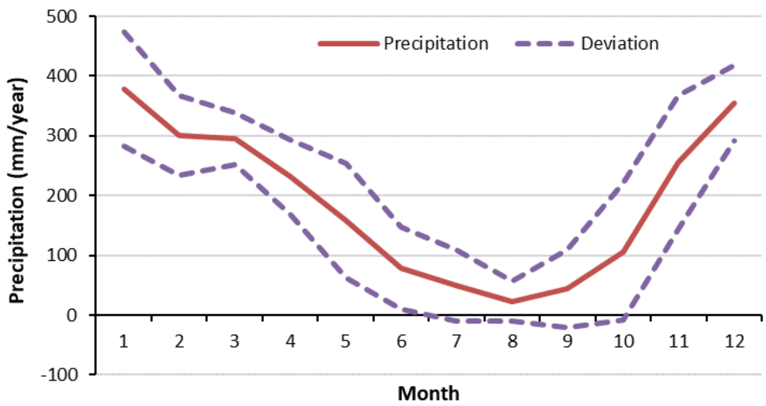

Figure 2. Average rainfall for 2010-2019 on the slopes of Mount Argopura

3.2. Geological Characteristics and Land Physiography

The geological formations that make up the southern foot of Mount Argopura are six, including alluvium, Argopura volcanic rocks, Argopura tuff, Semeru volcanic deposits, Puger formations, and Mandalika formations (Basuki *et al*., 2021; Basuki *et al*., 2022b). The Argopura Tuff makes up the dominant area at the foot of Mount Argopura, with a percentage of 83.62%. Argopura tuff is a formation composed of tuff, intervening tuff, ash tuff, and lava tuff (Verdiana *et al*., 2014). Tuff has a grain texture characteristic of fine to coarse ash with a thickness of 0.5–2.8 meters and is composed of quartz, felsfar, lithic fragments, glass with medium to moderately rounded grain shapes, well-sorted to medium, and dominantly massive rocks with a brittle hardness level. Tuff is part of a megastrophic pyroclastic rock that is brown, yellow, or grayish yellow (Tufaila, 2014). Volcanic tuff is composed of matrix and fragments. Fragments containing minerals in volcanic tuff consist of 7.5% plagioclase, 4% pyroxene, 3% quartz, 4% fexspar, and 13% rock fragments. The volcanic tuff matrix is composed of 35% volcanic glass and 30% clay.

The second dominant constituent formation after tuff is alluvial. Alluvial arranged the research location by 14.87%. Alluvial is formed in the basin area or plains at the foot of the mountain due to the accumulation of sedimentation from the top carried by water. The materials that make up alluvial formations are gravel, sand, dust, clay, and silt (Apriyanto *et al*., 2020; Prasetyo & Setyorini, 2008). The constituent material comes from Mount Argopura through several rivers, such as the Tanggul River and the Puger River.

Argopura volcanic rock formations make up 0.99% of the study site (Table 2). The Argopura volcanic rock formation is composed of lava and andesitic volcanic breccia. Lava is material released by volcanoes during eruptions that is thick and flows slowly (Takayuki *et al*., 2019). Lava contains rhyolite, basalt, and other materials such as silicate rock. Lava contains potassium, with a mixture of silica oxide (SiO_2) at 57%. Lava contains nutrients needed by plants when it is weathered and contains several minerals such as olivine, hornblende, hyperstene, and plagioclase (Sukarman *et al*., 2020). Breccia composed of andesite at the foot of Mount Argopura is a constituent part of this formation and has an acidic nature (Sophian *et al*., 2011). The chemical composition of andesite rocks generally contains SiO_2 54.21%, Fe total 9.78%, Fe_2O_3 3.90%, FeO 5.26%, Al_2O_3 18.27%, Na_2O 1.93%, CaO 8.98%, MgO 4.28%, K_2O 1.60%, P_2O_5 0.45%, TiO_2 1.01%.

Table 2. Geological formation at the foot of Mount Argopura

No	Formation	Area (ha)	Percentage (%)
1.	Alluvial	5,890.34	14.87
2.	Argapuro volcanic rocks	391.39	0.99
3.	Tuff Argopura	33,119.56	83.62
4.	Semeru Volcano deposits	94.53	0.24
5.	Puger formation	96.88	0.24
6.	Mandalika formation	16.16	0.04
	Sum	39,608.86	100.00

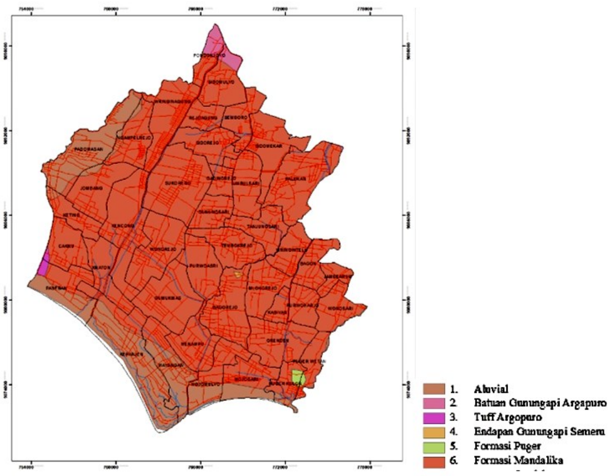

Figure 3. Geological formation map at the foot of Mount Argopura

The Semeru volcanic deposits and the Puger formation affect the study area by 0.24% each. Semeru volcanic deposits are composed of andesite-basal lava, tuff, volcanic breccias, and lava breccias. The area composed of the Semeru volcanic deposit formation has alkaline soil characteristics with low-moderate potassium content because some of the andesitic lava contains 55.4-60.76% SiO_2 and 1.90–2.89% K_2O. The minerals contained in the andesite basalt at the foot of Mount Argopura include hyperstene, volcanic glass, biotite, hornblende, and labrodorite. The rock forms are fine-textured, slightly vesicular, massive, and generally basalt andesite rocks in this region are gray in color.

3.3. Soil Profile Morphological Characteristics and Soil Physical Properties

The morphological characteristics of the paddy soil profile based on the horizon arrangement are different from those of dry soil (Sukarman *et al*., 2020). Paddy field soil has a general horizon arrangement of Apg, Adg, Bwg, and Cg (Table 3). There is an additional new symbol behind the main horizon g that indicates that the soil has gleized, which is indicated by a grayish-black to brown color (Tufaila, 2014). The surface color of the soil at location 1 is grayish brown (10YR5/2), location 2 is gray (10YR5/1), and location 3 is brown (10YR5/3). The dark color on the surface is caused by organic matter and glacial conditions. Figure 2 also shows that after the p (management) horizon there is a symbol behind the main horizon, and this is also one that distinguishes it from non-paddy soil, namely the symbol d. The d symbol behind the main horizon A indicates that there is a compacted and cemented layer that is impermeable and inhibits water from infiltrating downward. This layer is often called the plow tread layer. The tread steel layer is formed due to mechanical compaction from both heavy equipment and human activities in cultivating the soil. The color of the plow tread layer is darker than the layer above it, as in location 1 it is dark brown (10YR 3/3), location 2 is dark gray (10YR 4/1), and location 3 is dark grayish brown (10YR 4/2). The darker color of the plow layer is caused by the content of clay and organic matter, which is cemented and supported by gleized anaerobic conditions (Kautsar, 2017).

Table 3. Morphology of paddy fields at the foot of Mount Raung

Horizon	Depth (cm)	Soil colour	Soil texture	Soil structure	Soil consistence	
					Moist	Wet
Location 1						
Apg	0-19	10YR5/2	SL	M	G	AL,TP
Adg	19-26	10YR3/3	L	GM h-c	AT	AL,AP
Bwg	26-68	10YR3/2	L	GM h-l	AT	AL,AP
Bwg	68-120	10YR3/1	L	GM h-l	T	AL,AP
Location 2						
Apg	0-23	10YR5/1	L	M	G	AL,AP
Adg	23-35	10YR4/1	L	M	T	AL,AP
Bwg	35-87	10YR3/2	CIL	GM h-l	AT	TL,TP
Cg	87-110	10YR5/1	LS	BT	T	TL,TP
Location 3						
Apg	0-14	10YR5/3	SL	M	G	AL,AP
Adg	14-24	10YR4/2	SL	M	AT	TL,TP
Bwg	24-50	10YR3/3	L	GM h-c	AT	AL,AP
Cg	50-90	10YR5/2	LS	BT	AT	TL,TP

Note: Texture SL sandy loam, CIL loamy loam, L loam, LS loamy sand; Massive M structure, globular GM, single grain BT; Structure size h fine; development of soil structure c sufficient, l weak; The moist consistency of AT is rather firm, G is loose, T is firm; The consistency of wet soil AL is slightly sticky, TP is not plastic, TL is not sticky, AP is slightly plastic.

The soil textures of the three locations varied, and the surface textures were sandy loam and loam. The soil texture of paddy fields has not made much difference because most of the study sites are made of weathered alluvial and volcanic tuff (Wildani *et al*., 2013; Andreas & Putra, 2018; Sukarman *et al*., 2020). The parent material has a young age, and from that base, the texture is found to be gritty. The consistency of moist soil on the surface of the three locations did not differ; all had a loose consistency, while the plow tread layer had a rather firm consistency. The somewhat firm consistency is due to cementation (Ferdeanty *et al*., 2020; Yanto *et al*., 2014). The wet consistency of most of the categories is rather sticky and somewhat plastic. Soil in paddy fields is sticky and plastic because paddy soil has a high clay content (Marlina *et al*., 2015; Nasution & Nuh, 2018).

Structure of the subsoil on the surface of the three massive structure profiles (Table 3). Massive structures in paddy fields, especially the surface layer, are due to flooding and muddiness. Soil that is processed in a flooded state through plowing twice perpendicular to each other causes the soil to disintegrate, does not form aggregates, and is supported by harrowing, which causes the soil to become muddy (Kautsar, 2017). The plow tread layer (horison Adg) has a massive structure except for the first location of rounded lumps of smooth size with sufficient development. The formation of a lumpy structure bends due to the great pressure from above and is supported by the durability of the bottom layer (Bwg horizon), causing this type of structure to form (Ferdeanty *et al*., 2020). The horizon under the plow tread layer is all in a rounded lumpy structure with a smooth size and weak development except for the location of three categories, which are sufficient.

3.4. Soil Chemical Characteristics

The potential hydrogen (pH) of paddy fields at the foot of Mount Argopura has a neutral soil pH with a value range of 6.60–7.14 (Table 4). Table 4 shows that the soil pH value of each layer is different and decreases in the direction of soil depth. The decrease in soil pH is caused by the accumulation of dissolved and infiltrated Fe, Al, and Mn nutrients into the soil (Harista & Soemarno, 2017; Nazir *et al*., 2017). In addition to these reasons, it is possible that the composting of remaining straw, roots, and organic matter through the natural decomposition process in the rice fields is more inhibited and lowers soil pH (Basuki & Winarso, 2021). Alkaline and acid soils can be neutralized by flooding. The ph value of flooded soil will be close to neutral (6.5–7.5). Soils with organic main material and flooding still cause a decreasing pH effect caused by jarosite and organic acids. The redox potential value indicates that the soil is undergoing reduction and oxidation processes. The results of the redox potential analysis showed that the observed location was reduced to a value of 270–343 mV.

C-organic of paddy soil on the soil surface between 1.93 and 2.50%. The high C-Organic value on the surface of paddy soil is caused by the addition of decomposed rice plant roots in addition to the application of manure from outside the field (Ferdeanty *et al*., 2020). Table 4 shows that the C-Organic content decreases with soil depth. This condition is caused by organic matter in the top soil layer because it is hampered by the plow tread layer and is supported by microbial types that work mostly aerobically (Pranoro, 2021). Cations are secondary macronutrients consisting of Ca, mg, K, and Na. Cations at the study site showed that most of the height on the soil surface was caused by unleached cations. Most of the cations can be exchanged in almost all layers of the soil horizon in the high category.

Table 4. Laboratory analysis of soil chemical characteristics

Horizon	Depth (cm)	pH	C-Organic (%)	Exchangeable cations (cmol/kg)				CEC (cmol/kg)	BS (%)	Redox potential (mV)
				K	Ca	Mg	Na			
Location 1										
Apg	0-19	7,10	2,17	1,07	13,67	5,11	0,89	34,23	60,59	343
Adg	19-26	7,12	2,20	0,96	14,56	8,13	0,96	32,56	75,58	321
Bwg	26-68	6,78	1,47	0,86	12,21	6,12	0,41	32,21	60,85	342
Bwg	68-120	6,91	1,34	0,79	12,02	6,54	0,42	29,02	68,13	298
Location 2										
Apg	0-23	6,99	1,93	0,78	10,99	7,45	0,76	33,32	59,96	286
Adg	23-35	6,86	2,09	0,88	12,54	6,12	0,66	33,03	61,16	278
Bwg	35-87	6,77	1,54	0,75	10,00	6,87	0,54	28,32	64,12	298
Cg	87-110	7,14	1,23	0,72	9,06	5,77	0,54	26,13	61,58	270
Location 3										
Apg	0-14	6,82	2,50	0,96	9,89	6,89	0,87	32,89	56,58	321
Adg	14-24	6,67	2,23	0,87	10,12	8,34	0,76	34,23	58,69	309
Bwg	24-50	6,60	1,87	0,54	8,76	7,79	0,54	29,03	60,73	280
Cg	50-90	6,63	1,20	0,41	8,76	7,67	0,57	28,76	60,54	290

The cation exchange capacity (CEC) at the three observation sites showed that most were in the high category. Paddy field soil has a high CEC because paddy field soil has a plow pad layer that inhibits leaching and the dissolution of exchanged bases into the lower layers (Sukarman et al., 2020). Table 4 shows that the first location of the Apg horizon has a high CEC with a value of 32.23 cmol/kg. The lower horizon has a lower CEC, with values ranging from 29.02 to 32.56 cmol/kg. The locations of the two CECs of the surface horizon soils are also higher than those of the subsoil below them. The CEC value of the soil in the surface layer of the Apg horizon was 33.32 cmol/kg, while the horizon below the soil CEC was 33.03 cmol/kg for the Adg horizon, 28.32 cmol/kg for the Bwg horizon, and 26.13 cmol/kg for the Cg horizon. The three highest soil CEC locations were in the plow tread layer with a value of 34.23 cmol/kg, followed by the surface layer with a value of 32.89 cmol/kg.

The base saturation (BS) of three research locations showed high values above 50%. Such conditions indicate that the observed paddy soil has high exchange bases due to the condition of the soil having plow tread layers, resulting in dissolving infiltration and decreased leaching of base cations (Firmansyah & Subowo, 2012). The highest first-location base saturation value was in the plow tread layer (Apg), with a value of 75.58%. Dissolved and precipitated cations in the plow tread layer. Such conditions are in accordance with Munir's statement (2005) that basic cations will accumulate on top of the plow tread layer, such as K, Mg, Ca, and Na. Likewise, at the second and third locations, the soil surface has a lower base saturation value.

3.5. Soil Classification

Soil classification in paddy fields is based on observations of land morphology and soil characteristics (Ferdeanty *et al*., 2020). The classification of paddy fields on the slopes of Mount Argopura is shown in Table 5. The first location has a height of 28 meters above sea level (masl) and a flat relief (0–3%). Location 1 has alluvial parent material, which includes accumulation from the sedimentation process, so that it has the characteristics of a mollic epipedon. Based on Dengiz *et al*. (2012) and Soil Survey Staff (2015), the mollic epipedon has characteristics with a thickness of > 18 cm, a dark color value, or chroma < 3, an organic matter content > 0.6% higher than in the C horizon, and a base saturation (KB) > 50%. The base saturation of the epipedon at location 1 has a value of 60.59%, a value and chroma of 5/2, and a soil color of 10YR5/2. The endopedon in this pedon is included in the argillic endopedon because there is a significant increase in clay in the B horizon from the A horizon by 4%. The results of laboratory analysis showed that location 1 was based on the USDA soil classification in the Inceptisol order category. The soil classification at location 1 based on the USDA classification is included in the Inceptisol order because the soil is included in the pedogenesis category. The sub-order of Aquepts exists because most of the soil on the surface is in aquic conditions. This condition is characterized by other characteristics of redoximorphic conditions resulting from repeated flooding and drying processes. The subgroup at location 1 is included in Hydraquentic humaquepts because it has an epipedon with a soil organic C value of 2.17%. Based on the national soil classification system, location 1 is classified as a mollic Gleisol soil type. Gleisol mollic is a type of soil that has an ABgC horizon where hydromorphic conditions occur to a depth of 50 cm, an A mollic epipedon, and a base saturation of >50% (D. S. Subardja et al., 2014). Meanwhile, based on the FAO/WRB soil classification, location 1 is in the Molic epireductic Gleisol (Aphihumic) category. Epireductic is a condition where the soil is reductive at a depth of up to 50 cm. Aphihumic is a soil condition containing organic matter in all conditions with a value of >1% (Azuka *et al*., 2015; IUSS Working Group WRB, 2014).

Location 2 is at an altitude of 27 meters above sea level with a flat land topography and the parent material of Mount Argopura volcanic tuff. Location 2 epipedons form in the category of ochric epipedons. It is said that the epipedon is okric at this location because the results of the identification of the features and characteristics of the epipedon do not meet the seven epipedons considering the thin thickness of 18 cm and supported by a color value > 3 (bright) (Dengiz *et al*., 2012; Sitinjak *et al*., 2019; Ferdeanty *et al*., 2020). The light color in epipedon location 2 is bright because C-organic has a lower value than endopedon. C-organic in the epipedon has a value of 1.93%. The endopedon from Pedon 2 location analysis is included in the cambic category because the development of newly developed soil with the level of clay accumulation is not much different from the horizon above it. Soil types based on the USDA are in the Inceptisol order and the Aquepts sub-order. Aquepts is an inceptisol soil condition in a saturated condition and undergoing a process of gleization, as indicated by the arrangement of the horizon at this location. ApgAdgBwgCg. The subgroup is typic epiaquepts because at the location of pedon 2, the soil experiences episaturation (Abate *et al*., 2014; Soil Survey Staff, 2015). The type of clay mineralogy is classified as a 1:1 type of kaolinite, so that in the USDA classification system, the family level is composed of Typic Epiaquepts, fine, kaolinitic, and isohyperthermic.

The national classification of soils in Pedon 2 is classified at the level of gleisol types, and gleisol types are eutric. Gleisols are soils with hydromorphic conditions from the surface to a depth of 50cm, having an Aokric epipedon and a B-cambic endopedon (Rahayu *et al*., 2014; D. Subardja *et al*., 2014). The types of soil in this classification system in Pedon 2 include eutric gleisols because they have a base saturation of more than 50%. According to the WRB/FAO in Pedon 2, it is classified as an epiutric reductive gleysol (ochric, clayic) soil type.

Table 5. Characteristic horizons and soil classification of paddy fields in the study area

Pedons/Classifications	Location Pedon 1	Location Pedon 2	Location Pedon 3
Epipedon	Mollic	Okric	Okric
Endopedon	Argillic	Cambic	Cambic
Humidity regime	Aquic	Aquic	Aquic
Soil temperature	isohyperthermic	isohyperthermic	isohyperthermic
USDA Soil Taxonomy			
Ordo	Inceptisols	Inceptisols	Inceptisols
Subordo	Aquepts	Aquepts	Aquepts
Grup	Humaquepts	Epiaquepts	Epiaquepts
Subgrup	Hydraquentic Humaquepts	Typic Epiaquepts	Aeric Epiaquepts
Family	Hydraquentic Humaquepts, medium, smectit, isohipertermik	Typic Epiaquepts, fine, kaolinitic, isohyperthermic	Aeric Epiaquepts, medium, kaolinitic, isohyperthermic
Indonesian soil classification			
Type of soil	Gleisol	Gleisol	Gleisol
Subgrup	Gleisol mollic	Gleisol eutrik	Gleisol eutrik
FAO soil classification			
Type of soil	Molik epireductic Gleisol (Aphihumic)	epiutric reductive gleysol (ochric, clayic)	epiutric reductive gleysol (ochric, siltic)

The third pedon is located at an altitude of 38 meters above sea level, with the parent material being Mount Argopura volcanic tuff. The topographical condition in this pedon is in the flat category, and the results of the identification of the ochric epipedon indicate a soil color of 10YR5/3. Soil depth of 50 cm consisting of Apg, Adg, and Bwg horizons. Endopedon analysis results in the category of cambic endopedon because the development of new soil develops with the level of clay accumulation not much different from the horizon above it (Odunze & Kureh, 2009; Soil Survey Staff, 2015). The results of laboratory analysis showed that the USDA soil classification was Inceptisol with the Aquepts sub-order due to long periods of inundation and gleization. The subgroup in pedon 3 Aeric Epiaquepts is inceptisol with a soil depth of 75 cm, which includes the Cg horizon from the soil surface, which has a hue value of 10 with a value > 3 and chroma > 3. Family level in the USDA soil classification system is Aeric Epiaquepts, medium, cholinitic, isohyperthermic due to the fine soil fraction with a clay content of 18–35%, a mineralogy type of 1:1 clay type with kaolinite type, and a temperature difference of 2.4 ^{o}C. The national soil classification in Pedon 3 includes gleisol soil types and eutric gleisol soil types. Gleisols are eutric because gleized paddy soil has a base saturation of >50% (KB epipedon 56.58–58.69%, endopedon 60.73%). The WRB/FAO soil classification in pedon 3 is included in the epiutric reductive gleysol (ochric, siltic).

4.CONCLUSIONS

Based on the research, it was concluded that the average rainfall of paddy fields at the foot of Mount Argopura is 2,275±514 mm/year and that a coefficient of variation of 23% is formed in alluvium formations, Argopura volcanic rocks, Argopura tuff, Semeru volcanic deposits, Puger formations, and Mandalika formations. The morphological horizons of the soil resulting from genesis in paddy fields are generally Apg, Adg, Bwg, and Cg. Soil classification in pedon 1 according to USDA Hydraquentic Humaquepts, medium, smectite, isohyperthermic; Gleisol Molik national soil classification; and according to WRB/FAO Molik epireductic Gleisol (Aphihumic). Soil classification in Pedon 2 according to USDA Typic Epiaquepts: fine, kaolinitic, isohyperthermic; Gleisol national soil classification: eutric; WRB/FAO epiutric reductive gleysol (ochric, clayic). Soil classification in Pedon 3 Aeric Epiaquepts: moderate, cholinitic, isohyperthermic; Gleisol national soil classification: eutric; WRB/FAO epiutric reductive gleysol (ochric, siltic).

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