SUBMISSION

UNGMail

Nurdin <nurdin@ung.ac.id>

[Dokuchaev Soil Bulletin] Submission Acknowledgement

1 pesan

Редакция ж. Бюллетень Почвенного института <no-reply@subs.elpub.science> 12 Juli 2021 pukul 15.31
Balas Ke: "Редакция ж. Бюллетень Почвенного института" <bulletin@esoil.ru>
Kepada: Nurdin Kyai Baderan <nurdin@ung.ac.id>

Nurdin Kyai Baderan:

Thank you for submitting the manuscript, "Characterization and Soil Classification as Determining of Upland Quality in Bulia Micro Watershed, Indonesia" to Dokuchaev Soil Bulletin. With the online journal management system that we are using, you will be able to track its progress through the editorial process by logging in to the journal web site:

Manuscript URL: https://bulletin.esoil.ru/jour/author/submission/665

Username: nurdin

If you have any questions, please contact me. Thank you for considering this journal as a venue for your work.

Редакция ж. Бюллетень Почвенного института
Dokuchaev Soil Bulletin

---

journal

Bulletin of V.V. Dokuchaev Soil Science Institute

#665 RESUME

- Summary
- Reviews
- Editorial

Article

Authors	Nurdin ., Rayes ML, Soemarno ., Sudarto ., Listyarini E., Agustina C., Rahman R., Rauf A., Husain J.
Name	Soils in the Bulia micro watershed of Gorontalo province, Indonesia, and their quality assessment
Orig. file	665-1936-1-SM.docx 07/12/2021
Add. files	No
Sent	Nurdin Nurdin Kyai Baderan
Deposited (date)	July 12, 2021 - 00:00
Chapter	Articles
Editor	Anna Romanovskaya
Viewing Annotations	367

Status

Status	Published No. 108 (2021)
In progress	19.10.2021
Changed	19.10.2021

Article metadata

Authors

Surname	Nurdin
Institutions (list)	Gorontalo State University
A country	Indonesia
Briefly about yourself	Department of Agrotechnology
ORCID	0000-0001-5725-5694

Person (author) for communication with the editors.

Surname	M. L. Rayes
Institutions (list)	Brawijaya University
A country	Indonesia
Briefly about yourself	Soil Science
ORCID	
Surname	Soemarno
Institutions (list)	Brawijaya University
A country	Indonesia
Briefly about yourself	Soil Science
ORCID	
Surname	Sudarto
Institutions (list)	Brawijaya University
A country	Indonesia
Briefly about yourself	Soil Science
ORCID	
Surname	E. Listyarini
Institutions (list)	Brawijaya University

A country	Indonesia
Briefly about yourself	Soil Science
ORCID	
Surname	C. Agustina
Institutions (list)	Brawijaya University
A country	Indonesia
Briefly about yourself	Soil Science
ORCID	
Surname	R. Rahman
Institutions (list)	Gorontalo State University
A country	Indonesia
Briefly about yourself	Agrotechnology
ORCID	
Surname	A. Rauf
Institutions (list)	Gorontalo State University
A country	Indonesia
Briefly about yourself	Agribusiness
ORCID	
Surname	J. Husain
Institutions (list)	Sam Ratulangi University
A country	Indonesia
Briefly about yourself	Soil Science
ORCID	

Title and abstract

Name: Soils in the Bulia micro watershed of Gorontalo province, Indonesia, and their quality assessment

annotation: Ten representative pedons from the Bulia micro watershed of Gorontalo Province, Indonesia, were characterized and classified to determine its land quality (LQ) class. Angular blocky, sticky, plastic consistencies and a hard consistency prevailed in the soil structure. In the alluvial plains the soil texture is dominated by the clay fraction, while in the hills and volcanic mountains the sand fraction is dominated. The soils in the Bulia micro watershed also have acid to neutral reaction, with the range of very low to high OC (organic carbon) levels, the reserve of exchangeable bases was dominated by Ca 2+ in two series patterns, namely : $Ca^{2+} > Mg^{+} > Na^{+} > K^{+}$ and $Ca2^{+} > Na+ > Mg^{+} > K^{+}$, cation exchange capacity (CEC) ranged from low to very high, and the base saturation varied from moderate to very high. The alluvial plain is represented by Inceptisol in P1 and Typic Humustepts (P7), also by Oxic Humustepts (P3), then Mollisol on P4 (Typic Argiudolls) and Typic Haplustolls (P6), Alfisol on P5 (Typic Paleustalfs). Entisol on P2 (Typic Ustipsamments) was found in volcanic mountains and P9 (Typic Paleustolls) P8 (Ultic Paleustalfs), P10 (Inceptic Haplustalfs) are typical of volcanic hills. On the alluvial plains the land was categorized as the LQ class II, III and IV, the volcanic mountains were the LQ class IV, while the land on the volcanic hills was categorized as the LQ class VI. River bank erosion on the land river terraces can be held by the manufacture of gabions, talud, cliff reinforcement plants and terraces.

Indexing

Keywords: characterization; classification; soils of Indonesia; land quality; the Bulia watershed

Language: en

Sponsors

Organizations: Faculty of Agriculture, Brawijaya University

OpenAIRE Specific Metadata

ProjectID: –

Bibliography

Bibliography

1. Afandi FN, Siswanto B., Nuraini Y., Effect of giving various types of organic material on soil chemical properties on the growth and production of sweet potato plants in Entisol Ngrangkah Pawon, Kediri, Soil and Land Resources, 2015, Vol. 2(2), pp. 237–244, URL: http://jtsl.ub.ac.id.
2. Anastasia I., Izatti M., Suedy SWA, The effect of giving a combination of solid organic fertilizer and liquid organic on soil porosity and spinach plant growth (Amarantus tricolor L.), Biology Journal, 2014, Vol. 3(2), pp. 1–10.
3. Beinroth FH, Eswaran H., Reich PF, Global assessment of land quality, sustaining the global farm, Selected papers from the 10th International Soil Conservation Organization Meeting, 2001, pp. 569–574.
4. BPS Gorontalo Province, Gorontalo province in figure 2020, BPS Gorontalo Province, 2020, 1102001.75(75560.2004), pp. 1–535.
5. BPS Gorontalo Regency, Gorontalo regency in figure 2020, BPS Gorontalo Regency, 2020, 1102001.75(75020.2003), pp. 1–262.
6. Dutta M., Land use planning of Tipukjan watershed of Sivasagar district using GIS and remote sensing technique: Ph.D. Thesis, Assam Agricultural University, Jorhat, 2009.
7. Damaiyanti DRR, Aini N., Koesrihati, The study of organic mulch application on the growth and yield of red pepper (Capsicum annuum L.), Crop Production Journal, 2013, Vol. 1(2), pp. 25–32.
8. Devi PAV, Naidu MVS, Rao AR, Characterization and classification of sugarcane growing soils in southern agro-climatic zone: A case study in eastern mandals of Chittoor district in Andhra Pradesh, Journal of the Indian Society of Soil Science, 2015, Vol . 63(3), pp. 245–258, DOI: 10.5958/0974-0228.2015.00034.1.
9. Eruola AO, Bello NJ, Ufoegbune GC, Makinde AA, Effect of mulching on soil temperature and moisture regime on emergence, growth and yield of white yam in a tropical wet-and-dry climate, International Journal of Agriculture and Forestry, 2012 , Vol. 2(1), pp. 93–100, DOI: 10.5923/j.ijaf.20120201.15.
10. Eviyati, Sulaeman, Analysis of soil, chemical, plants, water, and fertilizer, Indonesia Center of Soil Research, 2009, pp. 1–203.
11. Husain J., Luntungan JN, Kamagi YEB, Nurdin B., Conservation-based corn farming model in Gorontalo Province. research report. Research, Development and Regional Environmental Impact Control Agency Gorontalo Province, Gorontalo, 2004.
12. Haridjaja O., Baskoro DPT, Setianingsih M., Different levels of field capacity by alhricks, free drainage, and pressure methods plate at different soil texture and relation for sunflower growth (Helianthus annuus L.), Soil Science and Environmental Journal, 2013, Vol. 15(2), 52p, DOI: 10.29244/jitl.15.2.52-59.
13. Intara YI, Sapei A., Sembiring EN, Djoefrie MHB, Affected of organic matter application at clay and clay loam soil texture on water holding capacity, Indonesian Agriculture Sciences Journal, 2011, Vol. 16(2), pp. 130–135.

14. Jambak MKFA, Baskoro DPT, Wahjunie ED, Characteristics of soil physic on soil conservation tillage system (Case study of Cikabayan Research Farm, Bogor), Soil and Land Bulletin, 2017, Vol. 1(1), pp. 44–50.
15. Jackson ML, Soil chemical analysis, New Delhi: Prentice Hall of India (Pvt.) Ltd., 1973, 498 p.
16. Kadao SH, Prasad J., Gajbhlye KS, Characterization and classification of some typical banana growing soils of Wardha district of Maharashtra, Agropedology, 2003, Vol. 13(2), pp. 28–34.
17. Ludwig A., Bradford P., David B., Anton W., Vegetation patches and runoff-erosion as interacting ecohydrological processes in semiarid landscapes, Ecology, 2007, Vol. 86, pp. 288–297, DOI: 10.1890/03-0569.
18. Mahapatra SK, Nagdev R., Gopal R., Surya JN, Meena RK, Yadav RP, Singh SK, Characterization and classification of the soils of Buraka micro-watershed in Haryana for integrated development, Journal of the Indian Society of Soil Science , 2019, Vol. 67(2), pp. 137–150, DOI: 10.5958/0974-0228.2019.00015.X.
19. Manik H., Marpaung P., Sabrina T., The level of soil development based on the pattern of clay mineral distribution in Subdistric Lumbanjulu, Distric of Toba Samosir, Agroteknologi FP USU, 2017, Vol. 5(2), pp. 422–433.
20. Nasruddin, Hanum H., Study of mulching effects on soil temperature, soil property, and growth of patchouli (Pogostemon cablin Benth), Floratek, 2015, Vol. 10, pp. 69–78.
21. Niranjana KV, Ramamurthy V., Hegde R., Srinivas S., Koyal A., Naidu LGK, Sarkar D., Characterization, classification and suitability evaluation of banana growing soils of Pulivendla region. Andhra Pradesh, Journal of the Indian Society of Soil Science, 2011, Vol. 59(1), pp. 1–5, URL: https://www.indianjournals.com/ijor.aspx?target=ijor:jisss&volume=59&issue=1&article=001.
22. Noor A., Vahlevi J., Fathurrozi., Slope stabilization for erosion control with soil bioengineering using vetiver grass, Poros Teknik, 2011, Vol. 3(2), pp. 69–74.
23. Nurdin, Development, classification and rainfed paddy soils potency derived from lacustrine materials in paguyaman, gorontalo. MSc Thesis Bogor Agriculture University, 2010a. URL: https://repository.ipb.ac.id/handle/123456789/57081
24. Nurdin, The morphology, physics and soil chemistry of inceptisol derived from lacustrine paguyaman of gorontalo relating to soil managements, Jurnal Agroteknotropika, 2010b, Vol. 1(1), pp. 13–22.
25. Nurdin, Development and rainfed paddy soils potency derived from lacustrine material in paguyaman, Gorontalo, J. Trop. Soils, 2011, Vol. 16(3), pp. 267–278, DOI: 10.5400/jts.2011.16.3.267.
26. Nurdin, Combination of soil conservation techniques and its effect on the yield of maize and soil erosion of dry land in biyonga sub-watershed, Gorontalo, J. Tek. Ling., 2012, Vol. 13(2), pp. 245–252.
27. Odjugo PAO, The effect of tillage systems and mulching on soil microclimate, growth and yield of yellow yam (Dioscorea cayenensis) in Midwestern Nigeria, African Journal of Biotechnology, 2008, Vol. 7(24), pp. 4500–4507, DOI: 10.4314/ajb.v7i24.59629.

28. Oldeman LR, Darmiyati S., An agroclimatic map of Sulawesi scale 1 – 2.500.000, Center Research for Agriculture, 1977, p. 1.
29. Puslitanak Research Team, Survey and mapping of semi-detailed soil resources (scale 1 : 50,000) in the North Sulawesi of Paguyaman area for the development of irrigation and sugarcane commodities. final report. Book III Attachment of the Land Series. Center for Soil and Agro-climate Research, Agency for Agricultural Research and Development, Indonesian Ministry of Agriculture, Bogor, 1995.
30. Prasetyo BH, Differentiation in Properties of vertisol from various parent materials, Indonesian Agriculture Sciences Journal, 2007, Vol. 9(1), pp. 20–31.
31. Rachman A., Gantzer J., Anderson SH, Soil hydraulic properties influenced by stiff-stemmed grass hedge systems, Soil Science Society of America Journal, 2004, Vol. 68(4), pp. 1386–1393, DOI: 10.2136/sssaj2004.1386.
32. Rachim DA, Characterization os soils with low activity clay, and the effect of iron oxides on some soil properties, PhD thesis, Bogor Agricultural University, 1994, URL: https://repository.ipb.ac.id/handle/123456789/2463?show=full.
33. Rachim DA, The foundamentals of soil genesis. Bogor: Departemen of Soil and Land Resources, Agriculture Faculty of Bogor Agriculture University, 2007, 41p.
34. Rahman A., Geographic information system model for estimating flow coefficient and its relationship with land cover in Riam Kanan River Basin of South Kalimantan Province, Bumi Lestari, 2013, Vol. 13(1), p. 1–8.
35. Sys C., Rast EV, Debaveye J., Land evaluation. Part II. Principles in land evaluation and crop production calculations. International Training Center for Post-Graduate Soil Scientists, University of Ghent, 1991.
36. Sarkar D., Gangipodhyay SK, Velayutham M., Soil toposequence relationship and classification in lower outlier of Chhotanagpur plateau, Agropedology, 2001, Vol. 11, pp. 29–36.
37. Swarnam TP, Velmurugan A., Rao YS, Characterization and classification of some soils from Shahibi basin in parts of Haryana and Delhi, Agropedology, 2004, Vol. 14, p. 114–122.
38. Singh C., Singh P., Singh R., Modern techniques of raising field crops, New Delhi: Oxford and IBH Publishing Co. Pvt. Ltd., 2004, pp. 1–583.
39. Satish S., Naidu MVS, Ramana KV, Munaswamy V., Reddy GP, Sudhakar P., Characterization and classification of the soils of Brahmanakotkur watershed in Kurnool district of Andhra Pradesh', Journal of the Indian Society of Soil Science, 2018 , Vol. 66(4), pp. 351–361, DOI: 10.5958/0974-0228.2018.00044.0.
40. Sinarta I., Methods of handling landslides with soil nailing', Paduraksa, 2014, Vol. 3(2), pp. 1–16.
41. Sireesha PVG, Naidu MVS, Clay mineralogy of soils developed from granite-gneiss of Kurnool District in Andhra Pradesh', Journal of the Indian Society of Soil Science, 2015, Vol. 63(1), pp. 16–23, DOI: 10.5958/0974-0228.2015.00003.1.

42. Soil survey manual, Soil Science Division Staff, United States Department of Agriculture (USDA), 2017, pp. 1–145, URL: https://www.iec.cat/mapasols/DocuInteres/PDF/Llibre50.pdf.
43. Soil Survey Staff, Keys to soil taxonomy, Soil Conservation Service - NRCS/USDA, 2014, Vol. 12, 360p.
44. Subardja D., Sudarsono, The influence of land quality on productivity of maize in soils derived from volcanic and sedimentary rocks in the bogor area, Soil and Climate Journal, 2005, Vol. 23, pp. 38–46.
45. Suharta N., The characteristic of soil developed from felsic sediments in west kalimantan province and its implication to land management, Soil and Climate Journal, 2007, Vol. 25, pp. 11–26.
46. Sukarman SR, Anda M., Suryani E., Guidelines for soil observation in the field, Agricultural Research and Development Agency, Ministry of Agriculture Republic of Indonesia, Bogor, 2017, pp. 1–149.
47. Supriya K., Naidu MVS, Kavitha P., Srinivasa MR, Characterization, classification and evaluation of soils in semi-arid region of Mahanandi Mandal in Kurnool district of Andhra Pradesh', Journal of the Indian Society of Soil Science, 2019, Vol. 67(2), pp. 125–136, DOI: 10.5958/0974-0228.2019.00014.8.
48. Susilawati S., Veronika V., Vetiver grass study as a continuous slope safety, Civil Engineering Communication Media, 2016, Vol. 22(2), p. 99, DOI: 10.14710/mkts.v22i2.12886.
49. Suyana J., Sumarno, Supriyono, Lestariningsih NP, Mulching and strengthening of terraces in three types of plants against surface runoff, erosion, growth and yield of plants in Andisols, Agrosains, 2017, Vol. 19(1), p. 15, DOI: 10.20961/agsjpa.v19i1.20924.
50. Vedadri U., Naidu MVS, Characterization, classification and evaluation of soils in semi-arid ecosystem of Chillakur mandal in SPSR Nellore district of Andhra Pradesh, Journal of the Indian Society of Soil Science, 2018, Vol. 66(1), pp. 9–19, DOI: 10.5958/0974-0228.2018.00002.6.
51. Walia CS, Rao YS, Characteristics and classification of some soils of the Trans-Yamuna plains, Journal of the Indian Society of Soil Science, 1997, Vol. 45(1), pp. 156–162.
52. Yasin MGH, Langgi WF, White grain maize as an alternative for staple food, Iptek Tanaman Pangan, 2015, Vol. 9(2), pp. 108–117.
53. Yatno E., Mulyanto B., Characteristics of soils formed from schist and their land suitability for cocoa crop in Kolaka and East Kolaka Regencies, Southeast Sulawesi, Soil and Climate Journal, 2016, Vol. 39(2), pp. 109–118.
54. Zulkarnain M., Prasetya B., Soemarno, Effects of compost, manure, and custom-bio on soil properties, growth and yield of sugarcane (Saccharum officinarum L.) in Entisol Kebun Ngrangkah of Pawon, Kediri, Indonesian Green Technology Journal , 2013, Vol. 2(1), pp. 45–52, URL: https://igtj.ub.ac.id/index.php/igtj/article/view/103.

ISSN 0136-1694 (Print)
ISSN 2312-4202 (Online)

FSBSI FRC "Soil Institute named after V.V. Dokuchaev,
119017, Moscow, Pyzhevsky per.,
7/2 tel.: 8(916)078-70-57
E-mail: bulletin@esoil.ru

#665 REVIEW

- Summary
- Reviews
- Editorial

Article

Authors	Nurdin ., Rayes ML, Soemarno ., Sudarto ., Listyarini E., Agustina C., Rahman R., Rauf A., Husain J.
Name	Soils in the Bulia micro watershed of Gorontalo province, Indonesia, and their quality assessment
Chapter	Articles
Editor	Anna Romanovskaya

Review

Round 1

Version rec. articles	665-1937-2-RV.docx 07/12/2021
In progress	04.08.2021
Changed	08/23/2021
Cash Files	No

Editor's Decision

Solution	Accept for publication 08.09.2021
Notify Editor	Correspondence record Editor/Author 08/23/2021

Ed. version	665-1938-1-ED.docx	07/12/2021	
Author's version	665-1949-1-ED.docx	08/24/2021	Delete
Download author's version	Choose File No file chosen	Upload	

ISSN 0136-1694 (Print)
ISSN 2312-4202 (Online)

FSBSI FRC "Soil Institute named after V.V. Dokuchaev,
119017, Moscow, Pyzhevsky per., 7/2 tel
.: 8(916)078-70-57
E-mail: bulletin@esoil.ru

Characterization and Soil Classification as Determining of Upland Quality in Bulia Micro Watershed of Gorontalo Province, Indonesia

Nurdin[*1], Mochtar Lutfi Rayes[2], Soemarno[2], Sudarto[2], Endang Listyarini[2], Christanti Agustina[2], Asda Rauf[3], Rival Rahman[1], Jailani Husain[4]

[1]*Department of Agrotechnology, Agriculture Faculty, Gorontalo State University, No. 6 General Sudirman Str., Wumialo, 96122 Gorontalo, Indonesia*
[2]*Department of Soil Science, Agriculture Faculty, Brawijaya University, No. 54 Veteran Str., Lowokwaru, 65145, Malang, Indonesia*
[3]*Department of Agribussiness, Agriculture Faculty, Gorontalo State University, No. 6 General Sudirman Str., Wumialo, 96122 Gorontalo, Indonesia*
[4]*Department of Soil Science, Agriculture Faculty, Sam Ratulangi University, No. 1 Kleak Bahu Str., Kleak, 95115 Manado, Indonesia*
[*]*https://orcid.org/0000-0001-5725-5694, e-mail: nurdin@ung.ac.id*
Received …………, Revised ………, Accepted ……………..

Abstract: Ten pedon representatives from the Bulia micro watershed of Gorontalo Province, Indonesia were studied for their morphology and physcochemical properties, soil classification and determine of land quality (LQ) class. The soil structure was dominated by angular blocky, sticky and plastic consistency, and hard consistency. In the alluvial plain the soil texture was dominated by clay fraction, while in the hills and volkan mountains was more dominated by sand fraction. Soils in the Bulia micro watershed also react sour to neutral, with very low to high OC levels, bases can be exchanged dominated by Ca^{2+} with two series patterns, namely: $Ca^{2+} > Mg^{+} > Na^{+} > K^{+}$ and Ca^{2+} > Na+ > $Mg^{+} > K^{+}$, CEC were low to very high, and the base saturation was moderate to very high. The main soils found were Entisol on P2 (Typic Ustipsamments)., Inceptisol on P1 and P7 (Typic Humustepts), and P3 (Oxic Humustepts)., Mollisol on P4 (Typic Argiudolls), P6 (Typic Haplustolls), and P9 (Typic Paleustolls)., and Alfisol on P5 (Typic Paleustalfs), P8 (Ultic Paleustalfs) and P10 (Inceptic Haplustalfs). Land on the alluvial plains were categorized as the II, III and IV of LQ classes, the volcanic mountains was the IV class of LQ, while the land on the volcanic hills were categorized as the VI of LQ class. River bank erosion on the land river terraces can implemented of the manufacture of gabions, talud, cliff reinforcement plants and terraces. Soil temperatures and high clay content can be applied by mulching and organic materials.

Keywords: Characterization, classification, soil, land quality, Bulia watershed.

INTRODUCTION

Land is one of the most important components of land resources where plants grow and produce food. Land and plant productivity is largely determined by soil characteristics and other land characteristics related to land quality (Subardja and Sudarsono, 2005). However, the intensity of tillage in agricultural cultivation and the pressure of land use that ignores aspects of conservation and its sustainability have resulted in a decrease in land quality, so that agricultural production tends to levelling or even decrease (Nurdin, 2012). Corn is an excellent commodity in the province of Gorontalo Indonesia, which has been intensively and massively cultivated since it was established as a primes commodity in the agropolitan program since 2001. Until 2019, hybrid corn yileds in Gorontalo Province has reached 1.7 million tons or increased by 9.3% from the 2018 year, but the productivity of the maize was still low at only 5.0 tons ha (BPS Gorontalo, Province 2020). In fact, the potential yield of corn in Indonesia can produce 10-11 tons/ha (Yasin et al., 2015), while the achievement of national productivity in 2018 will only be 5.2 tons/ha (Indonesian Ministry of Agriculture 2019).

The Bulia micro watershed area as a corn production centers that also functions to support the agricultural area below. The watershed has a vital roles because it supplies irrigation water for agriculture and other activities (Mahapatra *et al.*, 2019). Corn cultivation in this watershed has exceeded the carrying capacity indicated by the planting of corn to the slope of > 25%, so that land degradation often occurs. Soil erosion that occurred from corn agropolitan program of Gorontalo has reached 1,396 tons/ha/year (Husain et al., 2004). Meanwhile the achievement of corn productivity in this area is only 5.0 tons/ha (BPS Gorontalo Regency, 2020). This is presumably because corn was cultivated on land that is not suitable with the soil characteristics and land quality.

Soil characterization provides important information about the physical, chemical, mineralogical and microbiological characteristics of the soil for growing plants (Devi et al., 2015). For sustainable management of soil resources in agroecological areas, timely monitoring of important physical, chemical and biological soil characteristics and responses to changes in land management are needed (Supriya *et al.*, 2019). These soil characteristics then form the basis for land classification. The combination of soil characterization and soil classification is a powerful tool for developing management strategies for food security and environmental sustainability

(Satish *et al.*, 2018). However, efforts to link the characteristics and classification of land with specific land quality are still relatively rare. In fact, land quality is the ability of land to show a specific performance function before the land is degraded (Beinroth et al., 2001). An understanding of soil types and their distribution, constraints and potential is important for proper management to increase productivity and yields (Niranjana et al., 2011).

The survey and mapping of soil resources in the Paguyaman watershed was carried out by the Soil and Agro-climate Research Center of Indonesian Ministry of Agriculture (Puslittanak Research Team, 1995), but the scale of mapping was 1: 50,000. In 2010, research has been carried out on the development, classification and potential of paddy soils based on lacustrin based on toposequence (Nurdin, 2010), but only focused on rainfed paddy soils, while on dry land only as a comparison with locations close to the soil pedon the rice fields. In the interval of that time until 2019 there has not been a sweet research conducted in this area, so with consideration of the high intensity of land management and the massive cultivation of corn in this sub-watershed, this research is very important.

MATERIALS AND METHODS

Study location

The Bulia micro watershed is a part of the Paguyaman watershed located in the northern part and covers Mootilango and Boliyohuto District of Gorontalo Regency of Gorontalo Province, Indonesia (Figure 1). Geographically, the research location is located between 0°39'123 "and 0°51'321" N and 122°35'21 "and 122°43'12" S (Table 1) which was 67 km from Gorontalo City, Indonesia.

Overall, the Bulia micro watershed has an area of 21,456.58 ha consisting of upland were 18,993.44 ha (32.59%) and paddy fileds were 2,991.15 ha (13.94%). Specifically of upland agriculture covers agricultural land areas were 6,993.44 ha (37.87%), settlement areas were 461.59 ha (2.50%) and forest areas were 11,010.40 ha (59.63%). Soils in this area generally develop from volcanic material at the upper watershed and lacustrine deposits in the middle and bottom of watershed. The study area includes a tropical climate consisting of the rainy and dry seasonal. The average of annual rainfall was only 1,478 mm with the wet month of 1 month only and the dry month of 4 months, so it belongs to the E2 agro-climate zone (Oldeman and Darmiyati, 1977). The average of annual air temperature reaches 28.19°C with the maximum temperature of 28.73°C and the minimum temperature of 27.63°C. Under these conditions, the soil moisture regime were ustic and the soil temperature regime were isohypermics (Soil Survey Staff, 2014).

Table 1. Site characteristics of pedons in Bulia micro watershed

Pedon/ Villages	Location	Elevation (m msl)	Landform	Slope (%)	Drainage
P1, Tolite	0°39'44.80" N 122°35'27.20" S	24	Alluvial plain	0 – 3	Bad drained
P2, Monggolito	0°40'01.20" N 122°37'57.20" S	159	Volcanic mountain	15 – 30	Well drained
P3, Huyula	0°42'59.9" N 122°39'43.2" S	63	Alluvial plain	0 – 3	Moderately
P4, Payu	0°44'04.4" N 122°37'48.4" S	53	Alluvial plain	0 – 3	Moderately
P5, Pilomonu	0°43'53.80" N 122°35'22.60" S	75	Alluvial plain	0 – 3	Moderately
P6, Karyamukti	0°42'20.50" N 122°41'05.50" S	109	Alluvial plain	3 – 8	Moderately
P7, Karyamukti	0°42'10.30" N 122°41'19.40" S	114	Alluvial plain	3 – 8	Moderately
P8, Sukamaju	0°44'05" N 122°40'04" S	253	Volcanic hill	8 – 15	Well drained
P9, Payu	0°45'12" N 122°38'08" S	285	Volcanic hill	8 – 15	Well drained
P10, Huyula	0°43'11.10" N 122°40'31.20" S	262	Volcanic hill	8 – 15	Well drained

msl: mean sea level.

Soil surveying, soil characterization and classification

The soil survey was conducted on representative pedon through ten soil profiles. Description of soil morphology refers to the Soil Survey Manual (Soil Science Division Staff, 2017; Sukarman et al., 2017). Soil samples were taken at each horizon and analyzed the soil physical and chemical properties according to standard procedures (Jackson, 1973; Eviyati and Sulaeman, 2009). Together with climate and terrain conditions data, morphological data and soil properties were used for soil characterization. The soil classification according to the key soil taxonomy (Soil Survey Staff, 2014).

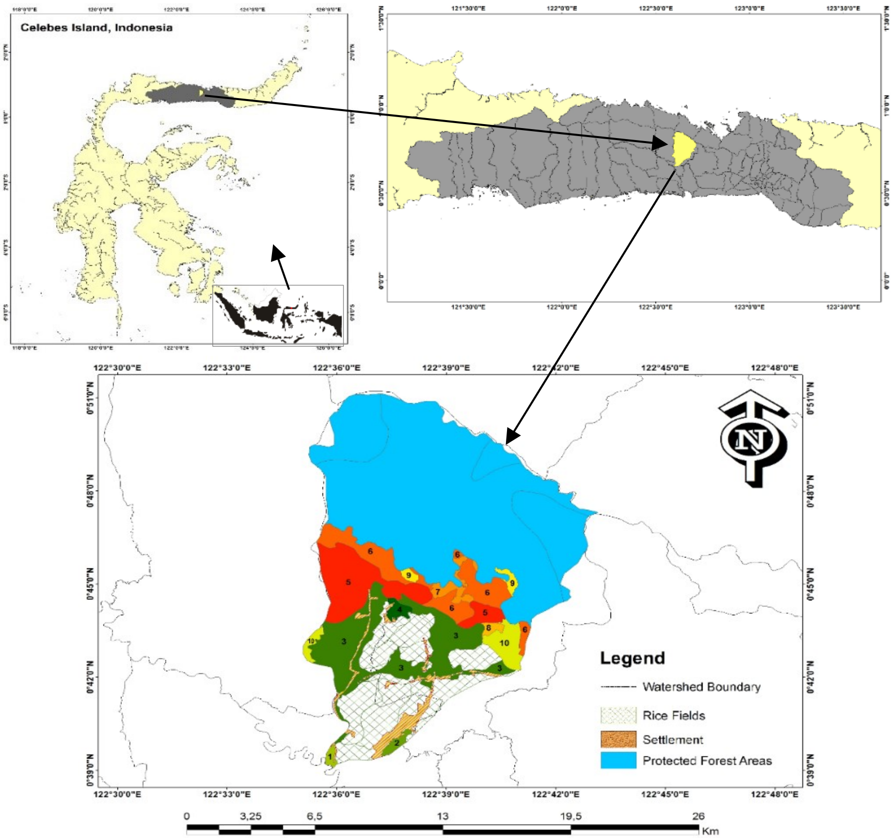


Fig 1. Location Map of Bulia Micro Watershed

Land quality assessment

Land quality (LQ) class assessment follows the method according to Beinroth et al. (2001) were modified based on previous soil characteristics and classifications. Soil pedons (P) that have been classified in taxa according to the Soil Taxonomy System (Soil Survey Staff, 2014) were combined with a land unit (LU) based on the similarity of criteria in the taxa. Soil and pedoklimat information was used to place each LU into I to IX land quality classes with class I having the most appropriate attributes and class IX attributes that are least suitable for crop production. The results of the land quality analysis are presented spatially with the help of Arc GIS and described.

RESULTS AND DISCUSSION

Morphology and soil physical properties

Based on the results of field studies and the laboratory characterization of ten soil pedons were presented in Table 2. Soils in the study area have been developed as indicated by the structuring of the horizon (horizons A and B) with the depth of soil solum varying from shallow to very deep. The soil color only consists of 7.5YR and 10YR hue, but 7.5YR is more dominantly. In the P1, P2, P3, P5, P8, P9 and P10 soil colors vary from dark brown, brown, to strong brown with hue 7.5YR, values range from 3 to 5 and chroma 1 to 6. While in P4, P6 and P7 soil color from very dark grayish brown, dark brown to dark yellowish brown with hue 10YR, values ranging from 3 to 4, and chroma 2 to 6. The higher the organic matter content, the darker the soil color (Suharta, 2007). The color of the soil horizon A is darker than horizon B due to the organic matter content in horizon A is higher than horizon B (Yatno and Mulyanto, 2016). Soil color seems to be a function of chemical and mineralogical composition (Swarnam *et al.*, 2004; Walia and Rao, 1997), as well as soil texture arrangements that are influenced by topographic position and humidity regimes (Walia and Rao, 1997).

The soil structure varies from crumbs, angular blocky, sub angular blocky to prismatics, but is more dominant angular blocky. In P1, P3, P4, P6, P7, P8, P9 and P10 were more dominant with angular blocky structure with sizes varying from fine, medium to coarse, and the level of structural development is weak and strong. While the soil structures of P2 and P5 varies from crumbs, angular blocky, sub angular blocky to prismatics with sizes ranging from fine, medium to coarse and the level of development of soil structures from weak, moderate to strong. The angular blocky soil structures was strongly associated with the presence of a higher number of clay fractions (Devi et al., 2015). While the crumbly soil structure shows newly developed soil (Manik et al., 2017), the addition of organic material continues to take care of organic material through plant biomass (Devi et al., 2015) or the tillage intensity which was carried out thoroughly by turning the soil over until damaged of structure soil (Jambak et al., 2017). Variation of soil structure will affecting the soil consistency.

Table 2. Morphological characteristics and soil physical properties in Bulia micro watershed

Pedon and Horizon	Depth (cm)	Color Moisture	Structures	Consitence			Sand	Silt	Clay	Texture Class
				w	m	d	%			
P1 (Aluvial Plain)										
Ap	0 - 23	7.5 YR 4/4	m, 3, abk	s, p	fi	h	9	40	51	Clay
Bw1	23 - 43	7.5 YR 4/2	m, 3, abk	ss, sp	fi	h	3	46	51	Silty Clay
Bw2	43 - 75	7.5 YR 4/4	m, 3, abk	ss, sp	fi	h	3	54	43	Silty Clay
Bw3	75 - 100	7.5 YR 4/2	m, 1, abk	ss, sp	vfi	vh	3	46	51	Silty Clay
P2 (Volcanic Mountains)										
Ap	0 - 5	7.5 YR 4/4	f, 1, cr	so, po	fr	l	85	10	5	Loamy sand
Bw1	5 - 37	7.5 YR 4/4	f, 2, sbk	so, po	fr	l	84	2	14	Loamy sand
Bw2	37 - 61	7.5 YR 4/4	m, 2, p	so, po	fr	l	75	10	15	Loamy sand
C	61+	7.5 YR 4/2	m, 3, p	so, po	fr	l	66	15	19	Clay Loam
P3 (Alluvial Plain)										
Ap	0 - 14	7.5 YR 3/3	f, 1, cr	ss, sp	fi	h	33	41	26	Loamy
Bw1	14 - 43	7.5 YR 4/4	f, 2, abk	s, p	fi	h	31	37	32	Clay Loam
Bw2	43 - 68	7.5 YR 4/4	f, 1, abk	ss, sp	fi	h	23	54	23	Silty Loam
Bw3	68+	10 YR 3/6	f, 1, cr	s, p	fi	h	23	48	29	Clay Loam
P4 (Alluvial Plain)										
Ap	0 - 14	10 YR 3/3	m, 3, abk	s, p	fi	h	27	26	47	Clay
Bw	14 - 50	10 YR 4/3	f, 1, abk	s, p	fi	h	32	34	34	Clay Loam
Bt1	50 - 81	10 YR 3/2	f, 1, abk	ss, sp	fi	h	12	24	64	Clay
Bt2	81+	7.5 YR 4/1	f, 1, abk	s, p	fi	h	16	25	59	Clay
P5 (Alluvial Plain)										
Ap	0 - 21	7.5 YR 4/4	f, 2, sbk	ss, sp	fi	h	23	43	34	Clay Loam
Bw	21 - 46	7.5 YR 4/4	f, 2, sbk	ss, sp	fi	h	23	48	29	Clay Loam
Bt1	46 - 84	7.5 YR 4/3	f, 2, abk	s, p	fi	h	25	35	40	Clay
Bt2	84 - 117	7.5 YR 4/6	m, 2, p	s, p	fi	h	24	36	40	Clay

Pedon and Horizon	Depth (cm)	Color Moisture	Structures	Consitence			Sand	Silt	Clay	Texture Class
				w	m	d	%			
Btg	117+	7.5 YR 5/8	m, 1, sbk	ss, sp	fi	h	8	46	46	Silty Loam
P6 (Alluvial Plain)										
Ap	0 - 12	10 YR 3/3	f, 1, abk	s, p	fi	h	84	15	1	Loamy Sand
Bw1	12-34	10 YR 3/4	f, 1, abk	s, p	fi	h	61	10	29	Sand Clay Loam
Bw2	34 - 71	10 YR 4/6	m, 3, abk	ss, sp	fi	h	61	24	15	Sandy Loam
C	71 - 90	7.5 YR 5/8	f, 1, cr	so, po	fr	l	84	5	11	Loamy Sand
P7 (Alluvial Plain)										
Ap	0 - 6	7.5 YR 4/6	m, 1, abk	s, p	fi	h	33	11	56	Clay
Bw1	6 - 17	10 YR 4/6	m, 3, sbk	s, p	fi	h	29	20	51	Clay
Bw2	17 - 33	10 YR 3/6	m, 1, abk	ss, sp	fi	h	21	20	59	Clay
Bt	33 - 49	10 YR 3/6	f, 1, p	ss, sp	fi	h	19	15	66	Clay
BC	49+	7.5 YR 4/6	f, 1, abk	ss, sp	fi	h	18	29	53	Clay
P8 (Volcanic Hills)										
Ap	0 - 7	7.5 YR 3/3	f, 1, abk	ss, sp	fi	h	64	10	26	Sandy Clay Loam
Bw	7 - 24	7.5 YR 3/3	m, 1, abk	s, p	fi	h	47	24	29	Sandy Clay Loam
Bt1	24 - 44	7.5 YR 4/6	f, 3, p	s, p	fi	h	45	15	40	Silty Loam
Bt2	44 - 63	7.5 YR 5/6	m, 3, abk	s, p	fi	h	42	16	42	Clay
Bt3	63+	7.5 YR 5/6	m, 1, abk	s, p	fi	h	42	6	52	Clay
P9 (Volcanic Hills)										
Ap	0 - 16	7.5 YR 3/2	m, 3, abk	vs, vp	vfi	vh	54	31	15	Loamy
Bw	16 - 34	7.5 YR 3/3	m, 1, abk	s, p	fi	h	42	24	34	Sandy Clay Loam
Bt	34+	7.5 YR 4/4	m, 1, abk	ss. sp	fi	h	50	15	35	Sandy Clay Loam
P10 (Volcanic Hills)										
Ap	0 - 20	7.5 YR 3/3	m, 3, abk	ss, sp	fi	h	48	26	26	Sandy clay loam
Bt1	20 - 44	7.5 YR 3/4	m, 3, abk	s, p	fi	h	41	15	44	Clay
Bt2	44 - 76	7.5 YR 4/6	c, 3, sbk	s, p	fi	h	42	14	44	Clay

Pedon and Horizon	Depth (cm)	Color Moisture	Structures	Consitence			Sand	Silt	Clay	Texture Class
				w	m	d	%			
BC	76+	5 YR 4/6	c, 3, p	vs, vp	vfi	vh	31	2	67	Clay

Structure: *size*: vf – very fine, f – fine, m – medium, c – coarse; *grade structureless*: 1 – weak, 2 – moderate, 3 – strong; *type*: cr – crumb, sg – single grain, abk – angular blocky,sbk – sub-angular blocky. Consistence: *dry* (d): s – soft, l – loose, sh – slightly hard, h – hard, vh – very hard, eh – extremely hard; *moist* (m): l – loose, fr – friable, fi – firm, vfi – very firm, efi – extremely firm, *wet* (w): so – non-sticky, ss – slightly sticky, s – sticky, vs – very sticky; po – non-plastic, ps – slightly plastic, p – plastic, vp – very plastic.

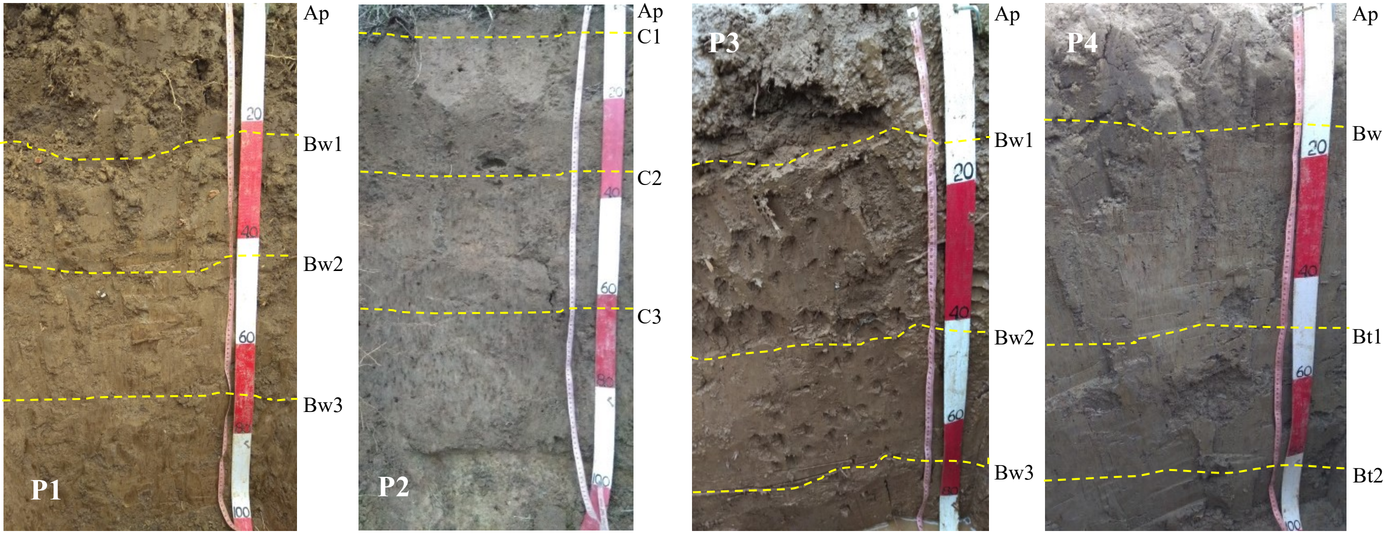


Fig 2. Soil profile appearance of pedon 1 (P1), 2 (P2), 3 (P3) and pedon 4 (P4)

Soil consistency in wet conditions varies from non-sticky and non-plastic on Pedon 2, slightly sticky and slightly plastic, sticky and plastic in the horizon on P1, P3, P4, P5, P6, P7, P8, P9 and P10, very sticky and very plastic on the surface horizon (Ap) of P9 and the subsurface horizon (BC) of P10, but more dominant slightly sticky and slightly plastic consistencies. While in moist conditions vary from loose, firm to very firm, but more dominantly firm consistencies. The P1, P3, P4, P5, P6, P7, P8, P9, and P10 were dominated by hard consistencies, while the P2 is loose. There is very hard consistency in P1 and P10 in the subsurface horizon (Bw and BC), while very hard consistency in surface horizon (Ap) is in P9 only. Consistency in dry conditions varies from loose, hard to very hard, but dominantly hard consistency. The P1, P3, P4, P5, P6, P7, P8, P9 and P10 were dominated by hard consistency, but in P1 and P10 in the subsurface horizon (Bw3 and BC) there is very hard consistency, while in P9 precisely the consistency is very hard found on the surface horizon (Ap). Sticky and plastic consistency might be due to high clay content in the soil (Sarkar et al., 2001); (Kadao et al., 2003), while non-sticky and non-plastic consistency might be caused by very little clay content (Sireesha and Naidu, 2015; Devi et al., 2015).

The soil texture of all pedons varies greatly from sandy clay loam, sandy loam, loamy sand, sandy loam, silty loam, clay loam, silty clay to clay, exceptly to P7 that was clay textured to all horizons. Wide variations of soil texture may be caused by variations in parent material, topography, in-situ weathering, and translocation of clays by eluviation and soil age (Satish et al. 2018). Apparently, pedons located in the alluvial group were more dominated by clay fractions, although the distribution patterns were irregular. Distribution of irregular clay fractions was typical of sediment material (Nurdin, 2010). While the volcanic group were dominated by the sand fraction. The distribution of sand and clay fractions shows the opposite pattern. The decrease in the sand fraction was not only due to the clay illuviation process, also due to the in situ mineral destruction process (Rachim 1994). The texture that engages in the subsurface horizon caused by higher weathering in the subsurface layer (Dutta, 2009). The clay content in the solum middles (B-iluviation) was higher than the upper horizon (A-eluviation) and the lower layer horizon which indicates the occurrence of a lessivage process with the discovery of the clay skins, so that an argillic horizon was formed in the P4, P5, P8, P9 and P10. While the remaining pedon, although the process of eluviation and iluviation has occurred, but has not found the clay skins, so the horizons were formed of cambic and candic.

Soil chemical properties

Soil chemical properties are presented in Table 3. Soil pH varies from acidity (pH 5.3) to neutral (pH 7.2). Apparently, pedons located on the upper watershed or volcanic groups (P2, P8, P9 and P10) has a lower pH than pedons located on the lower watershed or alluvial groups (P1, P3, P4, P5, P6, and P7). The pedon in the alluvial group was a depressed area which is the accumulation of bases carried by washing water from the hinterland section and the accumulation of more alkaline bases in soils with poorer drainage (Nurdin, 2010a). While pedon in the volcanic group experienced more intensive washing during rain due to better soil drainage. The trend of increasing pH with depth may be due to the release of organic acids during decomposition of organic matter and these acids may have lowered the pH at the surface of the soil (Satish *et al.*, 2018). The pH differences of KCl and pH of H_2O of all pedons shows a negative value. This means that all pedons are dominated by negatively charged clay minerals (Suharta, 2007). Acidic and slightly acidic soil pH values in P1, P3, P5, P9 and P10 indicate that the soil has undergone development but has not continued. While the neutral soil pH in P2, P4, P6, P7, and P8 shows that the soil is relatively new.

Organic carbon (OC) varies from very low to high (0.08 - 2.28%). The OC was all high in the surface horizon (Ap), exceptly P4 and P5. The height of OC at the ground surface was because in this part organic material accumulates. While the low OC at ground level in P4 and P5 were allegedly due to the intensity of tillage and transported during flooding because both pedons were around the border of the river. Low OC was thought to be due to faster degradation of organic material in the tropics and added the low of land cover, as stated by Vedadri and Naidu (2018). The high OC distribution pattern on the surface and decreases dramatically on the B horizon according to depth is a general pattern of soil that has developed (Prasetyo, 2007).

The bases can be exchanged for all pedons varying from very low, low, medium, high to very high. The bases can be exchanged more dominated by calcium (Ca^{2+}) which ranges from 2.54-18.02 cmol(+)kg^{-1}, while magnesium (Mg^{+}) ranges from 0.15-6.66 cmol(+)kg^{-1}, sodium (Na^{+}) ranges from 0.26-3.02 cmol(+)kg^{-1}, while potassium (K^{+}) ranges from 0.05-3.56 cmol(+)kg^{-1}. Based on the number of bases, the P1, P5, P7, and P10 patterns follow the sequence: $Ca^{2+} > Mg^{+} > Na^{+} > K^{+}$. This series pattern was the same as Nurdin (2011) and Satish et al. (2018) reported. While P2, P3, P4, P6, P8 and P9 follow the sequence: $Ca^{2+} > Na^{+} > Mg^{+} > K^{+}$. The high bases can be exchanged on the surface horizon (Ap) allegedly caused by fertilization.

The cation exchange capacity (CEC) varies from low (7.7 cmol(+)kg^{-1}) to very high (42.40 cmol(+)kg^{-1}) The CEC is influenced by levels of organic carbon and soil minerals (Prasetyo et al. 2007; Suharta 2007). It seems, the CEC in P1, P3, P4, P5, P7, P8, and P9 were more influenced by OC content than soil minerals. The higher the soil OC, the higher the CEC soils (Suharta, 2007). While P2, P6 and P10 were thought to be more influenced by soil minerals. These bases can be exchanged and this CEC will eventually affect the base saturation. Base saturation (BS) varies from moderate (40.55%) to very high (93%). All pedons generally have medium and high of BS, except P6 which has very high BS on the surface horizon (Ap). Variations in BS may be caused by variations in the nature and/or content of soil colloids and relatively high base saturation in surface layers can be attributed to recycling of cation base through vegetation (Devi and Kumar 2010). In addition, soil that has a number of bases was smaller than CEC, so BS tends to be lower, whereas soil that has a number of bases close to or higher than CEC, then BS tends to be higher (Nurdin, 2010b).

Soil classification

Based on morphological characteristics and soil characteristics, pedons are classified up to family level and found soil orders, namely Entisol, Inceptiol, Mollisol and Alfisol (Table 4). The P1 dan P7, which is located on a slope of 3% and 5%, founded of the molic epipedon on the 23 cm thick and the cambic horizon due to a clay texture class, did not has a combination of aquatic conditions within a depth of 50 cm from the ground or has been drained (humustept) and a moist color that has a color value of 4 , any color value with chroma of 2 or less as well as a angular blocky soil structures. In addition, it has more clay content than the below horizons or the above horizons. Based on these properties, then P1 and P7 were classified as fine, isohypermic, Typic Humustepts.

The P2, which is located on a slope of 15%, founded of the ochric epipedon on the 5 cm thick and the candic horizon due to an increase in the percentage of clay in the fine soil fraction with depths within a vertical distance of 15 cm or less, also a clay content of 4% or more (absolute), more than the horizon clay content above the horizon which has a total clay content in the fine soil fraction of less than 20%. In addition, it has a texture of sandy clay with particle size classes of sandy (psamments) and the CEC (NH_4OAc, pH 7) > 16 cmol(+)kg^{-1}. Based on these properties, P2 was classified as sandy, isohypermic, Typic Ustipsamments.

Table 3. Soil chemical properties in Bulia micro watershed

Pedon and Horizon	Depth (cm)	pH 1:1		OC (%)	Exchangeable cations				CEC	BS (%)
		H_2O	KCl 1N		K	Na	Ca	Mg		
					[cmol(+)kg^{-1}]					
P1 (Alluvial Plains)										
Ap	0 - 23	6.20	5.40	2.29	0.29	1.88	18.02	1.86	42.40	52.00
Bw1	23 - 43	6.00	5.20	0.90	0.18	2.01	15.47	2.97	39.19	52.62
Bw2	43 - 75	6.40	5.50	0.74	0.14	2.19	12.36	2.50	37.85	45.42
Bw3	75 - 100	6.50	5.60	0.65	0.14	2.23	15.22	3.26	37.58	55.49
P2 (Volcanic Mountains)										
Ap	0 - 5	6.50	5.60	1.19	0.10	0.34	3.77	0.30	11.13	40.55
Bw1	5 - 37	6.10	5.20	0.55	0.08	0.34	4.20	0.60	7.75	67.49
Bw2	37 - 61	6.20	5.30	0.63	0.08	0.35	3.91	0.15	8.87	50.52
C	61+	6.20	5.30	0.56	0.08	0.36	6.51	0.76	12.29	62.79
P3 (Alluvial Plain)										
Ap	0 - 14	5.60	4.60	0.80	0.05	1.46	4.84	0.61	16.15	43.00
Bw1	14 - 43	6.00	5.10	0.41	0.09	1.57	7.72	1.70	19.78	56.00
Bw2	43 - 68	5.80	4.90	0.32	0.05	1.55	8.95	0.91	21.58	53.00
Bw3	> 68	6.20	5.20	0.48	0.05	1.55	10.12	0.76	20.43	61.00
P4 (Alluvial Plains)										
Ap	0 - 14	6.50	6.10	0.41	0.06	1.49	11.87	0.62	25.55	55.00
Bw	14 - 50	6.70	6.30	0.96	0.19	1.43	9.71	2.12	21.60	62.00
Bt1	50 - 81	7.00	6.00	0.41	0.12	1.58	16.54	2.01	35.19	58.00
Bt2	81+	5.80	5.00	0.24	0.09	1.56	13.47	6.66	33.04	66.00
P5 (Alluvial Plains)										
Ap	0 - 21	5.20	4.50	0.08	0.16	2.29	9.39	2.93	28.39	52.00
Bw	21 - 46	5.10	4.30	0.49	0.20	2.30	8.62	3.08	28.40	50.00
Bt1	46 - 84	5.70	4.90	0.57	0.12	0.26	7.69	2.00	21.56	47.00

Pedon and Horizon	Depth (cm)	pH 1:1		OC (%)	Exchangeable cations				CEC	BS (%)
		H_2O	KCl 1N		K	Na	Ca	Mg		
					[cmol(+)kg^{-1}]					
Bt2	84 - 117	5.10	4.20	0.50	0.17	0.30	10.38	2.05	31.34	41.00
Btg	117+	5.10	4.10	0.42	0.25	0.34	15.37	1.90	38.58	46.00
P6 (Alluvial Plains)										
Ap	0 - 12	7.20	6.60	0.64	3.56	3.02	2.54	0.91	10.76	93.00
Bw1	12 - 34	7.10	6.60	0.32	0.28	1.72	6.03	0.30	11.79	71.00
Bw2	34 - 71	7.00	6.00	0.56	0.16	0.39	7.84	0.15	17.16	50.00
C	71 - 90	6.80	6.00	0.40	0.12	0.38	6.49	0.15	13.96	51.00
P7 (Alluvial Plains)										
Ap	0 - 6	6.30	5.40	0.76	0.10	0.42	5.31	2.41	18.31	45.00
Bw1	6 - 17	6.10	5.10	0.57	0.09	0.39	6.77	2.15	22.99	41.00
Bw2	17 - 33	5.90	5.00	0.57	0.07	0.44	8.55	4.04	25.45	51.00
Bt	33 - 49	5.60	4.80	0.33	0.08	0.45	13.64	3.72	29.79	60.00
BC	49+	5.90	5.00	0.41	0.12	2.04	13.16	0.31	33.06	47.00
P8 (Volcanic Hills)										
Ap	0 - 7	6.00	5.20	0.96	0.24	2.09	10.15	0.45	19.40	67.00
Bw	7 - 24	6.40	5.50	0.80	0.17	2.05	10.30	0.61	21.55	61.00
Bt1	24 - 44	6.70	5.80	0.48	0.24	2.21	10.07	1.83	26.06	55.00
Bt2	44 - 63	6.60	5.60	0.49	0.33	2.21	9.47	0.78	26.52	48.00
Bt3	63+	6.60	5.60	0.50	0.49	2.35	13.84	1.27	32.83	55.00
P9 (Volcanic Hills)										
Ap	0 - 16	5.30	4.50	0.80	0.13	2.15	10.15	0.61	24.80	53.00
Bw	16 - 34	6.20	5.30	0.57	0.10	2.30	12.44	0.77	29.51	53.00
Bt	34+	6.20	5.20	0.48	0.06	2.25	13.49	0.46	30.54	53.00
P10 (Volcanic Hills)										
Ap	0 - 20	5.80	4.90	0.72	0.12	0.40	5.90	1.21	18.31	41.69

Pedon and Horizon	Depth (cm)	pH 1:1		OC (%)	Exchangeable cations				CEC	BS (%)
		H_2O	KCl 1N		K	Na	Ca	Mg		
					[cmol(+)kg^{-1}]					
Bt1	20 - 44	6.10	5.20	0.64	0.05	0.40	8.23	0.46	18.44	49.59
Bt2	44 - 76	6.30	5.30	0.48	0.05	0.39	7.26	0.76	19.36	43.66
BC	76+	5.80	5.30	0.33	0.06	0.42	11.28	2.04	25.64	53.82

CEC: cation exchange capacity, OC: organic carbon, BS: base saturation.

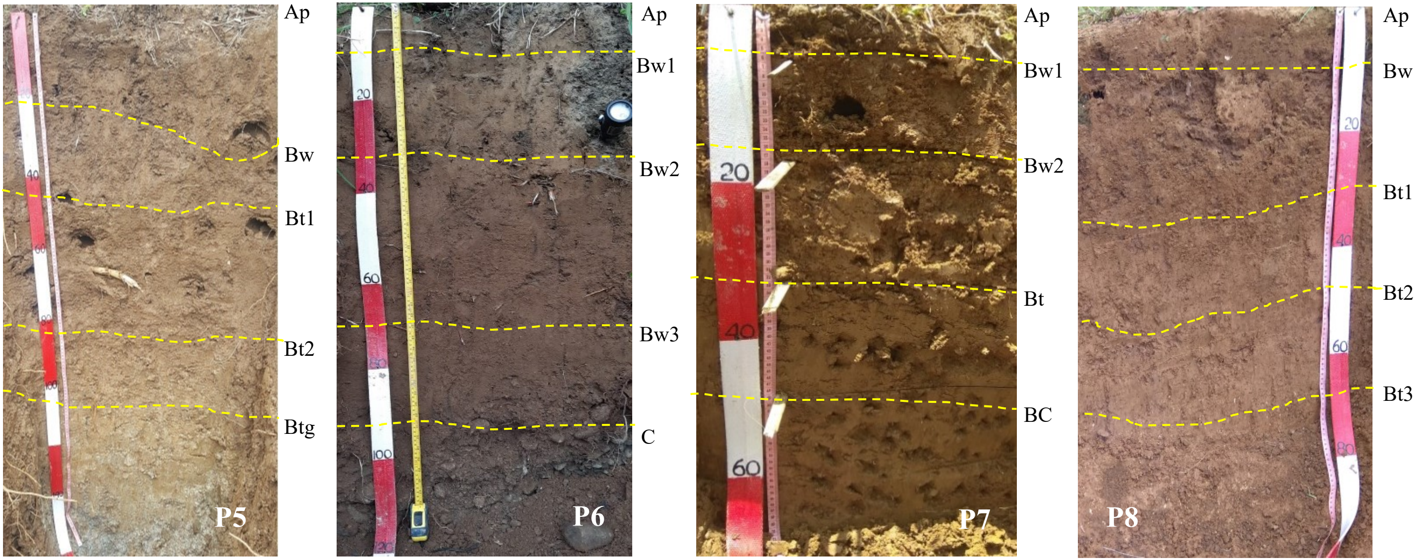


Fig 3. Soil profile appearance of pedon 5 (P5), 6 (P6), 7 (P7) and pedon 8 (P8)

The P3 which is located on a slope of 1%, founded of the umbric epipedon on the 14 cm thick and the cambic horizon due to clay loam textures, did not has a combination of aquatic conditions within 50 cm from the ground surface or has been drained (humustept) and moist colors that has color values 4, any color value with chroma 2 or less and already has a sub angular blocky soil structure. In addition, it has more clay content than the below horizons or the above horizons and the CEC (NH_4OAc 1N) value was 17.96 cmol(+)kg^{-1} only or oxic. Based on these properties, the P3 was classified as fine loamy, isohypermic, Oxic Humustepts.

The P4, which is located on a slope of 15%, founded of the molic epipedon (BS 55%) on the 14 thick and the argillic horizon because it has a fine loamy of particle size classes, and also has a clay skin that it coating of the pore walls and the ped surface. In addition, clay was added by 13% (> 8%) of the eluvial horizon and 10YR hue by having chroma ≤ 3, and BS > 75%. Based on these properties, P4 was classified as fine loamy, isohyperthermic, Typic Argiustolls.

The P5, which is located on a slope of 3%, founded of the ochric epipedon on the 21 cm thick and the argillic horizon because it has a fine loamy of particle size classes, and also has a clay skin that it coating of the pore walls and the ped surface. In addition, clay was added by 5 - 11% (> 1.2%) of the eluvial horizon and has the 7.5YR hue in all horizons (paleustalf). Based on these properties, P5 was classified as fine loamy, isohypermic, Typic Paleustalfs.

The P6, which is located on a slope of 3%, founded of the molic epipedon (BS 93%) on the 12 cm thick and the cambic horizon due to a sandy clay textures, did not has a combination of aquatic conditions within 50 cm from the ground or has drained (ustoll) and any color value with chroma <6 and has a sub angular blocky soil structure. In addition, it has more clay content than the below horizons. Based on these properties, P6 was classified as coarse loamy, isohyperthermic, Typic Haplustolls.

The P8 which is located on a slope of 5%, founded of the molic epipedon on the 7 cm thick and the argillic horizon due to a fine loamy of particle size classes, also has a clay skin that it coating of the pore walls and the ped surface. In addition, clay was added by 2 - 11% (> 1.2%) of the eluvial horizon and has the 7.5YR hue in all horizons (paleustalf), and the BS was 61% or > 75% only (ultic). Based on these properties, P8 was classified as fine loamy, isohypermic, Ultic Paleustalfs.

Table 4. Soil classification in Bulia micro watershed

Pedon	Soil Classification					Area	
	Order	Sub Order	Great Group	Sub Group	Family	ha	%
P1	Inceptisol	Ustept	Humustepts	Typic Humustepts	Fine, isohypertermic, Typic Humustepts	596.88	8.53
P2	Entisol	Psamment	Ustipsamments	Typic Ustipsamments	Sandy, isohypertermic, Typic Ustipsamments	472.68	6.76
P3	Inceptisol	Ustept	Humustepts	Oxic Humustepts	Fine loamy, isohypertermic, Oxic Humustepts	2,297.78	32.86
P4	Mollisol	Ustoll	Argiustolls	Typic Argiudolls	Fine, isohypertermic, Typic Argiustolls	107.35	1.54
P5	Alfisol	Ustalf	Paleustalfs	Typic Paleustalfs	Fine loamy, isohypertermic, Typic Paleustalfs	1,066.95	15.26
P6	Mollisol	Ustoll	Haplustolls	Typic Haplustolls	Coarse loamy, isohypertermic, Typic Haplustolls	1,026.23	14.67
P7	Inceptisol	Ustept	Humustepts	Typic Humustepts	Fine, isohypertermic, Typic Humustepts	248.4	3.55
P8	Alfisol	Ustalf	Paleustalfs	Ultic Paleustalfs	Fine loamy, isohypertermic, Ultic Paleustalfs	61.87	0.88

Pedon	Soil Classification					Area	
	Order	Sub Order	Great Group	Sub Group	Family	ha	%
P9	Mollisol	Ustoll	Paleustolls	Typic Paleustolls	Fine loamy, isohypertermic, Typic Paleustolls	48.35	0.69
P10	Alfisol	Ustalf	Haplustalfs	Inceptic Haplustalfs	Fine, isohypertermic, Inceptic Haplustalfs	1,066.95	15.26
Total						6,993.44	100.00

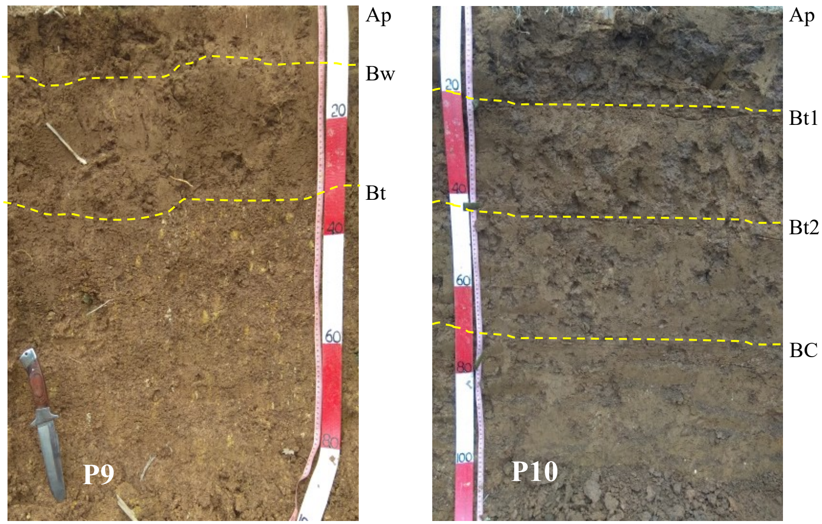


Fig 4. Soil profile appearance of pedon 9 (P9), and pedon 10 (P10)

The P9, which was located on an 8% slope, founded of the molic epipedon (BS 53%) on the 7 cm thick and the argillic horizon due to a fine loamy of particle size classes, also has a clay skin that it coating of the pore walls and the ped surface. In addition, clay was added by 19% (> 1.2%) of the eluvial horizon and has the 7.5YR hue with chroma of ≤ 4, and the BS of >75%. Based on these properties, P9 was classified as fine loamy, isohypermic, Typic Paleustolls.

The P10 which was located on a slope of 15%, founded of the molic epipedon (BS 57% 50%) on the 23 cm thick and the argillic horizon due to a fine clay of particle size classes, also has a clay skin that it coating of the pore walls and the ped surface. In addition, clay was added by 29% (> 1.2%) of the eluvial horizon and 10YR hue with chroma of ≤ 3, and BS >75%. Based on these properties, P10 was classified as fine, isohypermic, Inceptic Haplustalfs.

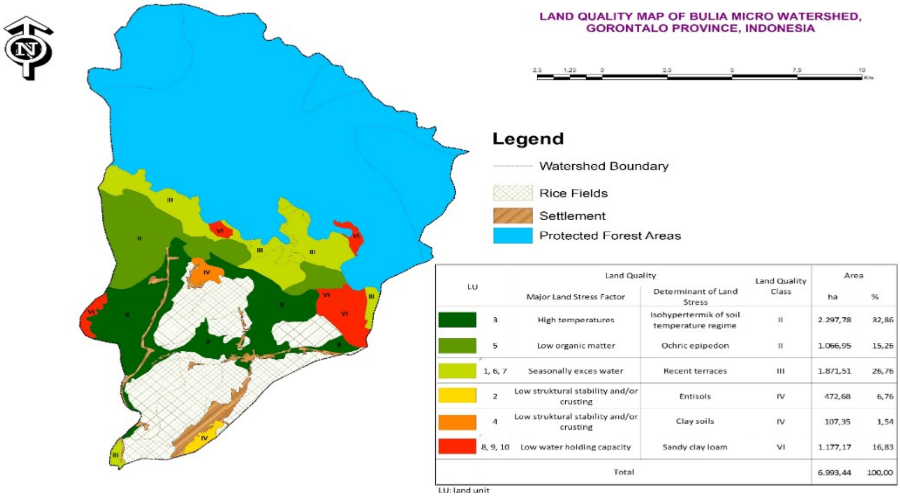
Land quality classes

The land quality (LQ) of the Bulia micro watershed was presented at Table 5 and Figure 5. The LQ of class II with the main factor determinant of land stress was high temperature and low organic matter factors. The high temperature of main factor with an indicator of isohypermic soil temperature regime at LU 3 (P3), and the factor of low ognic matter with an indicator of the ochric epipedon at LU 5 (P5) only. The LQ of class II is good land and has few problems for sustainable production, productivity is generally very high and as a result, the response to management is high (Beinroth et al., 2001). Land management through the addition of organic matter including green manure may be adopted along with recommended fertilizer doses (Sys et al., 1991; Singh et al., 2004; Mahaputra et al., 2019), the mulching to stabilize temperatures and maintain soil moisture (Odjugo, 2008); Eruola et al., 2012; Damaiyanti et al., 2013) were very important. In addition, the use of rice straw mulch and sawdust mulch influences soil properties by decreasing the value of bulk density, increasing soil porosity, increasing soil organic matter (Nasruddin and Hanum, 2015).

The LQ of class III with the main factor determining of land stress was seasonally exces water. The indicators determining of land stress in class III was the new terraces which were spread over of LU 1 (P1), LU 6 (P6) and LU 7 (P7). These new terraces are generally located around the border or river meanders which were prone to erosion and river bank landslides. The LQ of land class III was still considered good land and has few problems for sustainable production, but has a higher risk, especially for low input of corn production which results in a response to high management (Beinroth et al., 2001). Land management through the manufacture of gabions and riverbanks (Rahman, 2013), planting of river bank reinforcement plants and terrace reinforcement plants (Suyana *et al.*, 2017) was very important. Bioengineering methods for river bank erosion control commonly used include planting bamboo (Noor et al., 2011). Fine roots of plants play a role in strengthening the shear strength of the soil (Ludwig et al., 2007). The effectiveness of plants in reducing the rate of erosion is influenced by (1) the canopy or canopy of the plant, (2) the organic material produced, (3) the root system and the ability of plants to cover the soil (Rachman *et al.*, 2004). Vetiver plants were useful for stabilizing river banks, irrigation canals, river erosion control and coastal embankments, excavation slopes and embankments on highways, sand dunes, erosion on sloped agricultural land (Noor et al., 2011). Vetiver grass which has strong fibrous roots holds the ground (Susilawati and Veronika, 2016). Soil nailing was one of the most economical techniques for the stability of slopes of retaining walls because the system works quickly and does not require a large space (Sinarta, 2014); Noor et al., 2011).

Table 5. Land quality classes in Bulia micro watershed

Land Unit	Land Quality		Land Quality Class	Area	
	Major Land Stress Factor	Determinant of Land Stress		ha	%
3	High temperatures	Isohypertermik of soil temperature regime	II	2,297.78	32.86
5	Low organic matter	Ochric epipedon	II	1,066.95	15.26
1, 6, 7	Seasonally exces water	Recent terraces	III	1,871.51	26.76
2	Low struktural stability and/or crusting	Entisols	IV	472.68	6.76
4	Low struktural stability and/or crusting	Clay soils	IV	107.35	1.54
8, 9, 10	Low water holding capacity	Sandy clay loam	VI	1177.17	16.83
Total				3,628.71	51.89



LU		Land Quality		Land Quality Class	Area	
		Major Land Stress Factor	Determinant of Land Stress		ha	%
	3	High temperatures	Isohypertermik of soil temperature regime	II	2.297,78	32,86
	5	Low organic matter	Ochric epipedon	II	1.066,95	15,26
	1, 6, 7	Seasonally exces water	Recent terraces	III	1.871,51	26,76
	2	Low struktural stability and/or crusting	Entisols	IV	472,68	6,76
	4	Low struktural stability and/or crusting	Clay soils	IV	107,35	1,54
	8, 9, 10	Low water holding capacity	Sandy clay loam	VI	1.177,17	16,83
		Total			6.993,44	100,00

LU: land unit

Fig 5. Land Quality Map of Bulia Micro Watershed

The LQ of class IV with the main factors determining of land stress was low structural stability and/or crusting. These main factors consists of two indicators, namely clay soil and Entisol. The indicator of heavy clay (> 50%) was scattered in LU 4 (P4). This indicator of clay soil was related to the soil crusting which was shown by the average soil structure with sub angular blocky and soil consistency when wet condition was very sticky and very plastic, but in the dry conditions was very hard. Clay and organic matter are binding agents for aggregates (Rachim, 2007). Apparently, the influence of clay is more dominant than organic matter as an aggregate binding agent because the OC content was very low. The Entisol indicators was spread on the LU 2 (P2) only. Entisol is a soil that is still young and underdeveloped (Rachim, 2007). The results of the morphological analysis of the soil indicated that this Entisol has a granular structure (not solid), fine sized with the weak level of development, therefore the stability was low relatively. In addition, the texture of the Entisol was classified as loamy sand with the sandy of particle size classes which is also causes low relatively of soil structure stability. This class requires important inputs from conservation management and the lack of plant nutrition is a major obstacle, therefore a plan to use a good fertilizer must be adopted (Beinroth et al., 2001). Land management through the addition of organic matter can be applied together with recommended fertilizer doses (Sys et al., 1991; Singh et al., 2004;

Mahaputra et al., 2019). Provision of organic matter in soils with clay texture can increase soil water content and available water capacity and reduce soil volume weight (Intara *et al.*, 2011), increase soil porosity (Anastasia et al., 2014), increase uptake, N, P, and K and crop yields in Entisol soils (Afandi et al., 2015). Addition of manure, compost and custom bio can reduce the content weight, soil density, increase aggregate stability, soil porosity and moisture content in Entisol soil (Zulkarnain et al., 2013).

The LQ of class VI with the main factor determining of land stress was low water holding capacity with the sandy clay loam texture as indicators were spread over of LU 8 (P8), LU 9 (P9) and LU 10 (P10). The value of water available on the sandy clay loam texture was only around 20.42 mm (Haridjaja et al., 2013). The available water (pF) was indicated that under conditions of field capacity (pF 2.0) on the LU 8, 9 and LU 10 each one as much 34 mm, 38 mm, and 37 mm and at permanent wilting conditions (pF 4.2) each one as much 24 mm, 24 mm and 17 mm only 19, therefore causes of low water holding capacity. This land should not be used for food production i.e corn because this class requires important inputs from conservation management and lack of plant nutrition is a major obstacle and therefore a plan to use a good fertilizer must be adopted or this land can be used as a biodiversity zone (Beinroth et al., 2001). However, if this land to be used for agricultural cultivation, then land management is through the addition of organic matter along with the recommended fertilizer dosage (Sys et al., 1991; Singh et al., 2004; Mahaputra et al., 2019). Provision of organic material in soils with clay texture can increase soil water content and available water capacity and reduce soil volume weight (Intara et al., 2011), increase soil porosity (Anastasia et al., 2014).

CONCLUSIONS

Based on morphology and physicochemichal properties in Bulia micro watershed of Gorontalo Province of Indonesia shown that the soil structure was dominated by angular blocky, sticky and plastic consistency, and hard consistency. In the alluvial plain the soil texture was dominated by clay fraction, while in the hills and volkan mountains was more dominated by sand fraction. Soils in the Bulia micro watershed also react sour to neutral, with very low to high OC levels, bases can be exchanged dominated by Ca2+ with two series patterns, namely: $Ca^{2+} > Mg^{+} > Na^{+} > K^{+}$ and $Ca^{2+} > Na^{+} > Mg^{+} > K^{+}$, CEC were low to very high, so that the base saturation was moderate to very high. The main soils found were Entisol on P1 (Typic

Ustipsamments)., Inceptisol on P1 (Typic Humustepts), P3 (Oxic Humustepts) and P7 (Typic Humustepts)., Mollisol on P4 (Typic Argiudolls), P6 (Typic Haplustolls), and P7 (Typic Humustepts), P9 (Typic Paleustolls)., and Alfisol on P5 (Typic Paleustalfs), P8 (Ultic Paleustalfs) and P10 (Inceptic Haplustalfs). Land on the alluvial plains were categorized in land quality classes of II, III and IV, land on the volcanic mountains was class IV, while the land on the volcanic hills were categorized as land quality class VI. River bank erosion was the major problem in watersheds, so that lands on river terraces must implement appropriate of soil and water conservation such as the manufacture of gabions, talud, cliff reinforcement plants and terraces. Soil temperatures and high clay content can be applied to mulching and adding organic material as well as good agronomic practices in order to increase land productivity and crop yield.

ACKNOWLEDGMENT

Thank you to the Faculty of Agriculture, Brawijaya University who has funded this research with a non-tax state revenue grant in accordance with the Budget Implementation List Number: DIPA-042.01.2.400919/2019

REFERENCES

1. Afandi, F. N., Siswanto, B. and Nuraini, Y., Effect of giving various types of organic material on soil chemical properties on the growth and production of sweet potato plants in Entisol Ngrangkah Pawon, Kediri, *Soil and Land Resources*, (2015), 2(2), pp. 237–244. Available at: http://jtsl.ub.ac.id.

2. Anastasia, I., Izatti, M. and Suedy, S. W. A., The effect of giving a combination of solid organic fertilizer and liquid organic on soil porosity and spinach plant growth (Amarantus tricolor L.), *Biology Journal*, (2014), 3(2), pp. 1–10.

3. Beinroth, F. H., Eswaran, H. and Reich, P. F., Global assessment of land quality, *sustaining the global farm: Selected papers from the 10th International Soil Conservation Organization Meeting*, (2001), pp. 569-574.

4. BPS Gorontalo Province, Gorontalo province in figure 2020, *BPS Gorontalo Province*, (2020), 1102001.75(75560.2004), pp. 1–535.

5. BPS Gorontalo Regency, Gorontalo regency in figure 2020, *BPS Gorontalo Regency*, (2020), 1102001.75(75020.2003), pp. 1–262.

6. Dutta, M., Land use planning of Tipukjan watershed of Sivasagar district using GIS and remote sensing technique. Ph.D. Thesis, Assam Agricultural University, Jorhat. (2009).
7. Damaiyanti, D. R. R., Aini, N. and Koesrihati., The study of organic mulch application on the growth and yield of red pepper (Capsicum annuum L.), *Crop Production Journal*, (2013), 1(2), pp. 25–32.
8. Devi, P. A. V, Naidu, M. V. S. and Rao, A. R., Characterization and classification of sugarcane growing soils in southern agro-climatic zone: A case study in eastern mandals of Chittoor district in Andhra Pradesh, *Journal of the Indian Society of Soil Science*, (2015), 63(3), pp. 245–258. doi: 10.5958/0974-0228.2015.00034.1.
9. Eruola, A. O., Bello N. J, Ufoegbune G. C, and Makinde, A. A., Effect of mulching on soil temperature and moisture regime on emergence, growth and yield of white yam in a tropical wet-and-dry climate, *International Journal of Agriculture and Forestry*, (2012), 2(1), pp. 93–100. doi: 10.5923/j.ijaf.20120201.15.
10. Eviyati and Sulaeman, Analysis of soil, chemical, plants, water, and fertilizer, *Indonesia Centre of Soil Research*, (2009), pp. 1–203.
11. Husain, J., J. N. Luntungan, Y. E. B. Kamagi, and Nurdin., Conservation-based corn farming model in Gorontalo Province. Research Report. Research, Development and Regional Environmental Impact Control Agency Gorontalo Province, Gorontalo. (2004)
12. Haridjaja, O., Baskoro, D. P. T. and Setianingsih, M., Different levels of field capacity by alhricks, free drainage, and pressure plate methods at different soil texture and relation for sunflower growth (Helianthus annuus L.), *Soil Science and Environmental Journal*, (2013), 15(2), p. 52. doi: 10.29244/jitl.15.2.52-59.
13. Intara, Y. I., A. Sapei, Erizal, N. Sembiring, and M. H. B. Djoefrie., Affected of organic matter application at clay and clay loam soil texture on water holding capacity, *Indonesian Agriculture Sciences Journal*, (2011), 16(2), pp. 130–135.
14. Jambak, M. K. F. A., Baskoro, D. P. T. and Wahjunie, E. D., Characteristics of Soil Physic on Soil Conservation Tillage System (Case Study Of Cikabayan Research Farm, Bogor), *Soil and Land Bulletin*, (2017), 1(1), pp. 44–50.
15. Jackson, M. L., Soil chemical analysis. Prentice Hall of India (Pvt.) Ltd., New Delhi. (1973).

16. Kadao, S. H., Prasad, J. and Gajbhlye, K. S., Characterization and classification of some typical banana growing soils of Wardha district of Maharashtra, *Agropedology*, (2003), 13(2), pp. 28–34.
17. Ludwig, A., Bradford, P., David, B., and Anton, W., Vegetation patches and runoff-erosion as interacting ecohydrological processes in semiarid landscapes. Ecology, (2007), 86, pp. 288-297. doi: https://doi.org/10.1890/03-0569.
18. Mahapatra, S. K., R. Nagdev, R. Gopal, J.N. Surya, R.K. Meena, R.P. Yadav and S.K. Singh., Characterization and classification of the soils of Buraka micro-watershed in Haryana for integrated development, *Journal of the Indian Society of Soil Science*, (2019), 67(2), pp. 137–150. doi: 10.5958/0974-0228.2019.00015.X.
19. Manik, H., Marpaung, P. and Sabrina, T., The level of soil development based on the pattern of clay mineral distribution in Subdistric Lumbanjulu, Distric of Toba Samosir, *Agroteknologi FP USU*, (2017), 5(2), pp. 422–433.
20. Nasruddin and Hanum, H., Study of mulching effects on soil temperature, soil property, and growth of patchouli (Pogostemon cablin Benth), *Floratek*, (2015), 10(2015), pp. 69–78.
21. Noor, A., Vahlevi, J. and Fathurrozi., Slope stabilization for erosion control with soil bioengineering using vetiver grass, *Poros Teknik*, (2011), 3(2), pp. 69–74.
22. Nurdin, *Development, classification and rainfed paddy soils potency derived from lacustrine materials in paguyaman, gorontalo*. MSc Thesis Bogor Agriculture University, (2010a). Available at: https://repository.ipb.ac.id/handle/123456789/57081.
23. Nurdin, The morfology, physics and soil chemistry of inceptisol derived from lacustrine paguyaman of gorontalo relating to soil managements, *Jurnal Agroteknotropika*, (2010b), 1(1), pp. 13–22.
24. Nurdin, Development and rainfed paddy soils potency derived from lacustrine material in paguyaman, gorontalo, *J Trop Soils*, (2011), 16(3), pp. 267–278. doi: 10.5400/jts.2011.16.3.267.
25. Nurdin, Combination of soil conservation techniques and its effect on the yield of maize and soil erosion of dry land in biyonga sub-watershed, gorontalo, *J. Tek. Ling*. (2012), 13(2), pp. 245–252.
26. Odjugo, P. A. O., The effect of tillage systems and mulching on soil microclimate, growth and yield of yellow yam (Dioscorea cayenensis) in Midwestern Nigeria, *African Journal of Biotechnology*, (2008), 7(24), pp.

4500–4507. doi: 10.4314/ajb.v7i24.59629.
27. Oldeman, L. R. and Darmiyati, S., An agroclimatic map of Sulawesi scale 1 - 2.500.000, *Center Research for Agriculture*, (1977), p. 1.
28. Puslitanak Research Team, Survey and mapping of semi-detailed soil resources (scale 1: 50,000) in the North Sulawesi of Paguyaman area for the development of irrigation and sugarcane commodities. Final report. Book III Attachment of the Land Series. Center for Soil and Agro-climate Research, Agency for Agricultural Research and Development, Indonesian Ministry of Agriculture, Bogor, (1995).
29. Prasetyo, B. H., Differentiation in Properties of vertisol from various parent materials, *Indonesian Agriculture Sciences Journal*, (2007), 9(1), pp. 20–31.
30. Rachman, A., Gantzer, J., and Anderson, S. H., Soil hydraulic properties influenced by stiff-stemmed grass hedge systems, *Soil Science Society of America Journal*, (2004), 68(4), pp. 1386–1393. doi: 10.2136/sssaj2004.1386.
31. Rahman, A., Geographic information system model for estimating flow coefficient and its relationship with land cover in Riam Kanan River Basin of South Kalimantan Province, *Bumi Lestari*, (2013), 13(1), p. 1-8.
32. Sys, C., E. V, Rast and Debaveye, J., Land evaluation. Part II. Principles in land evaluation and crop production calculations. International Training Centre for Post-Graduate Soil Scientists, University of Ghent. (1991).
33. Sarkar, D., Gangipodhyay, S. K. and Velayutham, M., Soil toposequence relationship and classification in lower outlier of Chhotanagpur plateau, *Agropedology*, (2001), 11, pp. 29–36.
34. Swarnam, T. P., Velmurugan, A. and Rao, Y. S., Characterization and classification of some soils from Shahibi basin in parts of Haryana and Delhi. *Agropedology*, (2004), 14, p. 114-122.
35. Singh, C., Singh, P and Singh, R., Modern techniques of raising field crops. Oxford and IBH Publishing Co. Pvt. Ltd., New Delhi, (2004), pp. 1-583.
36. Satish, S., M. V. S. Naidu, K. V. Ramana, V. Munaswamy, G. P. Reddy and P. Sudhakar., Characterization and classification of the soils of Brahmanakotkur watershed in Kurnool district of Andhra Pradesh', *Journal of the Indian Society of Soil Science*, (2018), 66(4), pp. 351–361. doi: 10.5958/0974-0228.2018.00044.0.

37. Sinarta, I., Methods of handling landslides with soil nailing', *Paduraksa*, (2014), 3(2), pp. 1–16.
38. Sireesha, P. V. G. and Naidu, M. V. S., Clay mineralogy of soils developed from granite-gneiss of Kurnool District in Andhra Pradesh', *Journal of the Indian Society of Soil Science*, (2015), 63(1), pp. 16–23. doi: 10.5958/0974-0228.2015.00003.1.
39. Soil Science Division Staff, Soil survey manual, *United States Department of Agricultur US*, (2017), pp. 1–145. doi: 10.2307/1233734.
40. Soil Survey Staff, Keys to soil taxonomy, *Soil Conservation Service - NRCS/USDA*, (2014), 12, p. 360.
41. Subardja, D. and Sudarsono, The influence of land quality on productivity of maize in soils derived from volcanic and sedimentary rocks in the bogor area, *Soil and Climate Journal*, (2005), 23, pp. 38–46.
42. Suharta, N., The characteristic of soil developed from felsic sediments in west kalimantan province and its implication to land management, *Soil and Climate Journal*, (2007), (25), pp. 11–26.
43. Sukarman, S. Ritung, M. Anda, and E. Suryani., Guidelines for soil observation in the field, *Agricultural Research and Development Agency, Ministry of Agriculture Republic of Indonesia, Bogor*, (2017), pp. 1–149.
44. Supriya, K., M. V. S. Naidu, P. Kavitha and M. Srinivasa Reddy., Characterization, classification and evaluation of soils in semi-arid region of Mahanandi Mandal in Kurnool district of Andhra Pradesh', *Journal of the Indian Society of Soil Science*, (2019), 67(2), pp. 125–136. doi: 10.5958/0974-0228.2019.00014.8.
45. Susilawati, S. and Veronika, V., Vetiver grass study as a continuous slope safety, *Civil Engineering Communication Media*, (2016), 22(2), p. 99. doi: 10.14710/mkts.v22i2.12886.
46. Suyana, J., Sumarno, Supriyono, and N. P Lestariningsih., Mulching and strengthening of terraces in three types of plants against surface runoff, erosion, growth and yield of plants in Andisols, *Agrosains*, (2017), 19(1), p. 15. doi: 10.20961/agsjpa.v19i1.20924.
47. Vedadri, U. and Naidu, M. V. S., Characterization, classification and evaluation of soils in semi-arid ecosystem of Chillakur mandal in SPSR Nellore district of Andhra Pradesh. Journal of the Indian Society of Soil Science, (2018), 66 (1), p. 9-19. doi: 10.5958/0974-0228.2018.00002.6.
48. Walia, C.S., and Rao, Y. S., Characteristics and classification of some soils of Trans-Yamuna plains. Journal of the Indian Society of Soil Science, (1997), 45 (1), p. 156-162.

49. Yasin, M. G. H., Langgi, W and Faesal, White grain maize as an alternative for staple food, *Iptek Tanaman Pangan*, (2015), 9(2), pp. 108–117.
50. Yatno, E. and Mulyanto, B., Characteristics of soils formed from schist and their land suitability for cocoa crop in Kolaka and East Kolaka Regencies, Southeast Sulawesi, *Soil and Climate Journal*, (2016), 39(2), pp. 109–118.
51. Zulkarnain, M., Prasetya, B and Soemarno, Effects of compost, manure, and custom-bio on soil properties, growth and yield of sugarcane (Saccharum officinarum L.) in Entisol Kebun Ngrangkah of Pawon, Kediri, *Indonesian Green Technology Journal*, (2013), 2(1), pp. 45–52. Available at: https://igtj.ub.ac.id/index.php/igtj/article/view/103.

INSTRUKSI REVISI

Nurdin <nurdin@ung.ac.id>

[Dokuchaev Soil Bulletin] Characterization and Soil Classification as Determining of Upland Quality in Bulia Micro Watershed, Indonesia

2 pesan

Анна Романовская <no-reply@subs.elpub.science> 19 Agustus 2021 pukul 18.55
Balas Ke: Анна Романовская <burmistrovaann13@mail.ru>
Kepada: Nurdin Kyai Baderan <nurdin@ung.ac.id>

Dear Mr. Nurdin,
thank You for the interest to our Bulletin and for sending the manuscript!

The manuscript "Characterization and Soil Classification as Determining of Upland Quality in Bulia Micro Watershed, Indonesia" was submitted to Dokuchaev Soil Bulletin on July, 12, 2021, and sent to the reviewer the same day. The **reviewer A** agreed to work with the manuscript, however, the **reviewer A** is now working at the Republic of South Afrcia, and we have not received the review paper yet. That is why we had to send the request to the **reviewer B** and we hope to get the answer in the nearest future. I'll contact You as soon as I get the review.

Best wishes,
Anna

--
With respect and best wishes,
Anna Romanovskaya,
PhD in Agri. Sci., V.V. Dokuchaev Soil Science Institute
8(916)078-70-57
Dokuchaev Soil Bulletin
https://bulletin.esoil.ru/jour
https://elibrary.ru/title_about.asp?id=28636

---

journal

Bulletin of V.V. Dokuchaev Soil Science Institute

Nurdin <nurdin@ung.ac.id>
Kepada: Анна Романовская <burmistrovaann13@mail.ru>

20 Agustus 2021 pukul 14.01

Thank You very much Dr. Anna

Nurdin

[Kutipan teks disembunyikan]

Characterization and Soil Classification as Determining of Upland Quality in Bulia Micro Watershed of Gorontalo Province, Indonesia

Received 12.07.2021, Revised ………, Accepted ……………..

Abstract: Ten pedon representatives from the Bulia micro watershed of Gorontalo Province, Indonesia were studied for their morphology and physcochemical properties, soil classification and determine of land quality (LQ) class. The soil structure was dominated by angular blocky, sticky and plastic consistency, and hard consistency. In the alluvial plain the soil texture was dominated by clay fraction, while in the hills and volkan mountains was more dominated by sand fraction. Soils in the Bulia micro watershed also react sour to neutral, with very low to high OC levels, bases can be exchanged dominated by Ca^{2+} with two series patterns, namely: $Ca^{2+} > Mg^{+} > Na^{+} > K^{+}$ and $Ca^{2+} > Na+ > Mg^{+} > K^{+}$, CEC were low to very high, and the base saturation was moderate to very high. The main soils found were Entisol on P2 (Typic Ustipsamments)., Inceptisol on P1 and P7 (Typic Humustepts), and P3 (Oxic Humustepts)., Mollisol on P4 (Typic Argiudolls), P6 (Typic Haplustolls), and P9 (Typic Paleustolls)., and Alfisol on P5 (Typic Paleustalfs), P8 (Ultic Paleustalfs) and P10 (Inceptic Haplustalfs). Land on the alluvial plains were categorized as the II, III and IV of LQ classes, the volcanic mountains was the IV class of LQ, while the land on the volcanic hills were categorized as the VI of LQ class. River bank erosion on the land river terraces can implemented of the manufacture of gabions, talud, cliff reinforcement plants and terraces. Soil temperatures and high clay content can be applied by mulching and organic materials.

Keywords: Characterization, classification, soil, land quality, Bulia watershed.

INTRODUCTION

Land is one of the most important components of land resources where plants grow and produce food. Land and plant productivity is largely determined by soil characteristics and other land characteristics related to land quality (Subardja and Sudarsono, 2005). However, the intensity of tillage in agricultural cultivation and the pressure of land use that ignores aspects of conservation and its sustainability have resulted in a decrease in land quality, so that agricultural production tends to levelling or even decrease (Nurdin, 2012). Corn is an excellent commodity in the province of Gorontalo Indonesia, which has been intensively and massively cultivated since it was established as a primes commodity in the agropolitan program since 2001. Until 2019, hybrid corn yileds in Gorontalo Province has reached 1.7 million tons or increased by 9.3% from the 2018 year, but the productivity of the maize was still low at only 5.0 tons ha (BPS Gorontalo, Province 2020). In fact, the potential yield of corn in Indonesia can produce 10-11 tons/ha (Yasin et al., 2015), while the achievement of national productivity in 2018 will only be 5.2 tons/ha (Indonesian Ministry of Agriculture 2019).

The Bulia micro watershed area as a corn production centers that also functions to support the agricultural area below. The watershed has a vital roles because it supplies irrigation water for agriculture and other activities (Mahapatra *et al.*, 2019). Corn cultivation in this watershed has exceeded the carrying capacity indicated by the planting of corn to the slope of > 25%, so that land degradation often occurs. Soil erosion that occurred from corn agropolitan program of Gorontalo has reached 1,396 tons/ha/year (Husain et al., 2004). Meanwhile the achievement of corn productivity in this area is only 5.0 tons/ha (BPS Gorontalo Regency, 2020). This is presumably because corn was cultivated on land that is not suitable with the soil characteristics and land quality.

Soil characterization provides important information about the physical, chemical, mineralogical and microbiological characteristics of the soil for growing plants (Devi et al., 2015). For sustainable management of soil resources in agroecological areas, timely monitoring of important physical, chemical and biological soil characteristics and responses to changes in land management are needed (Supriya *et al.*, 2019). These soil characteristics then form the basis for land classification. The combination of soil characterization and soil classification is a powerful tool for developing management strategies for food security and environmental sustainability (Satish *et al.*, 2018). However, efforts to link the characteristics and classification of land with specific land quality are still relatively rare. In fact, land quality is the ability of land to show a specific performance function before the land is degraded (Beinroth et al., 2001). An understanding of soil types and their distribution, constraints and potential is important for proper management to increase productivity and yields (Niranjana et al., 2011).

The survey and mapping of soil resources in the Paguyaman watershed was carried out by the Soil and Agro-climate Research Center of Indonesian Ministry of Agriculture (Puslittanak Research Team, 1995), but the scale of mapping was 1: 50,000. In 2010, research has been carried out on the development, classification and potential of paddy soils based on lacustrin based on toposequence (Nurdin, 2010), but only focused on rainfed paddy soils, while on dry land only as a comparison with locations close to the soil pedon the rice fields. In the interval of that time until 2019 there has not been a sweet research conducted in this area, so with consideration of the high intensity of land management and the massive cultivation of corn in this sub-watershed, this research is very important.

MATERIALS AND METHODS

Study location

The Bulia micro watershed is a part of the Paguyaman watershed located in the northern part and covers Mootilango and Boliyohuto District of Gorontalo Regency of Gorontalo Province, Indonesia (Figure 1). Geographically, the research location is located between 0°39'123 "and 0°51'321" N and 122°35'21 "and 122°43'12" S (Table 1) which was 67 km from Gorontalo City, Indonesia.

Overall, the Bulia micro watershed has an area of 21,456.58 ha consisting of upland were 18,993.44 ha (32.59%) and paddy fileds were 2,991.15 ha (13.94%). Specifically of upland agriculture covers agricultural land areas were 6,993.44 ha (37.87%), settlement areas were 461.59 ha (2.50%) and forest areas were 11,010.40 ha (59.63%). Soils in this area generally develop from volcanic material at the upper watershed and lacustrine deposits in the middle and bottom of watershed. The study area includes a tropical climate consisting of the rainy and dry seasonal. The average of annual rainfall was only 1,478 mm with the wet month of 1 month only and the dry month of 4 months, so it belongs to the E2 agro-climate zone (Oldeman and Darmiyati, 1977). The average of annual air temperature reaches 28.19°C with the maximum temperature of 28.73°C and the minimum temperature of 27.63°C. Under these conditions, the soil moisture regime were ustic and the soil temperature regime were isohypermics (Soil Survey Staff, 2014).

Table 1. Site characteristics of pedons in Bulia micro watershed

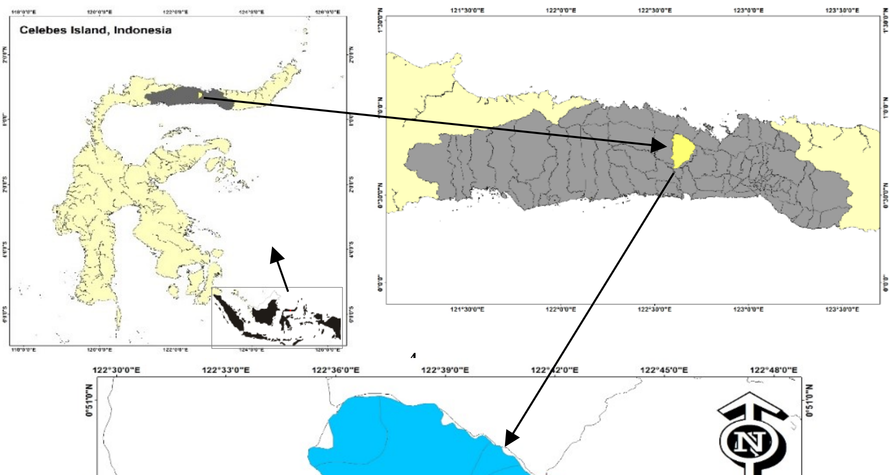
Pedon/ Villages	Location	Elevation (m msl)	Landform	Slope (%)	Drainage
P1, Tolite	0°39’44.80” N 122°35’27.20” S	24	Alluvial plain	0 – 3	Bad drained
P2,	0°40’01.20” N	159	Volcanic	15 –	Well drained

Monggolito	122°37’57.20” S		mountain	30	
P3, Huyula	0°42’59.9” N 122°39’43.2” S	63	Alluvial plain	0 – 3	Moderately
P4, Payu	0°44’04.4” N 122°37’48.4” S	53	Alluvial plain	0 – 3	Moderately
P5, Pilomonu	0°43’53.80” N 122°35’22.60” S	75	Alluvial plain	0 – 3	Moderately
P6, Karyamukti	0°42’20.50” N 122°41’05.50” S	109	Alluvial plain	3 – 8	Moderately
P7, Karyamukti	0°42’10.30” N 122°41’19.40” S	114	Alluvial plain	3 – 8	Moderately
P8, Sukamaju	0°44’05” N 122°40’04” S	253	Volcanic hill	8 – 15	Well drained
P9, Payu	0°45’12” N 122°38’08” S	285	Volcanic hill	8 – 15	Well drained
P10, Huyula	0°43’11.10” N 122°40’31.20” S	262	Volcanic hill	8 – 15	Well drained

msl: mean sea level.

Soil surveying, soil characterization and classification

The soil survey was conducted on representative pedon through ten soil profiles. Description of soil morphology refers to the Soil Survey Manual (Soil Science Division Staff, 2017; Sukarman et al., 2017). Soil samples were taken at each horizon and analyzed the soil physical and chemical properties according to standard procedures (Jackson, 1973; Eviyati and Sulaeman, 2009). Together with climate and terrain conditions data, morphological data and soil properties were used for soil characterization. The soil classification according to the key soil taxonomy (Soil Survey Staff, 2014).



Land quality assessment

Land quality (LQ) class assessment follows the method according to Beinroth et al. (2001) were modified based on previous soil characteristics and classifications. Soil pedons (P) that have been classified in taxa according to the Soil Taxonomy System (Soil Survey Staff, 2014) were combined with a land unit (LU) based on the similarity of criteria in the taxa. Soil and pedoklimat information was used to place each LU into I to IX land quality classes with class I having the most appropriate attributes and class IX attributes that are least suitable for crop production. The results of the land quality analysis are presented spatially with the help of Arc GIS and described.

RESULTS AND DISCUSSION

Morphology and soil physical properties

Based on the results of field studies and the laboratory characterization of ten soil pedons were presented in Table 2. Soils in the study area have been developed as indicated by the structuring of the horizon (horizons A and B) with the depth of soil solum varying from shallow to very deep. The soil color only consists of 7.5YR and 10YR hue, but 7.5YR is more dominantly. In the P1, P2, P3, P5, P8, P9 and P10 soil colors vary from dark brown, brown, to strong brown with hue 7.5YR, values range from 3 to 5 and chroma 1 to 6. While in P4, P6 and P7 soil color from very dark grayish brown, dark brown to dark yellowish brown with hue 10YR, values ranging from 3 to 4, and chroma 2 to 6. The higher the organic matter content, the darker the soil color (Suharta, 2007). The color of the soil horizon A is darker than horizon B due to the organic matter content in horizon A is higher than horizon B (Yatno and Mulyanto, 2016). Soil color seems to be a function of chemical and mineralogical composition (Swarnam *et al.*, 2004; Walia and Rao, 1997), as well as soil texture arrangements that are influenced by topographic position and humidity regimes (Walia and Rao, 1997).

The soil structure varies from crumbs, angular blocky, sub angular blocky to prismatics, but is more dominant angular blocky. In P1, P3, P4, P6, P7, P8, P9 and P10 were more dominant with angular blocky structure with sizes varying from fine, medium to coarse, and the level of structural development is weak and strong. While the soil structures of P2 and P5 varies from crumbs, angular blocky, sub angular blocky to prismatics with sizes ranging from fine, medium to coarse and the level of development of soil structures from weak, moderate to strong. The angular blocky soil structures was strongly associated with the presence of a higher number of clay fractions (Devi et al., 2015). While the crumbly soil structure shows newly developed soil (Manik et al., 2017), the addition of organic material continues to take care of organic material through plant biomass (Devi et al., 2015) or the tillage intensity which was carried out thoroughly by turning the soil over until damaged of structure soil (Jambak et al., 2017). Variation of soil structure will affecting the soil consistency.

Table 2. Morphological characteristics and soil physical properties in Bulia micro watershed

Pedon and Horizon	Depth (cm)	Color Moisture	Structures	Consitence			Sand	Silt	Clay	Texture Class
				w	m	d	%			
P1 (Aluvial Plain)										
Ap	0 - 23	7.5 YR 4/4	m, 3, abk	s, p	fi	h	9	40	51	Clay
Bw1	23 - 43	7.5 YR 4/2	m, 3, abk	ss, sp	fi	h	3	46	51	Silty Clay
Bw2	43 - 75	7.5 YR 4/4	m, 3, abk	ss, sp	fi	h	3	54	43	Silty Clay
Bw3	75 - 100	7.5 YR 4/2	m, 1, abk	ss, sp	vfi	vh	3	46	51	Silty Clay
P2 (Volcanic Mountains)										
Ap	0 - 5	7.5 YR 4/4	f, 1, cr	so, po	fr	l	85	10	5	Loamy sand
Bw1	5 - 37	7.5 YR 4/4	f, 2, sbk	so, po	fr	l	84	2	14	Loamy sand
Bw2	37 - 61	7.5 YR 4/4	m, 2, p	so, po	fr	l	75	10	15	Loamy sand
C	61+	7.5 YR 4/2	m, 3, p	so, po	fr	l	66	15	19	Clay Loam
P3 (Alluvial Plain)										
Ap	0 - 14	7.5 YR 3/3	f, 1, cr	ss, sp	fi	h	33	41	26	Loamy
Bw1	14 - 43	7.5 YR 4/4	f, 2, abk	s, p	fi	h	31	37	32	Clay Loam
Bw2	43 - 68	7.5 YR 4/4	f, 1, abk	ss, sp	fi	h	23	54	23	Silty Loam
Bw3	68+	10 YR 3/6	f, 1, cr	s, p	fi	h	23	48	29	Clay Loam
P4 (Alluvial Plain)										
Ap	0 - 14	10 YR 3/3	m, 3, abk	s, p	fi	h	27	26	47	Clay
Bw	14 - 50	10 YR 4/3	f, 1, abk	s, p	fi	h	32	34	34	Clay Loam
Bt1	50 - 81	10 YR 3/2	f, 1, abk	ss, sp	fi	h	12	24	64	Clay
Bt2	81+	7.5 YR 4/1	f, 1, abk	s, p	fi	h	16	25	59	Clay
P5 (Alluvial Plain)										
Ap	0 - 21	7.5 YR 4/4	f, 2, sbk	ss, sp	fi	h	23	43	34	Clay Loam
Bw	21 - 46	7.5 YR 4/4	f, 2, sbk	ss, sp	fi	h	23	48	29	Clay Loam
Bt1	46 - 84	7.5 YR 4/3	f, 2, abk	s, p	fi	h	25	35	40	Clay
Bt2	84 - 117	7.5 YR 4/6	m, 2, p	s, p	fi	h	24	36	40	Clay

Pedon and Horizon	Depth (cm)	Color Moisture	Structures	Consitence			Sand	Silt	Clay	Texture Class
				w	m	d	%			
Btg	117+	7.5 YR 5/8	m, 1, sbk	ss, sp	fi	h	8	46	46	Silty Loam
P6 (Alluvial Plain)										
Ap	0 - 12	10 YR 3/3	f, 1, abk	s, p	fi	h	84	15	1	Loamy Sand
Bw1	12-34	10 YR 3/4	f, 1, abk	s, p	fi	h	61	10	29	Sand Clay Loam
Bw2	34 - 71	10 YR 4/6	m, 3, abk	ss, sp	fi	h	61	24	15	Sandy Loam
C	71 - 90	7.5 YR 5/8	f, 1, cr	so, po	fr	l	84	5	11	Loamy Sand
P7 (Alluvial Plain)										
Ap	0 - 6	7.5 YR 4/6	m, 1, abk	s, p	fi	h	33	11	56	Clay
Bw1	6 - 17	10 YR 4/6	m, 3, sbk	s, p	fi	h	29	20	51	Clay
Bw2	17 - 33	10 YR 3/6	m, 1, abk	ss, sp	fi	h	21	20	59	Clay
Bt	33 - 49	10 YR 3/6	f, 1, p	ss, sp	fi	h	19	15	66	Clay
BC	49+	7.5 YR 4/6	f, 1, abk	ss, sp	fi	h	18	29	53	Clay
P8 (Volcanic Hills)										
Ap	0 - 7	7.5 YR 3/3	f, 1, abk	ss, sp	fi	h	64	10	26	Sandy Clay Loam
Bw	7 - 24	7.5 YR 3/3	m, 1, abk	s, p	fi	h	47	24	29	Sandy Clay Loam
Bt1	24 - 44	7.5 YR 4/6	f, 3, p	s, p	fi	h	45	15	40	Silty Loam
Bt2	44 - 63	7.5 YR 5/6	m, 3, abk	s, p	fi	h	42	16	42	Clay
Bt3	63+	7.5 YR 5/6	m, 1, abk	s, p	fi	h	42	6	52	Clay
P9 (Volcanic Hills)										
Ap	0 - 16	7.5 YR 3/2	m, 3, abk	vs, vp	vfi	vh	54	31	15	Loamy
Bw	16 - 34	7.5 YR 3/3	m, 1, abk	s, p	fi	h	42	24	34	Sandy Clay Loam
Bt	34+	7.5 YR 4/4	m, 1, abk	ss. sp	fi	h	50	15	35	Sandy Clay Loam
P10 (Volcanic Hills)										
Ap	0 - 20	7.5 YR 3/3	m, 3, abk	ss, sp	fi	h	48	26	26	Sandy clay loam
Bt1	20 - 44	7.5 YR 3/4	m, 3, abk	s, p	fi	h	41	15	44	Clay
Bt2	44 - 76	7.5 YR 4/6	c, 3, sbk	s, p	fi	h	42	14	44	Clay

Pedon and Horizon	Depth (cm)	Color Moisture	Structures	Consitence			Sand	Silt	Clay	Texture Class
				w	m	d	%			
BC	76+	5 YR 4/6	c, 3, p	vs, vp	vfi	vh	31	2	67	Clay

Structure: *size*: vf – very fine, f – fine, m – medium, c – coarse; *grade structureless*: l – weak, 2 – moderate, 3 – strong; *type*: cr – crumb, sg – single grain, abk – angular blocky,sbk – sub-angular blocky. Consistence: *dry* (d): s – soft, l – loose, sh – slightly hard, h – hard, vh – very hard, eh – extremely hard; *moist* (m): l – loose, fr – friable, fi – firm, vfi – very firm, efi – extremely firm, *wet* (w): so – non-sticky, ss – slightly sticky, s – sticky, vs – very sticky; po – non-plastic, ps – slightly plastic, p – plastic, vp – very plastic.

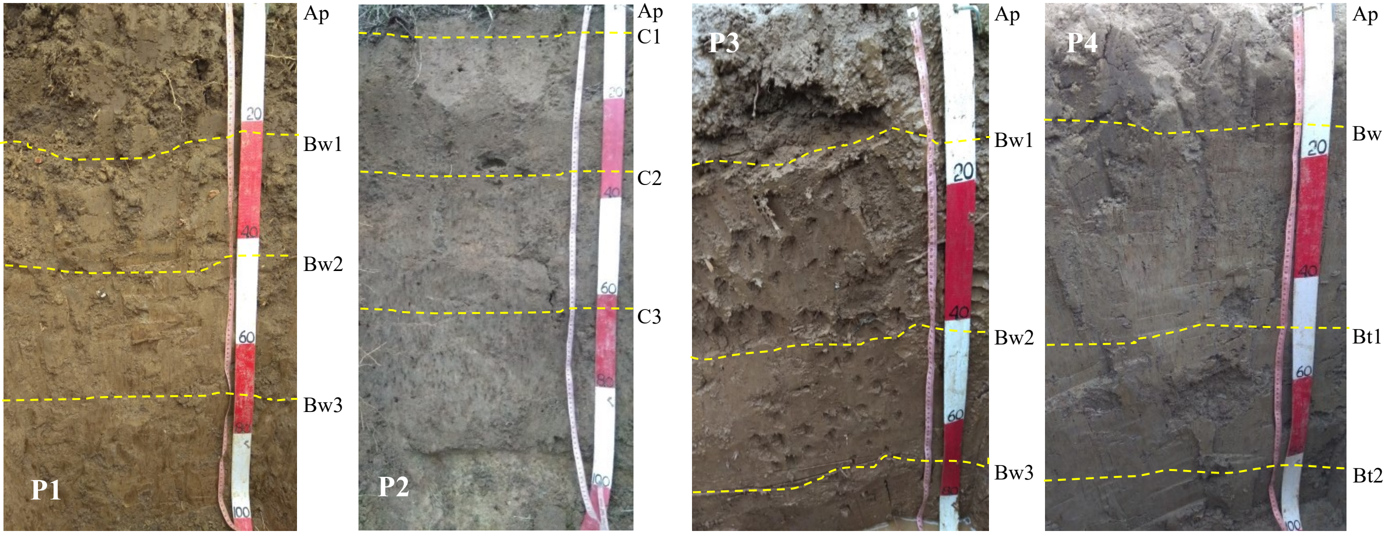


Fig 2. Soil profile appearance of pedon 1 (P1), 2 (P2), 3 (P3) and pedon 4 (P4)

Soil consistency in wet conditions varies from non-sticky and non-plastic on Pedon 2, slightly sticky and slightly plastic, sticky and plastic in the horizon on P1, P3, P4, P5, P6, P7, P8, P9 and P10, very sticky and very plastic on the surface horizon (Ap) of P9 and the subsurface horizon (BC) of P10, but more dominant slightly sticky and slightly plastic consistencies. While in moist conditions vary from loose, firm to very firm, but more dominantly firm consistencies. The P1, P3, P4, P5, P6, P7, P8, P9, and P10 were dominated by hard consistencies, while the P2 is loose. There is very hard consistency in P1 and P10 in the subsurface horizon (Bw and BC), while very hard consistency in surface horizon (Ap) is in P9 only. Consistency in dry conditions varies from loose, hard to very hard, but dominantly hard consistency. The P1, P3, P4, P5, P6, P7, P8, P9 and P10 were dominated by hard consistency, but in P1 and P10 in the subsurface horizon (Bw3 and BC) there is very hard consistency, while in P9 precisely the consistency is very hard found on the surface horizon (Ap). Sticky and plastic consistency might be due to high clay content in the soil (Sarkar et al., 2001); (Kadao et al., 2003), while non-sticky and non-plastic consistency might be caused by very little clay content (Sireesha and Naidu, 2015; Devi et al., 2015).

The soil texture of all pedons varies greatly from sandy clay loam, sandy loam, loamy sand, sandy loam, silty loam, clay loam, silty clay to clay, exceptly to P7 that was clay textured to all horizons. Wide variations of soil texture may be caused by variations in parent material, topography, in-situ weathering, and translocation of clays by eluviation and soil age (Satish et al. 2018). Apparently, pedons located in the alluvial group were more dominated by clay fractions, although the distribution patterns were irregular. Distribution of irregular clay fractions was typical of sediment material (Nurdin, 2010). While the volcanic group were dominated by the sand fraction. The distribution of sand and clay fractions shows the opposite pattern. The decrease in the sand fraction was not only due to the clay illuviation process, also due to the in situ mineral destruction process (Rachim 1994). The texture that engages in the subsurface horizon caused by higher weathering in the subsurface layer (Dutta, 2009). The clay content in the solum middles (B-iluviation) was higher than the upper horizon (A-eluviation) and the lower layer horizon which indicates the occurrence of a lessivage process with the discovery of the clay skins, so that an argillic horizon was formed in the P4, P5, P8, P9 and P10. While the remaining pedon, although the process of eluviation and iluviation has occurred, but has not found the clay skins, so the horizons were formed of cambic and candic.

Soil chemical properties

Soil chemical properties are presented in Table 3. Soil pH varies from acidity (pH 5.3) to neutral (pH 7.2). Apparently, pedons located on the upper watershed or volcanic groups (P2, P8, P9 and P10) has a lower pH than pedons located on the lower watershed or alluvial groups (P1, P3, P4, P5, P6, and P7). The pedon in the alluvial group was a depressed area which is the accumulation of bases carried by washing water from the hinterland section and the accumulation of more alkaline bases in soils with poorer drainage (Nurdin, 2010a). While pedon in the volcanic group experienced more intensive washing during rain due to better soil drainage. The trend of increasing pH with depth may be due to the release of organic acids during decomposition of organic matter and these acids may have lowered the pH at the surface of the soil (Satish *et al.*, 2018). The pH differences of KCl and pH of H_2O of all pedons shows a negative value. This means that all pedons are dominated by negatively charged clay minerals (Suharta, 2007). Acidic and slightly acidic soil pH values in P1, P3, P5, P9 and P10 indicate that the soil has undergone development but has not continued. While the neutral soil pH in P2, P4, P6, P7, and P8 shows that the soil is relatively new.

Organic carbon (OC) varies from very low to high (0.08 - 2.28%). The OC was all high in the surface horizon (Ap), exceptly P4 and P5. The height of OC at the ground surface was because in this part organic material accumulates. While the low OC at ground level in P4 and P5 were allegedly due to the intensity of tillage and transported during flooding because both pedons were around the border of the river. Low OC was thought to be due to faster degradation of organic material in the tropics and added the low of land cover, as stated by Vedadri and Naidu (2018). The high OC distribution pattern on the surface and decreases dramatically on the B horizon according to depth is a general pattern of soil that has developed (Prasetyo, 2007).

The bases can be exchanged for all pedons varying from very low, low, medium, high to very high. The bases can be exchanged more dominated by calcium (Ca^{2+}) which ranges from 2.54-18.02 cmol(+)kg^{-1}, while magnesium (Mg^{+}) ranges from 0.15-6.66 cmol(+)kg^{-1}, sodium (Na^{+}) ranges from 0.26-3.02 cmol(+)kg^{-1}, while potassium (K^{+}) ranges from 0.05-3.56 cmol(+)kg^{-1}. Based on the number of bases, the P1, P5, P7, and P10 patterns follow the sequence: $Ca^{2+} > Mg^{+} > Na^{+} > K^{+}$. This series pattern was the same as Nurdin (2011) and Satish et al. (2018) reported. While P2, P3, P4, P6, P8 and P9 follow the sequence: $Ca^{2+} > Na^{+} > Mg^{+} > K^{+}$. The high bases can be exchanged on the surface horizon (Ap) allegedly caused by fertilization.

The cation exchange capacity (CEC) varies from low (7.7 cmol(+)kg^{-1}) to very high (42.40 cmol(+)kg^{-1}) The CEC is influenced by levels of organic carbon and soil minerals (Prasetyo et al. 2007; Suharta 2007). It seems, the CEC in P1, P3, P4, P5, P7, P8, and P9 were more influenced by OC content than soil minerals. The higher the soil OC, the higher the CEC soils (Suharta, 2007). While P2, P6 and P10 were thought to be more influenced by soil minerals. These bases can be exchanged and this CEC will eventually affect the base saturation. Base saturation (BS) varies from moderate (40.55%) to very high (93%). All pedons generally have medium and high of BS, except P6 which has very high BS on the surface horizon (Ap). Variations in BS may be caused by variations in the nature and/or content of soil colloids and relatively high base saturation in surface layers can be attributed to recycling of cation base through vegetation (Devi and Kumar 2010). In addition, soil that has a number of bases was smaller than CEC, so BS tends to be lower, whereas soil that has a number of bases close to or higher than CEC, then BS tends to be higher (Nurdin, 2010b).

Soil classification

Based on morphological characteristics and soil characteristics, pedons are classified up to family level and found soil orders, namely Entisol, Inceptiol, Mollisol and Alfisol (Table 4). The P1 dan P7, which is located on a slope of 3% and 5%, founded of the molic epipedon on the 23 cm thick and the cambic horizon due to a clay texture class, did not has a combination of aquatic conditions within a depth of 50 cm from the ground or has been drained (humustept) and a moist color that has a color value of 4 , any color value with chroma of 2 or less as well as a angular blocky soil structures. In addition, it has more clay content than the below horizons or the above horizons. Based on these properties, then P1 and P7 were classified as fine, isohypermic, Typic Humustepts.

The P2, which is located on a slope of 15%, founded of the ochric epipedon on the 5 cm thick and the candic horizon due to an increase in the percentage of clay in the fine soil fraction with depths within a vertical distance of 15 cm or less, also a clay content of 4% or more (absolute), more than the horizon clay content above the horizon which has a total clay content in the fine soil fraction of less than 20%. In addition, it has a texture of sandy clay with particle size classes of sandy (psamments) and the CEC (NH_4OAc, pH 7) > 16 cmol(+)kg^{-1}. Based on these properties, P2 was classified as sandy, isohypermic, Typic Ustipsamments.

Table 3. Soil chemical properties in Bulia micro watershed

Pedon and Horizon	Depth (cm)	pH 1:1		OC (%)	Exchangeable cations				CEC	BS (%)
		H_2O	KCl 1N		K	Na	Ca	Mg		
					[cmol(+)kg^{-1}]					
P1 (Alluvial Plains)										
Ap	0 - 23	6.20	5.40	2.29	0.29	1.88	18.02	1.86	42.40	52.00
Bw1	23 - 43	6.00	5.20	0.90	0.18	2.01	15.47	2.97	39.19	52.62
Bw2	43 - 75	6.40	5.50	0.74	0.14	2.19	12.36	2.50	37.85	45.42
Bw3	75 - 100	6.50	5.60	0.65	0.14	2.23	15.22	3.26	37.58	55.49
P2 (Volcanic Mountains)										
Ap	0 - 5	6.50	5.60	1.19	0.10	0.34	3.77	0.30	11.13	40.55
Bw1	5 - 37	6.10	5.20	0.55	0.08	0.34	4.20	0.60	7.75	67.49
Bw2	37 - 61	6.20	5.30	0.63	0.08	0.35	3.91	0.15	8.87	50.52
C	61+	6.20	5.30	0.56	0.08	0.36	6.51	0.76	12.29	62.79
P3 (Alluvial Plain)										
Ap	0 - 14	5.60	4.60	0.80	0.05	1.46	4.84	0.61	16.15	43.00
Bw1	14 - 43	6.00	5.10	0.41	0.09	1.57	7.72	1.70	19.78	56.00
Bw2	43 - 68	5.80	4.90	0.32	0.05	1.55	8.95	0.91	21.58	53.00
Bw3	> 68	6.20	5.20	0.48	0.05	1.55	10.12	0.76	20.43	61.00
P4 (Alluvial Plains)										
Ap	0 - 14	6.50	6.10	0.41	0.06	1.49	11.87	0.62	25.55	55.00
Bw	14 - 50	6.70	6.30	0.96	0.19	1.43	9.71	2.12	21.60	62.00
Bt1	50 - 81	7.00	6.00	0.41	0.12	1.58	16.54	2.01	35.19	58.00
Bt2	81+	5.80	5.00	0.24	0.09	1.56	13.47	6.66	33.04	66.00
P5 (Alluvial Plains)										
Ap	0 - 21	5.20	4.50	0.08	0.16	2.29	9.39	2.93	28.39	52.00
Bw	21 - 46	5.10	4.30	0.49	0.20	2.30	8.62	3.08	28.40	50.00
Bt1	46 - 84	5.70	4.90	0.57	0.12	0.26	7.69	2.00	21.56	47.00

Pedon and Horizon	Depth (cm)	pH 1:1		OC (%)	Exchangeable cations				CEC	BS (%)
		H_2O	KCl 1N		K	Na	Ca	Mg		
					[cmol(+)kg^{-1}]					
Bt2	84 - 117	5.10	4.20	0.50	0.17	0.30	10.38	2.05	31.34	41.00
Btg	117+	5.10	4.10	0.42	0.25	0.34	15.37	1.90	38.58	46.00
P6 (Alluvial Plains)										
Ap	0 - 12	7.20	6.60	0.64	3.56	3.02	2.54	0.91	10.76	93.00
Bw1	12 - 34	7.10	6.60	0.32	0.28	1.72	6.03	0.30	11.79	71.00
Bw2	34 - 71	7.00	6.00	0.56	0.16	0.39	7.84	0.15	17.16	50.00
C	71 - 90	6.80	6.00	0.40	0.12	0.38	6.49	0.15	13.96	51.00
P7 (Alluvial Plains)										
Ap	0 - 6	6.30	5.40	0.76	0.10	0.42	5.31	2.41	18.31	45.00
Bw1	6 - 17	6.10	5.10	0.57	0.09	0.39	6.77	2.15	22.99	41.00
Bw2	17 - 33	5.90	5.00	0.57	0.07	0.44	8.55	4.04	25.45	51.00
Bt	33 - 49	5.60	4.80	0.33	0.08	0.45	13.64	3.72	29.79	60.00
BC	49+	5.90	5.00	0.41	0.12	2.04	13.16	0.31	33.06	47.00
P8 (Volcanic Hills)										
Ap	0 - 7	6.00	5.20	0.96	0.24	2.09	10.15	0.45	19.40	67.00
Bw	7 - 24	6.40	5.50	0.80	0.17	2.05	10.30	0.61	21.55	61.00
Bt1	24 - 44	6.70	5.80	0.48	0.24	2.21	10.07	1.83	26.06	55.00
Bt2	44 - 63	6.60	5.60	0.49	0.33	2.21	9.47	0.78	26.52	48.00
Bt3	63+	6.60	5.60	0.50	0.49	2.35	13.84	1.27	32.83	55.00
P9 (Volcanic Hills)										
Ap	0 - 16	5.30	4.50	0.80	0.13	2.15	10.15	0.61	24.80	53.00
Bw	16 - 34	6.20	5.30	0.57	0.10	2.30	12.44	0.77	29.51	53.00
Bt	34+	6.20	5.20	0.48	0.06	2.25	13.49	0.46	30.54	53.00
P10 (Volcanic Hills)										
Ap	0 - 20	5.80	4.90	0.72	0.12	0.40	5.90	1.21	18.31	41.69

Pedon and Horizon	Depth (cm)	pH 1:1		OC (%)	Exchangeable cations				CEC	BS (%)
		H_2O	KCl 1N		K	Na	Ca	Mg		
					[cmol(+)kg^{-1}]					
Bt1	20 - 44	6.10	5.20	0.64	0.05	0.40	8.23	0.46	18.44	49.59
Bt2	44 - 76	6.30	5.30	0.48	0.05	0.39	7.26	0.76	19.36	43.66
BC	76+	5.80	5.30	0.33	0.06	0.42	11.28	2.04	25.64	53.82

CEC: cation exchange capacity, OC: organic carbon, BS: base saturation.

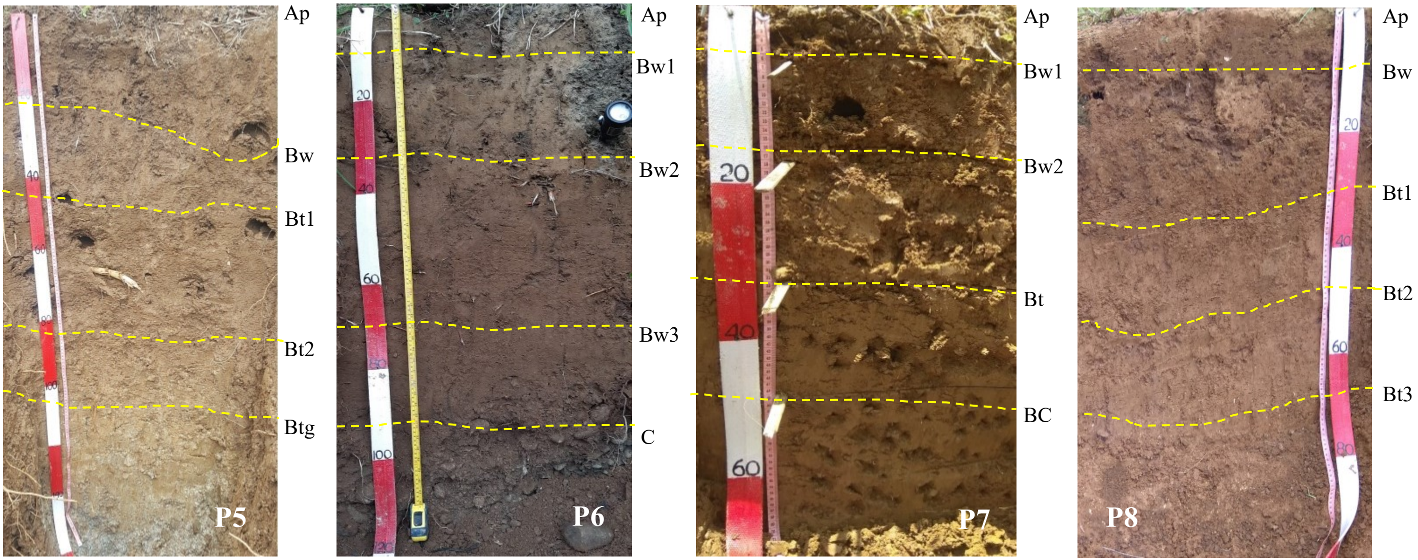


Fig 3. Soil profile appearance of pedon 5 (P5), 6 (P6), 7 (P7) and pedon 8 (P8)

The P3 which is located on a slope of 1%, founded of the umbric epipedon on the 14 cm thick and the cambic horizon due to clay loam textures, did not has a combination of aquatic conditions within 50 cm from the ground surface or has been drained (humustept) and moist colors that has color values 4, any color value with chroma 2 or less and already has a sub angular blocky soil structure. In addition, it has more clay content than the below horizons or the above horizons and the CEC (NH_4OAc 1N) value was 17.96 cmol(+)kg^{-1} only or oxic. Based on these properties, the P3 was classified as fine loamy, isohypermic, Oxic Humustepts.

The P4, which is located on a slope of 15%, founded of the molic epipedon (BS 55%) on the 14 thick and the argillic horizon because it has a fine loamy of particle size classes, and also has a clay skin that it coating of the pore walls and the ped surface. In addition, clay was added by 13% (> 8%) of the eluvial horizon and 10YR hue by having chroma ≤ 3, and BS > 75%. Based on these properties, P4 was classified as fine loamy, isohyperthermic, Typic Argiustolls.

The P5, which is located on a slope of 3%, founded of the ochric epipedon on the 21 cm thick and the argillic horizon because it has a fine loamy of particle size classes, and also has a clay skin that it coating of the pore walls and the ped surface. In addition, clay was added by 5 - 11% (> 1.2%) of the eluvial horizon and has the 7.5YR hue in all horizons (paleustalf). Based on these properties, P5 was classified as fine loamy, isohypermic, Typic Paleustalfs.

The P6, which is located on a slope of 3%, founded of the molic epipedon (BS 93%) on the 12 cm thick and the cambic horizon due to a sandy clay textures, did not has a combination of aquatic conditions within 50 cm from the ground or has drained (ustoll) and any color value with chroma <6 and has a sub angular blocky soil structure. In addition, it has more clay content than the below horizons. Based on these properties, P6 was classified as coarse loamy, isohyperthermic, Typic Haplustolls.

The P8 which is located on a slope of 5%, founded of the molic epipedon on the 7 cm thick and the argillic horizon due to a fine loamy of particle size classes, also has a clay skin that it coating of the pore walls and the ped surface. In addition, clay was added by 2 - 11% (> 1.2%) of the eluvial horizon and has the 7.5YR hue in all horizons (paleustalf), and the BS was 61% or > 75% only (ultic). Based on these properties, P8 was classified as fine loamy, isohypermic, Ultic Paleustalfs.

Table 4. Soil classification in Bulia micro watershed

Pedon	Soil Classification					Area	
	Order	Sub Order	Great Group	Sub Group	Family	ha	%
P1	Inceptisol	Ustept	Humustepts	Typic Humustepts	Fine, isohypertermic, Typic Humustepts	596.88	8.53
P2	Entisol	Psamment	Ustipsamments	Typic Ustipsamments	Sandy, isohypertermic, Typic Ustipsamments	472.68	6.76
P3	Inceptisol	Ustept	Humustepts	Oxic Humustepts	Fine loamy, isohypertermic, Oxic Humustepts	2,297.78	32.86
P4	Mollisol	Ustoll	Argiustolls	Typic Argiudolls	Fine, isohypertermic, Typic Argiustolls	107.35	1.54
P5	Alfisol	Ustalf	Paleustalfs	Typic Paleustalfs	Fine loamy, isohypertermic, Typic Paleustalfs	1,066.95	15.26
P6	Mollisol	Ustoll	Haplustolls	Typic Haplustolls	Coarse loamy, isohypertermic, Typic Haplustolls	1,026.23	14.67
P7	Inceptisol	Ustept	Humustepts	Typic Humustepts	Fine, isohypertermic, Typic Humustepts	248.4	3.55
P8	Alfisol	Ustalf	Paleustalfs	Ultic Paleustalfs	Fine loamy, isohypertermic, Ultic Paleustalfs	61.87	0.88

Pedon	Soil Classification					Area	
	Order	Sub Order	Great Group	Sub Group	Family	ha	%
P9	Mollisol	Ustoll	Paleustolls	Typic Paleustolls	Fine loamy, isohypertermic, Typic Paleustolls	48.35	0.69
P10	Alfisol	Ustalf	Haplustalfs	Inceptic Haplustalfs	Fine, isohypertermic, Inceptic Haplustalfs	1,066.95	15.26
Total						6,993.44	100.00

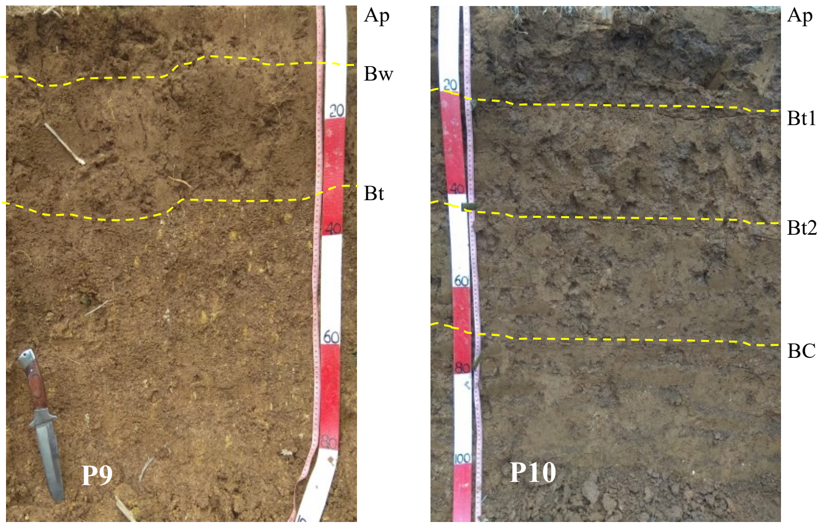


Fig 4. Soil profile appearance of pedon 9 (P9), and pedon 10 (P10)

The P9, which was located on an 8% slope, founded of the molic epipedon (BS 53%) on the 7 cm thick and the argillic horizon due to a fine loamy of particle size classes, also has a clay skin that it coating of the pore walls and the ped surface. In addition, clay was added by 19% (> 1.2%) of the eluvial horizon and has the 7.5YR hue with chroma of ≤ 4, and the BS of >75%. Based on these properties, P9 was classified as fine loamy, isohypermic, Typic Paleustolls.

The P10 which was located on a slope of 15%, founded of the molic epipedon (BS 57% 50%) on the 23 cm thick and the argillic horizon due to a fine clay of particle size classes, also has a clay skin that it coating of the pore walls and the ped surface. In addition, clay was added by 29% (> 1.2%) of the eluvial horizon and 10YR hue with chroma of ≤ 3, and BS >75%. Based on these properties, P10 was classified as fine, isohypermic, Inceptic Haplustalfs.

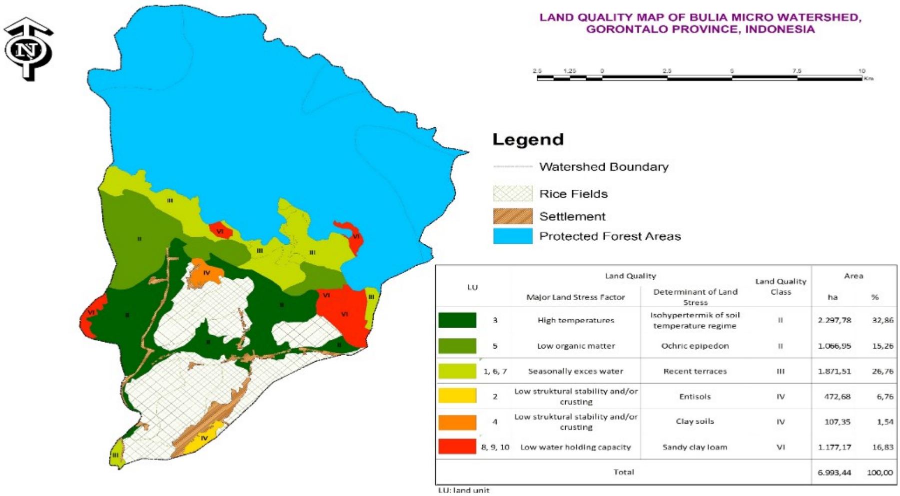
Land quality classes

The land quality (LQ) of the Bulia micro watershed was presented at Table 5 and Figure 5. The LQ of class II with the main factor determinant of land stress was high temperature and low organic matter factors. The high temperature of main factor with an indicator of isohypermic soil temperature regime at LU 3 (P3), and the factor of low ognic matter with an indicator of the ochric epipedon at LU 5 (P5) only. The LQ of class II is good land and has few problems for sustainable production, productivity is generally very high and as a result, the response to management is high (Beinroth et al., 2001). Land management through the addition of organic matter including green manure may be adopted along with recommended fertilizer doses (Sys et al., 1991; Singh et al., 2004; Mahaputra et al., 2019), the mulching to stabilize temperatures and maintain soil moisture (Odjugo, 2008); Eruola et al., 2012; Damaiyanti et al., 2013) were very important. In addition, the use of rice straw mulch and sawdust mulch influences soil properties by decreasing the value of bulk density, increasing soil porosity, increasing soil organic matter (Nasruddin and Hanum, 2015).

The LQ of class III with the main factor determining of land stress was seasonally exces water. The indicators determining of land stress in class III was the new terraces which were spread over of LU 1 (P1), LU 6 (P6) and LU 7 (P7). These new terraces are generally located around the border or river meanders which were prone to erosion and river bank landslides. The LQ of land class III was still considered good land and has few problems for sustainable production, but has a higher risk, especially for low input of corn production which results in a response to high management (Beinroth et al., 2001). Land management through the manufacture of gabions and riverbanks (Rahman, 2013), planting of river bank reinforcement plants and terrace reinforcement plants (Suyana *et al.*, 2017) was very important. Bioengineering methods for river bank erosion control commonly used include planting bamboo (Noor et al., 2011). Fine roots of plants play a role in strengthening the shear strength of the soil (Ludwig et al., 2007). The effectiveness of plants in reducing the rate of erosion is influenced by (1) the canopy or canopy of the plant, (2) the organic material produced, (3) the root system and the ability of plants to cover the soil (Rachman *et al.*, 2004). Vetiver plants were useful for stabilizing river banks, irrigation canals, river erosion control and coastal embankments, excavation slopes and embankments on highways, sand dunes, erosion on sloped agricultural land (Noor et al., 2011). Vetiver grass which has strong fibrous roots holds the ground (Susilawati and Veronika, 2016). Soil nailing was one of the most economical techniques for the stability of slopes of retaining walls because the system works quickly and does not require a large space (Sinarta, 2014); Noor et al., 2011).

Table 5. Land quality classes in Bulia micro watershed

Land Unit	Land Quality		Land Quality Class	Area	
	Major Land Stress Factor	Determinant of Land Stress		ha	%
3	High temperatures	Isohypertermik of soil temperature regime	II	2,297.78	32.86
5	Low organic matter	Ochric epipedon	II	1,066.95	15.26
1, 6, 7	Seasonally exces water	Recent terraces	III	1,871.51	26.76
2	Low struktural stability and/or crusting	Entisols	IV	472.68	6.76
4	Low struktural stability and/or crusting	Clay soils	IV	107.35	1.54
8, 9, 10	Low water holding capacity	Sandy clay loam	VI	1177.17	16.83
Total				3,628.71	51.89



LU		Land Quality: Major Land Stress Factor	Land Quality: Determinant of Land Stress	Land Quality Class	Area ha	Area %
	3	High temperatures	Isohypertermik of soil temperature regime	II	2.297,78	32,86
	5	Low organic matter	Ochric epipedon	II	1.066,95	15,26
	1, 6, 7	Seasonally exces water	Recent terraces	III	1.871,51	26,76
	2	Low struktural stability and/or crusting	Entisols	IV	472,68	6,76
	4	Low struktural stability and/or crusting	Clay soils	IV	107,35	1,54
	8, 9, 10	Low water holding capacity	Sandy clay loam	VI	1.177,17	16,83
Total					6.993,44	100,00

LU: land unit

Fig 5. Land Quality Map of Bulia Micro Watershed

The LQ of class IV with the main factors determining of land stress was low structural stability and/or crusting. These main factors consists of two indicators, namely clay soil and Entisol. The indicator of heavy clay (> 50%) was scattered in LU 4 (P4). This indicator of clay soil was related to the soil crusting which was shown by the average soil structure with sub angular blocky and soil consistency when wet condition was very sticky and very plastic, but in the dry conditions was very hard. Clay and organic matter are binding agents for aggregates (Rachim, 2007). Apparently, the influence of clay is more dominant than organic matter as an aggregate binding agent because the OC content was very low. The Entisol indicators was spread on the LU 2 (P2) only. Entisol is a soil that is still young and underdeveloped (Rachim, 2007). The results of the morphological analysis of the soil indicated that this Entisol has a granular structure (not solid), fine sized with the weak level of development, therefore the stability was low relatively. In addition, the texture of the Entisol was classified as loamy sand with the sandy of particle size classes which is also causes low relatively of soil structure stability. This class requires important inputs from conservation management and the lack of plant nutrition is a major obstacle, therefore a plan to use a good fertilizer must be adopted (Beinroth et al., 2001). Land management through the addition of organic matter can be applied together with recommended fertilizer doses (Sys et al., 1991; Singh et al., 2004;

Mahaputra et al., 2019). Provision of organic matter in soils with clay texture can increase soil water content and available water capacity and reduce soil volume weight (Intara *et al.*, 2011), increase soil porosity (Anastasia et al., 2014), increase uptake, N, P, and K and crop yields in Entisol soils (Afandi et al., 2015). Addition of manure, compost and custom bio can reduce the content weight, soil density, increase aggregate stability, soil porosity and moisture content in Entisol soil (Zulkarnain et al., 2013).

The LQ of class VI with the main factor determining of land stress was low water holding capacity with the sandy clay loam texture as indicators were spread over of LU 8 (P8), LU 9 (P9) and LU 10 (P10). The value of water available on the sandy clay loam texture was only around 20.42 mm (Haridjaja et al., 2013). The available water (pF) was indicated that under conditions of field capacity (pF 2.0) on the LU 8, 9 and LU 10 each one as much 34 mm, 38 mm, and 37 mm and at permanent wilting conditions (pF 4.2) each one as much 24 mm, 24 mm and 17 mm only 19, therefore causes of low water holding capacity. This land should not be used for food production i.e corn because this class requires important inputs from conservation management and lack of plant nutrition is a major obstacle and therefore a plan to use a good fertilizer must be adopted or this land can be used as a biodiversity zone (Beinroth et al., 2001). However, if this land to be used for agricultural cultivation, then land management is through the addition of organic matter along with the recommended fertilizer dosage (Sys et al., 1991; Singh et al., 2004; Mahaputra et al., 2019). Provision of organic material in soils with clay texture can increase soil water content and available water capacity and reduce soil volume weight (Intara et al., 2011), increase soil porosity (Anastasia et al., 2014).

CONCLUSIONS

Based on morphology and physicochemichal properties in Bulia micro watershed of Gorontalo Province of Indonesia shown that the soil structure was dominated by angular blocky, sticky and plastic consistency, and hard consistency. In the alluvial plain the soil texture was dominated by clay fraction, while in the hills and volkan mountains was more dominated by sand fraction. Soils in the Bulia micro watershed also react sour to neutral, with very low to high OC levels, bases can be exchanged dominated by Ca2+ with two series patterns, namely: $Ca^{2+} > Mg^{+} > Na^{+} > K^{+}$ and $Ca^{2+} > Na^{+} > Mg^{+} > K^{+}$, CEC were low to very high, so that the base saturation was moderate to very high. The main soils found were Entisol on P1 (Typic

Ustipsamments)., Inceptisol on P1 (Typic Humustepts), P3 (Oxic Humustepts) and P7 (Typic Humustepts)., Mollisol on P4 (Typic Argiudolls), P6 (Typic Haplustolls), and P7 (Typic Humustepts), P9 (Typic Paleustolls)., and Alfisol on P5 (Typic Paleustalfs), P8 (Ultic Paleustalfs) and P10 (Inceptic Haplustalfs). Land on the alluvial plains were categorized in land quality classes of II, III and IV, land on the volcanic mountains was class IV, while the land on the volcanic hills were categorized as land quality class VI. River bank erosion was the major problem in watersheds, so that lands on river terraces must implement appropriate of soil and water conservation such as the manufacture of gabions, talud, cliff reinforcement plants and terraces. Soil temperatures and high clay content can be applied to mulching and adding organic material as well as good agronomic practices in order to increase land productivity and crop yield.

ACKNOWLEDGMENT

Thank you to the Faculty of Agriculture, Brawijaya University who has funded this research with a non-tax state revenue grant in accordance with the Budget Implementation List Number: DIPA-042.01.2.400919/2019

REFERENCES

1. Afandi, F. N., Siswanto, B. and Nuraini, Y., Effect of giving various types of organic material on soil chemical properties on the growth and production of sweet potato plants in Entisol Ngrangkah Pawon, Kediri, *Soil and Land Resources*, (2015), 2(2), pp. 237–244. Available at: http://jtsl.ub.ac.id.

2. Anastasia, I., Izatti, M. and Suedy, S. W. A., The effect of giving a combination of solid organic fertilizer and liquid organic on soil porosity and spinach plant growth (Amarantus tricolor L.), *Biology Journal*, (2014), 3(2), pp. 1–10.

3. Beinroth, F. H., Eswaran, H. and Reich, P. F., Global assessment of land quality, *sustaining the global farm: Selected papers from the 10th International Soil Conservation Organization Meeting*, (2001), pp. 569-574.

4. BPS Gorontalo Province, Gorontalo province in figure 2020, *BPS Gorontalo Province*, (2020), 1102001.75(75560.2004), pp. 1–535.

5. BPS Gorontalo Regency, Gorontalo regency in figure 2020, *BPS Gorontalo Regency*, (2020), 1102001.75(75020.2003), pp. 1–262.

6. Dutta, M., Land use planning of Tipukjan watershed of Sivasagar district using GIS and remote sensing technique. Ph.D. Thesis, Assam Agricultural University, Jorhat. (2009).
7. Damaiyanti, D. R. R., Aini, N. and Koesrihati., The study of organic mulch application on the growth and yield of red pepper (Capsicum annuum L.), *Crop Production Journal*, (2013), 1(2), pp. 25–32.
8. Devi, P. A. V, Naidu, M. V. S. and Rao, A. R., Characterization and classification of sugarcane growing soils in southern agro-climatic zone: A case study in eastern mandals of Chittoor district in Andhra Pradesh, *Journal of the Indian Society of Soil Science*, (2015), 63(3), pp. 245–258. doi: 10.5958/0974-0228.2015.00034.1.
9. Eruola, A. O., Bello N. J, Ufoegbune G. C, and Makinde, A. A., Effect of mulching on soil temperature and moisture regime on emergence, growth and yield of white yam in a tropical wet-and-dry climate, *International Journal of Agriculture and Forestry*, (2012), 2(1), pp. 93–100. doi: 10.5923/j.ijaf.20120201.15.
10. Eviyati and Sulaeman, Analysis of soil, chemical, plants, water, and fertilizer, *Indonesia Centre of Soil Research*, (2009), pp. 1–203.
11. Husain, J., J. N. Luntungan, Y. E. B. Kamagi, and Nurdin., Conservation-based corn farming model in Gorontalo Province. Research Report. Research, Development and Regional Environmental Impact Control Agency Gorontalo Province, Gorontalo. (2004)
12. Haridjaja, O., Baskoro, D. P. T. and Setianingsih, M., Different levels of field capacity by alhricks, free drainage, and pressure plate methods at different soil texture and relation for sunflower growth (Helianthus annuus L.), *Soil Science and Environmental Journal*, (2013), 15(2), p. 52. doi: 10.29244/jitl.15.2.52-59.
13. Intara, Y. I., A. Sapei, Erizal, N. Sembiring, and M. H. B. Djoefrie., Affected of organic matter application at clay and clay loam soil texture on water holding capacity, *Indonesian Agriculture Sciences Journal*, (2011), 16(2), pp. 130–135.
14. Jambak, M. K. F. A., Baskoro, D. P. T. and Wahjunie, E. D., Characteristics of Soil Physic on Soil Conservation Tillage System (Case Study Of Cikabayan Research Farm, Bogor), *Soil and Land Bulletin*, (2017), 1(1), pp. 44–50.
15. Jackson, M. L., Soil chemical analysis. Prentice Hall of India (Pvt.) Ltd., New Delhi. (1973).

16. Kadao, S. H., Prasad, J. and Gajbhlye, K. S., Characterization and classification of some typical banana growing soils of Wardha district of Maharashtra, *Agropedology*, (2003), 13(2), pp. 28–34.
17. Ludwig, A., Bradford, P., David, B., and Anton, W., Vegetation patches and runoff-erosion as interacting ecohydrological processes in semiarid landscapes. Ecology, (2007), 86, pp. 288-297. doi: https://doi.org/10.1890/03-0569.
18. Mahapatra, S. K., R. Nagdev, R. Gopal, J.N. Surya, R.K. Meena, R.P. Yadav and S.K. Singh., Characterization and classification of the soils of Buraka micro-watershed in Haryana for integrated development, *Journal of the Indian Society of Soil Science*, (2019), 67(2), pp. 137–150. doi: 10.5958/0974-0228.2019.00015.X.
19. Manik, H., Marpaung, P. and Sabrina, T., The level of soil development based on the pattern of clay mineral distribution in Subdistric Lumbanjulu, Distric of Toba Samosir, *Agroteknologi FP USU*, (2017), 5(2), pp. 422–433.
20. Nasruddin and Hanum, H., Study of mulching effects on soil temperature, soil property, and growth of patchouli (Pogostemon cablin Benth), *Floratek*, (2015), 10(2015), pp. 69–78.
21. Noor, A., Vahlevi, J. and Fathurrozi., Slope stabilization for erosion control with soil bioengineering using vetiver grass, *Poros Teknik*, (2011), 3(2), pp. 69–74.
22. Nurdin, *Development, classification and rainfed paddy soils potency derived from lacustrine materials in paguyaman, gorontalo*. MSc Thesis Bogor Agriculture University, (2010a). Available at: https://repository.ipb.ac.id/handle/123456789/57081.
23. Nurdin, The morfology, physics and soil chemistry of inceptisol derived from lacustrine paguyaman of gorontalo relating to soil managements, *Jurnal Agroteknotropika*, (2010b), 1(1), pp. 13–22.
24. Nurdin, Development and rainfed paddy soils potency derived from lacustrine material in paguyaman, gorontalo, *J Trop Soils*, (2011), 16(3), pp. 267–278. doi: 10.5400/jts.2011.16.3.267.
25. Nurdin, Combination of soil conservation techniques and its effect on the yield of maize and soil erosion of dry land in biyonga sub-watershed, gorontalo, *J. Tek. Ling*. (2012), 13(2), pp. 245–252.
26. Odjugo, P. A. O., The effect of tillage systems and mulching on soil microclimate, growth and yield of yellow yam (Dioscorea cayenensis) in Midwestern Nigeria, *African Journal of Biotechnology*, (2008), 7(24), pp.

4500–4507. doi: 10.4314/ajb.v7i24.59629.
27. Oldeman, L. R. and Darmiyati, S., An agroclimatic map of Sulawesi scale 1 - 2.500.000, *Center Research for Agriculture*, (1977), p. 1.
28. Puslitanak Research Team, Survey and mapping of semi-detailed soil resources (scale 1: 50,000) in the North Sulawesi of Paguyaman area for the development of irrigation and sugarcane commodities. Final report. Book III Attachment of the Land Series. Center for Soil and Agro-climate Research, Agency for Agricultural Research and Development, Indonesian Ministry of Agriculture, Bogor, (1995).
29. Prasetyo, B. H., Differentiation in Properties of vertisol from various parent materials, *Indonesian Agriculture Sciences Journal*, (2007), 9(1), pp. 20–31.
30. Rachman, A., Gantzer, J., and Anderson, S. H., Soil hydraulic properties influenced by stiff-stemmed grass hedge systems, *Soil Science Society of America Journal*, (2004), 68(4), pp. 1386–1393. doi: 10.2136/sssaj2004.1386.
31. Rahman, A., Geographic information system model for estimating flow coefficient and its relationship with land cover in Riam Kanan River Basin of South Kalimantan Province, *Bumi Lestari*, (2013), 13(1), p. 1-8.
32. Sys, C., E. V, Rast and Debaveye, J., Land evaluation. Part II. Principles in land evaluation and crop production calculations. International Training Centre for Post-Graduate Soil Scientists, University of Ghent. (1991).
33. Sarkar, D., Gangipodhyay, S. K. and Velayutham, M., Soil toposequence relationship and classification in lower outlier of Chhotanagpur plateau, *Agropedology*, (2001), 11, pp. 29–36.
34. Swarnam, T. P., Velmurugan, A. and Rao, Y. S., Characterization and classification of some soils from Shahibi basin in parts of Haryana and Delhi. *Agropedology*, (2004), 14, p. 114-122.
35. Singh, C., Singh, P and Singh, R., Modern techniques of raising field crops. Oxford and IBH Publishing Co. Pvt. Ltd., New Delhi, (2004), pp. 1-583.
36. Satish, S., M. V. S. Naidu, K. V. Ramana, V. Munaswamy, G. P. Reddy and P. Sudhakar., Characterization and classification of the soils of Brahmanakotkur watershed in Kurnool district of Andhra Pradesh', *Journal of the Indian Society of Soil Science*, (2018), 66(4), pp. 351–361. doi: 10.5958/0974-0228.2018.00044.0.

37. Sinarta, I., Methods of handling landslides with soil nailing', *Paduraksa*, (2014), 3(2), pp. 1–16.
38. Sireesha, P. V. G. and Naidu, M. V. S., Clay mineralogy of soils developed from granite-gneiss of Kurnool District in Andhra Pradesh', *Journal of the Indian Society of Soil Science*, (2015), 63(1), pp. 16–23. doi: 10.5958/0974-0228.2015.00003.1.
39. Soil Science Division Staff, Soil survey manual, *United States Department of Agricultur US*, (2017), pp. 1–145. doi: 10.2307/1233734.
40. Soil Survey Staff, Keys to soil taxonomy, *Soil Conservation Service - NRCS/USDA*, (2014), 12, p. 360.
41. Subardja, D. and Sudarsono, The influence of land quality on productivity of maize in soils derived from volcanic and sedimentary rocks in the bogor area, *Soil and Climate Journal*, (2005), 23, pp. 38–46.
42. Suharta, N., The characteristic of soil developed from felsic sediments in west kalimantan province and its implication to land management, *Soil and Climate Journal*, (2007), (25), pp. 11–26.
43. Sukarman, S. Ritung, M. Anda, and E. Suryani., Guidelines for soil observation in the field, *Agricultural Research and Development Agency, Ministry of Agriculture Republic of Indonesia, Bogor*, (2017), pp. 1–149.
44. Supriya, K., M. V. S. Naidu, P. Kavitha and M. Srinivasa Reddy., Characterization, classification and evaluation of soils in semi-arid region of Mahanandi Mandal in Kurnool district of Andhra Pradesh', *Journal of the Indian Society of Soil Science*, (2019), 67(2), pp. 125–136. doi: 10.5958/0974-0228.2019.00014.8.
45. Susilawati, S. and Veronika, V., Vetiver grass study as a continuous slope safety, *Civil Engineering Communication Media*, (2016), 22(2), p. 99. doi: 10.14710/mkts.v22i2.12886.
46. Suyana, J., Sumarno, Supriyono, and N. P Lestariningsih., Mulching and strengthening of terraces in three types of plants against surface runoff, erosion, growth and yield of plants in Andisols, *Agrosains*, (2017), 19(1), p. 15. doi: 10.20961/agsjpa.v19i1.20924.
47. Vedadri, U. and Naidu, M. V. S., Characterization, classification and evaluation of soils in semi-arid ecosystem of Chillakur mandal in SPSR Nellore district of Andhra Pradesh. Journal of the Indian Society of Soil Science, (2018), 66 (1), p. 9-19. doi: 10.5958/0974-0228.2018.00002.6.
48. Walia, C.S., and Rao, Y. S., Characteristics and classification of some soils of Trans-Yamuna plains. Journal of the Indian Society of Soil Science, (1997), 45 (1), p. 156-162.

49. Yasin, M. G. H., Langgi, W and Faesal, White grain maize as an alternative for staple food, *Iptek Tanaman Pangan*, (2015), 9(2), pp. 108–117.
50. Yatno, E. and Mulyanto, B., Characteristics of soils formed from schist and their land suitability for cocoa crop in Kolaka and East Kolaka Regencies, Southeast Sulawesi, *Soil and Climate Journal*, (2016), 39(2), pp. 109–118.
51. Zulkarnain, M., Prasetya, B and Soemarno, Effects of compost, manure, and custom-bio on soil properties, growth and yield of sugarcane (Saccharum officinarum L.) in Entisol Kebun Ngrangkah of Pawon, Kediri, *Indonesian Green Technology Journal*, (2013), 2(1), pp. 45–52. Available at: https://igtj.ub.ac.id/index.php/igtj/article/view/103.

Soils in the Bulia Micro Watershed of Gorontalo Province, Indonesia and Their Quality Assessment

Received 12.07.2021, Revised ………., Accepted ……………..

Abstract: Ten representatives pedons from the Bulia micro watershed of Gorontalo Province, Indonesia were characterized and classified to determine its land quality (LQ) class. Angular blocky, sticky, plastic consistencies, and a demanding consistency prevailed in the soil structure. In the alluvial plain, a sand fraction prevailed in Volkan mountains. The soils in the Bulia micro watershed also react acid to neutral, with the range of very low to high OC (organic carbon) levels, the reserve of exchangeable bases was dominated by Ca^{2+} in two series patterns, namely: $Ca^{2+} > Mg^{+} > Na^{+} > K^{+}$ and $Ca^{2+} > Na+ > Mg^{+} > K^{+}$, CEC ranged from low to very high, and the base saturation varied from moderate to very high. The primary soils found were Entisol on P2 (Typic Ustipsamments), Inceptisol on P1 and P7 (Typic Humustepts), and P3 (Oxic Humustepts), Mollisol on P4 (Typic Argiudolls), P6 (Typic Haplustolls), and P9 (Typic Paleustolls), and Alfisol on P5 (Typic Paleustalfs), P8 (Ultic Paleustalfs) and P10 (Inceptic Haplustalfs). On the alluvial plains the land was categorized as the LQ class II, III and IV, the volcanic mountains were the LQ class IV, while the land on the volcanic hills was categorized as the LQ class VI. River bank erosion on the land river terraces can be held by the manufacture of gabions, talud, cliff reinforcement plants and terraces. The soil temperatures and high clay content can be regulated by mulching and organic materials

Keywords: Characterization, classification, soil, land quality, the Bulia watershed.

INTRODUCTION

Land is a crucial component of land resources which enables plants growth and food production. Land and plant productivity is primarily determined by soil and other land characteristics related to land quality (Subardja and Sudarsono, 2005). However, an intense tillage during agricultural cultivation and a pressure of the land use when its conservation and sustainability are ignored has resulted into a decrease of land quality. Agricultural production tends to level or even decrease (Nurdin, 2012). Corn is a traditional commercial crop in the province of Gorontalo, Indonesia, which has been intensively and massively cultivated since it was established as a prime commodity in the agropolitan program in 2001. Until 2019, hybrid corn yields in Gorontalo Province reached 1.7 million tons or increased by 9.3% compared to 2018, however, the productivity of maize was still low at only 5.0 tons/ha (BPS Gorontalo, Province 2020). In fact, the potential corn yield in Indonesia can reach 10-11 tons/ha (Yasin et al., 2015), while the achievement of the national productivity in 2018 was only 5.2 tons/ha (Indonesian Ministry of Agriculture 2019).

The Bulia micro watershed area is a corn production centre that also supports the agricultural area below. The watershed has a vital role because it supplies irrigation water for agriculture and other activities (Mahapatra *et al.*, 2019). The corn cultivation in this watershed has exceeded the carrying capacity indicated for the corn planting on the slope of >25%, so that the land degradation often occurs. Soil erosion, according to the corn agropolitan program of Gorontalo, reached 1,396 tons/ha/year (Husain et al., 2004). Meanwhile, the corn productivity in this area is only 5.0 tons/ha (BPS Gorontalo Regency, 2020), which could happen due to the fact that the crop was cultivated on a non-suitable land.

Soil characterization is essential because it provides some necessary information about the soil characteristics for growing plants (Devi et al., 2015). For sustainable management of soil resources in agroecological areas we need timely monitoring of significant physical, chemical and biological soil characteristics and responses to the changes in land management (Supriya et al., 2019). These soil characteristics then form the basis for land classification. Combining soil characterization with classification is a powerful tool for developing management strategies for food security and environmental sustainability (Satish *et al.*, 2018). However, the efforts to link land characteristics and classification with a specific land quality are still relatively rare. Land quality is a land ability to perform a specific function before the land is degraded (Beinroth et al., 2001). Understanding soil types and their distribution, its limits and potential is essential for a proper management to increase productivity and yields (Niranjana et al., 2011).

The survey and mapping of soil resources in the Paguyaman watershed were carried out by the Soil and Agro-climate Research Centre of the Indonesian Ministry of Agriculture (Puslittanak Research Team, 1995), however, the mapping scale was 1: 50,000. In 2010, some research was carried out on the development, classification and potential of the paddy soils on toposequence (Nurdin, 2010), however, it only focused on the rainfed paddy soils, while the dry land was only compared to the locations close to the soil pedon in the rice fields. Considering the high intensity of the land management and the massive corn cultivation in this sub-watershed, this research has become significant.

MATERIALS AND METHODS

Study location

The Bulia micro watershed is a part of the Paguyaman watershed located in the northern part, it covers Mootilango and Boliyohuto District of Gorontalo Regency of Gorontalo Province, Indonesia (Figure 1). Geographically, the research location is between 0°39'123 "and 0°51'321" N, 122°35'21 "and 122°43'12" S (Table 1), which is 67 km from Gorontalo City, Indonesia.

Overall, the Bulia micro watershed has 21,456.58 ha and consists of upland amounted to 18,993.44 ha (32.59%), and paddy fields amounted to 2,991.15 ha (13.94%). Specifically, the upland agriculture covers the agricultural land areas amounted to 6,993.44 ha (37.87%), settlement areas – 461.59 ha (2.50%), and forest areas amounted to 11,010.40 ha (59.63%). The soils in this area are generally developed from volcanic material in the upper watershed and lacustrine deposits in the middle and bottom of the watershed. The study area is located in tropical climate with rainy and dry seasons. The average annual rainfall was only 1,478 mm with 1 wet month only and 4 dry months, so it belongs to the E2 agro-climate zone (Oldeman and Darmiyati, 1977). The average annual air temperature reaches 28.19°C with the maximum temperature of 28.73°C and the minimum temperature of 27.63°C. Under these conditions, the soil moisture regime is determined ustic and the soil temperature regime – isohyperthermic (Soil Survey Staff, 2014).

Table 1. Site characteristics of the pedons in the Bulia micro watershed

Pedon/ Villages	Location	Elevation (m msl)	Landform	Slope (%)	Drainage
P1, Tolite	0°39’44.80” N 122°35’27.20” S	24	Alluvial plain	0 – 3	Badly-drained
P2, Monggolito	0°40’01.20” N 122°37’57.20” S	159	Volcanic mountain	15 – 30	Well-drained
P3, Huyula	0°42’59.9” N 122°39’43.2” S	63	Alluvial plain	0 – 3	Moderately
P4, Payu	0°44’04.4” N 122°37’48.4” S	53	Alluvial plain	0 – 3	Moderately
P5, Pilomonu	0°43’53.80” N 122°35’22.60” S	75	Alluvial plain	0 – 3	Moderately
P6, Karyamukti	0°42’20.50” N 122°41’05.50” S	109	Alluvial plain	3 – 8	Moderately
P7, Karyamukti	0°42’10.30” N 122°41’19.40” S	114	Alluvial plain	3 – 8	Moderately

Commented [ed1]: Poorly drained

P8, Sukamaju	0°44’05” N 122°40’04” S	253	Volcanic hill	8 – 15	Well-drained
P9, Payu	0°45’12” N 122°38’08” S	285	Volcanic hill	8 – 15	Well-drained
P10, Huyula	0°43’11.10” N 122°40’31.20” S	262	Volcanic hill	8 – 15	Well-drained

msl: mean sea level.

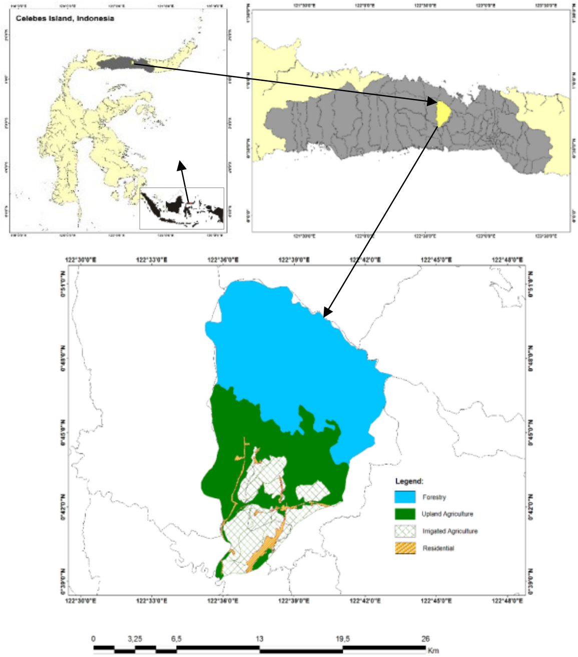


Fig 1. Location Map of the Bulia Micro watershed

Soil surveying, characterization and classification

Ten representative pedons were selected to conduct the soil survey, The description of soil morphology refers to the Soil Survey Manual (Soil Science Division Staff, 2017; Sukarman et al., 2017). According to standard procedures, soil samples were taken at each horizon and their physical and chemical properties were analyzed (Jackson, 1973; Eviyati and Sulaeman, 2009). The morphological and the soil properties data obtained during the laboratory analysis are used for the soil characterization together with the climate and the terrain conditions data, according to Sukarman et al., (2017). The soil characteristics are used for soil classification according to the keys to soil taxonomy (Soil Survey Staff, 2014).

Land quality assessment

Land quality (LQ) class assessment follows the method according to Beinroth et al. (2001) were modified based on previous soil characteristics and classifications. Soil pedons (P), which were classified in taxa according to the Soil Taxonomy System (Soil Survey Staff, 2014), were combined with a land unit (LU) basing on the similarity of the criteria in taxa. Soil and pedoklimat information was used to place each LU into I to IX land quality classes with class I having the most appropriate attributes and class IX having the least suitable ones for crop production. The results of the land quality analysis are widely presented and described with the help of Arc GIS.

Commented [E2]: Could you please paraphrase the sentence and/or break it into two smaller ones? Do you mean that the initial method or the assessment itself was modified?

Commented [E3]: I didn't find the term "pedoklimat". Do you mean pedo+climate=pedoclimate?

RESULTS AND DISCUSSION

Morphology and soil physical properties

The results of field studies and the laboratory characterization of ten soil pedons were presented in Table 2. The soils in the study area have been developed as indicated by the horizon structuring (horizons A and B), with the depth of the soil solum varying from shallow to very deep. The soil colour is only of 7.5YR and 10YR hue, where 7.5YR is dominant. P1, P2, P3, P5, P8, P9 and P10 soil colour varies from dark brown, brown to strong brown with hue 7.5YR, ranging from 3 to 5 and chroma – from 1 to 6. While in P4, P6 and P7, soil colour varies from very dark grayish brown, dark brown to dark yellowish-brown with hue 10YR, values ranging from 3 to 4, and chroma – from 2 to 6. The colour of soil horizon A is darker than of horizon B due to the fact that the organic matter content in horizon A is higher than in horizon B (Yatno et al., 2015). The higher the organic matter content, the darker the soil colour is (Suharta, 2007). Soil colour seems to be a function of chemical and mineralogical composition (Swarnam *et al.*, 2004; Walia and Rao, 1997), and soil texture arrangements are influenced by topographic position and humidity regimes (Walia and Rao, 1997).

The soil structure varies from crumbs, angular blocky, sub angular blocky to prismatic, with the dominant angular blocky. P1, P3, P4, P6, P7, P8, P9 and P10 were mostly of angular blocky structure with the sizes varying from fine, medium to coarse, with weak and strong structural development. While the soil structures of P2 and P5 varies between crumbs, angular blocky, sub angular blocky and prismatic with the sizes ranging from fine, medium to coarse and the level of the soil structure development varying from weak, moderate to strong. The angular blocky soil structures were strongly associated with higher clay fractions (Devi et al., 2015). While newly developed soil shows crumbly soil structure (Manik et al., 2017), the addition of organic material continues to take care of organic material through plant biomass (Devi et al., 2015) or the tillage intensity, which was carried out thoroughly by turning over the soil until reaching the damaged soil structure (Jambak et al., 2017). The variation of soil structure will be consistently affecting the soil.

The soil consistency in wet conditions varies between non-sticky and non-plastic on Pedon 2, slightly sticky and slightly plastic, sticky and plastic in the horizon on P1, P3, P4, P5, P6, P7, P8, P9 and P10, very sticky and very plastic on the surface horizon (Ap) of P9 and the subsurface horizon (BC) of P10, however, slightly sticky and slightly plastic consistencies prevail. While in moist conditions the consistencies vary from loose, firm to very firm, the firm consistencies are still dominant. P1, P3, P4, P5, P6, P7, P8, P9 and P10 were dominated by hard consistencies, while P2 – by loose ones. There is a very hard consistency in P1 and P10 in the subsurface horizon (Bw and BC), while in the surface horizon (Ap) a very hard consistency can be only found in P9. The consistency in dry conditions varies from loose, hard to very hard, with a dominant hard consistency. P1, P3, P4, P5, P6, P7, P8, P9 and P10 were dominated by a hard consistency, however, in P1 and P10 in the subsurface horizon (Bw3 and BC) one could notice a very hard consistency, while in P9 precisely a very hard consistency was found on the surface horizon (Ap). Sticky and plastic consistency might form due to a high clay content in the soil (Sarkar et al., 2001); (Kadao et al., 2003), while non-sticky and non-plastic consistency might form due to a very little clay content (Sireesha and Naidu, 2015; Devi et al., 2015).

Commented [E4]: What do you mean by “arrangements”?

Commented [E5]: Do you mean that “the content of organic materials is still determined by plant biomass organic material” by that sentence? If not – couldn’t you paraphrase it or explain the other way?

Table 2. Morphological characteristics and soil physical properties in the Bulia micro watershed

Pedon and Horizon	Depth (cm)	Colour Moisture	Structures	Consistence			Sand	Silt	Clay	Texture Class
				w	m	d	%			
P1 (Alluvial Plain)										
Ap	0 - 23	7.5 YR 4/4	m, 3, abk	s, p	fi	h	9	40	51	Silty Clay
Bw1	23 - 43	7.5 YR 4/2	m, 3, abk	ss, sp	fi	h	3	46	51	Silty Clay
Bw2	43 - 75	7.5 YR 4/4	m, 3, abk	ss, sp	fi	h	3	54	43	Silty Clay
Bw3	75 - 100	7.5 YR 4/2	m, 1, abk	ss, sp	vfi	vh	3	46	51	Silty Clay
P2 (Volcanic Mountains)										
Ap	0 - 5	7.5 YR 4/4	f, 1, cr	so, po	fr	l	85	10	5	Loamy sand
Bw1	5 - 37	7.5 YR 4/4	f, 2, sbk	so, po	fr	l	84	2	14	Loamy sand
Bw2	37 - 61	7.5 YR 4/4	m, 2, p	so, po	fr	l	75	10	15	Sandy Loam
C	61+	7.5 YR 4/2	m, 3, p	so, po	fr	l	66	15	19	Sandy Loam
P3 (Alluvial Plain)										
Ap	0 - 14	7.5 YR 3/3	f, 1, cr	ss, sp	fi	h	33	41	26	Loam
Bw1	14 - 43	7.5 YR 4/4	f, 2, abk	s, p	fi	h	31	37	32	Clay Loam
Bw2	43 - 68	7.5 YR 4/4	f, 1, abk	ss, sp	fi	h	23	54	23	Silty Loam
Bw3	68+	10 YR 3/6	f, 1, cr	s, p	fi	h	23	48	29	Clay Loam
P4 (Alluvial Plain)										
Ap	0 - 14	10 YR 3/3	m, 3, abk	s, p	fi	h	27	26	47	Clay
Bw	14 - 50	10 YR 4/3	f, 1, abk	s, p	fi	h	32	34	34	Clay Loam
Bt1	50 - 81	10 YR 3/2	f, 1, abk	ss, sp	fi	h	12	24	64	Clay
Bt2	81+	7.5 YR 4/1	f, 1, abk	s, p	fi	h	16	25	59	Clay
P5 (Alluvial Plain)										
Ap	0 - 21	7.5 YR 4/4	f, 2, sbk	ss, sp	fi	h	23	43	34	Clay Loam
Bw	21 - 46	7.5 YR 4/4	f, 2, sbk	ss, sp	fi	h	23	48	29	Clay Loam
Bt1	46 - 84	7.5 YR 4/3	f, 2, abk	s, p	fi	h	25	35	40	Clay
Bt2	84 - 117	7.5 YR 4/6	m, 2, p	s, p	fi	h	24	36	40	Clay

Pedon and Horizon	Depth (cm)	Colour Moisture	Structures	Consistence			Sand	Silt	Clay	Texture Class
				w	m	d	%			
Btg	117+	7.5 YR 5/8	m, 1, sbk	ss, sp	fi	h	8	46	46	Silty Clay
P6 (Alluvial Plain)										
Ap	0 - 12	10 YR 3/3	f, 1, abk	s, p	fi	h	84	15	1	Loamy Sand
Bw1	12-34	10 YR 3/4	f, 1, abk	s, p	fi	h	61	10	29	Sandy Clay Loam
Bw2	34 - 71	10 YR 4/6	m, 3, abk	ss, sp	fi	h	61	24	15	Sandy Loam
C	71 - 90	7.5 YR 5/8	f, 1, cr	so, po	fr	l	84	5	11	Loamy Sand
P7 (Alluvial Plain)										
Ap	0 - 6	7.5 YR 4/6	m, 1, abk	s, p	fi	h	33	11	56	Clay
Bw1	6 - 17	10 YR 4/6	m, 3, sbk	s, p	fi	h	29	20	51	Clay
Bw2	17 - 33	10 YR 3/6	m, 1, abk	ss, sp	fi	h	21	20	59	Clay
Bt	33 - 49	10 YR 3/6	f, 1, p	ss, sp	fi	h	19	15	66	Clay
BC	49+	7.5 YR 4/6	f, 1, abk	ss, sp	fi	h	18	29	53	Clay
P8 (Volcanic Hills)										
Ap	0 - 7	7.5 YR 3/3	f, 1, abk	ss, sp	fi	h	64	10	26	Sandy Clay Loam
Bw	7 - 24	7.5 YR 3/3	m, 1, abk	s, p	fi	h	47	24	29	Sandy Clay Loam
Bt1	24 - 44	7.5 YR 4/6	f, 3, p	s, p	fi	h	45	15	40	Sandy Clay
Bt2	44 - 63	7.5 YR 5/6	m, 3, abk	s, p	fi	h	42	16	42	Clay
Bt3	63+	7.5 YR 5/6	m, 1, abk	s, p	fi	h	42	6	52	Clay
P9 (Volcanic Hills)										
Ap	0 - 16	7.5 YR 3/2	m, 3, abk	vs, vp	vfi	vh	54	31	15	Sandy Loam
Bw	16 - 34	7.5 YR 3/3	m, 1, abk	s, p	fi	h	42	24	34	Clay Loam
Bt	34+	7.5 YR 4/4	m, 1, abk	ss. sp	fi	h	50	15	35	Sandy Clay
P10 (Volcanic Hills)										
Ap	0 - 20	7.5 YR 3/3	m, 3, abk	ss, sp	fi	h	48	26	26	Sandy Clay Loam
Bt1	20 - 44	7.5 YR 3/4	m, 3, abk	s, p	fi	h	41	15	44	Clay
Bt2	44 - 76	7.5 YR 4/6	c, 3, sbk	s, p	fi	h	42	14	44	Clay

Pedon and Horizon	Depth (cm)	Colour Moisture	Structures	Consistence			Sand	Silt	Clay	Texture Class
				w	m	d	%			
BC	76+	5 YR 4/6	c, 3, p	vs, vp	vfi	vh	31	2	67	Clay

Structure: *size*: vf – very fine, f – fine, m – medium, c – coarse; *structureless grade*: 1 – weak, 2 – moderate, 3 – strong; *type*: cr – crumb, sg – single grain, abk – angular blocky, sbk – sub-angular blocky. Consistence: *dry* (d): s – soft, l – loose, sh – slightly hard, h – hard, vh – very hard, eh – extremely hard; *moist* (m): l – loose, fr – friable, fi – firm, vfi – very firm, efi – extremely firm, *wet* (w): so – non-sticky, ss – slightly sticky, s – sticky, vs – very sticky; po – non-plastic, ps – slightly plastic, p – plastic, vp – very plastic.

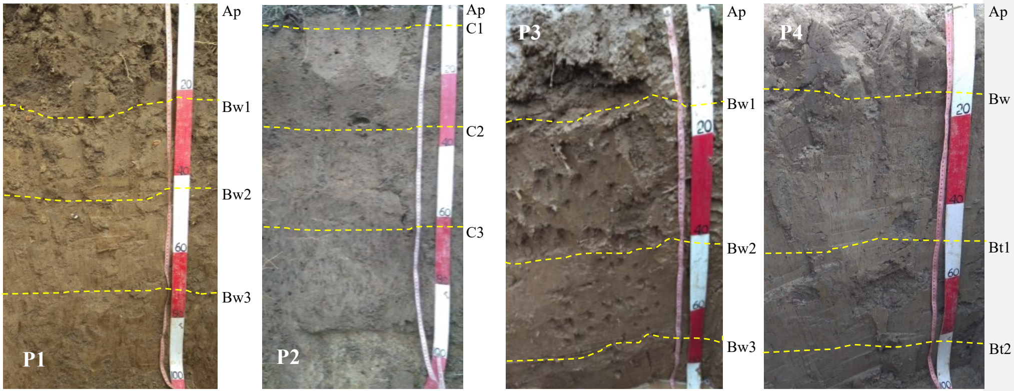


Fig 2. Soil profile appearance of pedon 1 (P1), 2 (P2), 3 (P3) and pedon 4 (P4)

The soil texture of all pedons varies greatly between sandy clay loam, sandy loam, loamy sand, sandy loam, silty loam, clay loam, silty clay and clay, except for P7 that was of clay texture in all horizons. Wide variations of soil texture may be caused by the variations in parent material, topography, in-situ weathering, translocation of clays by eluviation and soil age (Satish et al. 2018). Apparently, pedons located in the alluvial group were more dominated by clay fractions, although the distribution patterns were irregular. The distribution of irregular clay fractions was typical for sediment materials (Nurdin, 2010). While a sand fraction dominated the volcanic group, the distribution of sand and clay fractions shows the opposite pattern. A decrease in the sand fraction is due to the clay illuviation and in-situ mineral destruction process, which was characterized by a decline in the absolute amount of sand in the middle of the solum (Rachim, 1994). The texture that is found in the subsurface horizon is caused by higher weathering in the subsurface layer (Dutta, 2009). The clay content in the solum middles (B-illuviation) was higher than in the upper horizon (A-eluviation) and in the lower layer horizon. This indicates the occurrence of a lessivage process with some clay skins seen, so that an argillic horizon was formed in P4, P5, P8, P9 and P10. Although the process of eluviation and illuviation occurred, the pedon remained, but the clay skins were not found, so the horizons were formed of cambic and candic.

Commented [E6]: I tried to correct the sentence but I'm still not sure about the meaning

Soil chemical properties

Soil chemical properties are presented in Table 3. Soil pH varies from acid (pH 5.3) to neutral (pH 7.2). The pedons located on the upper watershed or in volcanic groups (P2, P8, P9 and P10) have a lower pH than the ones located on the lower watershed or in alluvial groups (P1, P3, P4, P5, P6, and P7). The pedon in the alluvial group represented a depressed area which is the accumulation of the bases carried by washing water from the hinterland section and the accumulation of more alkaline bases in soils with poorer drainage (Nurdin, 2010a). The pedons in the volcanic group experienced more intensive washing during the rain due to a better soil drainage. The trend of pH increasing with more depth may be explained by the release of organic acids during the decomposition of organic matter, these acids may have lowered the pH at the soil surface (Satish *et al.*, 2018). The pH differences of KCl and the pH of H_2O of all pedons show negative values. This means that all pedons are dominated by negatively charged clay minerals (Suharta, 2007). Acid and slightly acid soil pH values in P1, P3, P5, P9 and P10 indicate that the soil has undergone some development that was not continued, while a neutral soil pH

Commented [E7]: Do you mean that the development was not continued?

in P2, P4, P6, P7, and P8 shows that the soil is relatively new.

Organic carbon (OC) varies from very low to high (0.08 - 2.28%). The OC value was high in the surface horizon (Ap), except for P4 and P5. The OC value on the surface is higher due to the accumulation of organic materials, while its low values in P4 and P5 were due to the river flooding. The low OC value was also determined by a faster degradation of the organic material in the tropics and a low addition of farmyard manure (Vedadri and Naidu, 2018). A high OC distribution pattern on the surface and its dramatical decrease in horizon B in accordance with the depth is a general soil development pattern (Prasetyo, 2007).

Commented [E8]: Did I save the meaning paraphrasing the sentence this way? If not – please explain the meaning of the highlighted sentences, probably dividing it into smaller ones.

The reserve (sum) of exchangeable bases vary between very low, low, medium, high and very high. Calcium cation is the dominating one in the exchangeable bases reserve, which ranges from 2.54-18.02 cmol(+)kg^{-1}, while magnesium (Mg^{+}) ranges from 0.15-6.66 cmol(+)kg^{-1}, sodium (Na^{+}) ranges from 0.26-3.02 cmol(+)kg^{-1}, potassium (K^{+}) ranges from 0.05-3.56 cmol(+)kg^{-1}. Based on the number of bases, the P1, P5, P7, and P10 patterns follow the sequence: $Ca^{2+} > Mg^{+} > Na^{+} > K^{+}$. This series pattern was the same as Nurdin (2011) and Satish et al. (2018) reported. At the same time P2, P3, P4, P6, P8 and P9 follow the sequence: $Ca^{2+} > Na^{+} > Mg^{+} > K^{+}$. A high rate of exchangeable bases in the surface horizon (Ap) results from fertilization during corn cultivation, while in the lower layer rainfall washing together with good drainage conditions make it possible to wash in the soil solum.

The cation exchange capacity (CEC) varies from low (7.7 cmol(+)kg^{-1}) to very high (42.40 cmol(+)kg^{-1}). The CEC is influenced by the levels of organic carbon and soil minerals (Prasetyo et al. 2007; Suharta 2007). It seems that CEC in P1, P3, P4, P5, P7, P8, and P9 were more influenced by OC content than by soil minerals. The higher the soil OC, the higher the soil CEC is (Suharta, 2007). While P2, P6 and P10 were thought to be more influenced by soil minerals, these bases can be exchanged and this CEC will eventually affect base saturation. Base saturation (BS) varies from moderate (40.55%) to very high (93%). All pedons generally have a medium and a high BS, except P6, which has a very high BS on the surface horizon (Ap). The variations in BS may be caused by the variations in nature and/or the content of soil colloids, and the relatively high base saturation in the surface layers can be attributed to the recycling of cation base through vegetation (Devi and Kumar 2010). In addition, if soil has a number of bases which is smaller than CEC, BS tends to be lower, whereas when the soil has a number of bases close to or higher than CEC, BS tends to be higher (Nurdin, 2010b).

Soil classification

Based on morphological and soil characteristics, the pedons are classified according to their family level and the orders of the soils found, namely Entisol, Inceptiol, Mollisol and Alfisol (Table 4). P1 and P7, which are located on a slope of 3% and 5%, are based on the molic epipedon with a 23 cm thickness and a cambic horizon. These pedons did not experience aquatic conditions at the depth of 50 cm from the soil surface (humustept), the soil colour had a value of 4 with a chroma of 2 or less and the soil structure was sub angular blocky. In addition, it had more clay content than the horizons below or above it. Based on these properties, P1 was classified as Typic Humustepts, fine, isohyperthermic.

P2, located on a slope of 15%, is represented by the ochric epipedon with a 5 cm thickness and a candic horizon. In this pedon there was an increase in the percentage of clay in the fine soil fraction with a depth of 15 cm or less in the vertical distance. The clay content was 4% or more (absolute value), which is more than that of the horizon above it which has a total clay content in the soil fine fraction less than 20%. In addition, it had a loamy sand texture (psamments) and a CEC value (NH4OAc, pH 7) > 16 cmol(p+)kg-1. Based on these characteristics, P2 was classified as Typic Ustipsamments, sandy, isohyperthermic.

P3 is located on a slope of 1%, represented by the umbric epipedon with a 14 cm thickness and a cambic horizon. This pedon did not experience aquatic conditions at the depth of 50 cm from the soil surface (humustept), the soil colour had a value of 4 with a chroma of 2 or less and the soil structure is sub angular blocky. In addition, it had more clay content than the horizons below or above and its CEC (NH_4OAc 1N) value was 17.96 cmol(+)kg^{-1} only (oxic). Based on these properties, P3 was classified as Oxic Humustepts, fine loamy, isohyperthermic.

P4 is located on a slope of 15%, represented by the molic epipedon (BS 55%) with a 14 cm thickness and an argillic horizon. This pedon had a fine loamy class of particle size with a typical clay coating of the pore walls and the ped surface. In addition, there was 13% (> 8%) of clay on the eluvial horizon and 10YR hue with a chroma ≤ 3, and BS > 75%. Based on these properties, P4 was classified as Typic Argiustolls, fine loamy, isohyperthermic.

Table 3. Soil chemical properties in the Bulia micro watershed

Pedon and Horizon	Depth (cm)	pH 1:1		OC (%)	Exchangeable cations				CEC	BS (%)
		H_2O	KCl 1N		K	Na	Ca	Mg		
					[cmol(+)kg^{-1}]					
P1 (Alluvial Plains)										
Ap	0 – 23	6.20	5.40	2.29	0.29	1.88	18.02	1.86	42.40	52.00
Bw1	23 – 43	6.00	5.20	0.90	0.18	2.01	15.47	2.97	39.19	52.62
Bw2	43 – 75	6.40	5.50	0.74	0.14	2.19	12.36	2.50	37.85	45.42
Bw3	75 - 100	6.50	5.60	0.65	0.14	2.23	15.22	3.26	37.58	55.49
P2 (Volcanic Mountains)										
Ap	0 - 5	6.50	5.60	1.19	0.10	0.34	3.77	0.30	11.13	40.55
Bw1	5 - 37	6.10	5.20	0.55	0.08	0.34	4.20	0.60	7.75	67.49
Bw2	37 - 61	6.20	5.30	0.63	0.08	0.35	3.91	0.15	8.87	50.52
C	61+	6.20	5.30	0.56	0.08	0.36	6.51	0.76	12.29	62.79
P3 (Alluvial Plain)										
Ap	0 - 14	5.60	4.60	0.80	0.05	1.46	4.84	0.61	16.15	43.00
Bw1	14 - 43	6.00	5.10	0.41	0.09	1.57	7.72	1.70	19.78	56.00
Bw2	43 - 68	5.80	4.90	0.32	0.05	1.55	8.95	0.91	21.58	53.00
Bw3	> 68	6.20	5.20	0.48	0.05	1.55	10.12	0.76	20.43	61.00
P4 (Alluvial Plains)										
Ap	0 - 14	6.50	6.10	0.41	0.06	1.49	11.87	0.62	25.55	55.00
Bw	14 - 50	6.70	6.30	0.96	0.19	1.43	9.71	2.12	21.60	62.00
Bt1	50 - 81	7.00	6.00	0.41	0.12	1.58	16.54	2.01	35.19	58.00
Bt2	81+	5.80	5.00	0.24	0.09	1.56	13.47	6.66	33.04	66.00
P5 (Alluvial Plains)										
Ap	0 - 21	5.20	4.50	0.08	0.16	2.29	9.39	2.93	28.39	52.00
Bw	21 - 46	5.10	4.30	0.49	0.20	2.30	8.62	3.08	28.40	50.00
Bt1	46 - 84	5.70	4.90	0.57	0.12	0.26	7.69	2.00	21.56	47.00

Pedon and Horizon	Depth (cm)	pH 1:1		OC (%)	Exchangeable cations				CEC	BS (%)
		H_2O	KCl 1N		K	Na	Ca	Mg		
					[cmol(+)kg^{-1}]					
Bt2	84 - 117	5.10	4.20	0.50	0.17	0.30	10.38	2.05	31.34	41.00
Btg	117+	5.10	4.10	0.42	0.25	0.34	15.37	1.90	38.58	46.00
P6 (Alluvial Plains)										
Ap	0 - 12	7.20	6.60	0.64	3.56	3.02	2.54	0.91	10.76	93.00
Bw1	12 - 34	7.10	6.60	0.32	0.28	1.72	6.03	0.30	11.79	71.00
Bw2	34 - 71	7.00	6.00	0.56	0.16	0.39	7.84	0.15	17.16	50.00
C	71 - 90	6.80	6.00	0.40	0.12	0.38	6.49	0.15	13.96	51.00
P7 (Alluvial Plains)										
Ap	0 - 6	6.30	5.40	0.76	0.10	0.42	5.31	2.41	18.31	45.00
Bw1	6 - 17	6.10	5.10	0.57	0.09	0.39	6.77	2.15	22.99	41.00
Bw2	17 - 33	5.90	5.00	0.57	0.07	0.44	8.55	4.04	25.45	51.00
Bt	33 - 49	5.60	4.80	0.33	0.08	0.45	13.64	3.72	29.79	60.00
BC	49+	5.90	5.00	0.41	0.12	2.04	13.16	0.31	33.06	47.00
P8 (Volcanic Hills)										
Ap	0 - 7	6.00	5.20	0.96	0.24	2.09	10.15	0.45	19.40	67.00
Bw	7 - 24	6.40	5.50	0.80	0.17	2.05	10.30	0.61	21.55	61.00
Bt1	24 - 44	6.70	5.80	0.48	0.24	2.21	10.07	1.83	26.06	55.00
Bt2	44 - 63	6.60	5.60	0.49	0.33	2.21	9.47	0.78	26.52	48.00
Bt3	63+	6.60	5.60	0.50	0.49	2.35	13.84	1.27	32.83	55.00
P9 (Volcanic Hills)										
Ap	0 - 16	5.30	4.50	0.80	0.13	2.15	10.15	0.61	24.80	53.00
Bw	16 - 34	6.20	5.30	0.57	0.10	2.30	12.44	0.77	29.51	53.00
Bt	34+	6.20	5.20	0.48	0.06	2.25	13.49	0.46	30.54	53.00
P10 (Volcanic Hills)										
Ap	0 - 20	5.80	4.90	0.72	0.12	0.40	5.90	1.21	18.31	41.69

Pedon and Horizon	Depth (cm)	pH 1:1		OC (%)	Exchangeable cations				CEC	BS (%)
		H_2O	KCl 1N		K	Na	Ca	Mg		
					[cmol(+)kg^{-1}]					
Bt1	20 - 44	6.10	5.20	0.64	0.05	0.40	8.23	0.46	18.44	49.59
Bt2	44 - 76	6.30	5.30	0.48	0.05	0.39	7.26	0.76	19.36	43.66
BC	76+	5.80	5.30	0.33	0.06	0.42	11.28	2.04	25.64	53.82

CEC: cation exchange capacity, OC: organic carbon, BS: base saturation.

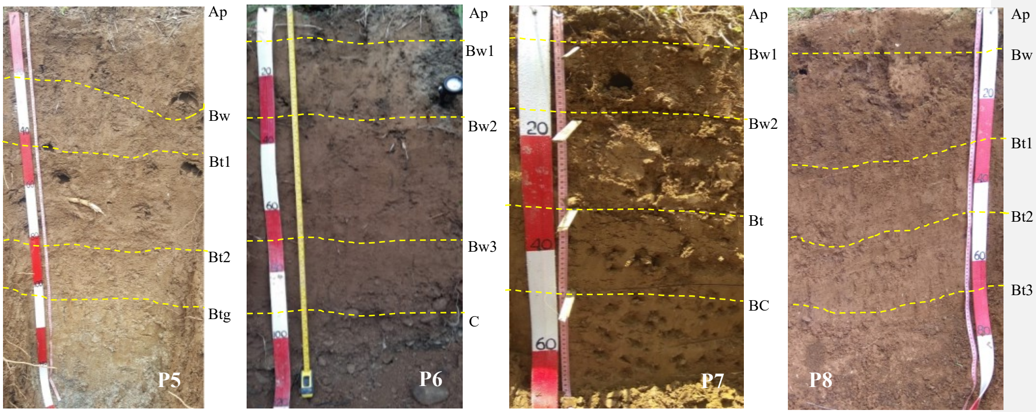


Fig 3. Soil profile appearance of pedon 5 (P5), 6 (P6), 7 (P7) and pedon 8 (P8)

P5 is located on a slope of 3%, represented by the ochric epipedon with a 21 cm thickness and an argillic horizon. According to the aggregate size distribution the pedon refers to the fine loam class with a typical clay coating of the pore walls and the ped (aggregate) surface. In addition, clay was added at 5 - 11% (> 1.2%) of the eluvial horizon, and 7.5 YR was typical of all horizons (paleustalf). Based on these properties, P5 was classified as Typic Paleustalfs, fine loamy, isohyperthermic.

P6, is located on a slope of 3%, represented by the molic epipedon (BS 93%) with a 12 cm thickness and a cambic horizon. This pedon had a sandy clay texture and does not have a combination of aquatic conditions within 50 cm from the ground (ustoll). The colour value was with a chroma <6 and it had a sub angular blocky soil structure. In addition, it had more clay content than the below horizons. Based on these properties, P6 was classified as Typic Haplustolls, coarse loamy, isohyperthermic.

P8 is located on a slope of 5%, represented by the molic epipedon with a 7 cm thickness and an argillic horizon. According to the aggregate size distribution the pedon refers to the fine loam class with a typical clay coating of the pore walls and the ped surface. In addition, clay was added at 2 - 11% (> 1.2%) of the eluvial horizon and 7.5YR hue was typical in all horizons (paleustalf), with BS of 61% or > 75% only (ultic). Based on these properties, P8 was classified as Ultic Paleustalfs, fine loamy, isohyperthermic.

P9 is located on an 8% slope, represented by the molic epipedon (BS 53%) with 7 cm thickness and the argillic horizon. According to the aggregate size distribution the pedon refers to the fine loam class with a typical clay coating of the pore walls and the ped surface. In addition, clay was added at 19% (> 1.2%) of the eluvial horizon and had 7.5YR hue with a chroma of ≤ 4, with BS of >75%. Based on these properties, P9 was classified as Typic Paleustolls, fine loamy, isohyperthermic.

P10 is located on a slope of 15%, represented by the molic epipedon (BS 57% 50%) with a 23 cm thickness and an argillic horizon. According to the aggregate size distribution the pedon refers to the fine clay class with a typical clay coating of the pore walls and the ped surface. In addition, the clay was added at 29% (> 1.2%) of the eluvial horizon and had 10YR hue with a chroma of ≤ 3, with BS >75%. Based on these properties, P10 was classified as Inceptic Haplustalfs, fine, isohyperthermic.

Commented [ed9]: Please, explain this phrase, what does it mean? Is it a percentage of clay in the pedon as a whole? Or is it the contribution of clay only in eluvial horizon, which is quite unusual because as a rule silt ant clay is accumulated in argillic horizon

Commented [ed10]: Please, explain the meaning. Water does not penetrate to the horizons deeper than 50 cm, does it? Or something else?

Table 4. Soil classification in the Bulia micro watershed

Pedon	Soil Classification					Area	
	Order	Sub Order	Great Group	Sub Group	Family	ha	%
P1	Inceptisol	Ustept	Humustepts	Typic Humustepts	Fine, isohypertermic, Typic Humustepts	596.88	8.53
P2	Entisol	Psamment	Ustipsamments	Typic Ustipsamments	Sandy, isohypertermic, Typic Ustipsamments	472.68	6.76
P3	Inceptisol	Ustept	Humustepts	Oxic Humustepts	Fine loamy, isohypertermic, Oxic Humustepts	2,297.78	32.86
P4	Mollisol	Ustoll	Argiustolls	Typic Argiudolls	Fine, isohypertermic, Typic Argiustolls	107.35	1.54
P5	Alfisol	Ustalf	Paleustalfs	Typic Paleustalfs	Fine loamy, isohypertermic, Typic Paleustalfs	1,066.95	15.26
P6	Mollisol	Ustoll	Haplustolls	Typic Haplustolls	Coarse loamy, isohypertermic, Typic Haplustolls	1,026.23	14.67
P7	Inceptisol	Ustept	Humustepts	Typic Humustepts	Fine, isohypertermic, Typic Humustepts	248.4	3.55
P8	Alfisol	Ustalf	Paleustalfs	Ultic Paleustalfs	Fine loamy, isohypertermic, Ultic Paleustalfs	61.87	0.88

Pedon	Soil Classification					Area	
	Order	Sub Order	Great Group	Sub Group	Family	ha	%
P9	Mollisol	Ustoll	Paleustolls	Typic Paleustolls	Fine loamy, isohypertermic, Typic Paleustolls	48.35	0.69
P10	Alfisol	Ustalf	Haplustalfs	Inceptic Haplustalfs	Fine, isohypertermic, Inceptic Haplustalfs	1,066.95	15.26
Total						6,993.44	100.00

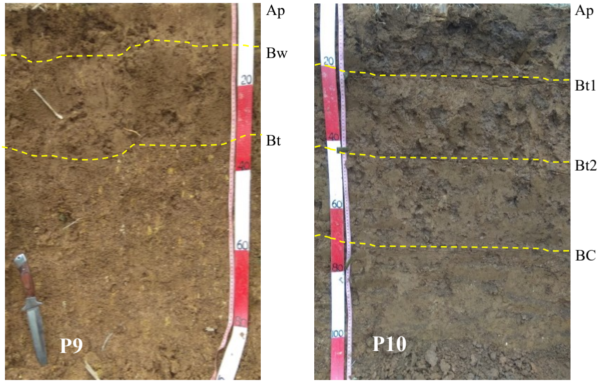


Fig 4. Soil profile appearance of pedon 9 (P9), and pedon 10 (P10)

Land quality classes

The land quality (LQ) of the Bulia micro watershed was presented in Table 5 and Figure 5. The LQ of class II with the main factor determining the land stress was high temperature and low organic matter. The high temperature of main factor with an indicator of isohypermic soil temperature regime at LU 3 (P3), and the factor of low ognic matter with an indicator of the ochric epipedon at LU 5 (P5) only. The LQ of class II is determined as good and this land has few problems for sustainable production, its productivity is generally very high and as a result, the response to management is high (Beinroth et al., 2001). Land management through the addition of organic matter, including green manure, may be adopted along with the recommended fertilizer doses (Sys et al., 1991; Singh et al., 2004; Mahaputra et al., 2019) and mulching to stabilize temperatures and maintain soil moisture (Odjugo, 2008); Eruola et al., 2012; Damaiyanti et al., 2013), which is of great importance. In addition, the use of rice straw mulch and sawdust mulch influences soil properties by decreasing the value of bulk density, increasing soil porosity and soil organic matter (Nasruddin and Hanum, 2015).

The LQ of class III with the main factor determining the land stress was a seasonal excess of water. The indicators determining the land stress in class III were new terraces spread over LU 1 (P1), LU 6 (P6) and LU 7 (P7). These new terraces are generally located around the border or river meanders which were prone to erosion and river bank landslides. The LQ of land class III was still considered good and this land has few problems for sustainable production, but has the higher risk of low input of corn production specifically, which results in a response to high management (Beinroth et al., 2001). The land management through the manufacture of gabions and riverbanks (Rahman, 2013), planting river bank reinforcement plants and terraces (Suyana *et al.*, 2017) was of great importance. Bioengineering methods for river bank erosion control commonly used include planting bamboo (Noor et al., 2011). Fine plant roots play a significant role in increasing the shear strength of the soil (Ludwig et al., 2007). The effectiveness of plants in reducing erosion rate is influenced by (1) the canopy or plant canopy, (2) the organic material produced, (3) the root system and the ability of plants to cover the soil (Rachman *et al.*, 2004). Vetiver plants were useful for stabilizing river banks, irrigation canals, river erosion control and coastal embankments, excavation slopes and embankments on highways, sand dunes, erosion on sloped agricultural land (Noor et al., 2011). Vetiver grass, which has strong fibrous roots, holds the ground (Susilawati and Veronika, 2016). Soil nailing

Commented [E11]: Please paraphrase or explain it the other way was one of the most economical techniques for slopes stabilization of retaining walls because the system works quickly and does not require large space (Sinarta, 2014); Noor et al., 2011).

Table 5. Land quality classes in the Bulia micro watershed

Land Unit	Land Quality		Land Quality Class	Area	
	Major Land Stress Factor	Determinant of Land Stress		ha	%
3	High temperatures	Isohypertermik of soil temperature regime	II	2,297.78	32.86
5	Low organic matter	Ochric epipedon	II	1,066.95	15.26
1, 6, 7	Seasonal water excess	Recent terraces	III	1,871.51	26.76
2	Low structural stability and/or crusting	Entisols	IV	472.68	6.76
4	Low structural stability and/or crusting	Clay soils	IV	107.35	1.54
8, 9, 10	Low water holding capacity	Sandy clay loam	VI	1177.17	16.83
		Total		3,628.71	51.89

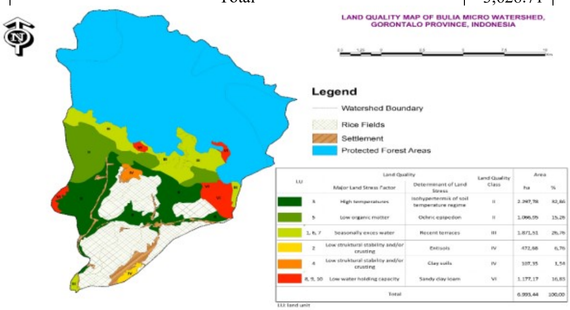


Fig 5. Land Quality Map of the Bulia Micro Watershed

The LQ of class IV with the main factors determining land stress was low structural stability and/or crusting. These main factors consist of two indicators, namely clay soil and Entisol. The indicator of heavy clay (> 50%) was scattered in LU 4 (P4). This indicator of clay soil was related to soil crusting which was shown by the average sub angular blocky soil structure and the soil consistency under wet conditions was very sticky and very plastic, while it was very hard under dry conditions. Clay and organic matter are binding agents for aggregates (Rachim, 2007). Apparently, the influence of clay is more dominant than of organic matter as an aggregate binding agent because the OC content was very low. The Entisol indicators were spread on LU 2 (P2) only. Entisol is a soil that is still young and underdeveloped (Rachim, 2007). The results of the morphological analysis of the soil indicated that this Entisol has a granular structure (not solid), fine sized with a weak level of development, therefore the stability was relatively low. In addition, the texture of Entisol was classified as loamy sand with the sand of particle size which makes the relatively of soil structure stability low. This class requires major inputs from conservation management; since a lack of plant nutrition is a major obstacle, therefore a plan to use good fertilizers should be adopted (Beinroth et al., 2001). Land management through the addition of organic matter can be applied together with recommended fertilizer doses (Sys et al., 1991; Singh et al., 2004; Mahaputra et al., 2019). Provision of organic matter in soils with clay texture can increase soil water content and available water capacity and reduce soil volume weight (Intara *et al.*, 2011), increase soil porosity (Anastasia et al., 2014), increase N, P, and K uptake and crop yields in Entisol soils (Afandi et al., 2015). Addition of manure, compost and custom bio can reduce soil content weight, soil density, increase aggregate stability, soil porosity and moisture content in Entisol soil (Zulkarnain et al., 2013).

Commented [E12]: I haven't found this term

The LQ of class VI with the main factor determining the land stress was low water holding capacity. The indicators of the sandy clay loam texture were spread on LU 8 (P8), LU 9 (P9) and LU 10 (P10). The value of water available on the sandy clay loam texture was only around 20.42 mm (Haridjaja et al., 2013). The available water (pF) under conditions of field capacity (pF 2.0) on LU 8, 9 and LU 10 was indicated as 34 mm, 38 mm, and 37 mm respectively, and at permanent wilting conditions (pF 4.2) ~~as 24 mm,~~ 24 mm and 17 mm only 19 respectively, therefore, causing a low water holding capacity. This land should not be used for food production (i.e corn) because this class requires major inputs from conservation management; since a lack of plant nutrition is a major obstacle, therefore a plan to use good fertilizers should be adopted or this land can be used as a biodiversity zone (Beinroth et al., 2001). However, if this land is used for agricultural cultivation, then the land management should consider the addition of organic matter along with the recommended fertilizer dosage (Sys et al., 1991; Singh et al., 2004; Mahaputra et al., 2019). Provision of organic material in soils with clay texture can increase soil water content and available water capacity and reduce soil volume weight (Intara et al., 2011), increase soil porosity (Anastasia et al., 2014).

CONCLUSIONS

Angular blocky, sticky, plastic consistencies, demanding and hard consistencies prevailed in the soil structure of the Bulia micro watershed of Gorontalo Province, Indonesia. In the alluvial plain, a sand fraction prevailed in Volkan mountains. The soils in the Bulia micro watershed also react acid to neutral, with the range of very low to high OC levels, the reserve of exchangeable bases was dominated by Ca2+ in two series patterns, namely: Ca2+ > Mg+ > Na+ > K+ and Ca2+ > Na+ > Mg+ > K+, CEC ranged from low to very high, and the base saturation varied from moderate to very high. The primary soils found were Entisol on P2 (Typic Ustipsamments), Inceptisol on P1 and P7 (Typic Humustepts), and P3 (Oxic Humustepts), Mollisol on P4 (Typic Argiudolls), P6 (Typic Haplustolls), and P9 (Typic Paleustolls), and Alfisol on P5 (Typic Paleustalfs), P8 (Ultic Paleustalfs) and P10 (Inceptic Haplustalfs). On the alluvial plains the land was categorized as the LQ class II, III and IV, the volcanic mountains were the LQ class IV, while the land on the volcanic hills was categorized as the LQ class VI. River bank erosion on the land river terraces can be held by the manufacture of gabions, talud, cliff reinforcement plants and terraces. The soil temperatures and high clay content can be regulated by mulching and organic materials

ACKNOWLEDGMENT

We would like to pay our regards to the Faculty of Agriculture, Brawijaya University who has funded this research with a non-tax state revenue grant in accordance with the Budget Implementation List Number: DIPA-042.01.2.400919/2019

REFERENCES

1. Afandi, F. N., Siswanto, B. and Nuraini, Y., Effect of giving various types of organic material on soil chemical properties on the growth and production of sweet potato plants in Entisol Ngrangkah Pawon, Kediri, *Soil and Land Resources*, (2015), 2(2), pp. 237–244. Available at: http://jtsl.ub.ac.id.

2. Anastasia, I., Izatti, M. and Suedy, S. W. A., The effect of giving a combination of solid organic fertilizer and liquid organic on soil porosity and spinach plant growth (Amarantus tricolor L.), *Biology Journal*, (2014), 3(2), pp. 1–10.

3. Beinroth, F. H., Eswaran, H. and Reich, P. F., Global assessment of land quality, *sustaining the global farm: Selected papers from the 10th International Soil Conservation Organization Meeting*, (2001), pp. 569-574.

4. BPS Gorontalo Province, Gorontalo province in figure 2020, *BPS Gorontalo Province*, (2020), 1102001.75(75560.2004), pp. 1–535.

5. BPS Gorontalo Regency, Gorontalo regency in figure 2020, *BPS Gorontalo Regency*, (2020), 1102001.75(75020.2003), pp. 1–262.

6. Dutta, M., Land use planning of Tipukjan watershed of Sivasagar district using GIS and remote sensing technique. Ph.D. Thesis, Assam Agricultural University, Jorhat. (2009).

7. Damaiyanti, D. R. R., Aini, N. and Koesrihati., The study of organic mulch application on the growth and yield of red pepper (Capsicum annuum L.), *Crop Production Journal*, (2013), 1(2), pp. 25–32.

8. Devi, P. A. V, Naidu, M. V. S. and Rao, A. R., Characterization and classification of sugarcane growing soils in southern agro-climatic zone: A case study in eastern mandals of Chittoor district in Andhra Pradesh, *Journal of the Indian Society of Soil Science*, (2015), 63(3), pp. 245–258. doi: 10.5958/0974-0228.2015.00034.1.

9. Eruola, A. O., Bello N. J, Ufoegbune G. C, and Makinde, A. A., Effect of mulching on soil temperature and moisture regime on emergence, growth and yield of white yam in a tropical wet-and-dry climate, *International Journal of Agriculture and Forestry*, (2012), 2(1), pp. 93–100. doi: 10.5923/j.ijaf.20120201.15.

10. Eviyati and Sulaeman, Analysis of soil, chemical, plants, water, and fertilizer, *Indonesia Centre of Soil Research*, (2009), pp. 1–203.

11. Husain, J., J. N. Luntungan, Y. E. B. Kamagi, and Nurdin., Conservation-based corn farming model in Gorontalo Province. Research

Report. Research, Development and Regional Environmental Impact Control Agency Gorontalo Province, Gorontalo. (2004)
12. Haridjaja, O., Baskoro, D. P. T. and Setianingsih, M., Different levels of field capacity by alhricks, free drainage, and pressure plate methods at different soil texture and relation for sunflower growth (Helianthus annuus L.), *Soil Science and Environmental Journal*, (2013), 15(2), p. 52. doi: 10.29244/jitl.15.2.52-59.
13. Intara, Y. I., A. Sapei, Erizal, N. Sembiring, and M. H. B. Djoefrie., Affected of organic matter application at clay and clay loam soil texture on water holding capacity, *Indonesian Agriculture Sciences Journal*, (2011), 16(2), pp. 130–135.
14. Jambak, M. K. F. A., Baskoro, D. P. T. and Wahjunie, E. D., Characteristics of Soil Physic on Soil Conservation Tillage System (Case Study Of Cikabayan Research Farm, Bogor), *Soil and Land Bulletin*, (2017), 1(1), pp. 44–50.
15. Jackson, M. L., Soil chemical analysis. Prentice Hall of India (Pvt.) Ltd., New Delhi. (1973).
16. Kadao, S. H., Prasad, J. and Gajbhlye, K. S., Characterization and classification of some typical banana growing soils of Wardha district of Maharashtra, *Agropedology*, (2003), 13(2), pp. 28–34.
17. Ludwig, A., Bradford, P., David, B., and Anton, W., Vegetation patches and runoff-erosion as interacting ecohydrological processes in semiarid landscapes. Ecology, (2007), 86, pp. 288-297. doi: https://doi.org/10.1890/03-0569.
18. Mahapatra, S. K., R. Nagdev, R. Gopal, J.N. Surya, R.K. Meena, R.P. Yadav and S.K. Singh., Characterization and classification of the soils of Buraka micro-watershed in Haryana for integrated development, *Journal of the Indian Society of Soil Science*, (2019), 67(2), pp. 137–150. doi: 10.5958/0974-0228.2019.00015.X.
19. Manik, H., Marpaung, P. and Sabrina, T., The level of soil development based on the pattern of clay mineral distribution in Subdistric Lumbanjulu, Distric of Toba Samosir, *Agroteknologi FP USU*, (2017), 5(2), pp. 422–433.
20. Nasruddin and Hanum, H., Study of mulching effects on soil temperature, soil property, and growth of patchouli (Pogostemon cablin Benth), *Floratek*, (2015), 10(2015), pp. 69–78.
21. Noor, A., Vahlevi, J. and Fathurrozi., Slope stabilization for erosion control with soil bioengineering using vetiver grass, *Poros Teknik*, (2011), 3(2), pp. 69–74.

22. Nurdin, *Development, classification and rainfed paddy soils potency derived from lacustrine materials in paguyaman, gorontalo*. MSc Thesis Bogor Agriculture University, (2010a). Available at: https://repository.ipb.ac.id/handle/123456789/57081.
23. Nurdin, The morfology, physics and soil chemistry of inceptisol derived from lacustrine paguyaman of gorontalo relating to soil managements, *Jurnal Agroteknotropika*, (2010b), 1(1), pp. 13–22.
24. Nurdin, Development and rainfed paddy soils potency derived from lacustrine material in paguyaman, gorontalo, *J Trop Soils*, (2011), 16(3), pp. 267–278. doi: 10.5400/jts.2011.16.3.267.
25. Nurdin, Combination of soil conservation techniques and its effect on the yield of maize and soil erosion of dry land in biyonga sub-watershed, gorontalo, *J. Tek. Ling*. (2012), 13(2), pp. 245–252.
26. Odjugo, P. A. O., The effect of tillage systems and mulching on soil microclimate, growth and yield of yellow yam (Dioscorea cayenensis) in Midwestern Nigeria, *African Journal of Biotechnology*, (2008), 7(24), pp. 4500–4507. doi: 10.4314/ajb.v7i24.59629.
27. Oldeman, L. R. and Darmiyati, S., An agroclimatic map of Sulawesi scale 1 - 2.500.000, *Center Research for Agriculture*, (1977), p. 1.
28. Puslitanak Research Team, Survey and mapping of semi-detailed soil resources (scale 1: 50,000) in the North Sulawesi of Paguyaman area for the development of irrigation and sugarcane commodities. Final report. Book III Attachment of the Land Series. Center for Soil and Agro-climate Research, Agency for Agricultural Research and Development, Indonesian Ministry of Agriculture, Bogor, (1995).
29. Prasetyo, B. H., Differentiation in Properties of vertisol from various parent materials, *Indonesian Agriculture Sciences Journal*, (2007), 9(1), pp. 20–31.
30. Rachman, A., Gantzer, J., and Anderson, S. H., Soil hydraulic properties influenced by stiff-stemmed grass hedge systems, *Soil Science Society of America Journal*, (2004), 68(4), pp. 1386–1393. doi: 10.2136/sssaj2004.1386.
31. Rahman, A., Geographic information system model for estimating flow coefficient and its relationship with land cover in Riam Kanan River Basin of South Kalimantan Province, *Bumi Lestari*, (2013), 13(1), p. 1-8.
32. Sys, C., E. V, Rast and Debaveye, J., Land evaluation. Part II. Principles in land evaluation and crop production calculations. International Training Centre for Post-Graduate Soil Scientists, University of Ghent.

(1991).
33. Sarkar, D., Gangipodhyay, S. K. and Velayutham, M., Soil toposequence relationship and classification in lower outlier of Chhotanagpur plateau, *Agropedology*, (2001), 11, pp. 29–36.
34. Swarnam, T. P., Velmurugan, A. and Rao, Y. S., Characterization and classification of some soils from Shahibi basin in parts of Haryana and Delhi. *Agropedology*, (2004), 14, p. 114-122.
35. Singh, C., Singh, P and Singh, R., Modern techniques of raising field crops. Oxford and IBH Publishing Co. Pvt. Ltd., New Delhi, (2004), pp. 1-583.
36. Satish, S., M. V. S. Naidu, K. V. Ramana, V. Munaswamy, G. P. Reddy and P. Sudhakar., Characterization and classification of the soils of Brahmanakotkur watershed in Kurnool district of Andhra Pradesh', *Journal of the Indian Society of Soil Science*, (2018), 66(4), pp. 351–361. doi: 10.5958/0974-0228.2018.00044.0.
37. Sinarta, I., Methods of handling landslides with soil nailing', *Paduraksa*, (2014), 3(2), pp. 1–16.
38. Sireesha, P. V. G. and Naidu, M. V. S., Clay mineralogy of soils developed from granite-gneiss of Kurnool District in Andhra Pradesh', *Journal of the Indian Society of Soil Science*, (2015), 63(1), pp. 16–23. doi: 10.5958/0974-0228.2015.00003.1.
39. Soil Science Division Staff, Soil survey manual, *United States Department of Agricultur US*, (2017), pp. 1–145. doi: 10.2307/1233734.
40. Soil Survey Staff, Keys to soil taxonomy, *Soil Conservation Service - NRCS/USDA*, (2014), 12, p. 360.
41. Subardja, D. and Sudarsono, The influence of land quality on productivity of maize in soils derived from volcanic and sedimentary rocks in the bogor area, *Soil and Climate Journal*, (2005), 23, pp. 38–46.
42. Suharta, N., The characteristic of soil developed from felsic sediments in west kalimantan province and its implication to land management, *Soil and Climate Journal*, (2007), (25), pp. 11–26.
43. Sukarman, S. Ritung, M. Anda, and E. Suryani., Guidelines for soil observation in the field, *Agricultural Research and Development Agency, Ministry of Agriculture Republic of Indonesia, Bogor*, (2017), pp. 1–149.
44. Supriya, K., M. V. S. Naidu, P. Kavitha and M. Srinivasa Reddy., Characterization, classification and evaluation of soils in semi-arid region of Mahanandi Mandal in Kurnool district of Andhra Pradesh', *Journal of the Indian Society of Soil Science*, (2019), 67(2), pp. 125–136. doi:

10.5958/0974-0228.2019.00014.8.
45. Susilawati, S. and Veronika, V., Vetiver grass study as a continuous slope safety, *Civil Engineering Communication Media*, (2016), 22(2), p. 99. doi: 10.14710/mkts.v22i2.12886.
46. Suyana, J., Sumarno, Supriyono, and N. P Lestariningsih., Mulching and strengthening of terraces in three types of plants against surface runoff, erosion, growth and yield of plants in Andisols, *Agrosains*, (2017), 19(1), p. 15. doi: 10.20961/agsjpa.v19i1.20924.
47. Vedadri, U. and Naidu, M. V. S., Characterization, classification and evaluation of soils in semi-arid ecosystem of Chillakur mandal in SPSR Nellore district of Andhra Pradesh. Journal of the Indian Society of Soil Science, (2018), 66 (1), p. 9-19. doi: 10.5958/0974-0228.2018.00002.6.
48. Walia, C.S., and Rao, Y. S., Characteristics and classification of some soils of Trans-Yamuna plains. Journal of the Indian Society of Soil Science, (1997), 45 (1), p. 156-162.
49. Yasin, M. G. H., Langgi, W and Faesal, White grain maize as an alternative for staple food, *Iptek Tanaman Pangan*, (2015), 9(2), pp. 108–117.
50. Yatno, E. and Mulyanto, B., Characteristics of soils formed from schist and their land suitability for cocoa crop in Kolaka and East Kolaka Regencies, Southeast Sulawesi, *Soil and Climate Journal*, (2016), 39(2), pp. 109–118.
51. Zulkarnain, M., Prasetya, B and Soemarno, Effects of compost, manure, and custom-bio on soil properties, growth and yield of sugarcane (Saccharum officinarum L.) in Entisol Kebun Ngrangkah of Pawon, Kediri, *Indonesian Green Technology Journal*, (2013), 2(1), pp. 45–52. Available at: https://igtj.ub.ac.id/index.php/igtj/article/view/103.

Soils in the Bulia Micro Watershed of Gorontalo Province, Indonesia and Their Quality Assessment

Received 12.07.2021, Revised ………, Accepted ……………..

Abstract: Ten representatives pedons from the Bulia micro watershed of Gorontalo Province, Indonesia were characterized and classified to determine its land quality (LQ) class. Angular blocky, sticky, plastic consistencies, and a demanding consistency prevailed in the soil structure. In the alluvial plain, a sand fraction prevailed in Volkan mountains. The soils in the Bulia micro watershed also react acid to neutral, with the range of very low to high OC (organic carbon) levels, the reserve of exchangeable bases was dominated by Ca^{2+} in two series patterns, namely: $Ca^{2+} > Mg^{+} > Na^{+} > K^{+}$ and $Ca^{2+} > Na+ > Mg^{+} > K^{+}$, CEC ranged from low to very high, and the base saturation varied from moderate to very high. The primary soils found were Entisol on P2 (Typic Ustipsamments), Inceptisol on P1 and P7 (Typic Humustepts), and P3 (Oxic Humustepts), Mollisol on P4 (Typic Argiudolls), P6 (Typic Haplustolls), and P9 (Typic Paleustolls), and Alfisol on P5 (Typic Paleustalfs), P8 (Ultic Paleustalfs) and P10 (Inceptic Haplustalfs). On the alluvial plains the land was categorized as the LQ class II, III and IV, the volcanic mountains were the LQ class IV, while the land on the volcanic hills was categorized as the LQ class VI. River bank erosion on the land river terraces can be held by the manufacture of gabions, talud, cliff reinforcement plants and terraces. The soil temperatures and high clay content can be regulated by mulching and organic materials

Keywords: Characterization, classification, soil, land quality, the Bulia watershed.

INTRODUCTION

Land is a crucial component of land resources which enables plants growth and food production. Land and plant productivity is primarily determined by soil and other land characteristics related to land quality (Subardja and Sudarsono, 2005). However, an intense tillage during agricultural cultivation and a pressure of the land use when its conservation and sustainability are ignored has resulted into a decrease of land quality. Agricultural production tends to level or even decrease (Nurdin, 2012). Corn is a traditional commercial crop in the province of Gorontalo, Indonesia, which has been intensively and massively cultivated since it was established as a prime commodity in the agropolitan program in 2001. Until 2019, hybrid corn yields in Gorontalo Province reached 1.7 million tons or increased by 9.3% compared to 2018, however, the productivity of maize was still low at only 5.0 tons/ha (BPS Gorontalo, Province 2020). In fact, the potential corn yield in Indonesia can reach 10-11 tons/ha (Yasin et al., 2015), while the achievement of the national productivity in 2018 was only 5.2 tons/ha (Indonesian Ministry of Agriculture 2019).

The Bulia micro watershed area is a corn production centre that also supports the agricultural area below. The watershed has a vital role because it supplies irrigation water for agriculture and other activities (Mahapatra *et al.*, 2019). The corn cultivation in this watershed has exceeded the carrying capacity indicated for the corn planting on the slope of >25%, so that the land degradation often occurs. Soil erosion, according to the corn agropolitan program of Gorontalo, reached 1,396 tons/ha/year (Husain et al., 2004). Meanwhile, the corn productivity in this area is only 5.0 tons/ha (BPS Gorontalo Regency, 2020), which could happen due to the fact that the crop was cultivated on a non-suitable land.

Soil characterization is essential because it provides some necessary information about the soil characteristics for growing plants (Devi et al., 2015). For sustainable management of soil resources in agroecological areas we need timely monitoring of significant physical, chemical and biological soil characteristics and responses to the changes in land management (Supriya et al., 2019). These soil characteristics then form the basis for land classification. Combining soil characterization with classification is a powerful tool for developing management strategies for food security and environmental sustainability (Satish *et al.*, 2018). However, the efforts to link land characteristics and classification with a specific land quality are still relatively rare. Land quality is a land ability to perform a specific function before the land is degraded (Beinroth et al., 2001). Understanding soil types and their distribution, its limits and potential is essential for a proper management to increase productivity and yields (Niranjana et al., 2011).

The survey and mapping of soil resources in the Paguyaman watershed were carried out by the Soil and Agro-climate Research Centre of the Indonesian Ministry of Agriculture (Puslittanak Research Team, 1995), however, the mapping scale was 1: 50,000. In 2010, some research was carried out on the development, classification and potential of the paddy soils on toposequence (Nurdin, 2010), however, it only focused on the rainfed paddy soils, while the dry land was only compared to the locations close to the soil pedon in the rice fields. Considering the high intensity of the land management and the massive corn cultivation in this sub-watershed, this research has become significant.

MATERIALS AND METHODS

Study location

The Bulia micro watershed is a part of the Paguyaman watershed located in the northern part, it covers Mootilango and Boliyohuto District of Gorontalo Regency of Gorontalo Province, Indonesia (Figure 1). Geographically, the research location is between 0°39'123 "and 0°51'321" N, 122°35'21 "and 122°43'12" S (Table 1), which is 67 km from Gorontalo City, Indonesia.

Overall, the Bulia micro watershed has 21,456.58 ha and consists of upland amounted to 18,993.44 ha (32.59%), and paddy fields amounted to 2,991.15 ha (13.94%). Specifically, the upland agriculture covers the agricultural land areas amounted to 6,993.44 ha (37.87%), settlement areas – 461.59 ha (2.50%), and forest areas amounted to 11,010.40 ha (59.63%). The soils in this area are generally developed from volcanic material in the upper watershed and lacustrine deposits in the middle and bottom of the watershed. The study area is located in tropical climate with rainy and dry seasons. The average annual rainfall was only 1,478 mm with 1 wet month only and 4 dry months, so it belongs to the E2 agro-climate zone (Oldeman and Darmiyati, 1977). The average annual air temperature reaches 28.19°C with the maximum temperature of 28.73°C and the minimum temperature of 27.63°C. Under these conditions, the soil moisture regime is determined ustic and the soil temperature regime – isohyperthermic (Soil Survey Staff, 2014).

Table 1. Site characteristics of the pedons in the Bulia micro watershed

Pedon/ Villages	Location	Elevation (m msl)	Landform	Slope (%)	Drainage
P1, Tolite	0°39’44.80” N 122°35’27.20” S	24	Alluvial plain	0 – 3	Poorly-drained
P2, Monggolito	0°40’01.20” N 122°37’57.20” S	159	Volcanic mountain	15 – 30	Well-drained
P3, Huyula	0°42’59.9” N 122°39’43.2” S	63	Alluvial plain	0 – 3	Moderately
P4, Payu	0°44’04.4” N 122°37’48.4” S	53	Alluvial plain	0 – 3	Moderately
P5, Pilomonu	0°43’53.80” N 122°35’22.60” S	75	Alluvial plain	0 – 3	Moderately
P6, Karyamukti	0°42’20.50” N 122°41’05.50” S	109	Alluvial plain	3 – 8	Moderately
P7, Karyamukti	0°42’10.30” N 122°41’19.40” S	114	Alluvial plain	3 – 8	Moderately

P8, Sukamaju	0°44’05” N 122°40’04” S	253	Volcanic hill	8 – 15	Well-drained
P9, Payu	0°45’12” N 122°38’08” S	285	Volcanic hill	8 – 15	Well-drained
P10, Huyula	0°43’11.10” N 122°40’31.20” S	262	Volcanic hill	8 – 15	Well-drained

msl: mean sea level.

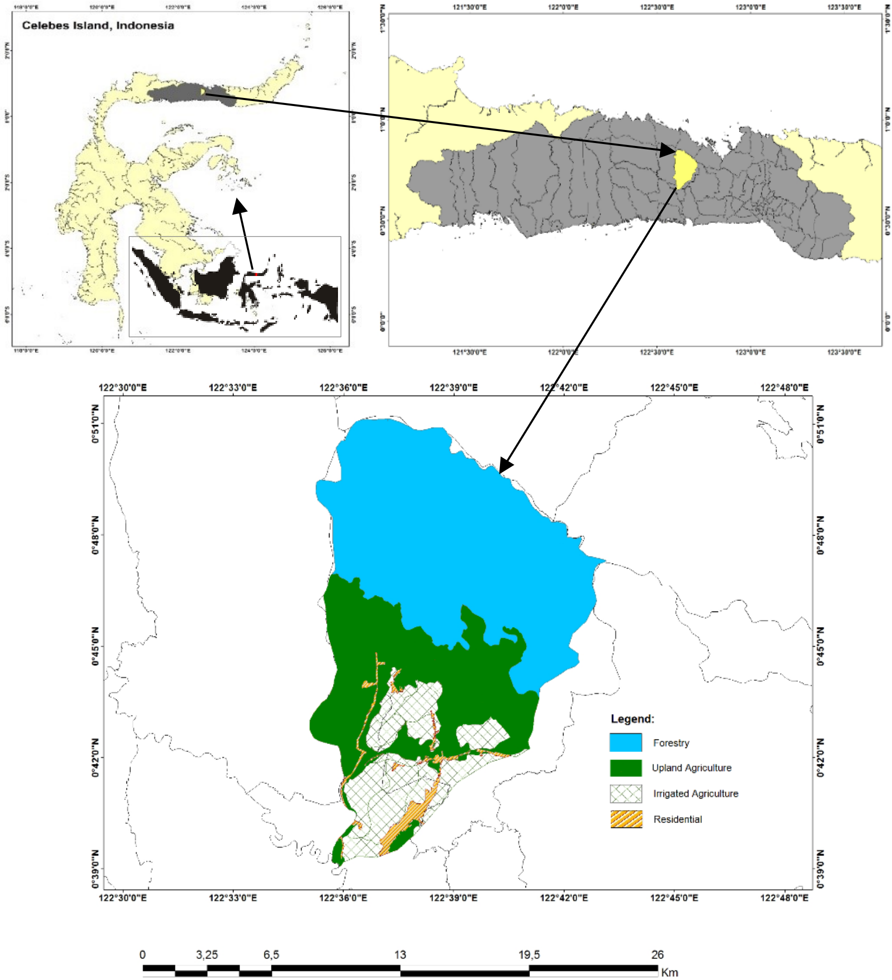


Fig 1. Location Map of the Bulia Micro watershed

Soil surveying, characterization and classification

Ten representative pedons were selected to conduct the soil survey, The description of soil morphology refers to the Soil Survey Manual (Soil Science Division Staff, 2017; Sukarman et al., 2017). According to standard procedures, soil samples were taken at each horizon and their physical and chemical properties were analyzed (Jackson, 1973; Eviyati and Sulaeman, 2009). The morphological and the soil properties data obtained during the laboratory analysis are used for the soil characterization together with the climate and the terrain conditions data, according to Sukarman et al., (2017). The soil characteristics are used for soil classification according to the keys to soil taxonomy (Soil Survey Staff, 2014).

Land quality assessment

Land quality (LQ) class assessment follows the method according to Beinroth et al. (2001). This method has been modified based on the availability of soil characteristics and classification data without including local population data. Soil pedons (P), which were classified in taxa according to the Soil Taxonomy System (Soil Survey Staff, 2014), were combined with a land unit (LU) basing on the similarity of the criteria in taxa. Soil and pedoclimate information was used to place each LU into I to IX land quality classes with class I having the most appropriate attributes and class IX having the least suitable ones for crop production. The results of the land quality analysis are widely presented and described with the help of Arc GIS.

RESULTS AND DISCUSSION

Morphology and soil physical properties

The results of field studies and the laboratory characterization of ten soil pedons were presented in Table 2. The soils in the study area have been developed as indicated by the horizon structuring (horizons A and B), with the depth of the soil solum varying from shallow to very deep. The soil colour is only of 7.5YR and 10YR hue, where 7.5YR is dominant. P1, P2, P3, P5, P8, P9 and P10 soil colour varies from dark brown, brown to strong brown with hue 7.5YR, ranging from 3 to 5 and chroma – from 1 to 6. While in P4, P6 and P7, soil colour varies from very dark grayish brown, dark brown to dark yellowish-brown with hue 10YR, values ranging from 3 to 4, and chroma – from 2 to 6. The colour of soil horizon A is darker than of horizon B due to the fact that the organic matter content in horizon A is higher than in horizon

B (Yatno et al., 2015). The higher the organic matter content, the darker the soil colour is (Suharta, 2007). Soil colour seems to be a function of chemical and mineralogical composition (Swarnam *et al.*, 2004; Walia and Rao, 1997), and the soil texture are influenced by topographic position and humidity regimes (Walia and Rao, 1997).

The soil structure varies from crumbs, angular blocky, sub angular blocky to prismatic, with the dominant angular blocky. P1, P3, P4, P6, P7, P8, P9 and P10 were mostly of angular blocky structure with the sizes varying from fine, medium to coarse, with weak and strong structural development. While the soil structures of P2 and P5 varies between crumbs, angular blocky, sub angular blocky and prismatic with the sizes ranging from fine, medium to coarse and the level of the soil structure development varying from weak, moderate to strong. The angular blocky soil structures were strongly associated with higher clay fractions (Devi et al., 2015). While newly developed soil shows crumbly soil structure (Manik et al., 2017), continuous addition of organic matter through natural plant biomass (Devi et al., 2015) or the tillage intensity, which was carried out thoroughly by turning over the soil until reaching the damaged soil structure (Jambak et al., 2017). The variation of soil structure will be consistently affecting the soil.

The soil consistency in wet conditions varies between non-sticky and non-plastic on Pedon 2, slightly sticky and slightly plastic, sticky and plastic in the horizon on P1, P3, P4, P5, P6, P7, P8, P9 and P10, very sticky and very plastic on the surface horizon (Ap) of P9 and the subsurface horizon (BC) of P10, however, slightly sticky and slightly plastic consistencies prevail. While in moist conditions the consistencies vary from loose, firm to very firm, the firm consistencies are still dominant. P1, P3, P4, P5, P6, P7, P8, P9 and P10 were dominated by hard consistencies, while P2 – by loose ones. There is a very hard consistency in P1 and P10 in the subsurface horizon (Bw and BC), while in the surface horizon (Ap) a very hard consistency can be only found in P9. The consistency in dry conditions varies from loose, hard to very hard, with a dominant hard consistency. P1, P3, P4, P5, P6, P7, P8, P9 and P10 were dominated by a hard consistency, however, in P1 and P10 in the subsurface horizon (Bw3 and BC) one could notice a very hard consistency, while in P9 precisely a very hard consistency was found on the surface horizon (Ap). Sticky and plastic consistency might form due to a high clay content in the soil (Sarkar et al., 2001); (Kadao et al., 2003), while non-sticky and non-plastic consistency might form due to a very little clay content (Sireesha and Naidu, 2015; Devi et al., 2015).

Table 2. Morphological characteristics and soil physical properties in the Bulia micro watershed

Pedon and Horizon	Depth (cm)	Colour Moisture	Structures	Consistence			Sand	Silt	Clay	Texture Class
				w	m	d	%			
P1 (Alluvial Plain)										
Ap	0 - 23	7.5 YR 4/4	m, 3, abk	s, p	fi	h	9	40	51	Silty Clay
Bw1	23 - 43	7.5 YR 4/2	m, 3, abk	ss, sp	fi	h	3	46	51	Silty Clay
Bw2	43 - 75	7.5 YR 4/4	m, 3, abk	ss, sp	fi	h	3	54	43	Silty Clay
Bw3	75 - 100	7.5 YR 4/2	m, 1, abk	ss, sp	vfi	vh	3	46	51	Silty Clay
P2 (Volcanic Mountains)										
Ap	0 - 5	7.5 YR 4/4	f, 1, cr	so, po	fr	l	85	10	5	Loamy sand
Bw1	5 - 37	7.5 YR 4/4	f, 2, sbk	so, po	fr	l	84	2	14	Loamy sand
Bw2	37 - 61	7.5 YR 4/4	m, 2, p	so, po	fr	l	75	10	15	Sandy Loam
C	61+	7.5 YR 4/2	m, 3, p	so, po	fr	l	66	15	19	Sandy Loam
P3 (Alluvial Plain)										
Ap	0 - 14	7.5 YR 3/3	f, 1, cr	ss, sp	fi	h	33	41	26	Loam
Bw1	14 - 43	7.5 YR 4/4	f, 2, abk	s, p	fi	h	31	37	32	Clay Loam
Bw2	43 - 68	7.5 YR 4/4	f, 1, abk	ss, sp	fi	h	23	54	23	Silty Loam
Bw3	68+	10 YR 3/6	f, 1, cr	s, p	fi	h	23	48	29	Clay Loam
P4 (Alluvial Plain)										
Ap	0 - 14	10 YR 3/3	m, 3, abk	s, p	fi	h	27	26	47	Clay
Bw	14 - 50	10 YR 4/3	f, 1, abk	s, p	fi	h	32	34	34	Clay Loam
Bt1	50 - 81	10 YR 3/2	f, 1, abk	ss, sp	fi	h	12	24	64	Clay
Bt2	81+	7.5 YR 4/1	f, 1, abk	s, p	fi	h	16	25	59	Clay
P5 (Alluvial Plain)										
Ap	0 - 21	7.5 YR 4/4	f, 2, sbk	ss, sp	fi	h	23	43	34	Clay Loam
Bw	21 - 46	7.5 YR 4/4	f, 2, sbk	ss, sp	fi	h	23	48	29	Clay Loam
Bt1	46 - 84	7.5 YR 4/3	f, 2, abk	s, p	fi	h	25	35	40	Clay
Bt2	84 - 117	7.5 YR 4/6	m, 2, p	s, p	fi	h	24	36	40	Clay

Pedon and Horizon	Depth (cm)	Colour Moisture	Structures	Consistence			Sand	Silt	Clay	Texture Class
				w	m	d		%		
Btg	117+	7.5 YR 5/8	m, 1, sbk	ss, sp	fi	h	8	46	46	Silty Clay
P6 (Alluvial Plain)										
Ap	0 - 12	10 YR 3/3	f, 1, abk	s, p	fi	h	84	15	1	Loamy Sand
Bw1	12-34	10 YR 3/4	f, 1, abk	s, p	fi	h	61	10	29	Sandy Clay Loam
Bw2	34 - 71	10 YR 4/6	m, 3, abk	ss, sp	fi	h	61	24	15	Sandy Loam
C	71 - 90	7.5 YR 5/8	f, 1, cr	so, po	fr	l	84	5	11	Loamy Sand
P7 (Alluvial Plain)										
Ap	0 - 6	7.5 YR 4/6	m, 1, abk	s, p	fi	h	33	11	56	Clay
Bw1	6 - 17	10 YR 4/6	m, 3, sbk	s, p	fi	h	29	20	51	Clay
Bw2	17 - 33	10 YR 3/6	m, 1, abk	ss, sp	fi	h	21	20	59	Clay
Bt	33 - 49	10 YR 3/6	f, 1, p	ss, sp	fi	h	19	15	66	Clay
BC	49+	7.5 YR 4/6	f, 1, abk	ss, sp	fi	h	18	29	53	Clay
P8 (Volcanic Hills)										
Ap	0 - 7	7.5 YR 3/3	f, 1, abk	ss, sp	fi	h	64	10	26	Sandy Clay Loam
Bw	7 - 24	7.5 YR 3/3	m, 1, abk	s, p	fi	h	47	24	29	Sandy Clay Loam
Bt1	24 - 44	7.5 YR 4/6	f, 3, p	s, p	fi	h	45	15	40	Sandy Clay
Bt2	44 - 63	7.5 YR 5/6	m, 3, abk	s, p	fi	h	42	16	42	Clay
Bt3	63+	7.5 YR 5/6	m, 1, abk	s, p	fi	h	42	6	52	Clay
P9 (Volcanic Hills)										
Ap	0 - 16	7.5 YR 3/2	m, 3, abk	vs, vp	vfi	vh	54	31	15	Sandy Loam
Bw	16 - 34	7.5 YR 3/3	m, 1, abk	s, p	fi	h	42	24	34	Clay Loam
Bt	34+	7.5 YR 4/4	m, 1, abk	ss. sp	fi	h	50	15	35	Sandy Clay
P10 (Volcanic Hills)										
Ap	0 - 20	7.5 YR 3/3	m, 3, abk	ss, sp	fi	h	48	26	26	Sandy Clay Loam
Bt1	20 - 44	7.5 YR 3/4	m, 3, abk	s, p	fi	h	41	15	44	Clay
Bt2	44 - 76	7.5 YR 4/6	c, 3, sbk	s, p	fi	h	42	14	44	Clay

Pedon and Horizon	Depth (cm)	Colour Moisture	Structures	Consistence			Sand	Silt	Clay	Texture Class
				w	m	d	%			
BC	76+	5 YR 4/6	c, 3, p	vs, vp	vfi	vh	31	2	67	Clay

Structure: *size*: vf – very fine, f – fine, m – medium, c – coarse; *structureless grade*: 1 – weak, 2 – moderate, 3 – strong; *type*: cr – crumb, sg – single grain, abk – angular blocky, sbk – sub-angular blocky. Consistence: *dry* (d): s – soft, l – loose, sh – slightly hard, h – hard, vh – very hard, eh – extremely hard; *moist* (m): l – loose, fr – friable, fi – firm, vfi – very firm, efi – extremely firm, *wet* (w): so – non-sticky, ss – slightly sticky, s – sticky, vs – very sticky; po – non-plastic, ps – slightly plastic, p – plastic, vp – very plastic.

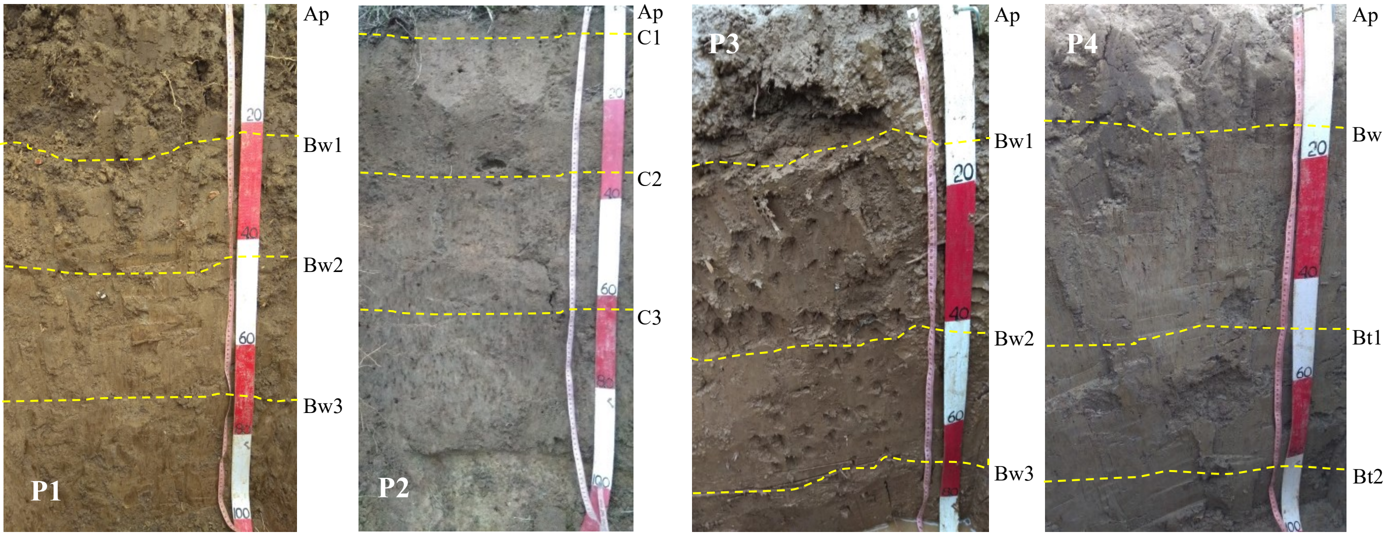


Fig 2. Soil profile appearance of pedon 1 (P1), 2 (P2), 3 (P3) and pedon 4 (P4)

The soil texture of all pedons varies greatly between sandy clay loam, sandy loam, loamy sand, sandy loam, silty loam, clay loam, silty clay and clay, except for P7 that was of clay texture in all horizons. Wide variations of soil texture may be caused by the variations in parent material, topography, in-situ weathering, translocation of clays by eluviation and soil age (Satish et al. 2018). Apparently, pedons located in the alluvial group were more dominated by clay fractions, although the distribution patterns were irregular. The distribution of irregular clay fractions was typical for sediment materials (Nurdin, 2010). While a sand fraction dominated the volcanic group, the distribution of sand and clay fractions shows the opposite pattern. A decrease in the sand fraction is due to the clay illuviation and in-situ mineral destruction process, which was characterized by a decline in the absolute amount of sand in the middle of the solum (Rachim, 1994). The texture that is found in the subsurface horizon is caused by higher weathering in the subsurface layer (Dutta, 2009). The clay content in the solum middles (B-illuviation) was higher than in the upper horizon (A-eluviation) and in the lower layer horizon. This indicates the occurrence of a lessivage process with some clay skins seen, so that an argillic horizon was formed in P4, P5, P8, P9 and P10. Although the process of eluviation and illuviation occurred, the pedon remained, but the clay skins were not found, so the cambic and candic horizons were formed.

Soil chemical properties

Soil chemical properties are presented in Table 3. Soil pH varies from acid (pH 5.3) to neutral (pH 7.2). The pedons located on the upper watershed or in volcanic groups (P2, P8, P9 and P10) have a lower pH than the ones located on the lower watershed or in alluvial groups (P1, P3, P4, P5, P6, and P7). The pedon in the alluvial group represented a depressed area which is the accumulation of the bases carried by washing water from the hinterland section and the accumulation of more alkaline bases in soils with poorer drainage (Nurdin, 2010a). The pedons in the volcanic group experienced more intensive washing during the rain due to a better soil drainage. The trend of pH increasing with more depth may be explained by the release of organic acids during the decomposition of organic matter, these acids may have lowered the pH at the soil surface (Satish *et al.*, 2018). The pH differences of KCl and the pH of H_2O of all pedons show negative values. This means that all pedons are dominated by negatively charged clay minerals (Suharta, 2007). Acid and slightly acid soil pH values in P1, P3, P5, P9 and P10 indicated that the soil had developed but the level of soil development was not yet advanced, while a neutral soil pH in P2, P4, P6, P7, and P8 shows that the soil is relatively new.

Organic carbon (OC) varies from very low to high (0.08 - 2.28%). The OC value was high in the surface horizon (Ap), except for P4 and P5. The OC value on the surface is higher due to the accumulation of organic materials, while its low values in P4 and P5 were due to the river flooding. The low OC value was also determined by a faster degradation of the organic material in the tropics and a low addition of farmyard manure (Vedadri and Naidu, 2018). A high OC distribution pattern on the surface and its dramatical decrease in horizon B in accordance with the depth is a general soil development pattern (Prasetyo, 2007).

The reserve (sum) of exchangeable bases vary between very low, low, medium, high and very high. Calcium cation is the dominating one in the exchangeable bases reserve, which ranges from 2.54-18.02 cmol(+)kg^{-1}, while magnesium (Mg^{+}) ranges from 0.15-6.66 cmol(+)kg^{-1}, sodium (Na^{+}) ranges from 0.26-3.02 cmol(+)kg^{-1}, potassium (K^{+}) ranges from 0.05-3.56 cmol(+)kg^{-1}. Based on the number of bases, the P1, P5, P7, and P10 patterns follow the sequence: $Ca^{2+} > Mg^{+} > Na^{+} > K^{+}$. This series pattern was the same as Nurdin (2011) and Satish et al. (2018) reported. At the same time P2, P3, P4, P6, P8 and P9 follow the sequence: $Ca^{2+} > Na^{+} > Mg^{+} > K^{+}$. A high rate of exchangeable bases in the surface horizon (Ap) results from fertilization during corn cultivation, while in the lower layer rainfall washing together with good drainage conditions make it possible to wash in the soil solum.

The cation exchange capacity (CEC) varies from low (7.7 cmol(+)kg^{-1}) to very high (42.40 cmol(+)kg^{-1}). The CEC is influenced by the levels of organic carbon and soil minerals (Prasetyo et al. 2007; Suharta 2007). It seems that CEC in P1, P3, P4, P5, P7, P8, and P9 were more influenced by OC content than by soil minerals. The higher the soil OC, the higher the soil CEC is (Suharta, 2007). While P2, P6 and P10 were thought to be more influenced by soil minerals, these bases can be exchanged and this CEC will eventually affect base saturation. Base saturation (BS) varies from moderate (40.55%) to very high (93%). All pedons generally have a medium and a high BS, except P6, which has a very high BS on the surface horizon (Ap). The variations in BS may be caused by the variations in nature and/or the content of soil colloids, and the relatively high base saturation in the surface layers can be attributed to the recycling of cation base through vegetation (Devi and Kumar 2010). In addition, if soil has a number of bases which is smaller than CEC, BS tends to be lower, whereas when the soil has a number of bases close to or higher than CEC, BS tends to be higher (Nurdin, 2010b).

Soil classification

Based on morphological and soil characteristics, the pedons are classified according to their family level and the orders of the soils found, namely Entisol, Inceptiol, Mollisol and Alfisol (Table 4). P1 and P7, which are located on a slope of 3% and 5%, are based on the molic epipedon with a 23 cm thickness and a cambic horizon. These pedons did not experience aquatic conditions at the depth of 50 cm from the soil surface (humustept), the soil colour had a value of 4 with a chroma of 2 or less and the soil structure was sub angular blocky. In addition, it had more clay content than the horizons below or above it. Based on these properties, P1 was classified as Typic Humustepts, fine, isohyperthermic.

P2, located on a slope of 15%, is represented by the ochric epipedon with a 5 cm thickness and a candic horizon. In this pedon there was an increase in the percentage of clay in the fine soil fraction with a depth of 15 cm or less in the vertical distance. The clay content was 4% or more (absolute value), which is more than that of the horizon above it which has a total clay content in the soil fine fraction less than 20%. In addition, it had a loamy sand texture (psamments) and a CEC value (NH4OAc, pH 7) > 16 cmol(p+)kg-1. Based on these characteristics, P2 was classified as Typic Ustipsamments, sandy, isohyperthermic.

P3 is located on a slope of 1%, represented by the umbric epipedon with a 14 cm thickness and a cambic horizon. This pedon did not experience aquatic conditions at the depth of 50 cm from the soil surface (humustept), the soil colour had a value of 4 with a chroma of 2 or less and the soil structure is sub angular blocky. In addition, it had more clay content than the horizons below or above and its CEC (NH_4OAc 1N) value was 17.96 cmol(+)kg^{-1} only (oxic). Based on these properties, P3 was classified as Oxic Humustepts, fine loamy, isohyperthermic.

P4 is located on a slope of 15%, represented by the molic epipedon (BS 55%) with a 14 cm thickness and an argillic horizon. This pedon had a fine loamy class of particle size with a typical clay coating of the pore walls and the ped surface. In addition, there was 13% (> 8%) of clay on the eluvial horizon and 10YR hue with a chroma ≤ 3, and BS > 75%. Based on these properties, P4 was classified as Typic Argiustolls, fine loamy, isohyperthermic.

Table 3. Soil chemical properties in the Bulia micro watershed

Pedon and Horizon	Depth (cm)	pH 1:1		OC (%)	Exchangeable cations				CEC	BS (%)
		H_2O	KCl 1N		K	Na	Ca	Mg		
					[cmol(+)kg^{-1}]					
P1 (Alluvial Plains)										
Ap	0 – 23	6.20	5.40	2.29	0.29	1.88	18.02	1.86	42.40	52.00
Bw1	23 – 43	6.00	5.20	0.90	0.18	2.01	15.47	2.97	39.19	52.62
Bw2	43 – 75	6.40	5.50	0.74	0.14	2.19	12.36	2.50	37.85	45.42
Bw3	75 - 100	6.50	5.60	0.65	0.14	2.23	15.22	3.26	37.58	55.49
P2 (Volcanic Mountains)										
Ap	0 - 5	6.50	5.60	1.19	0.10	0.34	3.77	0.30	11.13	40.55
Bw1	5 - 37	6.10	5.20	0.55	0.08	0.34	4.20	0.60	7.75	67.49
Bw2	37 - 61	6.20	5.30	0.63	0.08	0.35	3.91	0.15	8.87	50.52
C	61+	6.20	5.30	0.56	0.08	0.36	6.51	0.76	12.29	62.79
P3 (Alluvial Plain)										
Ap	0 - 14	5.60	4.60	0.80	0.05	1.46	4.84	0.61	16.15	43.00
Bw1	14 - 43	6.00	5.10	0.41	0.09	1.57	7.72	1.70	19.78	56.00
Bw2	43 - 68	5.80	4.90	0.32	0.05	1.55	8.95	0.91	21.58	53.00
Bw3	> 68	6.20	5.20	0.48	0.05	1.55	10.12	0.76	20.43	61.00
P4 (Alluvial Plains)										
Ap	0 - 14	6.50	6.10	0.41	0.06	1.49	11.87	0.62	25.55	55.00
Bw	14 - 50	6.70	6.30	0.96	0.19	1.43	9.71	2.12	21.60	62.00
Bt1	50 - 81	7.00	6.00	0.41	0.12	1.58	16.54	2.01	35.19	58.00
Bt2	81+	5.80	5.00	0.24	0.09	1.56	13.47	6.66	33.04	66.00
P5 (Alluvial Plains)										
Ap	0 - 21	5.20	4.50	0.08	0.16	2.29	9.39	2.93	28.39	52.00
Bw	21 - 46	5.10	4.30	0.49	0.20	2.30	8.62	3.08	28.40	50.00
Bt1	46 - 84	5.70	4.90	0.57	0.12	0.26	7.69	2.00	21.56	47.00

Pedon and Horizon	Depth (cm)	pH 1:1		OC (%)	Exchangeable cations				CEC	BS (%)
		H_2O	KCl 1N		K	Na	Ca	Mg		
					[cmol(+)kg^{-1}]					
Bt2	84 - 117	5.10	4.20	0.50	0.17	0.30	10.38	2.05	31.34	41.00
Btg	117+	5.10	4.10	0.42	0.25	0.34	15.37	1.90	38.58	46.00
P6 (Alluvial Plains)										
Ap	0 - 12	7.20	6.60	0.64	3.56	3.02	2.54	0.91	10.76	93.00
Bw1	12 - 34	7.10	6.60	0.32	0.28	1.72	6.03	0.30	11.79	71.00
Bw2	34 - 71	7.00	6.00	0.56	0.16	0.39	7.84	0.15	17.16	50.00
C	71 - 90	6.80	6.00	0.40	0.12	0.38	6.49	0.15	13.96	51.00
P7 (Alluvial Plains)										
Ap	0 - 6	6.30	5.40	0.76	0.10	0.42	5.31	2.41	18.31	45.00
Bw1	6 - 17	6.10	5.10	0.57	0.09	0.39	6.77	2.15	22.99	41.00
Bw2	17 - 33	5.90	5.00	0.57	0.07	0.44	8.55	4.04	25.45	51.00
Bt	33 - 49	5.60	4.80	0.33	0.08	0.45	13.64	3.72	29.79	60.00
BC	49+	5.90	5.00	0.41	0.12	2.04	13.16	0.31	33.06	47.00
P8 (Volcanic Hills)										
Ap	0 - 7	6.00	5.20	0.96	0.24	2.09	10.15	0.45	19.40	67.00
Bw	7 - 24	6.40	5.50	0.80	0.17	2.05	10.30	0.61	21.55	61.00
Bt1	24 - 44	6.70	5.80	0.48	0.24	2.21	10.07	1.83	26.06	55.00
Bt2	44 - 63	6.60	5.60	0.49	0.33	2.21	9.47	0.78	26.52	48.00
Bt3	63+	6.60	5.60	0.50	0.49	2.35	13.84	1.27	32.83	55.00
P9 (Volcanic Hills)										
Ap	0 - 16	5.30	4.50	0.80	0.13	2.15	10.15	0.61	24.80	53.00
Bw	16 - 34	6.20	5.30	0.57	0.10	2.30	12.44	0.77	29.51	53.00
Bt	34+	6.20	5.20	0.48	0.06	2.25	13.49	0.46	30.54	53.00
P10 (Volcanic Hills)										
Ap	0 - 20	5.80	4.90	0.72	0.12	0.40	5.90	1.21	18.31	41.69

Pedon and Horizon	Depth (cm)	pH 1:1		OC (%)	Exchangeable cations				CEC	BS (%)
		H_2O	KCl 1N		K	Na	Ca	Mg		
					[cmol(+)kg^{-1}]					
Bt1	20 - 44	6.10	5.20	0.64	0.05	0.40	8.23	0.46	18.44	49.59
Bt2	44 - 76	6.30	5.30	0.48	0.05	0.39	7.26	0.76	19.36	43.66
BC	76+	5.80	5.30	0.33	0.06	0.42	11.28	2.04	25.64	53.82

CEC: cation exchange capacity, OC: organic carbon, BS: base saturation.

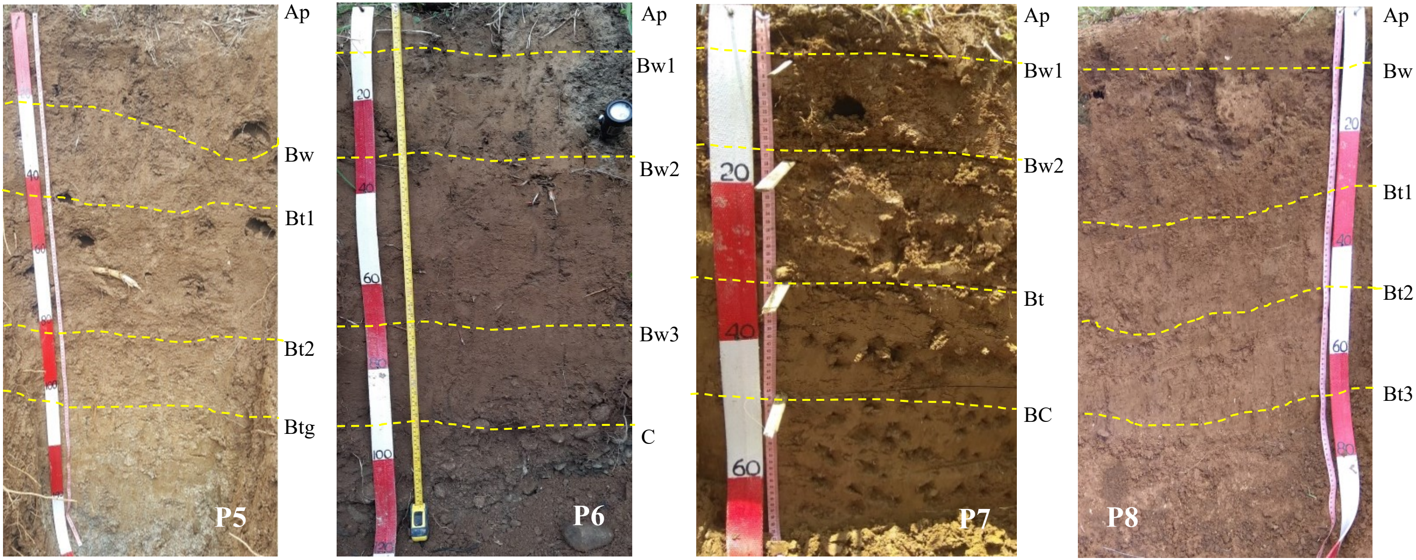


Fig 3. Soil profile appearance of pedon 5 (P5), 6 (P6), 7 (P7) and pedon 8 (P8)

P5 is located on a slope of 3%, represented by the ochric epipedon with a 21 cm thickness and an argillic horizon. According to the particle-size class the pedon refers to the fine loam and clayey class of 25 cm (> 7.5 cm) with a typical clay coating of the pore walls and the ped (aggregate) surface. In addition, there was an average clay increase of 26.46% or 1.2 times more than the eluvial horizon which was only 11% and 7.5 YR was typical of all horizons (paleustalf). Based on these properties, P5 was classified as Typic Paleustalfs, fine loamy, isohyperthermic.

P6, is located on a slope of 3%, represented by the molic epipedon (BS 93%) with a 12 cm thickness and a cambic horizon. This pedon had a sandy clay texture and does not have the combination of aquic conditions within 50 cm of the soil surface or artificial drainage (ustoll). The colour value was with a chroma <6 and it had a sub angular blocky soil structure. In addition, it had more clay content than the below horizons. Based on these properties, P6 was classified as Typic Haplustolls, coarse loamy, isohyperthermic.

P8 is located on a slope of 5%, represented by the molic epipedon with a 7 cm thickness and an argillic horizon. According to the aggregate size distribution the pedon refers to the fine loam class with a typical clay coating of the pore walls and the ped surface. In addition, clay was added at 2 - 11% (> 1.2%) of the eluvial horizon and 7.5YR hue was typical in all horizons (paleustalf), with BS of 61% or > 75% only (ultic). Based on these properties, P8 was classified as Ultic Paleustalfs, fine loamy, isohyperthermic.

P9 is located on an 8% slope, represented by the molic epipedon (BS 53%) with 7 cm thickness and the argillic horizon. According to the aggregate size distribution the pedon refers to the fine loam class with a typical clay coating of the pore walls and the ped surface. In addition, clay was added at 19% (> 1.2%) of the eluvial horizon and had 7.5YR hue with a chroma of ≤ 4, with BS of >75%. Based on these properties, P9 was classified as Typic Paleustolls, fine loamy, isohyperthermic.

P10 is located on a slope of 15%, represented by the molic epipedon (BS 57% 50%) with a 23 cm thickness and an argillic horizon. According to the aggregate size distribution the pedon refers to the fine clay class with a typical clay coating of the pore walls and the ped surface. In addition, the clay was added at 29% (> 1.2%) of the eluvial horizon and had 10YR hue with a chroma of ≤ 3, with BS >75%. Based on these properties, P10 was classified as Inceptic Haplustalfs, fine, isohyperthermic.

Table 4. Soil classification in the Bulia micro watershed

Pedon	Soil Classification					Area	
	Order	Sub Order	Great Group	Sub Group	Family	ha	%
P1	Inceptisol	Ustept	Humustepts	Typic Humustepts	Fine, isohypertermic, Typic Humustepts	596.88	8.53
P2	Entisol	Psamment	Ustipsamments	Typic Ustipsamments	Sandy, isohypertermic, Typic Ustipsamments	472.68	6.76
P3	Inceptisol	Ustept	Humustepts	Oxic Humustepts	Fine loamy, isohypertermic, Oxic Humustepts	2,297.78	32.86
P4	Mollisol	Ustoll	Argiustolls	Typic Argiudolls	Fine, isohypertermic, Typic Argiustolls	107.35	1.54
P5	Alfisol	Ustalf	Paleustalfs	Typic Paleustalfs	Fine loamy, isohypertermic, Typic Paleustalfs	1,066.95	15.26
P6	Mollisol	Ustoll	Haplustolls	Typic Haplustolls	Coarse loamy, isohypertermic, Typic Haplustolls	1,026.23	14.67
P7	Inceptisol	Ustept	Humustepts	Typic Humustepts	Fine, isohypertermic, Typic Humustepts	248.4	3.55
P8	Alfisol	Ustalf	Paleustalfs	Ultic Paleustalfs	Fine loamy, isohypertermic, Ultic Paleustalfs	61.87	0.88

Pedon	Soil Classification					Area	
	Order	Sub Order	Great Group	Sub Group	Family	ha	%
P9	Mollisol	Ustoll	Paleustolls	Typic Paleustolls	Fine loamy, isohypertermic, Typic Paleustolls	48.35	0.69
P10	Alfisol	Ustalf	Haplustalfs	Inceptic Haplustalfs	Fine, isohypertermic, Inceptic Haplustalfs	1,066.95	15.26
Total						6,993.44	100.00

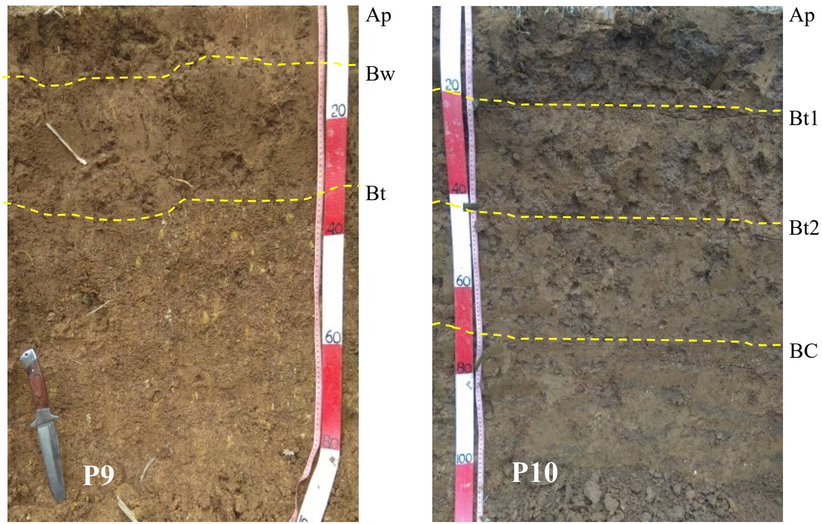


Fig 4. Soil profile appearance of pedon 9 (P9), and pedon 10 (P10)

Land quality classes

The land quality (LQ) of the Bulia micro watershed was presented in Table 5 and Figure 5. The LQ of class II with the main factor determining the land stress was high temperature and low organic matter. The high temperature factor with an isohyperthermic soil temperature regime as an indicator was found on LU 3 (P3), while the low organic matter factor with an ochric epipedon indicator was only on LU 5 (P5). The LQ of class II is determined as good and this land has few problems for sustainable production, its productivity is generally very high and as a result, the response to management is high (Beinroth et al., 2001). Land management through the addition of organic matter, including green manure, may be adopted along with the recommended fertilizer doses (Sys et al., 1991; Singh et al., 2004; Mahaputra et al., 2019) and mulching to stabilize temperatures and maintain soil moisture (Odjugo, 2008); Eruola et al., 2012; Damaiyanti et al., 2013), which is of great importance. In addition, the use of rice straw mulch and sawdust mulch influences soil properties by decreasing the value of bulk density, increasing soil porosity and soil organic matter (Nasruddin and Hanum, 2015).

The LQ of class III with the main factor determining the land stress was a seasonal excess of water. The indicators determining the land stress in class III were new terraces spread over LU 1 (P1), LU 6 (P6) and LU 7 (P7). These new terraces are generally located around the border or river meanders which were prone to erosion and river bank landslides. The LQ of land class III was still considered good and this land has few problems for sustainable production, but has the higher risk of low input of corn production specifically, which results in a response to high management (Beinroth et al., 2001). The land management through the manufacture of gabions and riverbanks (Rahman, 2013), planting river bank reinforcement plants and terraces (Suyana *et al.*, 2017) was of great importance. Bioengineering methods for river bank erosion control commonly used include planting bamboo (Noor et al., 2011). Fine plant roots play a significant role in increasing the shear strength of the soil (Ludwig et al., 2007). The effectiveness of plants in reducing erosion rate is influenced by (1) the canopy or plant canopy, (2) the organic material produced, (3) the root system and the ability of plants to cover the soil (Rachman *et al.*, 2004). Vetiver plants were useful for stabilizing river banks, irrigation canals, river erosion control and coastal embankments, excavation slopes and embankments on highways, sand dunes, erosion on sloped agricultural land (Noor et al., 2011). Vetiver grass, which has strong fibrous roots, holds the ground (Susilawati and Veronika, 2016). Soil nailing was one of the most economical techniques for slopes stabilization of retaining walls because the system works quickly and does not require large space (Sinarta, 2014); Noor et al., 2011).

Table 5. Land quality classes in the Bulia micro watershed

Land Unit	Land Quality		Land Quality Class	Area	
	Major Land Stress Factor	Determinant of Land Stress		ha	%
3	High temperatures	Isohyperthermic of soil temperature regime	II	2,297.78	32.86
5	Low organic matter	Ochric epipedon	II	1,066.95	15.26
1, 6, 7	Seasonal water excess	Recent terraces	III	1,871.51	26.76
2	Low structural stability and/or crusting	Entisols	IV	472.68	6.76
4	Low structural stability and/or crusting	Clay soils	IV	107.35	1.54
8, 9, 10	Low water holding capacity	Sandy clay loam	VI	1177.17	16.83
Total				3,628.71	51.89

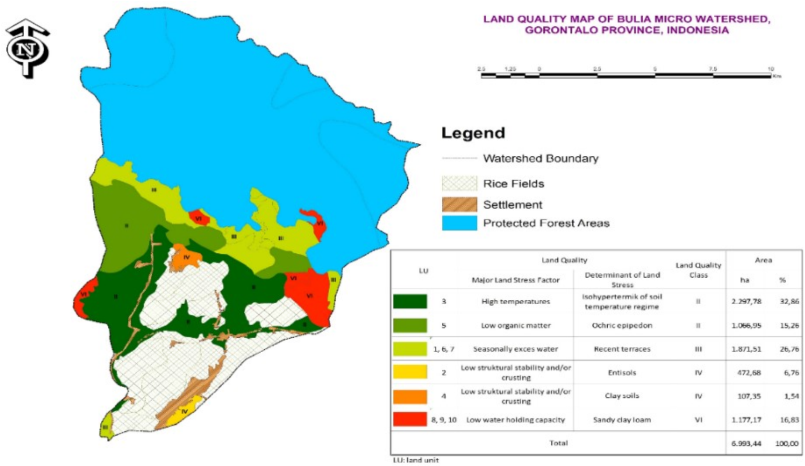


Fig 5. Land Quality Map of the Bulia Micro

The LQ of class IV with the main factors determining land stress was low structural stability and/or crusting. These main factors consist of two indicators, namely clay soil and Entisol. The indicator of heavy clay (> 50%) was scattered in LU 4 (P4). This indicator of clay soil was related to soil crusting which was shown by the average sub angular blocky soil structure and the soil consistency under wet conditions was very sticky and very plastic, while it was very hard under dry conditions. Clay and organic matter are binding agents for aggregates (Rachim, 2007). Apparently, the influence of clay is more dominant than of organic matter as an aggregate binding agent because the OC content was very low. The Entisol indicators were spread on LU 2 (P2) only. Entisol is a soil that is still young and underdeveloped (Rachim, 2007). The results of the morphological analysis of the soil indicated that this Entisol has a granular structure (not solid), fine sized with a weak level of development, therefore the stability was relatively low. In addition, the texture of Entisol was classified as loamy sand with the sand of particle size which makes the relatively of soil structure stability low. This class requires major inputs from conservation management; since a lack of plant nutrition is a major obstacle, therefore a plan to use good fertilizers should be adopted (Beinroth et al., 2001). Land management through the addition of organic matter can be applied together with recommended fertilizer doses (Sys et al., 1991; Singh et al., 2004; Mahaputra et al., 2019). Provision of organic matter in soils with clay texture can increase soil water content and available water capacity and reduce soil volume weight (Intara *et al.*, 2011), increase soil porosity (Anastasia et al., 2014), increase N, P, and K uptake and crop yields in Entisol soils (Afandi et al., 2015). Addition of manure, compost and beneficial bacteria technology (custom bio) can reduce soil content weight, soil density, increase aggregate stability, soil porosity and moisture content in Entisol soil (Zulkarnain et al., 2013).

The LQ of class VI with the main factor determining the land stress was low water holding capacity. The indicators of the sandy clay loam texture were spread on LU 8 (P8), LU 9 (P9) and LU 10 (P10). The value of water available on the sandy clay loam texture was only around 20.42 mm (Haridjaja et al., 2013). The available water (pF) under conditions of field capacity (pF 2.0) on LU 8, 9 and LU 10 was indicated as 34 mm, 38 mm, and 37 mm respectively, and at permanent wilting conditions (pF 4.2) 24 mm and 17 mm only 19 respectively, therefore, causing a low water holding capacity. This land should not be used for food production (i.e corn) because this class requires major inputs from conservation management; since a lack of plant nutrition is a major obstacle, therefore a plan to use good fertilizers should be adopted or this land can be used as a biodiversity zone (Beinroth et al., 2001). However, if this land is used for agricultural cultivation, then the land management should consider the addition of organic matter along with the recommended fertilizer dosage (Sys et al., 1991; Singh et al., 2004; Mahaputra et al., 2019). Provision of organic material in soils with clay texture can increase soil water content and available water capacity and reduce soil volume weight (Intara et al., 2011), increase soil porosity (Anastasia et al., 2014).

CONCLUSIONS

Angular blocky, sticky, plastic consistencies, demanding and hard consistencies prevailed in the soil structure of the Bulia micro watershed of Gorontalo Province, Indonesia. In the alluvial plain, a sand fraction prevailed in Volkan mountains. The soils in the Bulia micro watershed also react acid to neutral, with the range of very low to high OC levels, the reserve of exchangeable bases was dominated by Ca^{2+} in two series patterns, namely: $Ca^{2+} > Mg^{+} > Na^{+} > K^{+}$ and $Ca^{2+} > Na^{+} > Mg^{+} > K^{+}$, CEC ranged from low to very high, and the base saturation varied from moderate to very high. The primary soils found were Entisol on P2 (Typic Ustipsamments), Inceptisol on P1 and P7 (Typic Humustepts), and P3 (Oxic Humustepts), Mollisol on P4 (Typic Argiudolls), P6 (Typic Haplustolls), and P9 (Typic Paleustolls), and Alfisol on P5 (Typic Paleustalfs), P8 (Ultic Paleustalfs) and P10 (Inceptic Haplustalfs). On the alluvial plains the land was categorized as the LQ class II, III and IV, the volcanic mountains were the LQ class IV, while the land on the volcanic hills was categorized as the LQ class VI. River bank erosion on the land river terraces can be held by the manufacture of gabions, talud, cliff reinforcement plants and terraces. The soil temperatures and high clay content can be regulated by mulching and organic materials

ACKNOWLEDGMENT

We would like to pay our regards to the Faculty of Agriculture, Brawijaya University who has funded this research with a non-tax state revenue grant in accordance with the Budget Implementation List Number: DIPA-042.01.2.400919/2019

REFERENCES

1. Afandi, F. N., Siswanto, B. and Nuraini, Y., Effect of giving various types of organic material on soil chemical properties on the growth and production of sweet potato plants in Entisol Ngrangkah Pawon, Kediri, *Soil and Land Resources*, (2015), 2(2), pp. 237–244. Available at: http://jtsl.ub.ac.id.
2. Anastasia, I., Izatti, M. and Suedy, S. W. A., The effect of giving a combination of solid organic fertilizer and liquid organic on soil porosity and spinach plant growth (Amarantus tricolor L.), *Biology Journal*, (2014), 3(2), pp. 1–10.
3. Beinroth, F. H., Eswaran, H. and Reich, P. F., Global assessment of land quality, *sustaining the global farm: Selected papers from the 10th International Soil Conservation Organization Meeting*, (2001), pp. 569-574.
4. BPS Gorontalo Province, Gorontalo province in figure 2020, *BPS Gorontalo Province*, (2020), 1102001.75(75560.2004), pp. 1–535.
5. BPS Gorontalo Regency, Gorontalo regency in figure 2020, *BPS Gorontalo Regency*, (2020), 1102001.75(75020.2003), pp. 1–262.
6. Dutta, M., Land use planning of Tipukjan watershed of Sivasagar district using GIS and remote sensing technique. Ph.D. Thesis, Assam Agricultural University, Jorhat. (2009).
7. Damaiyanti, D. R. R., Aini, N. and Koesrihati., The study of organic mulch application on the growth and yield of red pepper (Capsicum annuum L.), *Crop Production Journal*, (2013), 1(2), pp. 25–32.
8. Devi, P. A. V, Naidu, M. V. S. and Rao, A. R., Characterization and classification of sugarcane growing soils in southern agro-climatic zone: A case study in eastern mandals of Chittoor district in Andhra Pradesh, *Journal of the Indian Society of Soil Science*, (2015), 63(3), pp. 245–258. doi: 10.5958/0974-0228.2015.00034.1.
9. Eruola, A. O., Bello N. J, Ufoegbune G. C, and Makinde, A. A., Effect of mulching on soil temperature and moisture regime on emergence, growth and yield of white yam in a tropical wet-and-dry climate, *International Journal of Agriculture and Forestry*, (2012), 2(1), pp. 93–100. doi: 10.5923/j.ijaf.20120201.15.
10. Eviyati and Sulaeman, Analysis of soil, chemical, plants, water, and fertilizer, *Indonesia Centre of Soil Research*, (2009), pp. 1–203.
11. Husain, J., J. N. Luntungan, Y. E. B. Kamagi, and Nurdin., Conservation-based corn farming model in Gorontalo Province. Research

Report. Research, Development and Regional Environmental Impact Control Agency Gorontalo Province, Gorontalo. (2004)
12. Haridjaja, O., Baskoro, D. P. T. and Setianingsih, M., Different levels of field capacity by alhricks, free drainage, and pressure plate methods at different soil texture and relation for sunflower growth (Helianthus annuus L.), *Soil Science and Environmental Journal*, (2013), 15(2), p. 52. doi: 10.29244/jitl.15.2.52-59.
13. Intara, Y. I., A. Sapei, Erizal, N. Sembiring, and M. H. B. Djoefrie., Affected of organic matter application at clay and clay loam soil texture on water holding capacity, *Indonesian Agriculture Sciences Journal*, (2011), 16(2), pp. 130–135.
14. Jambak, M. K. F. A., Baskoro, D. P. T. and Wahjunie, E. D., Characteristics of Soil Physic on Soil Conservation Tillage System (Case Study Of Cikabayan Research Farm, Bogor), *Soil and Land Bulletin*, (2017), 1(1), pp. 44–50.
15. Jackson, M. L., Soil chemical analysis. Prentice Hall of India (Pvt.) Ltd., New Delhi. (1973).
16. Kadao, S. H., Prasad, J. and Gajbhlye, K. S., Characterization and classification of some typical banana growing soils of Wardha district of Maharashtra, *Agropedology*, (2003), 13(2), pp. 28–34.
17. Ludwig, A., Bradford, P., David, B., and Anton, W., Vegetation patches and runoff-erosion as interacting ecohydrological processes in semiarid landscapes. Ecology, (2007), 86, pp. 288-297. doi: https://doi.org/10.1890/03-0569.
18. Mahapatra, S. K., R. Nagdev, R. Gopal, J.N. Surya, R.K. Meena, R.P. Yadav and S.K. Singh., Characterization and classification of the soils of Buraka micro-watershed in Haryana for integrated development, *Journal of the Indian Society of Soil Science*, (2019), 67(2), pp. 137–150. doi: 10.5958/0974-0228.2019.00015.X.
19. Manik, H., Marpaung, P. and Sabrina, T., The level of soil development based on the pattern of clay mineral distribution in Subdistric Lumbanjulu, Distric of Toba Samosir, *Agroteknologi FP USU*, (2017), 5(2), pp. 422–433.
20. Nasruddin and Hanum, H., Study of mulching effects on soil temperature, soil property, and growth of patchouli (Pogostemon cablin Benth), *Floratek*, (2015), 10(2015), pp. 69–78.
21. Noor, A., Vahlevi, J. and Fathurrozi., Slope stabilization for erosion control with soil bioengineering using vetiver grass, *Poros Teknik*, (2011), 3(2), pp. 69–74.

22. Nurdin, *Development, classification and rainfed paddy soils potency derived from lacustrine materials in paguyaman, gorontalo*. MSc Thesis Bogor Agriculture University, (2010a). Available at: https://repository.ipb.ac.id/handle/123456789/57081.
23. Nurdin, The morfology, physics and soil chemistry of inceptisol derived from lacustrine paguyaman of gorontalo relating to soil managements, *Jurnal Agroteknotropika*, (2010b), 1(1), pp. 13–22.
24. Nurdin, Development and rainfed paddy soils potency derived from lacustrine material in paguyaman, gorontalo, *J Trop Soils*, (2011), 16(3), pp. 267–278. doi: 10.5400/jts.2011.16.3.267.
25. Nurdin, Combination of soil conservation techniques and its effect on the yield of maize and soil erosion of dry land in biyonga sub-watershed, gorontalo, *J. Tek. Ling*. (2012), 13(2), pp. 245–252.
26. Odjugo, P. A. O., The effect of tillage systems and mulching on soil microclimate, growth and yield of yellow yam (Dioscorea cayenensis) in Midwestern Nigeria, *African Journal of Biotechnology*, (2008), 7(24), pp. 4500–4507. doi: 10.4314/ajb.v7i24.59629.
27. Oldeman, L. R. and Darmiyati, S., An agroclimatic map of Sulawesi scale 1 - 2.500.000, *Center Research for Agriculture*, (1977), p. 1.
28. Puslitanak Research Team, Survey and mapping of semi-detailed soil resources (scale 1: 50,000) in the North Sulawesi of Paguyaman area for the development of irrigation and sugarcane commodities. Final report. Book III Attachment of the Land Series. Center for Soil and Agro-climate Research, Agency for Agricultural Research and Development, Indonesian Ministry of Agriculture, Bogor, (1995).
29. Prasetyo, B. H., Differentiation in Properties of vertisol from various parent materials, *Indonesian Agriculture Sciences Journal*, (2007), 9(1), pp. 20–31.
30. Rachman, A., Gantzer, J., and Anderson, S. H., Soil hydraulic properties influenced by stiff-stemmed grass hedge systems, *Soil Science Society of America Journal*, (2004), 68(4), pp. 1386–1393. doi: 10.2136/sssaj2004.1386.
31. Rahman, A., Geographic information system model for estimating flow coefficient and its relationship with land cover in Riam Kanan River Basin of South Kalimantan Province, *Bumi Lestari*, (2013), 13(1), p. 1-8.
32. Sys, C., E. V, Rast and Debaveye, J., Land evaluation. Part II. Principles in land evaluation and crop production calculations. International Training Centre for Post-Graduate Soil Scientists, University of Ghent.

(1991).
33. Sarkar, D., Gangipodhyay, S. K. and Velayutham, M., Soil toposequence relationship and classification in lower outlier of Chhotanagpur plateau, *Agropedology*, (2001), 11, pp. 29–36.
34. Swarnam, T. P., Velmurugan, A. and Rao, Y. S., Characterization and classification of some soils from Shahibi basin in parts of Haryana and Delhi. *Agropedology*, (2004), 14, p. 114-122.
35. Singh, C., Singh, P and Singh, R., Modern techniques of raising field crops. Oxford and IBH Publishing Co. Pvt. Ltd., New Delhi, (2004), pp. 1-583.
36. Satish, S., M. V. S. Naidu, K. V. Ramana, V. Munaswamy, G. P. Reddy and P. Sudhakar., Characterization and classification of the soils of Brahmanakotkur watershed in Kurnool district of Andhra Pradesh', *Journal of the Indian Society of Soil Science*, (2018), 66(4), pp. 351–361. doi: 10.5958/0974-0228.2018.00044.0.
37. Sinarta, I., Methods of handling landslides with soil nailing', *Paduraksa*, (2014), 3(2), pp. 1–16.
38. Sireesha, P. V. G. and Naidu, M. V. S., Clay mineralogy of soils developed from granite-gneiss of Kurnool District in Andhra Pradesh', *Journal of the Indian Society of Soil Science*, (2015), 63(1), pp. 16–23. doi: 10.5958/0974-0228.2015.00003.1.
39. Soil Science Division Staff, Soil survey manual, *United States Department of Agricultur US*, (2017), pp. 1–145. doi: 10.2307/1233734.
40. Soil Survey Staff, Keys to soil taxonomy, *Soil Conservation Service - NRCS/USDA*, (2014), 12, p. 360.
41. Subardja, D. and Sudarsono, The influence of land quality on productivity of maize in soils derived from volcanic and sedimentary rocks in the bogor area, *Soil and Climate Journal*, (2005), 23, pp. 38–46.
42. Suharta, N., The characteristic of soil developed from felsic sediments in west kalimantan province and its implication to land management, *Soil and Climate Journal*, (2007), (25), pp. 11–26.
43. Sukarman, S. Ritung, M. Anda, and E. Suryani., Guidelines for soil observation in the field, *Agricultural Research and Development Agency, Ministry of Agriculture Republic of Indonesia, Bogor*, (2017), pp. 1–149.
44. Supriya, K., M. V. S. Naidu, P. Kavitha and M. Srinivasa Reddy., Characterization, classification and evaluation of soils in semi-arid region of Mahanandi Mandal in Kurnool district of Andhra Pradesh', *Journal of the Indian Society of Soil Science*, (2019), 67(2), pp. 125–136. doi:

10.5958/0974-0228.2019.00014.8.
45. Susilawati, S. and Veronika, V., Vetiver grass study as a continuous slope safety, *Civil Engineering Communication Media*, (2016), 22(2), p. 99. doi: 10.14710/mkts.v22i2.12886.
46. Suyana, J., Sumarno, Supriyono, and N. P Lestariningsih., Mulching and strengthening of terraces in three types of plants against surface runoff, erosion, growth and yield of plants in Andisols, *Agrosains*, (2017), 19(1), p. 15. doi: 10.20961/agsjpa.v19i1.20924.
47. Vedadri, U. and Naidu, M. V. S., Characterization, classification and evaluation of soils in semi-arid ecosystem of Chillakur mandal in SPSR Nellore district of Andhra Pradesh. Journal of the Indian Society of Soil Science, (2018), 66 (1), p. 9-19. doi: 10.5958/0974-0228.2018.00002.6.
48. Walia, C.S., and Rao, Y. S., Characteristics and classification of some soils of Trans-Yamuna plains. Journal of the Indian Society of Soil Science, (1997), 45 (1), p. 156-162.
49. Yasin, M. G. H., Langgi, W and Faesal, White grain maize as an alternative for staple food, *Iptek Tanaman Pangan*, (2015), 9(2), pp. 108–117.
50. Yatno, E. and Mulyanto, B., Characteristics of soils formed from schist and their land suitability for cocoa crop in Kolaka and East Kolaka Regencies, Southeast Sulawesi, *Soil and Climate Journal*, (2016), 39(2), pp. 109–118.
51. Zulkarnain, M., Prasetya, B and Soemarno, Effects of compost, manure, and custom-bio on soil properties, growth and yield of sugarcane (Saccharum officinarum L.) in Entisol Kebun Ngrangkah of Pawon, Kediri, *Indonesian Green Technology Journal*, (2013), 2(1), pp. 45–52. Available at: https://igtj.ub.ac.id/index.php/igtj/article/view/103.

Nurdin <nurdin@ung.ac.id>

[Dokuchaev Soil Bulletin] Editor Decision

1 pesan

Анна Романовская <no-reply@subs.elpub.science> 23 Agustus 2021 pukul 18.00
Balas Ke: Анна Романовская <burmistrovaann13@mail.ru>
Kepada: Nurdin Kyai Baderan <nurdin@ung.ac.id>

Dear Mr. Nurdin!

We received the review B of your submission to Dokuchaev Soil Bulletin, "Characterization and Soil Classification as Determining of Upland Quality in Bulia Micro Watershed, Indonesia". I import it below, some corrections are needed. After that You can send me the email with corrected manuscript enclosed, or You may download it as the author's version using Your personal account.

Regards,
Anna,
editor Dokuchaev Soil Bulletin,
https://bulletin.esoil.ru/jour
https://elibrary.ru/title_about.asp?id=28636

Reviewer B:

The article is devoted to an interesting topic of soil characterization of one of the watersheds of Indonesia. New data on soils of the region are given and their quality is evaluated on the basis of approaches widely used in the world. The article can be accepted for publication after correction according to the following remarks:
1. The title of the article could be made shorter. For example, Soils in Bulia Micro Watershed of Gorontalo Province, Indonesia and their quality assessment.
2. Figure 1 needs to be refined. It should not show classes of soil quality. It is better to show only land use type, or land cover classes.
3. The definition of soil texture classes in Table 2 are made with errors. It is necessary to correct them and make appropriate changes in the text of the article.

4. The English has to be corrected. Too many mistakes.

---

journal

Bulletin of V.V. Dokuchaev Soil Science Institute

Soils in the Bulia Micro Watershed of Gorontalo Province, Indonesia and Their Quality Assessment

Received 12.07.2021, Revised ………, Accepted ……………..

Abstract: Ten representative pedons from the Bulia micro watershed of Gorontalo Province, Indonesia, were characterized and classified to determine its land quality (LQ) class. Angular blocky, sticky, plastic consistencies and a hard consistency prevailed in the soil structure. In the alluvial plains the soil texture is dominated by the clay fraction, while in the hills and volcanic mountains the sand fraction is dominated. The soils in the Bulia micro watershed also have acid to neutral reaction, with the range of very low to high OC (organic carbon) levels, the reserve of exchangeable bases was dominated by Ca^{2+} in two series patterns, namely: $Ca^{2+} > Mg^{+} > Na^{+} > K^{+}$ and $Ca^{2+} > Na+ > Mg^{+} > K^{+}$, cation exchange capacity (CEC) ranged from low to very high, and the base saturation varied from moderate to very high. The alluvial plain is represented by Inceptisol on P1 and P7 (Typic Humustepts), also on P3 (Oxic Humustepts), then Mollisol on P4 (Typic Argiudolls) and P6 (Typic Haplustolls), Meanwhile the Alfisol on P5 (Typic Paleustalfs). Entisol on P2 (Typic Ustipsamments) was found in volcanic mountains and P9 (Typic Paleustolls) P8 (Ultic Paleustalfs), P10 (Inceptic Haplustalfs) are typical of volcanic hills. On the alluvial plains the land was categorized as the LQ class II, III and IV, the volcanic mountains were the LQ class IV, while the land on the volcanic hills was categorized as the LQ class VI. River bank erosion on the land river terraces can be held by the manufacture of gabions, talud, cliff reinforcement plants and terraces. The soil temperatures and high clay content can be regulated by mulching and organic materials

Keywords: Characterization, classification, soils of Indonesia, land quality, the Bulia watershed.

INTRODUCTION

Land is a crucial component of land resources which enables plants growth and food production. Land and plant productivity is primarily determined by soil and other land characteristics related to land quality (Subardja and Sudarsono, 2005). However, an intense tillage during agricultural cultivation and a pressure of the land use when its conservation and sustainability are ignored has resulted into a decrease of land quality. Agricultural production tends to level or even decrease (Nurdin, 2012). Corn is a traditional commercial crop in the province of Gorontalo, Indonesia, which has been intensively and massively cultivated since it was established as a prime commodity in the agropolitan program in 2001. Until 2019, hybrid corn yields in Gorontalo Province reached 1.7 million tons or increased by

9.3% compared to 2018, however, the productivity of maize was still low at only 5.0 tons/ha (BPS Gorontalo, Province 2020). In fact, the potential corn yield in Indonesia can reach 10-11 tons/ha (Yasin et al., 2015), while the achievement of the national productivity in 2018 was only 5.2 tons/ha (Indonesian Ministry of Agriculture 2019).

The Bulia micro watershed area is a corn production centre that also supports the agricultural area below. The watershed has a vital role because it supplies irrigation water for agriculture and other activities (Mahapatra *et al.*, 2019). The corn cultivation in this watershed has exceeded the carrying capacity indicated for the corn planting on the slope of >25%, so that the land degradation often occurs. Soil erosion, according to the corn agropolitan program of Gorontalo, reached 1,396 tons/ha/year (Husain et al., 2004). Meanwhile, the corn productivity in this area is only 5.0 tons/ha (BPS Gorontalo Regency, 2020), which could happen due to the fact that the crop was cultivated on a non-suitable land.

Soil characterization is essential because it provides some necessary information about the soil characteristics for growing plants (Devi et al., 2015). For sustainable management of soil resources in agroecological areas we need timely monitoring of significant physical, chemical and biological soil characteristics and responses to the changes in land management (Supriya et al., 2019). These soil characteristics then form the basis for land classification. Combining soil characterization with classification is a powerful tool to develop management strategies for food security and environmental sustainability (Satish *et al.*, 2018). However, the efforts to link land characteristics and classification with a specific land quality are still relatively rare. Land quality is a land ability to perform a specific function before the land is degraded (Beinroth et al., 2001). Understanding soil types and their distribution, its limits and potential is essential for a proper management to increase productivity and yields (Niranjana et al., 2011).

The survey and mapping of soil resources in the Paguyaman watershed were carried out by the Soil and Agro-climate Research Centre of the Indonesian Ministry of Agriculture (Puslittanak Research Team, 1995), however, the mapping scale was 1: 50,000. In 2010, some research was carried out on the development, classification and potential of the paddy soils on toposequence (Nurdin, 2010), however, it only focused on the rainfed paddy soils, while the dry land was only compared to the locations close to the soil pedon in the rice fields. Considering the high intensity of the land management and the massive corn cultivation in this sub-watershed, this research has become significant.

MATERIALS AND METHODS

Study location

The Bulia micro watershed is a part of the Paguyaman watershed located in the northern part, it covers Mootilango and Boliyohuto District of Gorontalo Regency of Gorontalo Province, Indonesia (Figure 1). Geographically, the research location is between 0°39'123 "and 0°51'321" N, 122°35'21 "and 122°43'12" S (Table 1), which is 67 km from Gorontalo City, Indonesia.

Overall, the Bulia micro watershed has 21,456.58 ha and consists of upland amounted to 18,993.44 ha (32.59%), and paddy fields amounted to 2,991.15 ha (13.94%). Specifically, the upland agriculture covers the agricultural land areas amounted to 6,993.44 ha (37.87%), settlement areas – 461.59 ha (2.50%), and forest areas amounted to 11,010.40 ha (59.63%). The soils in this area are generally developed from volcanic material in the upper watershed and lacustrine deposits in the middle and the bottom of the watershed. The study area is located in tropical climate with rainy and dry seasons. The average annual rainfall was only 1,478 mm with 1 wet month only and 4 dry months, so it belongs to the E2 agro-climate zone (Oldeman and Darmiyati, 1977). The average annual air temperature reaches 28.19°C with the maximum temperature of 28.73°C and the minimum temperature of 27.63°C. Under these conditions, the soil moisture regime is determined ustic and the soil temperature regime – isohyperthermic (Soil Survey Staff, 2014).

Table 1. Site characteristics of the pedons in the Bulia micro watershed

Pedon/ Villages	Location	Elevation (m msl)	Landform	Slope (%)	Drainage
P1, Tolite	0°39’44.80” N 122°35’27.20” S	24	Alluvial plain	0 – 3	Poorly-drained
P2, Monggolito	0°40’01.20” N 122°37’57.20” S	159	Volcanic mountain	15 – 30	Well-drained
P3, Huyula	0°42’59.9” N 122°39’43.2” S	63	Alluvial plain	0 – 3	Moderately
P4, Payu	0°44’04.4” N 122°37’48.4” S	53	Alluvial plain	0 – 3	Moderately
P5, Pilomonu	0°43’53.80” N 122°35’22.60” S	75	Alluvial plain	0 – 3	Moderately
P6, Karyamukti	0°42’20.50” N 122°41’05.50” S	109	Alluvial plain	3 – 8	Moderately

P7, Karyamukti	0°42’10.30” N 122°41’19.40” S	114	Alluvial plain	3 – 8	Moderately
P8, Sukamaju	0°44’05” N 122°40’04” S	253	Volcanic hill	8 – 15	Well-drained
P9, Payu	0°45’12” N 122°38’08” S	285	Volcanic hill	8 – 15	Well-drained
P10, Huyula	0°43’11.10” N 122°40’31.20” S	262	Volcanic hill	8 – 15	Well-drained

msl: mean sea level.

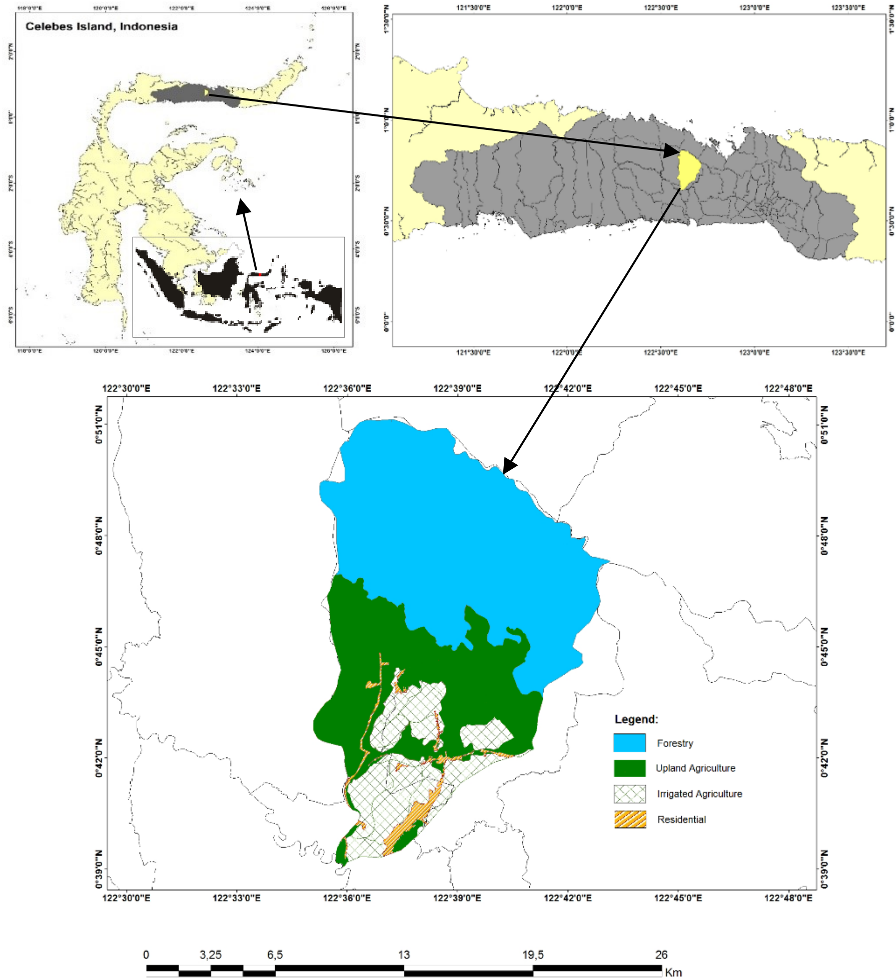


Fig 1. Location Map of the Bulia Micro watershed

Soil surveying, characterization and classification

Ten representative pedons were selected to conduct the soil survey, The description of soil morphology refers to the Soil Survey Manual (Soil Science Division Staff, 2017; Sukarman et al., 2017). According to standard procedures, soil samples were taken at each horizon and their physical and chemical properties were analyzed (Jackson, 1973; Eviyati and Sulaeman, 2009). The morphological and the soil properties data obtained during the laboratory analysis are used for the soil characterization together with the climate and the terrain conditions data, according to Sukarman et al., (2017). The soil characteristics are used for soil classification according to the keys to soil taxonomy (Soil Survey Staff, 2014).

Land quality assessment

Land quality (LQ) class assessment follows the method according to Beinroth et al. (2001). This method has been modified based on availability of soil characteristics and classification data without including local population data. Soil pedons (P), which were classified in taxa according to the Soil Taxonomy System (Soil Survey Staff, 2014), were combined with a land unit (LU) basing on the similarity of the criteria in taxa. Soil and pedoclimate information was used to place each LU into I to IX land quality classes with class I having the most appropriate attributes and class IX having the least suitable ones for crop production. The results of the land quality analysis are widely presented and described with the help of Arc GIS.

RESULTS AND DISCUSSION

Morphology and soil physical properties

The results of field studies and the laboratory characterization of ten soil pedons were presented in Table 2. The soils in the study area have been developed as indicated by the horizon structuring (horizons A and B), with the depth of the soil solum varying from shallow to very deep. The soil colour is only of 7.5YR and 10YR hue, where 7.5YR is dominant. P1, P2, P3, P5, P8, P9 and P10 soil colour varies from dark brown, brown to strong brown with hue 7.5YR, ranging from 3 to 5, and chroma – from 1 to 6. While in P4, P6 and P7, soil colour varies from very dark grayish brown, dark brown to dark yellowish-brown with hue 10YR, values ranging from 3 to 4, and chroma – from 2 to 6. The colour of soil horizon A is darker than of horizon B due to the fact that the organic matter content in horizon A is higher than in horizon

B (Yatno et al., 2015). The higher the organic matter content, the darker the soil colour is (Suharta, 2007). Soil colour seems to be a function of chemical and mineralogical composition (Swarnam *et al.*, 2004; Walia and Rao, 1997), and the soil texture is influenced by topographic position and humidity regimes (Walia and Rao, 1997).

The soil structure varies from crumbs, angular blocky, sub angular blocky to prismatic, with the dominant angular blocky. P1, P3, P4, P6, P7, P8, P9 and P10 were mostly of angular blocky structure with the sizes varying from fine, medium to coarse, with weak and strong structural development. While the soil structures of P2 and P5 varies between crumbs, angular blocky, sub angular blocky and prismatic with the sizes ranging from fine, medium to coarse and the level of the soil structure development varying from weak, moderate to strong. The angular blocky soil structures were strongly associated with higher clay fractions (Devi et al., 2015). Crumbly soil structure is indicated of newly developed soil (Manik et al., 2017). Intensive of soil tillages causes the soil structure to be damaged (Jambak et al., 2017). The variation of soil structure will be consistently affecting the soil.

The soil consistency in wet conditions varies between non-sticky and non-plastic on Pedon 2, slightly sticky and slightly plastic, sticky and plastic in the horizon on P1, P3, P4, P5, P6, P7, P8, P9 and P10, very sticky and very plastic on the surface horizon (Ap) of P9 and the subsurface horizon (BC) of P10, however, slightly sticky and slightly plastic consistencies prevail. While in moist conditions the consistencies vary from loose, firm to very firm, the firm consistencies are still dominant. P1, P3, P4, P5, P6, P7, P8, P9 and P10 were dominated by hard consistencies, while P2 – by loose ones. There is a very hard consistency in P1 and P10 in the subsurface horizon (Bw and BC), while in the surface horizon (Ap) a very hard consistency can be only found in P9. The consistency in dry conditions varies from loose, hard to very hard, with a dominant hard consistency. P1, P3, P4, P5, P6, P7, P8, P9 and P10 were dominated by a hard consistency, however, in P1 and P10 in the subsurface horizon (Bw3 and BC) one could notice a very hard consistency, while in P9 precisely a very hard consistency was found on the surface horizon (Ap). Sticky and plastic consistency might form due to a high clay content in the soil (Sarkar et al., 2001); (Kadao et al., 2003), while non-sticky and non-plastic consistency might form due to a very little clay content (Sireesha and Naidu, 2015; Devi et al., 2015).

Table 2. Morphological characteristics and soil physical properties in the Bulia micro watershed

Pedon and Horizon	Depth (cm)	Colour Moisture	Structures	Consistence			Sand	Silt	Clay	Texture Class
				w	m	D	%			
P1 (Alluvial Plain)										
Ap	0 - 23	7.5 YR 4/4	m, 3, abk	s, p	fi	H	9	40	51	Silty Clay
Bw1	23 - 43	7.5 YR 4/2	m, 3, abk	ss, sp	fi	H	3	46	51	Silty Clay
Bw2	43 - 75	7.5 YR 4/4	m, 3, abk	ss, sp	fi	H	3	54	43	Silty Clay
Bw3	75 - 100	7.5 YR 4/2	m, 1, abk	ss, sp	vfi	V h	3	46	51	Silty Clay
P2 (Volcanic Mountains)										
Ap	0 - 5	7.5 YR 4/4	f, 1, cr	so, po	fr	L	85	10	5	Loamy sand
Bw1	5 - 37	7.5 YR 4/4	f, 2, sbk	so, po	fr	L	84	2	14	Loamy sand
Bw2	37 - 61	7.5 YR 4/4	m, 2, p	so, po	fr	L	75	10	15	Sandy Loam
C	61+	7.5 YR 4/2	m, 3, p	so, po	fr	L	66	15	19	Sandy Loam
P3 (Alluvial Plain)										
Ap	0 - 14	7.5 YR 3/3	f, 1, cr	ss, sp	fi	H	33	41	26	Loam
Bw1	14 - 43	7.5 YR 4/4	f, 2, abk	s, p	fi	H	31	37	32	Clay Loam
Bw2	43 - 68	7.5 YR 4/4	f, 1, abk	ss, sp	fi	H	23	54	23	Silty Loam
Bw3	68+	10 YR 3/6	f, 1, cr	s, p	fi	H	23	48	29	Clay Loam
P4 (Alluvial Plain)										
Ap	0 - 14	10 YR 3/3	m, 3, abk	s, p	fi	H	27	26	47	Clay
Bw	14 - 50	10 YR 4/3	f, 1, abk	s, p	fi	H	32	34	34	Clay Loam
Bt1	50 - 81	10 YR 3/2	f, 1, abk	ss, sp	fi	H	12	24	64	Clay
Bt2	81+	7.5 YR 4/1	f, 1, abk	s, p	fi	H	16	25	59	Clay
P5 (Alluvial Plain)										
Ap	0 - 21	7.5 YR 4/4	f, 2, sbk	ss, sp	fi	H	23	43	34	Clay Loam
Bw	21 - 46	7.5 YR 4/4	f, 2, sbk	ss, sp	fi	H	23	48	29	Clay Loam
Bt1	46 - 84	7.5 YR 4/3	f, 2, abk	s, p	fi	H	25	35	40	Clay

Pedon and Horizon	Depth (cm)	Colour Moisture	Structures	Consistence			Sand	Silt	Clay	Texture Class
				w	m	D	%			
Bt2	84 - 117	7.5 YR 4/6	m, 2, p	s, p	fi	H	24	36	40	Clay
Btg	117+	7.5 YR 5/8	m, 1, sbk	ss, sp	fi	H	8	46	46	Silty Clay
P6 (Alluvial Plain)										
Ap	0 - 12	10 YR 3/3	f, 1, abk	s, p	fi	H	84	15	1	Loamy Sand
Bw1	12-34	10 YR 3/4	f, 1, abk	s, p	fi	H	61	10	29	Sandy Clay Loam
Bw2	34 - 71	10 YR 4/6	m, 3, abk	ss, sp	fi	H	61	24	15	Sandy Loam
C	71 - 90	7.5 YR 5/8	f, 1, cr	so, po	fr	L	84	5	11	Loamy Sand
P7 (Alluvial Plain)										
Ap	0 - 6	7.5 YR 4/6	m, 1, abk	s, p	fi	H	33	11	56	Clay
Bw1	6 - 17	10 YR 4/6	m, 3, sbk	s, p	fi	H	29	20	51	Clay
Bw2	17 - 33	10 YR 3/6	m, 1, abk	ss, sp	fi	H	21	20	59	Clay
Bt	33 - 49	10 YR 3/6	f, 1, p	ss, sp	fi	H	19	15	66	Clay
BC	49+	7.5 YR 4/6	f, 1, abk	ss, sp	fi	H	18	29	53	Clay
P8 (Volcanic Hills)										
Ap	0 - 7	7.5 YR 3/3	f, 1, abk	ss, sp	fi	H	64	10	26	Sandy Clay Loam
Bw	7 - 24	7.5 YR 3/3	m, 1, abk	s, p	fi	H	47	24	29	Sandy Clay Loam
Bt1	24 - 44	7.5 YR 4/6	f, 3, p	s, p	fi	H	45	15	40	Sandy Clay
Bt2	44 - 63	7.5 YR 5/6	m, 3, abk	s, p	fi	H	42	16	42	Clay
Bt3	63+	7.5 YR 5/6	m, 1, abk	s, p	fi	H	42	6	52	Clay
P9 (Volcanic Hills)										
Ap	0 - 16	7.5 YR 3/2	m, 3, abk	vs, vp	vfi	V h	54	31	15	Sandy Loam
Bw	16 - 34	7.5 YR 3/3	m, 1, abk	s, p	fi	H	42	24	34	Clay Loam
Bt	34+	7.5 YR 4/4	m, 1, abk	ss. sp	fi	H	50	15	35	Sandy Clay
P10 (Volcanic Hills)										
Ap	0 - 20	7.5 YR 3/3	m, 3, abk	ss, sp	fi	H	48	26	26	Sandy Clay Loam

Pedon and Horizon	Depth (cm)	Colour Moisture	Structures	Consistence			Sand	Silt	Clay	Texture Class
				w	m	D	%			
Bt1	20 - 44	7.5 YR 3/4	m, 3, abk	s, p	fi	H	41	15	44	Clay
Bt2	44 - 76	7.5 YR 4/6	c, 3, sbk	s, p	fi	H	42	14	44	Clay
BC	76+	5 YR 4/6	c, 3, p	vs, vp	vfi	V h	31	2	67	Clay

Structure: *size*: vf – very fine, f – fine, m – medium, c – coarse; *structureless grade*: 1 – weak, 2 – moderate, 3 – strong; *type*: cr – crumb, sg – single grain, abk – angular blocky, sbk – sub-angular blocky. Consistence: *dry* (d): s – soft, l – loose, sh – slightly hard, h – hard, vh – very hard, eh – extremely hard; *moist* (m): l – loose, fr – friable, fi – firm, vfi – very firm, efi – extremely firm, *wet* (w): so – non-sticky, ss – slightly sticky, s – sticky, vs – very sticky; po – non-plastic, ps – slightly plastic, p – plastic, vp – very plastic.

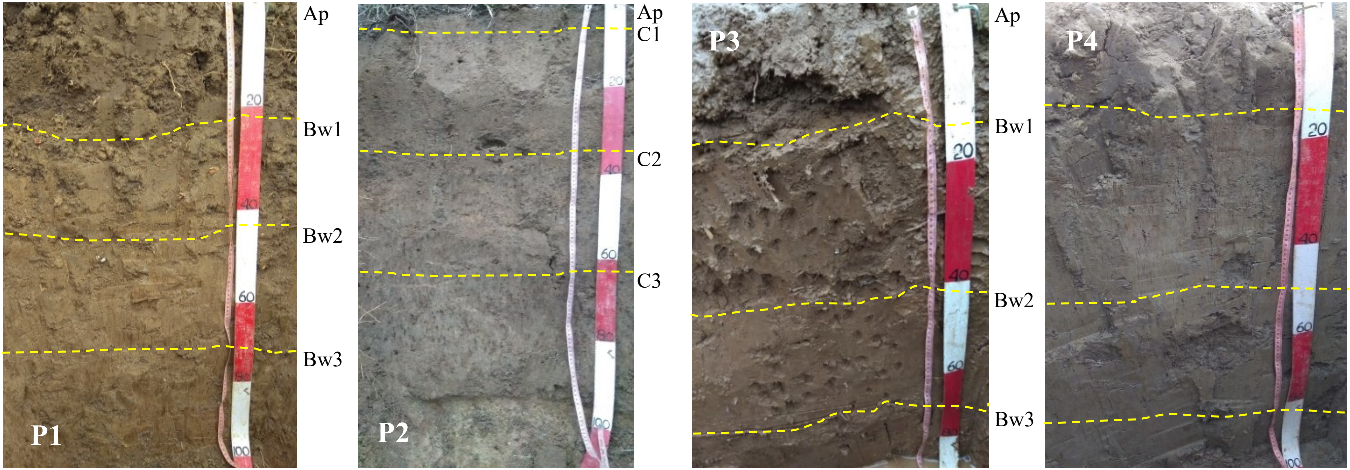


Fig 2. Soil profile appearance of pedon 1 (P1), 2 (P2), 3 (P3) and pedon 4 (P4)

The soil texture of all pedons varies greatly between sandy clay loam, sandy loam, loamy sand, sandy loam, silty loam, clay loam, silty clay and clay, except for P7 that was of clay texture in all horizons. Wide variations of soil texture may be caused by the variations in parent material, topography, in-situ weathering, translocation of clays by eluviation and soil age (Satish et al. 2018). Apparently, the pedons located in the alluvial group were more dominated by clay fractions, although the distribution patterns were irregular. The distribution of irregular clay fractions was typical for sediment materials (Nurdin, 2010). While a sand fraction dominated the volcanic group, the distribution of sand and clay fractions shows the opposite pattern. A decrease in the sand fraction is due to the clay illuviation and in-situ mineral destruction process, which was characterized by a decline in the absolute amount of sand in the middle of the solum (Rachim, 1994). The texture that is found in the subsurface horizon is caused by higher weathering in the subsurface layer (Dutta, 2009). The clay content in the solum middles (B-illuviation) was higher than in the upper horizon (A-eluviation) and in the lower layer horizon. This indicates the occurrence of a lessivage process with some clay skins seen, so that an argillic horizon was formed in P4, P5, P8, P9 and P10. Although the process of eluviation and illuviation occurred, the pedon remained, but the clay skins were not found, so the cambic and candic horizons were formed.

Soil chemical properties

Soil chemical properties are presented in Table 3. Soil pH varies from acid (pH 5.3) to neutral (pH 7.2). The pedons located on the upper watershed or in volcanic groups (P2, P8, P9 and P10) have a lower pH than the ones located on the lower watershed or in alluvial groups (P1, P3, P4, P5, P6, and P7). The pedon in the alluvial group represented a depressed area which is the accumulation of the bases carried by washing water from the hinterland section and the accumulation of more alkaline bases in soils with poorer drainage (Nurdin, 2010a). The pedons in the volcanic group experienced more intensive washing during the rain due to a better soil drainage. The trend of pH increasing with more depth may be explained by the release of organic acids during the decomposition of organic matter, these acids may have lowered the pH at the soil surface (Satish *et al.*, 2018). The pH differences of KCl and the pH of H_2O of all pedons show negative values. This means that all pedons are dominated by negatively charged clay minerals (Suharta, 2007). The acid and slightly acid soil pH values in P1, P3, P5, P9 and P10 indicated that the soil had developed but the level of soil development was not yet advanced, while the neutral soil pH in P2, P4, P6, P7, and P8 shows that the soil is relatively new.

Organic carbon (OC) varies from very low to high (0.08 - 2.28%). The OC value was high in the surface horizon (Ap), except for P4 and P5. The OC value on the surface is higher due to the accumulation of organic materials, while its low values in P4 and P5 were due to the river flooding. The low OC value was also determined by a faster degradation of the organic material in the tropics and a low addition of farmyard manure (Vedadri and Naidu, 2018). A high OC distribution pattern on the surface and its dramatic decrease in horizon B in accordance with the depth is a general soil development pattern (Prasetyo, 2007).

The reserve (sum) of exchangeable bases vary between very low, low, medium, high and very high. Calcium cation is the dominating one in the exchangeable bases reserve, which ranges from 2.54-18.02 cmol(+)kg^{-1}, while magnesium (Mg^+) ranges from 0.15-6.66 cmol(+)kg^{-1}, sodium (Na^+) ranges from 0.26-3.02 cmol(+)kg^{-1}, potassium (K^+) ranges from 0.05-3.56 cmol(+)kg^{-1}. Based on a number of bases, the P1, P5, P7, and P10 patterns follow the sequence: $Ca^{2+} > Mg^+ > Na^+ > K^+$. This series pattern was the same as Nurdin (2011) and Satish et al. (2018) reported. At the same time P2, P3, P4, P6, P8 and P9 follow the sequence: $Ca^{2+} > Na^+ > Mg^+ > K^+$. A high rate of exchangeable bases in the surface horizon (Ap) results from the fertilization during corn cultivation, while in the lower layer rainfall washing together with good drainage conditions make it possible to wash in the soil solum.

The cation exchange capacity (CEC) varies from low (7.7 cmol(+)kg^{-1}) to very high (42.40 cmol(+)kg^{-1}). The CEC is influenced by the levels of organic carbon and soil minerals (Prasetyo et al. 2007; Suharta 2007). It seems that CEC in P1, P3, P4, P5, P7, P8, and P9 were more influenced by OC content than by soil minerals. The higher the soil OC, the higher the soil CEC is (Suharta, 2007). While P2, P6 and P10 were thought to be more influenced by soil minerals, these bases can be exchanged and this CEC will eventually affect base saturation. Base saturation (BS) varies from moderate (40.55%) to very high (93%). All pedons generally have a medium and a high BS, except P6, which has a very high BS on the surface horizon (Ap). The variations in BS may be caused by the variations in nature and/or the content of soil colloids, and a relatively high base saturation in the surface layers can be attributed to the recycling of cation base through vegetation (Devi and Kumar 2010). In addition, if soil has a number of bases which are smaller than CEC, BS tends to be lower, whereas when the soil has a number of bases close to or higher than CEC, BS tends to be higher (Nurdin, 2010b).

Soil classification

Based on morphological and soil characteristics, the pedons are classified according to their family level and the orders of the soils found, namely Entisol, Inceptiol, Mollisol and Alfisol (Table 4). P1 and P7, which are located on a slope of 3% and 5%, are based on the molic epipedon with a 23 cm thickness and a cambic horizon. These pedons did not experience aquatic conditions at the depth of 50 cm from the soil surface (humustept), the soil colour had a value of 4 with a chroma of 2 or less and the soil structure was sub angular blocky. In addition, it had more clay content than the horizons below or above it. Based on these properties, P1 was classified as Typic Humustepts, fine, isohyperthermic.

P2, located on a slope of 15%, is represented by the ochric epipedon with a 5 cm thickness and a candic horizon. In this pedon there was an increase in the percentage of clay in the fine soil fraction with a depth of 15 cm or less in the vertical distance. The clay content was 4% or more (absolute value), which is more than that of the horizon above it, which has a total clay content in the soil fine fraction less than 20%. In addition, it had a loamy sand texture (psamments) and a CEC value (NH4OAc, pH 7) > 16 cmol(p+)kg-1. Based on these characteristics, P2 was classified as Typic Ustipsamments, sandy, isohyperthermic.

P3 is located on a slope of 1%, represented by the umbric epipedon with a 14 cm thickness and a cambic horizon. This pedon did not experience aquatic conditions at the depth of 50 cm from the soil surface (humustept), the soil colour had a value of 4 with a chroma of 2 or less and the soil structure is sub angular blocky. In addition, it had more clay content than the horizons below or above and its CEC (NH_4OAc 1N) value was 17.96 cmol(+)kg^{-1} only (oxic). Based on these properties, P3 was classified as Oxic Humustepts, fine loamy, isohyperthermic.

P4 is located on a slope of 15%, represented by the molic epipedon (BS 55%) with a 14 cm thickness and an argillic horizon. This pedon had a fine loamy class of particle size with a typical clay coating of the pore walls and the ped surface. In addition, there was 13% (> 8%) of clay on the eluvial horizon and 10YR hue with a chroma ≤ 3, and BS > 75%. Based on these properties, P4 was classified as Typic Argiustolls, fine loamy, isohyperthermic.

Table 3. Soil chemical properties in the Bulia micro watershed

Pedon and Horizon	Depth (cm)	pH 1:1		OC (%)	Exchangeable cations				CEC	BS (%)
		H_2O	KCl 1N		K	Na	Ca	Mg		
					[cmol(+)kg^{-1}]					
P1 (Alluvial Plains)										
Ap	0 – 23	6.20	5.40	2.29	0.29	1.88	18.02	1.86	42.40	52.00
Bw1	23 – 43	6.00	5.20	0.90	0.18	2.01	15.47	2.97	39.19	52.62
Bw2	43 – 75	6.40	5.50	0.74	0.14	2.19	12.36	2.50	37.85	45.42
Bw3	75 - 100	6.50	5.60	0.65	0.14	2.23	15.22	3.26	37.58	55.49
P2 (Volcanic Mountains)										
Ap	0 - 5	6.50	5.60	1.19	0.10	0.34	3.77	0.30	11.13	40.55
Bw1	5 - 37	6.10	5.20	0.55	0.08	0.34	4.20	0.60	7.75	67.49
Bw2	37 - 61	6.20	5.30	0.63	0.08	0.35	3.91	0.15	8.87	50.52
C	61+	6.20	5.30	0.56	0.08	0.36	6.51	0.76	12.29	62.79
P3 (Alluvial Plain)										
Ap	0 - 14	5.60	4.60	0.80	0.05	1.46	4.84	0.61	16.15	43.00
Bw1	14 - 43	6.00	5.10	0.41	0.09	1.57	7.72	1.70	19.78	56.00
Bw2	43 - 68	5.80	4.90	0.32	0.05	1.55	8.95	0.91	21.58	53.00
Bw3	> 68	6.20	5.20	0.48	0.05	1.55	10.12	0.76	20.43	61.00
P4 (Alluvial Plains)										
Ap	0 - 14	6.50	6.10	0.41	0.06	1.49	11.87	0.62	25.55	55.00
Bw	14 - 50	6.70	6.30	0.96	0.19	1.43	9.71	2.12	21.60	62.00
Bt1	50 - 81	7.00	6.00	0.41	0.12	1.58	16.54	2.01	35.19	58.00
Bt2	81+	5.80	5.00	0.24	0.09	1.56	13.47	6.66	33.04	66.00
P5 (Alluvial Plains)										
Ap	0 - 21	5.20	4.50	0.08	0.16	2.29	9.39	2.93	28.39	52.00
Bw	21 - 46	5.10	4.30	0.49	0.20	2.30	8.62	3.08	28.40	50.00
Bt1	46 - 84	5.70	4.90	0.57	0.12	0.26	7.69	2.00	21.56	47.00

Pedon and Horizon	Depth (cm)	pH 1:1		OC (%)	Exchangeable cations				CEC	BS (%)
		H_2O	KCl 1N		K	Na	Ca	Mg		
					[cmol(+)kg^{-1}]					
Bt2	84 - 117	5.10	4.20	0.50	0.17	0.30	10.38	2.05	31.34	41.00
Btg	117+	5.10	4.10	0.42	0.25	0.34	15.37	1.90	38.58	46.00
P6 (Alluvial Plains)										
Ap	0 - 12	7.20	6.60	0.64	3.56	3.02	2.54	0.91	10.76	93.00
Bw1	12 - 34	7.10	6.60	0.32	0.28	1.72	6.03	0.30	11.79	71.00
Bw2	34 - 71	7.00	6.00	0.56	0.16	0.39	7.84	0.15	17.16	50.00
C	71 - 90	6.80	6.00	0.40	0.12	0.38	6.49	0.15	13.96	51.00
P7 (Alluvial Plains)										
Ap	0 - 6	6.30	5.40	0.76	0.10	0.42	5.31	2.41	18.31	45.00
Bw1	6 - 17	6.10	5.10	0.57	0.09	0.39	6.77	2.15	22.99	41.00
Bw2	17 - 33	5.90	5.00	0.57	0.07	0.44	8.55	4.04	25.45	51.00
Bt	33 - 49	5.60	4.80	0.33	0.08	0.45	13.64	3.72	29.79	60.00
BC	49+	5.90	5.00	0.41	0.12	2.04	13.16	0.31	33.06	47.00
P8 (Volcanic Hills)										
Ap	0 - 7	6.00	5.20	0.96	0.24	2.09	10.15	0.45	19.40	67.00
Bw	7 - 24	6.40	5.50	0.80	0.17	2.05	10.30	0.61	21.55	61.00
Bt1	24 - 44	6.70	5.80	0.48	0.24	2.21	10.07	1.83	26.06	55.00
Bt2	44 - 63	6.60	5.60	0.49	0.33	2.21	9.47	0.78	26.52	48.00
Bt3	63+	6.60	5.60	0.50	0.49	2.35	13.84	1.27	32.83	55.00
P9 (Volcanic Hills)										
Ap	0 - 16	5.30	4.50	0.80	0.13	2.15	10.15	0.61	24.80	53.00
Bw	16 - 34	6.20	5.30	0.57	0.10	2.30	12.44	0.77	29.51	53.00
Bt	34+	6.20	5.20	0.48	0.06	2.25	13.49	0.46	30.54	53.00
P10 (Volcanic Hills)										
Ap	0 - 20	5.80	4.90	0.72	0.12	0.40	5.90	1.21	18.31	41.69

Pedon and Horizon	Depth (cm)	pH 1:1		OC (%)	Exchangeable cations				CEC	BS (%)
		H_2O	KCl 1N		K	Na	Ca	Mg		
					[cmol(+)kg^{-1}]					
Bt1	20 - 44	6.10	5.20	0.64	0.05	0.40	8.23	0.46	18.44	49.59
Bt2	44 - 76	6.30	5.30	0.48	0.05	0.39	7.26	0.76	19.36	43.66
BC	76+	5.80	5.30	0.33	0.06	0.42	11.28	2.04	25.64	53.82

CEC: cation exchange capacity, OC: organic carbon, BS: base saturation.

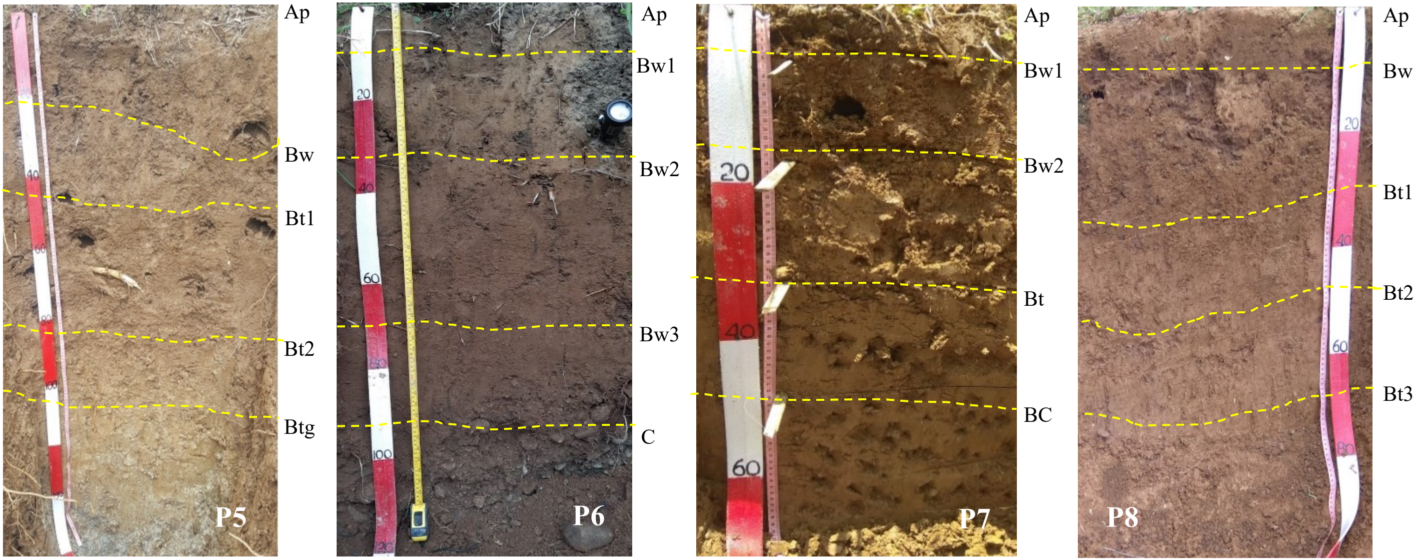


Fig 3. Soil profile appearance of pedon 5 (P5), 6 (P6), 7 (P7) and pedon 8 (P8)

P5 is located on a slope of 3%, represented by the ochric epipedon with a 21 cm thickness and an argillic horizon. According to the particle-size classification, this pedon belongs to the fine loam and clay class with an argillic horizon thickness of 25 cm (> 7.5 cm) of all overlying horizons, it also has a typical clay coating of the pore walls and the ped (aggregate) surface. In addition, the clay content in the argillic horizon is 64% or it contains 2.03 times more clay than the eluvial horizon, which was only 34%, and 7.5 YR was typical of all horizons (paleustalf). Based on these properties, P5 was classified as Typic Paleustalfs, fine loamy, isohyperthermic.

P6 is located on a slope of 3%, represented by the molic epipedon (BS 93%) with a 12 cm thickness and a cambic horizon. This pedon had a sandy clay texture and does not have the combination of aquic conditions within 50 cm of the soil surface or artificial drainage (ustoll). The colour value was with a chroma <6 and it had a sub angular blocky soil structure. In addition, it had more clay content than the below horizons. Based on these properties, P6 was classified as Typic Haplustolls, coarse loamy, isohyperthermic.

P8 is located on a slope of 5%, represented by the molic epipedon with a 7 cm thickness and an argillic horizon. According to the particle-size classification, this pedon belongs to the fine loam and fine clay class with an argillic horizon thickness of 20 cm (> 7.5 cm) of all overlying horizons, also it has a typical clay coating of the pore walls and the ped surface. In addition, the clay content in the argillic horizon is 69% or it contains 2.65 times more clay than the eluvial horizon, which was only 26%, and 7.5YR hue was typical in all horizons (paleustalf), with BS of 61% or > 75% only (ultic). Based on these properties, P8 was classified as Ultic Paleustalfs, fine loamy, isohyperthermic.

P9 is located on an 8% slope, represented by the molic epipedon (BS 53%) with a 7 cm thickness and an argillic horizon. According to the particle-size classification, this pedon belongs to the fine loam class with an argillic horizon thickness of 18 cm (> 7.5 cm) of all overlying horizons, it also has a typical clay coating of the pore walls and the ped surface. In addition, the clay content in the argillic horizon is 69% or it contains 4.60 times more clay than the eluvial horizon, which was only 18%, and 7.5YR hue with a chroma of ≤ 4, and BS of <75% of all horizons (paleustoll). Based on these properties, P9 was classified as Typic Paleustolls, fine loamy, isohyperthermic.

P10 is located on a slope of 15%, represented by the molic epipedon (BS 57% 50%) with a 23 cm thickness and an argillic horizon. According to the particle-size classification, this pedon belongs to the fine loam and fine clay class with an argillic horizon thickness of 24 cm (> 7.5 cm) of all overlying horizons, it also has a typical clay coating of the pore walls and the ped surface. In addition, the clay content in the argillic horizon is 88% or it contains 3.38 times more clay than the eluvial horizon, which was only 24%, and 10YR hue with a chroma of ≤ 3, and BS >75%. Based on these properties, P10 was classified as Inceptic Haplustalfs, fine, isohyperthermic.

Table 4. Soil classification in the Bulia micro watershed

Pedon	Soil Classification					Area	
	Order	Sub Order	Great Group	Sub Group	Family	ha	%
P1	Inceptisol	Ustept	Humustepts	Typic Humustepts	Fine, isohypertermic, Typic Humustepts	596.88	8.53
P2	Entisol	Psamment	Ustipsamments	Typic Ustipsamments	Sandy, isohypertermic, Typic Ustipsamments	472.68	6.76
P3	Inceptisol	Ustept	Humustepts	Oxic Humustepts	Fine loamy, isohypertermic, Oxic Humustepts	2,297.78	32.86
P4	Mollisol	Ustoll	Argiustolls	Typic Argiudolls	Fine, isohypertermic, Typic Argiustolls	107.35	1.54
P5	Alfisol	Ustalf	Paleustalfs	Typic Paleustalfs	Fine loamy, isohypertermic, Typic Paleustalfs	1,066.95	15.26
P6	Mollisol	Ustoll	Haplustolls	Typic Haplustolls	Coarse loamy, isohypertermic, Typic Haplustolls	1,026.23	14.67
P7	Inceptisol	Ustept	Humustepts	Typic Humustepts	Fine, isohypertermic, Typic Humustepts	248.4	3.55
P8	Alfisol	Ustalf	Paleustalfs	Ultic Paleustalfs	Fine loamy, isohypertermic, Ultic Paleustalfs	61.87	0.88

Pedon	Soil Classification					Area	
	Order	Sub Order	Great Group	Sub Group	Family	ha	%
P9	Mollisol	Ustoll	Paleustolls	Typic Paleustolls	Fine loamy, isohypertermic, Typic Paleustolls	48.35	0.69
P10	Alfisol	Ustalf	Haplustalfs	Inceptic Haplustalfs	Fine, isohypertermic, Inceptic Haplustalfs	1,066.95	15.26
Total						6,993.44	100.00

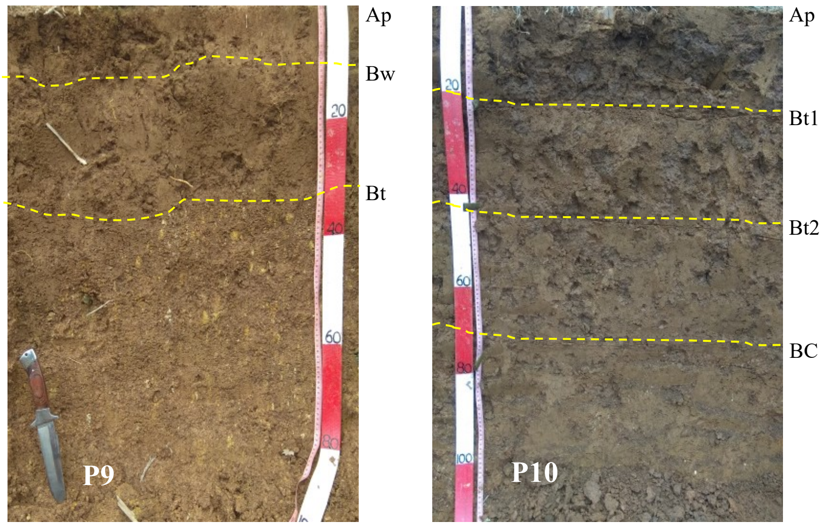


Fig 4. Soil profile appearance of pedon 9 (P9), and pedon 10 (P10)

Land quality classes

The land quality (LQ) of the Bulia micro watershed was presented in Table 5 and Figure 5. The LQ of class II with the main factor determining the land stress was high temperature and low organic matter. The high temperature factor with an isohyperthermic soil temperature regime as an indicator was found on LU 3 (P3), while the low organic matter factor with an ochric epipedon indicator was only on LU 5 (P5). The LQ of class II is determined as good and this land has few problems for sustainable production, its productivity is generally very high and as a result, the response to management is high (Beinroth et al., 2001). Land management through the addition of organic matter, including green manure, may be adopted along with the recommended fertilizer doses (Sys et al., 1991; Singh et al., 2004; Mahaputra et al., 2019) and mulching to stabilize temperatures and maintain soil moisture (Odjugo, 2008); (Eruola et al., 2012; Damaiyanti et al., 2013), which is of great importance. In addition, the use of rice straw mulch and sawdust mulch influences soil properties by decreasing the value of bulk density, increasing soil porosity and soil organic matter (Nasruddin and Hanum, 2015).

The LQ of class III with the main factor determining the land stress was a seasonal excess of water. The indicators determining the land stress in class III were new terraces spread over LU 1 (P1), LU 6 (P6) and LU 7 (P7). These new terraces are generally located around the border or river meanders which were prone to erosion and river bank landslides. The LQ of land class III was still considered good and this land has few problems for sustainable production, but has the higher risk of low input of corn production specifically, which results in a response to high management (Beinroth et al., 2001). The land management through the manufacture of gabions and riverbanks (Rahman, 2013), planting river bank reinforcement plants and terraces (Suyana *et al.*, 2017) was of great importance. Bioengineering methods for river bank erosion control commonly used include planting bamboo (Noor et al., 2011). Fine plant roots play a significant role in increasing the shear strength of the soil (Ludwig et al., 2007). The effectiveness of plants in reducing erosion rate is influenced by (1) the canopy or plant canopy, (2) the organic material produced, (3) the root system and the ability of plants to cover the soil (Rachman *et al.*, 2004). Vetiver plants were useful for stabilizing river banks, irrigation canals, river erosion control and coastal embankments, excavation slopes and embankments on highways, sand dunes, erosion on sloped agricultural land (Noor et al., 2011). Vetiver grass, which has strong fibrous roots, holds the ground (Susilawati and Veronika, 2016). Soil nailing was one of the most economical techniques for slopes stabilization of retaining walls because the system works quickly and does not require large space (Sinarta, 2014); Noor et al., 2011).

Table 5. Land quality classes in the Bulia micro watershed

Land Unit	Land Quality		Land Quality Class	Area	
	Major Land Stress Factor	Determinant of Land Stress		ha	%
3	High temperatures	Isohyperthermic of soil temperature regime	II	2,297.78	32.86
5	Low organic matter	Ochric epipedon	II	1,066.95	15.26
1, 6, 7	Seasonal water excess	Recent terraces	III	1,871.51	26.76
2	Low structural stability and/or crusting	Entisols	IV	472.68	6.76
4	Low structural stability and/or crusting	Clay soils	IV	107.35	1.54
8, 9, 10	Low water holding capacity	Sandy clay loam	VI	1177.17	16.83
Total				3,628.71	51.89

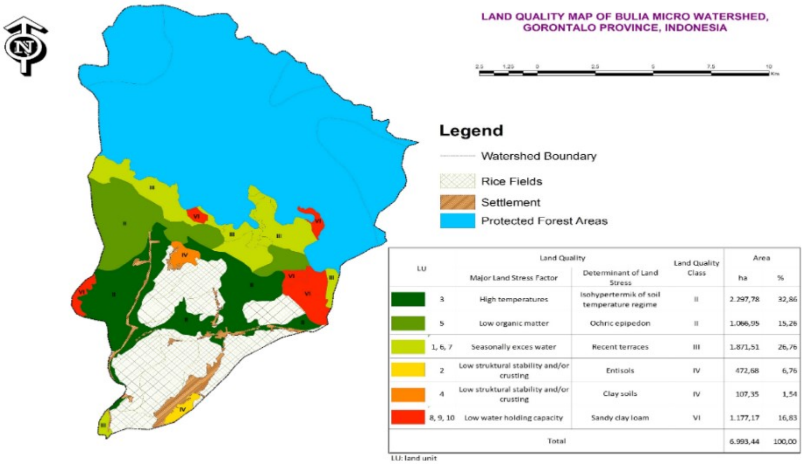


Fig 5. Land Quality Map of the Bulia Micro

The LQ of class IV with the main factors determining land stress was low structural stability and/or crusting. These main factors consist of two indicators, namely clay soil and Entisol. The indicator of heavy clay (> 50%) was scattered in LU 4 (P4). This indicator of clay soil was related to soil crusting which was shown by the average sub angular blocky soil structure, and the soil consistency under wet conditions was very sticky and very plastic, while it was very hard under dry conditions. Clay and organic matter are binding agents for aggregates (Rachim, 2007). Apparently, the influence of clay is more dominant than of organic matter as an aggregate binding agent because the OC content was very low. The Entisol indicators were spread on LU 2 (P2) only. Entisol is a soil that is still young and underdeveloped (Rachim, 2007). The results of the morphological analysis of the soil indicated that this Entisol has a granular structure (not solid), fine sized with a weak level of development, therefore the stability was relatively low. In addition, the texture of Entisol was classified as loamy sand with the sand of particle size which makes the soil structure stability relatively low. This class requires major inputs from conservation management; since a lack of plant nutrition is a major obstacle, therefore a plan to use good fertilizers should be adopted (Beinroth et al., 2001). Land management through the addition of organic matter can be applied together with recommended fertilizer doses (Sys et al., 1991; Singh et al., 2004; Mahaputra et al., 2019). Provision of organic matter in soils with clay texture can increase soil water content and available water capacity and reduce soil volume weight (Intara *et al.*, 2011), increase soil porosity (Anastasia et al., 2014), increase N, P, and K uptake and crop yields in Entisol soils (Afandi et al., 2015). Addition of manure, compost and beneficial bacteria technology (custom bio) can reduce soil content weight, soil density, increase aggregate stability, soil porosity and moisture content in Entisol soil (Zulkarnain et al., 2013).

The LQ of class VI with the main factor determining the land stress was low water holding capacity. The indicators of the sandy clay loam texture were spread on LU 8 (P8), LU 9 (P9) and LU 10 (P10). The value of water available on the sandy clay loam texture was only around 20.42 mm (Haridjaja et al., 2013). The available water (pF) under conditions of field capacity (pF 2.0) on LU 8, 9 and LU 10 was indicated as 34 mm, 38 mm, and 37 mm respectively, and at permanent wilting conditions (pF 4.2) 24 mm, 17 mm and only 19 respectively, therefore, causing a low water holding capacity. This land should not be used for food production (i.e corn) because this class requires major inputs from conservation management; since a lack of plant nutrition is a major obstacle, therefore a plan to use good fertilizers should be adopted or this land can be used as a biodiversity zone (Beinroth et al., 2001). However, if this land is used for agricultural cultivation, then the land management should consider the addition of organic matter along with the recommended fertilizer dosage (Sys et al., 1991; Singh et al., 2004; Mahaputra et al., 2019). Provision of organic material in soils with clay texture can increase soil water content and available water capacity and reduce soil volume weight (Intara et al., 2011), increase soil porosity (Anastasia et al., 2014).

CONCLUSIONS

Angular blocky, sticky, plastic consistencies, and hard consistencies prevailed in the soil structure of the Bulia micro watershed of Gorontalo Province, Indonesia. In the alluvial plain, a sand fraction prevailed in Volkan mountains. The soils in the Bulia micro watershed also react acid to neutral, with the range of very low to high OC levels, the reserve of exchangeable bases was dominated by Ca^{2+} in two series patterns, namely: $Ca^{2+} > Mg^{+} > Na^{+} > K^{+}$ and $Ca^{2+} > Na^{+} > Mg^{+} > K^{+}$, CEC ranged from low to very high, and the base saturation varied from moderate to very high. The primary soils found were Entisol on P2 (Typic Ustipsamments), Inceptisol on P1 and P7 (Typic Humustepts), and P3 (Oxic Humustepts), Mollisol on P4 (Typic Argiudolls), P6 (Typic Haplustolls), and P9 (Typic Paleustolls), and Alfisol on P5 (Typic Paleustalfs), P8 (Ultic Paleustalfs) and P10 (Inceptic Haplustalfs). On the alluvial plains the land was categorized as the LQ class II, III and IV, the volcanic mountains were the LQ class IV, while the land on the volcanic hills was categorized as the LQ class VI. River bank erosion on the land river terraces can be held by the manufacture of gabions, talud, cliff reinforcement plants and terraces. The soil temperatures and high clay content can be regulated by mulching and organic materials.

ACKNOWLEDGMENT

We would like to pay our regards to the Faculty of Agriculture, Brawijaya University who has funded this research with a non-tax state revenue grant in accordance with the Budget Implementation List Number: DIPA-042.01.2.400919/2019

REFERENCES

1. Afandi, F. N., Siswanto, B. and Nuraini, Y., Effect of giving various types of organic material on soil chemical properties on the growth and production of sweet potato plants in Entisol Ngrangkah Pawon, Kediri, *Soil and Land Resources*, (2015), 2(2), pp. 237–244. Available at: http://jtsl.ub.ac.id.

2. Anastasia, I., Izatti, M. and Suedy, S. W. A., The effect of giving a combination of solid organic fertilizer and liquid organic on soil porosity and spinach plant growth (Amarantus tricolor L.), *Biology Journal*, (2014), 3(2), pp. 1–10.

3. Beinroth, F. H., Eswaran, H. and Reich, P. F., Global assessment of land quality, *sustaining the global farm: Selected papers from the 10th International Soil Conservation Organization Meeting*, (2001), pp. 569-574.

4. BPS Gorontalo Province, Gorontalo province in figure 2020, *BPS Gorontalo Province*, (2020), 1102001.75(75560.2004), pp. 1–535.

5. BPS Gorontalo Regency, Gorontalo regency in figure 2020, *BPS Gorontalo Regency*, (2020), 1102001.75(75020.2003), pp. 1–262.

6. Dutta, M., Land use planning of Tipukjan watershed of Sivasagar district using GIS and remote sensing technique. Ph.D. Thesis, Assam Agricultural University, Jorhat. (2009).

7. Damaiyanti, D. R. R., Aini, N. and Koesrihati., The study of organic mulch application on the growth and yield of red pepper (Capsicum annuum L.), *Crop Production Journal*, (2013), 1(2), pp. 25–32.

8. Devi, P. A. V, Naidu, M. V. S. and Rao, A. R., Characterization and classification of sugarcane growing soils in southern agro-climatic zone: A case study in eastern mandals of Chittoor district in Andhra Pradesh, *Journal of the Indian Society of Soil Science*, (2015), 63(3), pp. 245–258. doi: 10.5958/0974-0228.2015.00034.1.

9. Eruola, A. O., Bello N. J, Ufoegbune G. C, and Makinde, A. A., Effect of mulching on soil temperature and moisture regime on emergence, growth and yield of white yam in a tropical wet-and-dry climate, *International Journal of Agriculture and Forestry*, (2012), 2(1), pp. 93–100. doi: 10.5923/j.ijaf.20120201.15.

10. Eviyati and Sulaeman, Analysis of soil, chemical, plants, water, and fertilizer, *Indonesia Centre of Soil Research*, (2009), pp. 1–203.

11. Husain, J., J. N. Luntungan, Y. E. B. Kamagi, and Nurdin., Conservation-based corn farming model in Gorontalo Province. Research

Report. Research, Development and Regional Environmental Impact Control Agency Gorontalo Province, Gorontalo. (2004)
12. Haridjaja, O., Baskoro, D. P. T. and Setianingsih, M., Different levels of field capacity by alhricks, free drainage, and pressure plate methods at different soil texture and relation for sunflower growth (Helianthus annuus L.), *Soil Science and Environmental Journal*, (2013), 15(2), p. 52. doi: 10.29244/jitl.15.2.52-59.
13. Intara, Y. I., A. Sapei, Erizal, N. Sembiring, and M. H. B. Djoefrie., Affected of organic matter application at clay and clay loam soil texture on water holding capacity, *Indonesian Agriculture Sciences Journal*, (2011), 16(2), pp. 130–135.
14. Jambak, M. K. F. A., Baskoro, D. P. T. and Wahjunie, E. D., Characteristics of Soil Physic on Soil Conservation Tillage System (Case Study Of Cikabayan Research Farm, Bogor), *Soil and Land Bulletin*, (2017), 1(1), pp. 44–50.
15. Jackson, M. L., Soil chemical analysis. Prentice Hall of India (Pvt.) Ltd., New Delhi. (1973).
16. Kadao, S. H., Prasad, J. and Gajbhlye, K. S., Characterization and classification of some typical banana growing soils of Wardha district of Maharashtra, *Agropedology*, (2003), 13(2), pp. 28–34.
17. Ludwig, A., Bradford, P., David, B., and Anton, W., Vegetation patches and runoff-erosion as interacting ecohydrological processes in semiarid landscapes. Ecology, (2007), 86, pp. 288-297. doi: https://doi.org/10.1890/03-0569.
18. Mahapatra, S. K., R. Nagdev, R. Gopal, J.N. Surya, R.K. Meena, R.P. Yadav and S.K. Singh., Characterization and classification of the soils of Buraka micro-watershed in Haryana for integrated development, *Journal of the Indian Society of Soil Science*, (2019), 67(2), pp. 137–150. doi: 10.5958/0974-0228.2019.00015.X.
19. Manik, H., Marpaung, P. and Sabrina, T., The level of soil development based on the pattern of clay mineral distribution in Subdistric Lumbanjulu, Distric of Toba Samosir, *Agroteknologi FP USU*, (2017), 5(2), pp. 422–433.
20. Nasruddin and Hanum, H., Study of mulching effects on soil temperature, soil property, and growth of patchouli (Pogostemon cablin Benth), *Floratek*, (2015), 10(2015), pp. 69–78.
21. Noor, A., Vahlevi, J. and Fathurrozi., Slope stabilization for erosion control with soil bioengineering using vetiver grass, *Poros Teknik*, (2011), 3(2), pp. 69–74.

22. Nurdin, *Development, classification and rainfed paddy soils potency derived from lacustrine materials in paguyaman, gorontalo*. MSc Thesis Bogor Agriculture University, (2010a). Available at: https://repository.ipb.ac.id/handle/123456789/57081.
23. Nurdin, The morfology, physics and soil chemistry of inceptisol derived from lacustrine paguyaman of gorontalo relating to soil managements, *Jurnal Agroteknotropika*, (2010b), 1(1), pp. 13–22.
24. Nurdin, Development and rainfed paddy soils potency derived from lacustrine material in paguyaman, gorontalo, *J Trop Soils*, (2011), 16(3), pp. 267–278. doi: 10.5400/jts.2011.16.3.267.
25. Nurdin, Combination of soil conservation techniques and its effect on the yield of maize and soil erosion of dry land in biyonga sub-watershed, gorontalo, *J. Tek. Ling*. (2012), 13(2), pp. 245–252.
26. Odjugo, P. A. O., The effect of tillage systems and mulching on soil microclimate, growth and yield of yellow yam (Dioscorea cayenensis) in Midwestern Nigeria, *African Journal of Biotechnology*, (2008), 7(24), pp. 4500–4507. doi: 10.4314/ajb.v7i24.59629.
27. Oldeman, L. R. and Darmiyati, S., An agroclimatic map of Sulawesi scale 1 - 2.500.000, *Center Research for Agriculture*, (1977), p. 1.
28. Puslitanak Research Team, Survey and mapping of semi-detailed soil resources (scale 1: 50,000) in the North Sulawesi of Paguyaman area for the development of irrigation and sugarcane commodities. Final report. Book III Attachment of the Land Series. Center for Soil and Agro-climate Research, Agency for Agricultural Research and Development, Indonesian Ministry of Agriculture, Bogor, (1995).
29. Prasetyo, B. H., Differentiation in Properties of vertisol from various parent materials, *Indonesian Agriculture Sciences Journal*, (2007), 9(1), pp. 20–31.
30. Rachman, A., Gantzer, J., and Anderson, S. H., Soil hydraulic properties influenced by stiff-stemmed grass hedge systems, *Soil Science Society of America Journal*, (2004), 68(4), pp. 1386–1393. doi: 10.2136/sssaj2004.1386.
31. Rahman, A., Geographic information system model for estimating flow coefficient and its relationship with land cover in Riam Kanan River Basin of South Kalimantan Province, *Bumi Lestari*, (2013), 13(1), p. 1-8.
32. Sys, C., E. V, Rast and Debaveye, J., Land evaluation. Part II. Principles in land evaluation and crop production calculations. International Training Centre for Post-Graduate Soil Scientists, University of Ghent.

(1991).
33. Sarkar, D., Gangipodhyay, S. K. and Velayutham, M., Soil toposequence relationship and classification in lower outlier of Chhotanagpur plateau, *Agropedology*, (2001), 11, pp. 29–36.
34. Swarnam, T. P., Velmurugan, A. and Rao, Y. S., Characterization and classification of some soils from Shahibi basin in parts of Haryana and Delhi. *Agropedology*, (2004), 14, p. 114-122.
35. Singh, C., Singh, P and Singh, R., Modern techniques of raising field crops. Oxford and IBH Publishing Co. Pvt. Ltd., New Delhi, (2004), pp. 1-583.
36. Satish, S., M. V. S. Naidu, K. V. Ramana, V. Munaswamy, G. P. Reddy and P. Sudhakar., Characterization and classification of the soils of Brahmanakotkur watershed in Kurnool district of Andhra Pradesh', *Journal of the Indian Society of Soil Science*, (2018), 66(4), pp. 351–361. doi: 10.5958/0974-0228.2018.00044.0.
37. Sinarta, I., Methods of handling landslides with soil nailing', *Paduraksa*, (2014), 3(2), pp. 1–16.
38. Sireesha, P. V. G. and Naidu, M. V. S., Clay mineralogy of soils developed from granite-gneiss of Kurnool District in Andhra Pradesh', *Journal of the Indian Society of Soil Science*, (2015), 63(1), pp. 16–23. doi: 10.5958/0974-0228.2015.00003.1.
39. Soil Science Division Staff, Soil survey manual, *United States Department of Agricultur US*, (2017), pp. 1–145. doi: 10.2307/1233734.
40. Soil Survey Staff, Keys to soil taxonomy, *Soil Conservation Service - NRCS/USDA*, (2014), 12, p. 360.
41. Subardja, D. and Sudarsono, The influence of land quality on productivity of maize in soils derived from volcanic and sedimentary rocks in the bogor area, *Soil and Climate Journal*, (2005), 23, pp. 38–46.
42. Suharta, N., The characteristic of soil developed from felsic sediments in west kalimantan province and its implication to land management, *Soil and Climate Journal*, (2007), (25), pp. 11–26.
43. Sukarman, S. Ritung, M. Anda, and E. Suryani., Guidelines for soil observation in the field, *Agricultural Research and Development Agency, Ministry of Agriculture Republic of Indonesia, Bogor*, (2017), pp. 1–149.
44. Supriya, K., M. V. S. Naidu, P. Kavitha and M. Srinivasa Reddy., Characterization, classification and evaluation of soils in semi-arid region of Mahanandi Mandal in Kurnool district of Andhra Pradesh', *Journal of the Indian Society of Soil Science*, (2019), 67(2), pp. 125–136. doi:

10.5958/0974-0228.2019.00014.8.
45. Susilawati, S. and Veronika, V., Vetiver grass study as a continuous slope safety, *Civil Engineering Communication Media*, (2016), 22(2), p. 99. doi: 10.14710/mkts.v22i2.12886.
46. Suyana, J., Sumarno, Supriyono, and N. P Lestariningsih., Mulching and strengthening of terraces in three types of plants against surface runoff, erosion, growth and yield of plants in Andisols, *Agrosains*, (2017), 19(1), p. 15. doi: 10.20961/agsjpa.v19i1.20924.
47. Vedadri, U. and Naidu, M. V. S., Characterization, classification and evaluation of soils in semi-arid ecosystem of Chillakur mandal in SPSR Nellore district of Andhra Pradesh. Journal of the Indian Society of Soil Science, (2018), 66 (1), p. 9-19. doi: 10.5958/0974-0228.2018.00002.6.
48. Walia, C.S., and Rao, Y. S., Characteristics and classification of some soils of Trans-Yamuna plains. Journal of the Indian Society of Soil Science, (1997), 45 (1), p. 156-162.
49. Yasin, M. G. H., Langgi, W and Faesal, White grain maize as an alternative for staple food, *Iptek Tanaman Pangan*, (2015), 9(2), pp. 108–117.
50. Yatno, E. and Mulyanto, B., Characteristics of soils formed from schist and their land suitability for cocoa crop in Kolaka and East Kolaka Regencies, Southeast Sulawesi, *Soil and Climate Journal*, (2016), 39(2), pp. 109–118.
51. Zulkarnain, M., Prasetya, B and Soemarno, Effects of compost, manure, and custom-bio on soil properties, growth and yield of sugarcane (Saccharum officinarum L.) in Entisol Kebun Ngrangkah of Pawon, Kediri, *Indonesian Green Technology Journal*, (2013), 2(1), pp. 45–52. Available at: https://igtj.ub.ac.id/index.php/igtj/article/view/103.

Nurdin <nurdin@ung.ac.id>

[Dokuchaev Soil Bulletin] Copyediting Review Request

1 pesan

Анна Романовская <no-reply@subs.elpub.science> 14 September 2021 pukul 16.22
Balas Ke: Анна Романовская <burmistrovaann13@mail.ru>
Kepada: Nurdin Kyai Baderan <nurdin@ung.ac.id>

Good day, Mr. Nurdin!

Your submission "Soils in the Bulia Micro Watershed of Gorontalo Province, Indonesia and Their Quality Assessment" for Dokuchaev Soil Bulletin has been through the first step of copyediting, and is available for you to review by following these steps.

1. Click on the Submission URL below.

2. Log into the journal and click on the File that appears in Step 1.

3. Open the downloaded submission.

4. Review the text, including copyediting proposals and Author Queries, I highlighted the corrected text by yellow colour. And there are some question to sentences which meaning I have not understood. Please read the comments and give the answers so that we could paraphrase them correctly.

5. Make any copyediting changes that would further improve the text.

6. When completed, upload the file in Step 2.

7. Click on METADATA to check indexing information for completeness and accuracy.

8. Send the COMPLETE email to the editor and copyeditor.

Submission URL: https://bulletin.esoil.ru/jour/author/submissionEditing/665

Username: nurdin

This is the last opportunity to make substantial copyediting changes to the submission. The proofreading stage, that follows the preparation of the galleys, is restricted to correcting typographical and layout errors.

If you are unable to undertake this work at this time or have any questions, please contact me. Thank you for your contribution to this journal.

--

Regards,
Anna,

editor Dokuchaev Soil Bulletin,
https://bulletin.esoil.ru/jour
https://elibrary.ru/title_about.asp?id=28636

---

journal

Bulletin of V.V. Dokuchaev Soil Science Institute

#665 EDITING

- Summary
- Reviews
- Editorial

Article

Authors	Nurdin ., Rayes ML, Soemarno ., Sudarto ., Listyarini E., Agustina C., Rahman R., Rauf A., Husain J.
Name	Soils in the Bulia micro watershed of Gorontalo province, Indonesia, and their quality assessment
Chapter	Articles
Editor	Anna Romanovskaya

Edit

View metadata

		REQUESTS	ON THE WAY	FINISHED
1.	Initial edit	09/14/2021	—	09/14/2021
	File: 665-1956-2-CE.docx 09/14/2021			
2.	Author's edit	09/14/2021	09/14/2021	09/14/2021
	File: 665-1962-1-CE.docx 09/14/2021			
	Choose File No file chosen Upload			
3.	final edit	09/14/2021	—	—
	File: No			

Editing Comments No Comments Editing Instructions

Layout

Galley Format			FILE		
1.	PDF (Eng)	View proofreading	665-1984-2-PB.pdf	10/19/2021	230

Additional files	FILE
	No

Design Comments No comments

proofreading

View metadata

		REQUESTS	ON THE WAY	FINISHED
1.	Author	—	—	
2.	Corrector	—	—	—
3.	Designer	—	—	—

Proofreading No comments Proofreading instructions

ISSN 0136-1694 (Print)
ISSN 2312-4202 (Online)

FSBSI FRC "Soil Institute named after V.V. Dokuchaev,
119017, Moscow, Pyzhevsky per., 7/2 tel
.: 8(916)078-70-57
E-mail: bulletin@esoil.ru

GALLEY PROOFS

Nurdin <nurdin@ung.ac.id>

Re: [Dokuchaev Soil Bulletin] Soils in the Bulia Micro Watershed of Gorontalo Province, Indonesia and Their Quality Assessment

2 pesan

Анна Романовская <burmistrovaann13@mail.ru> 14 September 2021 pukul 23.46
Balas Ke: Анна Романовская <burmistrovaann13@mail.ru>
Kepada: Nurdin Kyai Baderan <nurdin@ung.ac.id>

Mr. Nurdin, do not worry! Before the publication I will check all the information, moreover, I will send you the layout of the article again!

For now, we need to reach consensus on the text and the meaning of some sentences in the manuscript.

Best wishes,
Anna

> Вторник, 14 сентября 2021, 17:56 +03:00 от Nurdin Kyai Baderan <no-reply@subs.elpub.science>:
>
> Regards Dr. Anna
>
> After I checked the metadata, my name (Nurdin) as the main author and the correspondent writer did not appear? is there an error or how?? please confirm before publish.
>
> Regards
> Lead Author/Corresponding Author
> Nurdin
>
> ---
>
> journal
>
> Bulletin of V.V. Dokuchaev Soil Science Institute

This email was sent to burmistrovaann13@mail.ru unsubscribe from this list

--
С уважением,
А.Ю. Романовская

Nurdin <nurdin@ung.ac.id> 15 September 2021 pukul 00.21
Kepada: Анна Романовская <burmistrovaann13@mail.ru>

Thank you very much.

Pada tanggal Sel, 14 Sep 2021 pukul 23.46 Анна Романовская <burmistrovaann13@mail.ru> menulis:

> Mr. Nurdin, do not worry! Before the publication I will check all the information, moreover, I will send you the layout of the article again!
>
> For now, we need to reach consensus on the text and the meaning of some sentences in the manuscript.
>
> Best wishes,
> Anna
>
> > Вторник, 14 сентября 2021, 17:56 +03:00 от Nurdin Kyai Baderan <no-reply@subs.elpub.science>:
> >
> > Regards Dr. Anna
> >
> > After I checked the metadata, my name (Nurdin) as the main author and the correspondent writer did not appear? is there an error or how?? please confirm before publish.
> >
> > Regards
> > Lead Author/Corresponding Author
> > Nurdin
> >
> > ---
> >
> > journal
> >
> > Bulletin of V.V. Dokuchaev Soil Science Institute

--
С уважением,
А.Ю. Романовская

Nurdin <nurdin@ung.ac.id>

[Dokuchaev Soil Bulletin] Copyediting Review Acknowledgement

6 pesan

Анна Романовская <no-reply@subs.elpub.science> 17 September 2021 pukul 19.20
Balas Ke: Анна Романовская <burmistrovaann13@mail.ru>
Kepada: Nurdin Kyai Baderan <nurdin@ung.ac.id>

Mr. Nurdin,

Thank you for reviewing the copyediting of your manuscript, "Soils in the Bulia Micro Watershed of Gorontalo Province, Indonesia and Their Quality Assessment," for Dokuchaev Soil Bulletin.

However, I still have some question on the text.
First of all I am asking you to highlight your corrections, so that I could see them.

And the sentences on page 16 need to be grammatically corrected, for example:

1) According to the particle-size class the pedon refers to the fine loam and clayey class of 25 cm (> 7.5 cm) with a typical clay coating of the pore walls and the ped (aggregate) surface...

- what does it mean "class of 25 cm"? The upper layer of the pedon?

2) "In addition, clay was added at 19% (> 1.2%) of the eluvial horizon and had 7.5YR hue with a chroma of ≤ 4, with BS of >75%."

- what does it mean? in which horizon? or in the whole pedon?

etc.

Please paraphrase the description of pedons on page 16.

Regards,
Anna,
editor Dokuchaev Soil Bulletin,
https://bulletin.esoil.ru/jour
https://elibrary.ru/title_about.asp?id=28636

---

journal

Bulletin of V.V. Dokuchaev Soil Science Institute

Nurdin <nurdin@ung.ac.id> 17 September 2021 pukul 22.51
Kepada: Анна Романовская <burmistrovaann13@mail.ru>

Regards Dr. Anna

I have tried to improve the meaning and phrases in our writing. After I fixed it, I had trouble re-uploading the revision through the application (editing). Therefore, please allow me to send a revised revision of our article via this email. (Repair article attached)

Regards
Nurdin
[Kutipan teks disembunyikan]

665-1956-2-CE-Rev - 2.docx
10924K

Анна Романовская <burmistrovaann13@mail.ru> 26 September 2021 pukul 21.13
Balas Ke: Анна Романовская <burmistrovaann13@mail.ru>
Kepada: Nurdin <nurdin@ung.ac.id>

Dear Mr. Nurdin, good evening!

Your paper was accepted for publication by the Editorial Board, however, the members of the Editorial Board recommend the authors to improve in some way the Abstract (see the comments in the file enclosed) so that it would be more informative. And in the Keywords we added «soils of Indonesia».

My corrections are highlighted by the yellow color; and the red color shows the problematic sentences which need your comments or paraphrasing. Also I made some comments.

Please highlight Your corrections in this document by the other color or in the Revision regime, I need to see them, because I am going to copy them in the working file which I prepare to publication.

And finally, could you please check the metadata using the personal account. You were right and something went wrong with the system, and I had to refill the form with the information about the authors. Please take a look at this information, ORCID etc., and I beg your pardon, but please pay attention to the first name, middle name and the last name, I am a little bit confused about it.

Regards,
Anna

> Пятница, 17 сентября 2021, 18:52 +03:00 от Nurdin <nurdin@ung.ac.id>:
> [Kutipan teks disembunyikan]

--
С уважением,

А.Ю. Романовская

К этому письму приложены ссылки на следующие файлы:

1. Nurdin_edited_4.docx (10.8 Мб)

Ссылка для скачивания файлов: https://cloud.mail.ru/stock/dw3nFVYEqZK26VWpA8f8Yu9s

Файлы будут храниться до 25.03.2022

Nurdin <nurdin@ung.ac.id> 26 September 2021 pukul 23.21
Kepada: Анна Романовская <burmistrovaann13@mail.ru>

Regards Dr Anna

I hereby send the final revised manuscript from our author.
I hope it's well received

regards
Nurdin
[Kutipan teks disembunyikan]

Nurdin_edited_4-Rev.docx
8284K

Анна Романовская <burmistrovaann13@mail.ru> 13 Oktober 2021 pukul 04.26
Balas Ke: Анна Романовская <burmistrovaann13@mail.ru>
Kepada: Nurdin <nurdin@ung.ac.id>

Dear Mr. Nurdin,
the paper is ready for publication, the layout is enclosed. So, please, have a look at the final version of the article. I have one more question about citations:

1. page 106 — Niranjana et al., 2011 — I could not find it in the list of References
2. page 116 — Rachim, 1994 — I could not find it in the list of References
3. pages 129-130 Rachim, 2007 — I could not find it in the list of References

We can do the following

1. either delete them from the body of the article (from the pages listed above)
2. or I can add them to the list of References, in this case please send me in the letter the full bibliography for these three sources.

Also I would like to ask you to check the affiliations and information about the authors.

Best wishes,
Anna

> Пятница, 17 сентября 2021, 18:52 +03:00 от Nurdin <nurdin@ung.ac.id>:
>
> [Kutipan teks disembunyikan]

[Kutipan teks disembunyikan]

104-135_Nurdin.pdf
1101K

Nurdin <nurdin@ung.ac.id> 13 Oktober 2021 pukul 18.08
Kepada: Анна Романовская <burmistrovaann13@mail.ru>

Dear Dr Anna

On behalf of the writing team, I would like to thank you for the final improvement before publishing our article. Herewith I send 3 bibliography in question (attached), namely:

a. Niranjana K.V., Ramamurthy.V., Hegde R., Srinivas S., Koyal A., Naidu L.G.K., Sarkar D., Characterization, classification and suitability evaluation of banana growing soils of Pulivendla region. Andhra Pradesh. Journal of the Indian Society of Soil Science, 2011, Vol. 59(1), pp. 1-5. URL: https://www.indianjournals.com/ijor.aspx?target=ijor:jisss&volume=59&issue=1&article=001

b. Rachim D.A., Characterization of soils with low activity clay, and the effect of iron oxides on some soil properties. PhD Dissertation Bogor Agricultural University, 1994. URL: https://repository.ipb.ac.id/handle/123456789/2463?show=full

c. Rachim D.A., The foundations of soil genesis. Bogor: Department of Soil and Land Resources, Agriculture Faculty of Bogor Agriculture University, 2007, 41p.

In particular, my name as the first author and correspondent writer must use the name "**Nurdin**" only because it is the official name in the state civil registration, so Nurdin B.K or B.K Nurdin is replaced with "**Nurdin**" only. In addition, since 2021, the Department of Agrotechnology and Agribusiness of Gorontalo State University has moved to **Prof. Dr. Ing. B. J. Habibie Str., Moutong Village, 96554 Bone Bolango, Indonesia**. Therefore, please change the affiliation addresses of the two departments.

Once again, thank you

Regards,
Nurdin
[Kutipan teks disembunyikan]

References Article.docx
19K

UDC 631.4

DOI: 10.19047/0136-1694-2021-108-104-136

Cite this article as:
Nurdin, Rayes M.L., Soemarno, Sudarto, Listyarini E., Agustina C., Rahman R., Rauf A., Husain J., Soils in the Bulia micro watershed of Gorontalo province, Indonesia, and their quality assessment, Dokuchaev Soil Bulletin, 2021, V. 108, pp. 104-136, DOI: 10.19047/0136-1694-2021-108-104-136
Acknowledgments:
We would like to pay our regards to the Faculty of Agriculture, Brawijaya University who has funded this research with a non-tax state revenue grant in accordance with the Budget Implementation List Number: DIPA-042.01.2.400919/2019.

Soils in the Bulia micro watershed of Gorontalo province, Indonesia, and their quality assessment

© 2021 Nurdin[1*], M. L. Rayes[2], Soemarno[2], Sudarto[2], E. Listyarini[2], C. Agustina[2], R. Rahman[1], A. Rauf[3], J. Husain[4]

[1]*Department of Agrotechnology, Gorontalo State University, Prof. Dr. Ing. B. J. Habibie Str., Moutong Village, 96554 Bone Bolango, Indonesia,*
[*]*https://orcid.org/0000-0001-5725-5694, e-mail: nurdin@ung.ac.id.*

[2]*Department of Soil Science, Brawijaya University, No. 54 Veteran Str., Lowokwaru, 65145 Malang, Indonesia.*

[3]*Department of Agribussiness, Gorontalo State University, Prof. Dr. Ing. B. J. Habibie Str., Moutong Village, 96554 Bone Bolango, Indonesia.*

[4]*Department of Soil Science, Sam Ratulangi University, No. 1 Kleak Bahu Str., Kleak, 95115 Manado, Indonesia.*

Received 12.07.2021, *Revised* 24.08.2021, *Accepted* 20.09.2021

Abstract: Ten representative pedons from the Bulia micro watershed of Gorontalo Province, Indonesia, were characterized and classified to determine its land quality (LQ) class. Angular blocky, sticky, plastic consistencies and a hard consistency prevailed in the soil structure. In the alluvial plains the soil texture is dominated by the clay fraction, while in the hills and volcanic mountains the sand fraction is dominated. The soils in the Bulia micro watershed also have acid to neutral reaction, with the range of very low to high OC (organic carbon) levels, the reserve of exchangeable bases was dominated by Ca^{2+} in two series patterns, namely: $Ca^{2+} > Mg^{+} > Na^{+} > K^{+}$ and Ca^{2+} > Na+ > $Mg^{+} > K^{+}$, cation exchange capacity (CEC) ranged from low to very high, and the base saturation varied from moderate to very high. The alluvial plain is represented by Inceptisol in P1 and Typic Humustepts (P7), also by Oxic Humustepts (P3), then Mollisol on P4 (Typic Argiudolls) and Typic Haplustolls (P6), Alfisol on P5 (Typic Paleustalfs). Entisol on P2 (Typic Ustipsamments) was found in volcanic mountains and P9 (Typic Paleustolls) P8 (Ultic Paleustalfs), P10 (Inceptic Haplustalfs) are typical of volcanic hills. On the alluvial plains the land was categorized as the LQ class II, III and IV, the volcanic mountains were the LQ class IV, while the land on the volcanic hills was categorized as the LQ class VI. River bank erosion on the land river terraces can be held by the manufacture of gabions, talud, cliff reinforcement plants and terraces. The soil temperatures and high clay content can be regulated by mulching and organic materials.

Keywords: Characterization, classification, soils of Indonesia, land quality, the Bulia watershed.

INTRODUCTION

Land is a crucial component of land resources which enables plants growth and food production. Land and plant productivity is primarily determined by soil and other land characteristics related to land quality (Subardja, Sudarsono, 2005). However, an intense tillage during agricultural cultivation and a pressure of the land use when its conservation and sustainability are ignored has resulted into a decrease of land quality. Agricultural production tends to level or even decrease (Nurdin, 2012). Corn is a traditional commercial crop in the province of Gorontalo, Indonesia, which has been intensively and massively cultivated since it was established as a prime commodity in the agropolitan program in 2001. Until 2019, hybrid corn yields in Gorontalo Province reached 1.7 million tons or increased by 9.3% compared to 2018, however, the productivity of maize was still low at only 5.0 tons/ha (BPS Gorontalo Province, 2020). In fact, the potential corn yield in Indonesia can reach 10-11 tons/ha (Yasin et al., 2015), while the achievement of the national productivity in 2018 was only 5.2 tons/ha (Indonesian Ministry of Agriculture, 2019).

The Bulia micro watershed area is a corn production centre that also supports the agricultural area below. The watershed has a vital role because it supplies irrigation water for agriculture and other activities (Mahapatra et al., 2019). The corn cultivation in this watershed has exceeded the carrying capacity indicated for the corn planting on the slope of >25%, so that the land degradation often occurs. Soil erosion, according to the corn agropolitan program of Gorontalo, reached 1,396 tons/ha/year (Husain et al., 2004). Meanwhile, the corn productivity in this area is only 5.0 tons/ha (BPS Gorontalo Regency, 2020), which could happen due to the fact that the crop was cultivated on a non-suitable land.

Soil characterization is essential because it provides some necessary information about the soil characteristics for growing plants (Devi et al., 2015). For sustainable management of soil resources in agroecological areas we need timely monitoring of significant physical, chemical and biological soil characteristics and responses to the changes in land management (Supriya et al., 2019). These soil characteristics then form the basis for land classification. Combining soil characterization with classification is a powerful tool to develop management strategies for food security and environmental sustainability (Satish et al., 2018). However, the efforts to link land characteristics and classification with a specific land quality are still relatively rare. Land quality is a land ability to perform a specific function before the land is degraded (Beinroth et al., 2001). Understanding soil types and their distribution, its limits and potential is essential for a proper management to increase productivity and yields (Niranjana et al., 2011).

The survey and mapping of soil resources in the Paguyaman watershed were carried out by the Soil and Agro-climate Research Centre of the Indonesian Ministry of Agriculture (Puslittanak Research Team, 1995), however, the mapping scale was 1 : 50,000. In 2010, some research was carried out on the development, classification and potential of the paddy soils on toposequence (Nurdin, 2010), however, it only focused on the rainfed paddy soils, while the dry land was only compared to the locations close to the soil pedon in the rice fields. Considering the high intensity of the land management and the massive corn cultivation in this sub-watershed, this research has become significant.

MATERIALS AND METHODS

Study location

The Bulia micro watershed is a part of the Paguyaman watershed located in the northern part, it covers Mootilango and Boliyohuto District of Gorontalo Regency of Gorontalo Province, Indonesia (Figure 1). Geographically, the research location is between 0°39′123″ and 0°51′321″ N, 122°35′21″ and 122°43′12″ S (Table 1), which is 67 km from Gorontalo City, Indonesia.

Table 1. Site characteristics of the pedons in the Bulia micro watershed

Pedon/ Villages	Location	Elevation (m msl)	Landform	Slope (%)	Drainage
P1, Tolite	0°39′44.80″ N 122°35′27.20″ S	24	Alluvial plain	0–3	Poorly drained
P2, Monggolito	0°40′01.20″ N 122°37′57.20″ S	159	Volcanic mountain	15–30	Well drained
P3, Huyula	0°42′59.9″ N 122°39′43.2″ S	63	Alluvial plain	0–3	Moderately drained
P4, Payu	0°44′04.4″ N 122°37′48.4″ S	53	Alluvial plain	0–3	Moderately drained
P5, Pilomonu	0°43′53.80″ N 122°35′22.60″ S	75	Alluvial plain	0–3	Moderately drained
P6, Karyamukti	0°42′20.50″ N 122°41′05.50″ S	109	Alluvial plain	3–8	Moderately drained
P7, Karyamukti	0°42′10.30″ N 122°41′19.40″ S	114	Alluvial plain	3–8	Moderately drained
P8, Sukamaju	0°44′05″ N 122°40′04″ S	253	Volcanic hill	8–15	Well drained
P9, Payu	0°45′12″ N 122°38′08″ S	285	Volcanic hill	8–15	Well drained
P10, Huyula	0°43′11.10″ N 122°40′31.20″ S	262	Volcanic hill	8–15	Well drained

Overall, the Bulia micro watershed has 21,456.58 ha and consists of upland amounted to 18,993.44 ha (32.59%), and paddy fields amounted to 2,991.15 ha (13.94%). Specifically, the upland agriculture covers the agricultural land areas amounted to 6,993.44 ha (37.87%), settlement areas – 461.59 ha (2.50%), and forest areas amounted to 11,010.40 ha (59.63%). The soils in this area are generally developed from volcanic material in the upper watershed and lacustrine deposits in the middle and the bottom of the watershed. The study area is located in tropical climate with rainy and dry seasons. The average annual rainfall was only 1,478 mm with 1 wet month only and 4 dry months, so it belongs to the E2 agro-climate zone (Oldeman, Darmiyati, 1977). The average annual air temperature reaches 28.19 °C with the maximum temperature of 28.73 °C and the minimum temperature of 27.63°C. Under these conditions, the soil moisture regime is determined ustic and the soil temperature regime – isohyperthermic (Soil Survey Staff, 2014).

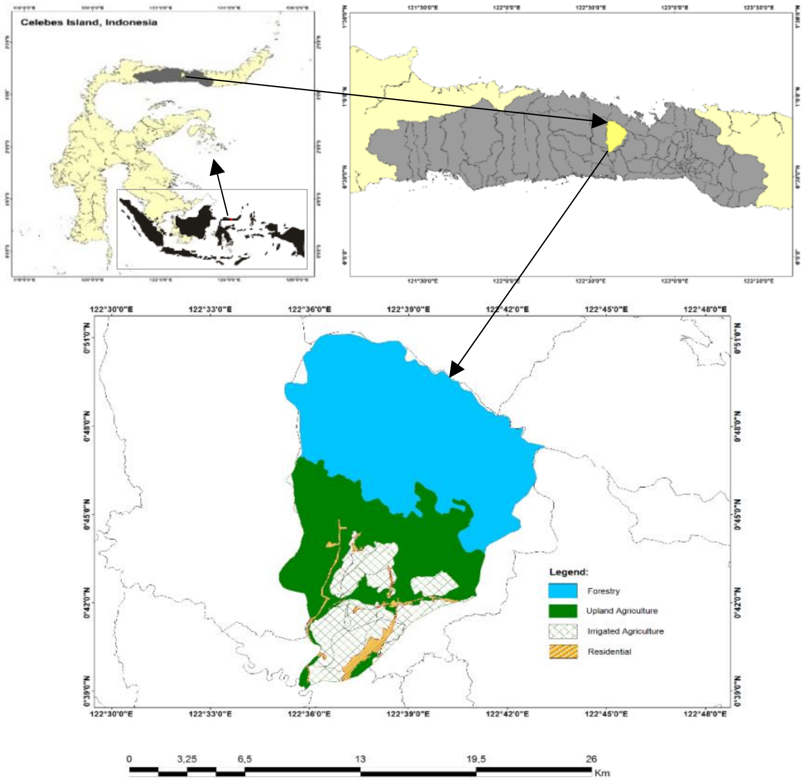


Fig 1. Location Map of the Bulia Micro watershed.

Soil surveying, characterization and classification

Ten representative pedons were selected to conduct the soil survey. The description of soil morphology refers to the Soil Survey Manual (Soil Science Manual, 2017; Sukarman et al., 2017). According to standard procedures, soil samples were taken at each horizon and their physical and chemical properties were analyzed (Jackson, 1973; Eviyati, Sulaeman, 2009). The morphological and the soil properties data obtained during the laboratory analysis are used for the soil characterization together with the climate and the terrain conditions data, according to Sukarman et al. (2017). The soil characteristics are used for soil classification according to the keys to soil taxonomy (Soil Survey Staff, 2014).

Land quality assessment

Land quality (LQ) class assessment follows the method according to Beinroth et al. (2001). This method has been modified based on availability of soil characteristics and classification data without including local population data. Soil pedons (P), which were classified in taxa according to the Soil Taxonomy System (Soil Survey Staff, 2014), were combined with a land unit (LU) basing on the similarity of the criteria in taxa. Soil and pedoclimate information was used to place each LU into I to IX land quality classes with class I having the most appropriate attributes and class IX having the least suitable ones for crop production. The results of the land quality analysis are widely presented and described with the help of Arc GIS.

RESULTS AND DISCUSSION

Morphology and soil physical properties

The results of field studies and the laboratory characterization of ten soil pedons were presented in Table 2, Figure 2. The soils in the study area have been developed as indicated by the horizon structuring (horizons A and B), with the depth of the soil solum varying from shallow to very deep. The soil colour is only of 7.5YR and 10YR hue, where 7.5YR is dominant. P1, P2, P3, P5, P8, P9 and P10 soil colour varies from dark brown, brown to strong brown with hue 7.5YR, ranging from 3 to 5, and chroma – from 1 to 6.

Table 2. Morphological characteristics and soil physical properties in the Bulia micro watershed

Pedon and Horizon	Depth (cm)	Colour Moisture	Struc-tures	Consistence			Sand	Silt	Clay	Texture Class
				w	m	D	%			
P1 (Alluvial Plain)										
Ap	0–23	7.5 YR 4/4	m, 3, abk	s, p	fi	H	9	40	51	Silty Clay
Bw1	23–43	7.5 YR 4/2	m, 3, abk	ss, sp	fi	H	3	46	51	Silty Clay
Bw2	43–75	7.5 YR 4/4	m, 3, abk	ss, sp	fi	H	3	54	43	Silty Clay
Bw3	75–100	7.5 YR 4/2	m, 1, abk	ss, sp	vfi	Vh	3	46	51	Silty Clay
P2 (Volcanic Mountains)										
Ap	0–5	7.5 YR 4/4	f, 1, cr	so, po	fr	L	85	10	5	Loamy sand
Bw1	5–37	7.5 YR 4/4	f, 2, sbk	so, po	fr	L	84	2	14	Loamy sand
Bw2	37–61	7.5 YR 4/4	m, 2, p	so, po	fr	L	75	10	15	Sandy Loam
C	61+	7.5 YR 4/2	m, 3, p	so, po	fr	L	66	15	19	Sandy Loam
P3 (Alluvial Plain)										
Ap	0–14	7.5 YR 3/3	f, 1, cr	ss, sp	fi	H	33	41	26	Loam
Bw1	14–43	7.5 YR 4/4	f, 2, abk	s, p	fi	H	31	37	32	Clay Loam
Bw2	43–68	7.5 YR 4/4	f, 1, abk	ss, sp	fi	H	23	54	23	Silty Loam
Bw3	68+	10 YR 3/6	f, 1, cr	s, p	fi	H	23	48	29	Clay Loam

Pedon and Horizon	Depth (cm)	Colour Moisture	Struc-tures	Consistence			Sand	Silt	Clay	Texture Class
				w	m	D				
P4 (Alluvial Plain)										
Ap	0–14	10 YR 3/3	m, 3, abk	s, p	fi	H	27	26	47	Clay
Bw	14–50	10 YR 4/3	f, 1, abk	s, p	fi	H	32	34	34	Clay Loam
Bt1	50–81	10 YR 3/2	f, 1, abk	ss, sp	fi	H	12	24	64	Clay
Bt2	81+	7.5 YR 4/1	f, 1, abk	s, p	fi	H	16	25	59	Clay
P5 (Alluvial Plain)										
Ap	0–21	7.5 YR 4/4	f, 2, sbk	ss, sp	fi	H	23	43	34	Clay Loam
Bw	21–46	7.5 YR 4/4	f, 2, sbk	ss, sp	fi	H	23	48	29	Clay Loam
Bt1	46–84	7.5 YR 4/3	f, 2, abk	s, p	fi	H	25	35	40	Clay
Bt2	84–117	7.5 YR 4/6	m, 2, p	s, p	fi	H	24	36	40	Clay
Btg	117+	7.5 YR 5/8	m, 1, sbk	ss, sp	fi	H	8	46	46	Silty Clay
P6 (Alluvial Plain)										
Ap	0–12	10 YR 3/3	f, 1, abk	s, p	fi	H	84	15	1	Loamy Sand
Bw1	12–34	10 YR 3/4	f, 1, abk	s, p	fi	H	61	10	29	Sandy Clay Loam
Bw2	34–71	10 YR 4/6	m, 3, abk	ss, sp	fi	H	61	24	15	Sandy Loam
C	71–90	7.5 YR 5/8	f, 1, cr	so, po	fr	L	84	5	11	Loamy Sand

Pedon and Horizon	Depth (cm)	Colour Moisture	Struc-tures	Consistence			Sand	Silt	Clay	Texture Class
				w	m	D				
P7 (Alluvial Plain)										
Ap	0–6	7.5 YR 4/6	m, 1, abk	s, p	fi	H	33	11	56	Clay
Bw1	6–17	10 YR 4/6	m, 3, sbk	s, p	fi	H	29	20	51	Clay
Bw2	17–33	10 YR 3/6	m, 1, abk	ss, sp	fi	H	21	20	59	Clay
Bt	33–49	10 YR 3/6	f, 1, p	ss, sp	fi	H	19	15	66	Clay
BC	49+	7.5 YR 4/6	f, 1, abk	ss, sp	fi	H	18	29	53	Clay
P8 (Volcanic Hills)										
Ap	0–7	7.5 YR 3/3	f, 1, abk	ss, sp	fi	H	64	10	26	Sandy Clay Loam
Bw	7–24	7.5 YR 3/3	m, 1, abk	s, p	fi	H	47	24	29	Sandy Clay Loam
Bt1	24–44	7.5 YR 4/6	f, 3, p	s, p	fi	H	45	15	40	Sandy Clay
Bt2	44–63	7.5 YR 5/6	m, 3, abk	s, p	fi	H	42	16	42	Clay
Bt3	63+	7.5 YR 5/6	m, 1, abk	s, p	fi	H	42	6	52	Clay

Pedon and Horizon	Depth (cm)	Colour Moisture	Struc-tures	Consistence			Sand	Silt	Clay	Texture Class
				w	m	D				
P9 (Volcanic Hills)										
Ap	0–16	7.5 YR 3/2	m, 3, abk	vs, vp	vfi	Vh	54	31	15	Sandy Loam
Bw	16–34	7.5 YR 3/3	m, 1, abk	s, p	fi	H	42	24	34	Clay Loam
Bt	34+	7.5 YR 4/4	m, 1, abk	ss. sp	fi	H	50	15	35	Sandy Clay
P10 (Volcanic Hills)										
Ap	0–20	7.5 YR 3/3	m, 3, abk	ss, sp	fi	H	48	26	26	Sandy Clay Loam
Bt1	20–44	7.5 YR 3/4	m, 3, abk	s, p	fi	H	41	15	44	Clay
Bt2	44–76	7.5 YR 4/6	c, 3, sbk	s, p	fi	H	42	14	44	Clay
BC	76+	5 YR 4/6	c, 3, p	vs, vp	vfi	Vh	31	2	67	Clay

Note. Structure: *size*: vf – very fine, f – fine, m – medium, c – coarse; *structureless grade*: l – weak, 2 – moderate, 3 – strong; *type*: cr – crumb, sg – single grain, abk – angular blocky, sbk – sub-angular blocky. Consistence: *dry* (d): s – soft, l – loose, sh – slightly hard, h – hard, vh – very hard, eh – extremely hard; *moist* (m): l – loose, fr – friable, fi – firm, vfi – very firm, efi – extremely firm, *wet* (w): so – non-sticky, ss – slightly sticky, s – sticky, vs – very sticky; po – non-plastic, ps – slightly plastic, p – plastic, vp – very plastic.

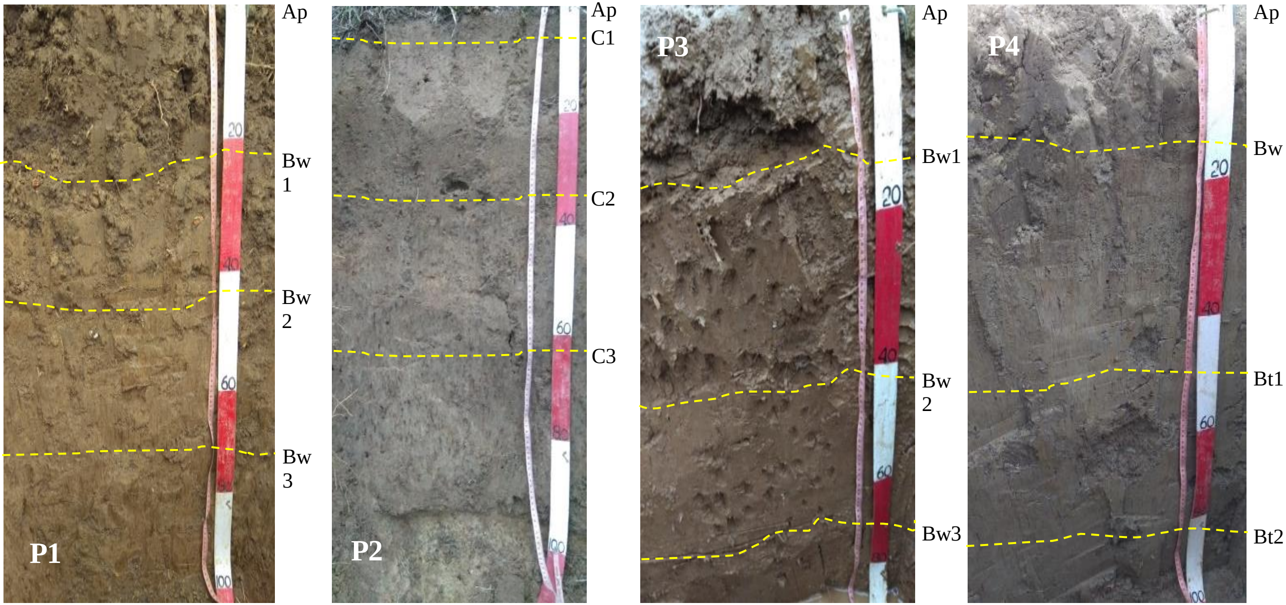


Fig. 2. Soil profile appearance of pedon 1 (P1), 2 (P2), 3 (P3) and pedon 4 (P4).

While in P4, P6 and P7, soil colour varies from very dark grayish brown, dark brown to dark yellowish-brown with hue 10YR, values ranging from 3 to 4, and chroma – from 2 to 6. The colour of soil horizon A is darker than of horizon B due to the fact that the organic matter content in horizon A is higher than in horizon B (Yatno et al., 2015). The higher the organic matter content, the darker the soil colour is (Suharta, 2007). Soil colour seems to be a function of chemical and mineralogical composition (Swarnam et al., 2004; Walia, Rao, 1997), and the soil texture is influenced by topographic position and humidity regimes (Walia, Rao, 1997).

The soil structure varies from crumbs, angular blocky, sub angular blocky to prismatic, with the dominant angular blocky. P1, P3, P4, P6, P7, P8, P9 and P10 were mostly of angular blocky structure with the sizes varying from fine, medium to coarse, with weak and strong structural development. While the soil structures of P2 and P5 varies between crumbs, angular blocky, sub angular blocky and prismatic with the sizes ranging from fine, medium to coarse and the level of the soil structure development varying from weak, moderate to strong. The angular blocky soil structures were strongly associated with higher clay fractions (Devi et al., 2015). Crumbly soil structure indicates newly developed soil (Manik et al., 2017). Intensive soil tillage results in soil structure disturbance (Jambak et al., 2017). The variation of soil structure will be consistently affecting the soil.

The soil consistency in wet conditions varies between non-sticky and non-plastic on Pedon 2, slightly sticky and slightly plastic, sticky and plastic in the horizon on P1, P3, P4, P5, P6, P7, P8, P9 and P10, very sticky and very plastic on the surface horizon (Ap) of P9 and the subsurface horizon (BC) of P10, however, slightly sticky and slightly plastic consistencies prevail. While in moist conditions the consistencies vary from loose, firm to very firm, the firm consistencies are still dominant. P1, P3, P4, P5, P6, P7, P8, P9 and P10 were dominated by hard consistencies, while P2 – by loose ones. There is a very hard consistency in P1 and P10 in the subsurface horizon (Bw and BC), while in the surface horizon (Ap) a very hard consistency can be only found in P9. The consistency in dry conditions varies from loose, hard to very hard, with a dominant hard consistency. P1, P3, P4, P5, P6, P7, P8, P9 and P10 were dominated by a hard consistency, however, in P1 and

P10 in the subsurface horizon (Bw3 and BC) one could notice a very hard consistency, while in P9 precisely a very hard consistency was found on the surface horizon (Ap). Sticky and plastic consistency might form due to a high clay content in the soil (Sarkar et al., 2001); (Kadao et al., 2003), while non-sticky and non-plastic consistency might form due to a very little clay content (Sireesha, Naidu, 2015; Devi et al., 2015).

The soil texture of all pedons varies greatly between sandy clay loam, sandy loam, loamy sand, sandy loam, silty loam, clay loam, silty clay and clay, except for P7 that was of clay texture in all horizons. Wide variations of soil texture may be caused by the variations in parent material, topography, in-situ weathering, translocation of clays by eluviation and soil age (Satish et al., 2018). Apparently, the pedons located in the alluvial group were more dominated by clay fractions, although the distribution patterns were irregular. The distribution of irregular clay fractions was typical for sediment materials (Nurdin, 2010). While a sand fraction dominated the volcanic group, the distribution of sand and clay fractions shows the opposite pattern. A decrease in the sand fraction is due to the clay illuviation and in-situ mineral destruction process, which was characterized by a decline in the absolute amount of sand in the middle of the solum (Rachim, 1994). The texture that is found in the subsurface horizon is caused by higher weathering in the subsurface layer (Dutta, 2009). The clay content in the solum middles (B-illuviation) was higher than in the upper horizon (A-eluviation) and in the lower layer horizon. This indicates the occurrence of a lessivage process with some clay skins seen, so that an argillic horizon was formed in P4, P5, P8, P9 and P10. Although the process of eluviation and illuviation occurred, the pedon remained, but the clay skins were not found, so the cambic and candic horizons were formed.

Soil chemical properties

Soil chemical properties are presented in Table 3. Soil pH varies from acid (pH 5.3) to neutral (pH 7.2). The pedons located on the upper watershed or in volcanic groups (P2, P8, P9 and P10) have a lower pH than the ones located on the lower watershed or in alluvial groups (P1, P3, P4, P5, P6, and P7).

Table 3. Soil chemical properties in the Bulia micro watershed

Pedon and Horizon	Depth (cm)	pH 1:1		OC (%)	Exchangeable cations				CEC	BS (%)
		H_2O	KCl 1N		K	Na	Ca	Mg		
					[cmol(+)kg^{-1}]					
P1 (Alluvial Plains)										
Ap	0–23	6.20	5.40	2.29	0.29	1.88	18.02	1.86	42.40	52.00
Bw1	23–43	6.00	5.20	0.90	0.18	2.01	15.47	2.97	39.19	52.62
Bw2	43–75	6.40	5.50	0.74	0.14	2.19	12.36	2.50	37.85	45.42
Bw3	75–100	6.50	5.60	0.65	0.14	2.23	15.22	3.26	37.58	55.49
P2 (Volcanic Mountains)										
Ap	0–5	6.50	5.60	1.19	0.10	0.34	3.77	0.30	11.13	40.55
Bw1	5–37	6.10	5.20	0.55	0.08	0.34	4.20	0.60	7.75	67.49
Bw2	37–61	6.20	5.30	0.63	0.08	0.35	3.91	0.15	8.87	50.52
C	61+	6.20	5.30	0.56	0.08	0.36	6.51	0.76	12.29	62.79
P3 (Alluvial Plain)										
Ap	0–14	5.60	4.60	0.80	0.05	1.46	4.84	0.61	16.15	43.00
Bw1	14–43	6.00	5.10	0.41	0.09	1.57	7.72	1.70	19.78	56.00
Bw2	43–68	5.80	4.90	0.32	0.05	1.55	8.95	0.91	21.58	53.00
Bw3	> 68	6.20	5.20	0.48	0.05	1.55	10.12	0.76	20.43	61.00
P4 (Alluvial Plains)										
Ap	0–14	6.50	6.10	0.41	0.06	1.49	11.87	0.62	25.55	55.00
Bw	14–50	6.70	6.30	0.96	0.19	1.43	9.71	2.12	21.60	62.00
Bt1	50–81	7.00	6.00	0.41	0.12	1.58	16.54	2.01	35.19	58.00
Bt2	81+	5.80	5.00	0.24	0.09	1.56	13.47	6.66	33.04	66.00

Pedon and Horizon	Depth (cm)	pH 1:1		OC (%)	Exchangeable cations				CEC	BS (%)
		H_2O	KCl 1N		K	Na	Ca	Mg		
					[cmol(+)kg^{-1}]					
P5 (Alluvial Plains)										
Ap	0–21	5.20	4.50	0.08	0.16	2.29	9.39	2.93	28.39	52.00
Bw	21–46	5.10	4.30	0.49	0.20	2.30	8.62	3.08	28.40	50.00
Bt1	46–84	5.70	4.90	0.57	0.12	0.26	7.69	2.00	21.56	47.00
Bt2	84–117	5.10	4.20	0.50	0.17	0.30	10.38	2.05	31.34	41.00
Btg	117+	5.10	4.10	0.42	0.25	0.34	15.37	1.90	38.58	46.00
P6 (Alluvial Plains)										
Ap	0–12	7.20	6.60	0.64	3.56	3.02	2.54	0.91	10.76	93.00
Bw1	12–34	7.10	6.60	0.32	0.28	1.72	6.03	0.30	11.79	71.00
Bw2	34–71	7.00	6.00	0.56	0.16	0.39	7.84	0.15	17.16	50.00
C	71–90	6.80	6.00	0.40	0.12	0.38	6.49	0.15	13.96	51.00
P7 (Alluvial Plains)										
Ap	0–6	6.30	5.40	0.76	0.10	0.42	5.31	2.41	18.31	45.00
Bw1	6–17	6.10	5.10	0.57	0.09	0.39	6.77	2.15	22.99	41.00
Bw2	17–33	5.90	5.00	0.57	0.07	0.44	8.55	4.04	25.45	51.00
Bt	33–49	5.60	4.80	0.33	0.08	0.45	13.64	3.72	29.79	60.00
BC	49+	5.90	5.00	0.41	0.12	2.04	13.16	0.31	33.06	47.00

Pedon and Horizon	**Depth (cm)**	**pH 1:1**		**OC (%)**	**Exchangeable cations**				**CEC**	**BS (%)**
		H_2O	**KCl 1N**		**K**	**Na**	**Ca**	**Mg**		
					[cmol(+)kg^{-1}]					
P8 (Volcanic Hills)										
Ap	0–7	6.00	5.20	0.96	0.24	2.09	10.15	0.45	19.40	67.00
Bw	7–24	6.40	5.50	0.80	0.17	2.05	10.30	0.61	21.55	61.00
Bt1	24–44	6.70	5.80	0.48	0.24	2.21	10.07	1.83	26.06	55.00
Bt2	44–63	6.60	5.60	0.49	0.33	2.21	9.47	0.78	26.52	48.00
Bt3	63+	6.60	5.60	0.50	0.49	2.35	13.84	1.27	32.83	55.00
P9 (Volcanic Hills)										
Ap	0–16	5.30	4.50	0.80	0.13	2.15	10.15	0.61	24.80	53.00
Bw	16–34	6.20	5.30	0.57	0.10	2.30	12.44	0.77	29.51	53.00
Bt	34+	6.20	5.20	0.48	0.06	2.25	13.49	0.46	30.54	53.00
P10 (Volcanic Hills)										
Ap	0–20	5.80	4.90	0.72	0.12	0.40	5.90	1.21	18.31	41.69
Bt1	20–44	6.10	5.20	0.64	0.05	0.40	8.23	0.46	18.44	49.59
Bt2	44–76	6.30	5.30	0.48	0.05	0.39	7.26	0.76	19.36	43.66
BC	76+	5.80	5.30	0.33	0.06	0.42	11.28	2.04	25.64	53.82

Note. CEC – cation exchange capacity, OC – organic carbon, BS – base saturation.

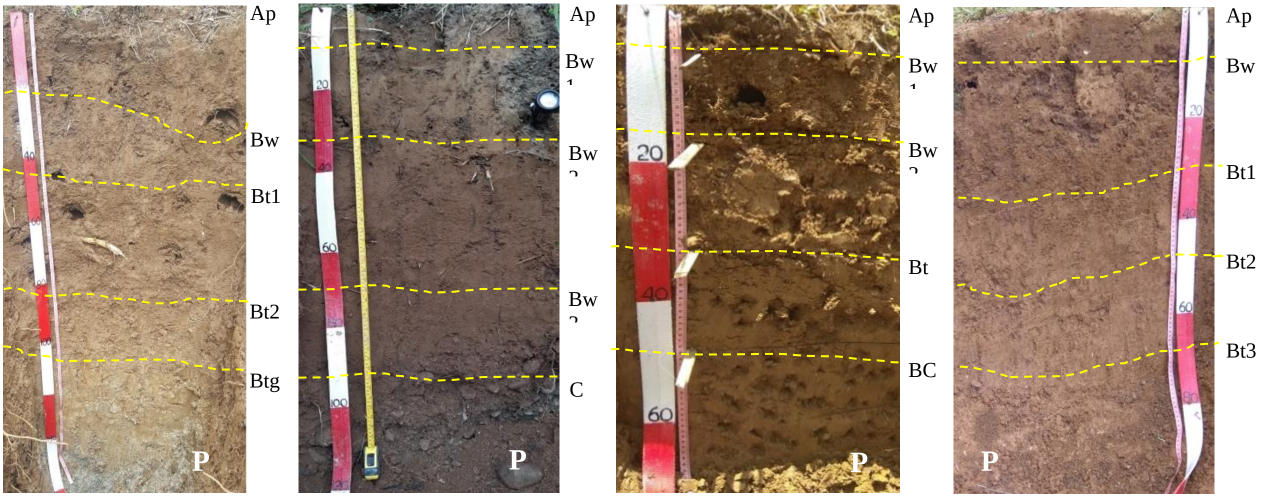


Fig. 3. Soil profile appearance of pedon 5 (P5), 6 (P6), 7 (P7) and pedon 8 (P8).

The pedon in the alluvial group represented a depressed area which is the accumulation of the bases carried by washing water from the hinterland section and the accumulation of more alkaline bases in soils with poorer drainage (Nurdin, 2010a). The pedons in the volcanic group experienced more intensive washing during the rain due to a better soil drainage. The trend of pH increasing with more depth may be explained by the release of organic acids during the decomposition of organic matter, these acids may have lowered the pH at the soil surface (Satish et al., 2018). The pH differences of KCl and the pH of H_2O of all pedons show negative values. This means that all pedons are dominated by negatively charged clay minerals (Suharta, 2007). The acid and slightly acid soil pH values in P1, P3, P5, P9 and P10 indicated that the soil had developed but the level of soil development was not yet advanced, while the neutral soil pH in P2, P4, P6, P7, and P8 shows that the soil is relatively new.

Organic carbon (OC) varies from very low to high (0.08–2.28%). The OC value was high in the surface horizon (Ap), except for P4 and P5. The OC value on the surface is higher due to the accumulation of organic materials, while its low values in P4 and P5 were due to the river flooding. The low OC value was also determined by a faster degradation of the organic material in the tropics and a low addition of farmyard manure (Vedadri, Naidu, 2018). A high OC distribution pattern on the surface and its dramatic decrease in horizon B in accordance with the depth is a general soil development pattern (Prasetyo, 2007).

The reserve (sum) of exchangeable bases vary between very low, low, medium, high and very high. Calcium cation is the dominating one in the exchangeable bases reserve, which ranges from 2.54–18.02 cmol(+)kg^{-1}, while magnesium (Mg^+) ranges from 0.15-6.66 cmol(+)kg^{-1}, sodium (Na^+) ranges from 0.26–3.02 cmol(+)kg^{-1}, potassium (K^+) ranges from 0.05–3.56 cmol(+)kg^{-1}. Based on a number of bases, the P1, P5, P7, and P10 patterns follow the sequence: $Ca^{2+} > Mg^+ > Na^+ > K^+$. This series pattern was the same as Nurdin (2011) and Satish et al. (2018) reported. At the same time P2, P3, P4, P6, P8 and P9 follow the sequence: $Ca^{2+} > Na^+ > Mg^+ > K^+$. A high rate of exchangeable bases in the surface horizon (Ap) results from the fertilization during corn cultivation, while in the lower layer rainfall washing together with good drainage conditions make it possible to wash in the soil solum.

The cation exchange capacity (CEC) varies from low (7.7 cmol(+)kg^{-1}) to very high (42.40 cmol(+)kg^{-1}). The CEC is influenced by the levels of organic carbon and soil minerals (Prasetyo et al., 2007; Suharta, 2007). It seems that CEC in P1, P3, P4, P5, P7, P8, and P9 were more influenced by OC content than by soil minerals. The higher the soil OC, the higher the soil CEC is (Suharta, 2007). While P2, P6 and P10 were thought to be more influenced by soil minerals, these bases can be exchanged and this CEC will eventually affect base saturation. Base saturation (BS) varies from moderate (40.55%) to very high (93%). All pedons generally have a medium and a high BS, except P6, which has a very high BS on the surface horizon (Ap). The variations in BS may be caused by the variations in nature and/or the content of soil colloids, and a relatively high base saturation in the surface layers can be attributed to the recycling of cation base through vegetation (Devi, Kumar, 2010). In addition, if soil has a number of bases which are smaller than CEC, BS tends to be lower, whereas when the soil has a number of bases close to or higher than CEC, BS tends to be higher (Nurdin, 2010b).

Soil classification

Based on morphological and soil characteristics, the pedons are classified according to their family level and the orders of the soils found, namely Entisol, Inceptiol, Mollisol and Alfisol (Table 4, Figure 4). P1 and P7, which are located on a slope of 3% and 5%, are based on the molic epipedon with a 23 cm thickness and a cambic horizon. These pedons did not experience aquatic conditions at the depth of 50 cm from the soil surface (humustept), the soil colour had a value of 4 with a chroma of 2 or less and the soil structure was sub angular blocky. In addition, it had more clay content than the horizons below or above it. Based on these properties, P1 was classified as Typic Humustepts, fine, isohyperthermic.

P2, located on a slope of 15%, is represented by the ochric epipedon with a 5 cm thickness and a candic horizon. In this pedon there was an increase in the percentage of clay in the fine soil fraction with a depth of 15 cm or less in the vertical distance.

Table 4. Soil classification in the Bulia micro watershed

Pedon	Soil Classification					Area	
	Order	Sub Order	Great Group	Sub Group	Family	ha	%
P1	Inceptisol	Ustept	Humustepts	Typic Humustepts	Fine, isohypertermic, Typic Humustepts	596.88	8.53
P2	Entisol	Psamment	Ustipsamme nts	Typic Ustipsamments	Sandy, isohypertermic, Typic Ustipsamments	472.68	6.76
P3	Inceptisol	Ustept	Humustepts	Oxic Humustepts	Fine loamy, isohypertermic, Oxic Humustepts	2,297.78	32.86
P4	Mollisol	Ustoll	Argiustolls	Typic Argiudolls	Fine, isohypertermic, Typic Argiustolls	107.35	1.54
P5	Alfisol	Ustalf	Paleustalfs	Typic Paleustalfs	Fine loamy, isohypertermic, Typic Paleustalfs	1,066.95	15.26
P6	Mollisol	Ustoll	Haplustolls	Typic Haplustolls	Coarse loamy, isohypertermic, Typic Haplustolls	1,026.23	14.67

Pedon	Soil Classification					Area	
	Order	**Sub Order**	**Great Group**	**Sub Group**	**Family**	**ha**	**%**
P7	Inceptisol	Ustept	Humustepts	Typic Humustepts	Fine, isohypertermic, Typic Humustepts	248.4	3.55
P8	Alfisol	Ustalf	Paleustalfs	Ultic Paleustalfs	Fine loamy, isohypertermic, Ultic Paleustalfs	61.87	0.88
P9	Mollisol	Ustoll	Paleustolls	Typic Paleustolls	Fine loamy, isohypertermic, Typic Paleustolls	48.35	0.69
P10	Alfisol	Ustalf	Haplustalfs	Inceptic Haplustalfs	Fine, isohypertermic, Inceptic Haplustalfs	1,066.95	15.26
Total						6,993.44	100.00

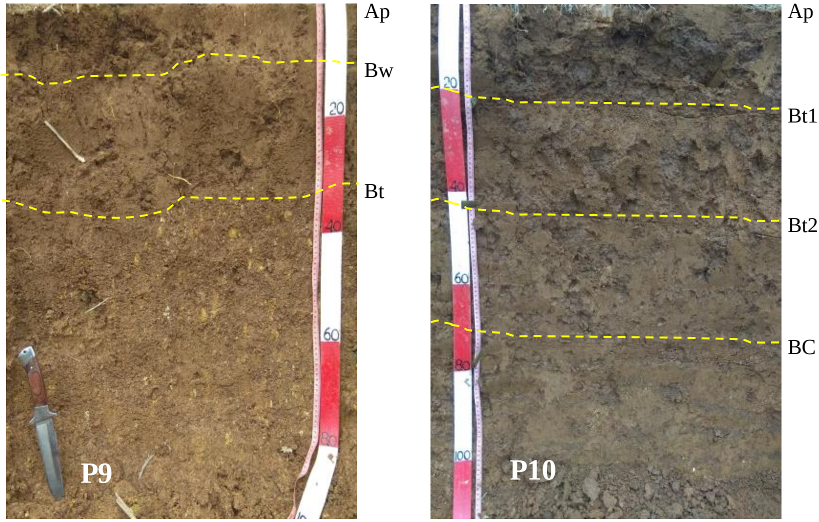


Fig. 4. Soil profile appearance of pedon 9 (P9), and pedon 10 (P10

The clay content was 4% or more (absolute value), which is more than that of the horizon above it, which has a total clay content in the soil fine fraction less than 20%. In addition, it had a loamy sand texture (psamments) and a CEC value (NH_4OAc, pH 7) > 16 cmol(p+)kg^{-1}. Based on these characteristics, P2 was classified as Typic Ustipsamments, sandy, isohyperthermic.

P3 is located on a slope of 1%, represented by the umbric epipedon with a 14 cm thickness and a cambic horizon. This pedon did not experience aquatic conditions at the depth of 50 cm from the soil surface (humustept), the soil colour had a value of 4 with a chroma of 2 or less and the soil structure is sub angular blocky. In addition, it had more clay content than the horizons below or above and its CEC (NH_4OAc 1N) value was 17.96 cmol(+)kg^{-1} only (oxic). Based on these properties, P3 was classified as Oxic Humustepts, fine loamy, isohyperthermic.

P4 is located on a slope of 15%, represented by the molic epipedon (BS 55%) with a 14 cm thickness and an argillic horizon. This pedon had a fine loamy class of particle size with a typical clay coating of the pore walls and the ped surface. In addition, there was 13% (> 8%) of clay on the eluvial horizon and 10YR hue with a chroma ≤ 3, and BS > 75%. Based on these properties, P4 was classified as Typic Argiustolls, fine loamy, isohyperthermic.

P5 is located on a slope of 3%, represented by the ochric epipedon with a 21 cm thickness and an argillic horizon. According to the particle-size classification, this pedon belongs to the fine loam and clay class with an argillic horizon thickness of 25 cm (> 7.5 cm), it also has a typical clay coating of the pore walls and the ped (aggregate) surface. In addition, the clay content in the argillic horizon is 64% or it contains 2.03 times more clay than the eluvial horizon, which was only 34%, and 7.5 YR was typical of all horizons (paleustalf). Based on these properties, P5 was classified as Typic Paleustalfs, fine loamy, isohyperthermic.

P6 is located on a slope of 3%, represented by the molic epipedon (BS 93%) with a 12 cm thickness and a cambic horizon. This pedon had a sandy clay texture and does not have the combination of aquic conditions within 50 cm of the soil surface or artificial drainage (ustoll). The colour value was with a chroma < 6 and it had a sub angular blocky soil structure. In addition, it had more clay content than the below horizons. Based on these properties, P6 was classified as Typic Haplustolls, coarse loamy, isohyperthermic.

P8 is located on a slope of 5%, represented by the molic epipedon with a 7 cm thickness and an argillic horizon. According to the particle-size classification, this pedon belongs to the fine loam and fine clay class with an argillic horizon thickness of 20 cm (> 7.5 cm), also it has a typical clay coating of the pore walls and the ped surface. In addition, the clay content in the argillic horizon is 69% or it contains 2.65 times more clay than the eluvial horizon, which was only 26%, and 7.5YR hue was typical in all horizons (paleustalf), with BS of 61% or > 75% only (ultic). Based on these properties, P8 was classified as Ultic Paleustalfs, fine loamy, isohyperthermic.

P9 is located on an 8% slope, represented by the molic epipedon (BS 53%) with a 7 cm thickness and an argillic horizon. According to the particle-size classification, this pedon belongs to the fine loam class with an argillic horizon thickness of 18 cm (> 7.5 cm), it also has a typical clay coating of the pore walls and the ped surface. In addition, the clay content in the argillic horizon is 69% or it contains 4.60 times more clay than the eluvial horizon, which was only 18%, and 7.5YR hue with a chroma of ≤ 4, and BS of < 75% of all horizons (paleustoll). Based on these properties, P9 was classified as Typic Paleustolls, fine loamy, isohyperthermic.

P10 is located on a slope of 15%, represented by the molic epipedon (BS 57%, 50%) with a 23 cm thickness and an argillic horizon. According to the particle-size classification, this pedon belongs to the fine loam and fine clay class with an argillic horizon thickness of 24 cm (> 7.5 cm), it also has a typical clay coating of the pore walls and the ped surface. In addition, the clay content in the argillic horizon is 88% or it contains 3.38 times more clay than the eluvial horizon, which was only 24%, and 10YR hue with a chroma of ≤ 3, and BS > 75%. Based on these properties, P10 was classified as Inceptic Haplustalfs, fine, isohyperthermic.

Land quality classes

The land quality (LQ) of the Bulia micro watershed was presented in Table 5 and Figure 5. The LQ of class II with the main factor determining the land stress was high temperature and low organic matter. The high temperature factor with an isohyperthermic soil temperature regime as an indicator was found on LU 3 (P3), while the low organic matter factor with an ochric epipedon indicator was only on LU 5 (P5). The LQ of class II is determined as good and this land has few problems for sustainable production, its productivity is generally very high and as a result, the response to management is high (Beinroth et al., 2001). Land management through the addition of organic matter, including green manure, may be adopted along with the recommended fertilizer doses (Sys et al., 1991; Singh et al., 2004; Mahaputra et al., 2019) and mulching to stabilize temperatures and maintain soil moisture (Odjugo, 2008; Eruola et al., 2012; Damaiyanti et al., 2013), which is of great importance. In addition, the use of rice straw mulch and sawdust mulch influences soil properties by decreasing the value of bulk density, increasing soil porosity and soil organic matter (Nasruddin, Hanum, 2015).

Table 5. Land quality classes in the Bulia micro watershed

Land Unit	Land Quality		Land Quality Class	Area	
	Major Land Stress Factor	Determinant of Land Stress		ha	%
3	High temperatures	Isohyperthermic of soil temperature regime	II	2,297.78	32.86
5	Low organic matter	Ochric epipedon	II	1,066.95	15.26
1, 6, 7	Seasonal water excess	Recent terraces	III	1,871.51	26.76
2	Low structural stability and/or crusting	Entisols	IV	472.68	6.76
4	Low structural stability and/or crusting	Clay soils	IV	107.35	1.54
8, 9, 10	Low water holding capacity	Sandy clay loam	VI	1177.17	16.83
Total				3,628.71	51.89

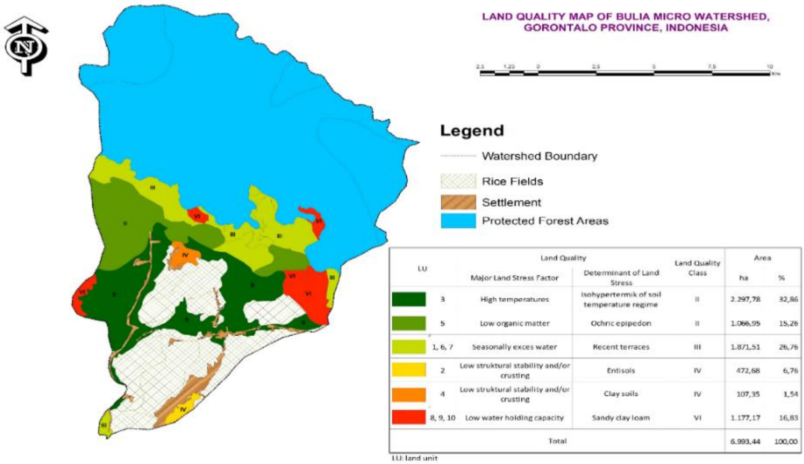


Fig. 5. Land quality map of the Bulia micro watershed.

The LQ of class III with the main factor determining the land stress was a seasonal excess of water. The indicators determining the land stress in class III were new terraces spread over LU 1 (P1), LU 6 (P6) and LU 7 (P7). These new terraces are generally located around the border or river meanders which were prone to erosion and river bank landslides. The LQ of land class III was still considered good and this land has few problems for sustainable production, but has the higher risk of low input of corn production specifically, which results in a response to high management (Beinroth et al., 2001). The land management through the manufacture of gabions and riverbanks (Rahman, 2013), planting river bank reinforcement plants and terraces (Suyana et al., 2017) was of great importance. Bioengineering methods for river bank erosion control commonly used include planting bamboo (Noor et al., 2011). Fine plant roots play a significant role in increasing the shear strength of the soil (Ludwig et al., 2007). The effectiveness of plants in reducing erosion rate is influenced by (1) the canopy or plant canopy, (2) the organic material produced, (3) the root system and the ability of plants to cover the soil (Rachman et al., 2004). Vetiver plants were useful for stabilizing river banks, irrigation canals, river erosion control and coastal embankments, excavation slopes and embankments on highways, sand dunes, erosion on sloped agricultural land (Noor et al., 2011). Vetiver grass, which has strong fibrous roots, holds the ground (Susilawati, Veronika, 2016). Soil nailing was one of the most economical techniques for slopes stabilization of retaining walls because the system works quickly and does not require large space (Sinarta, 2014; Noor et al., 2011).

The LQ of class IV with the main factors determining land stress was low structural stability and/or crusting. These main factors consist of two indicators, namely clay soil and Entisol. The indicator of heavy clay (> 50%) was scattered in LU 4 (P4). This indicator of clay soil was related to soil crusting which was shown by the average sub angular blocky soil structure, and the soil consistency under wet conditions was very sticky and very plastic, while it was very hard under dry conditions. Clay and organic matter are binding agents for aggregates (Rachim, 2007). Apparently, the influence of clay is more dominant than of organic matter as an aggregate binding agent because the OC content was very low. The Entisol indicators were spread on LU 2 (P2) only. Entisol is a soil that is still young and underdeveloped (Rachim, 2007). The results of the morphological analysis of the soil indicated that this Entisol has a granular structure (not solid), fine sized with a weak level of development, therefore the stability was relatively low. In addition, the texture of Entisol was classified as loamy sand with the sand of particle size which makes the soil structure stability relatively low. This class requires major inputs from conservation management; since a lack of plant nutrition is a major obstacle, therefore a plan to use good fertilizers should be adopted (Beinroth et al., 2001). Land management through the addition of organic matter can be applied together with recommended fertilizer doses (Sys et al., 1991; Singh et al., 2004; Mahaputra et al., 2019). Provision of organic matter in soils with clay texture can increase soil water content and available water capacity and reduce soil volume weight (Intara et al., 2011), increase soil porosity (Anastasia et al., 2014), increase N, P, and K uptake and crop yields in Entisol soils (Afandi et al., 2015). Addition of manure, compost and beneficial bacteria technology (custom bio) can reduce soil content weight, soil density, increase aggregate stability, soil porosity and moisture content in Entisol soil (Zulkarnain et al., 2013).

The LQ of class VI with the main factor determining the land stress was low water holding capacity. The indicators of the sandy clay loam texture were spread on LU 8 (P8), LU 9 (P9) and LU 10 (P10). The value of water available on the sandy clay loam texture was only around 20.42 mm (Haridjaja et al., 2013). The available water (pF) under conditions of field capacity (pF 2.0) on LU 8, 9 and LU 10 was indicated as 34 mm, 38 mm, and 37 mm respectively, and at permanent wilting conditions (pF 4.2) 24 mm, 17 mm and only 19 mm respectively, therefore, causing a low water holding capacity. This land should not be used for food production (i. e. corn) because this class requires major inputs from conservation management; since a lack of plant nutrition is a major obstacle, therefore a plan to use good fertilizers should be adopted or this land can be used as a biodiversity zone (Beinroth et al., 2001). However, if this land is used for agricultural cultivation, then the land management should consider the addition of organic matter along with the recommended fertilizer dosage (Sys et al., 1991; Singh et al., 2004; Mahaputra et al., 2019). Provision of organic material in soils with clay texture can increase soil water content and available water capacity and reduce soil volume weight (Intara et al., 2011), increase soil porosity (Anastasia et al., 2014).

CONCLUSIONS

Angular blocky, sticky, plastic consistencies, and hard consistencies prevailed in the soil structure of the Bulia micro watershed of Gorontalo Province, Indonesia. In the alluvial plain, a sand fraction prevailed in Volkan mountains. The soils in the Bulia micro watershed also react acid to neutral, with the range of very low to high OC levels, the reserve of exchangeable bases was dominated by Ca^{2+} in two series patterns, namely: $Ca^{2+} > Mg^{+} > Na^{+} > K^{+}$ and $Ca^{2+} > Na^{+} > Mg^{+} > K^{+}$, CEC ranged from low to very high, and the base saturation varied from moderate to very high. The primary soils found were Entisol on P2 (Typic Ustipsamments), Inceptisol on P1 and P7 (Typic Humustepts), and P3 (Oxic Humustepts), Mollisol on P4 (Typic Argiudolls), P6 (Typic Haplustolls), and P9 (Typic Paleustolls), and Alfisol on P5 (Typic Paleustalfs), P8 (Ultic Paleustalfs) and P10 (Inceptic Haplustalfs). On the alluvial plains the land was categorized as the LQ class II, III and IV, the volcanic mountains were the LQ class IV, while the land on the volcanic hills was categorized as the LQ class VI. River bank erosion on the land river terraces can be held by the manufacture of gabions, talud, cliff reinforcement plants and terraces. The soil temperatures and high clay content can be regulated by mulching and organic materials.

REFERENCES

1. Afandi F.N., Siswanto B., Nuraini Y., Effect of giving various types of organic material on soil chemical properties on the growth and production of sweet potato plants in Entisol Ngrangkah Pawon, Kediri, *Soil and Land Resources*, 2015, Vol. 2(2), pp. 237–244, URL: http://jtsl.ub.ac.id.
2. Anastasia I., Izatti M., Suedy S.W.A., The effect of giving a combination of solid organic fertilizer and liquid organic on soil porosity and spinach plant growth (*Amarantus tricolor* L.), *Biology Journal*, 2014, Vol. 3(2), pp. 1–10.
3. Beinroth F.H., Eswaran H., Reich P.F., Global assessment of land quality, sustaining the global farm, *Selected papers from the 10th International Soil Conservation Organization Meeting*, 2001, pp. 569–574.
4. BPS Gorontalo Province, *Gorontalo province in figure 2020*, BPS

Gorontalo Province, 2020, 1102001.75(75560.2004), pp. 1–535.
5. BPS Gorontalo Regency, Gorontalo regency in figure 2020, BPS Gorontalo Regency, 2020, 1102001.75(75020.2003), pp. 1–262.
6. Dutta M., *Land use planning of Tipukjan watershed of Sivasagar district using GIS and remote sensing technique: Ph.D. Thesis*, Assam Agricultural University, Jorhat, 2009.
7. Damaiyanti D.R.R., Aini N., Koesrihati, The study of organic mulch application on the growth and yield of red pepper (*Capsicum annuum* L.), *Crop Production Journal*, 2013, Vol. 1(2), pp. 25–32.
8. Devi P.A.V., Naidu M.V.S., Rao A.R., Characterization and classification of sugarcane growing soils in southern agro-climatic zone: A case study in eastern mandals of Chittoor district in Andhra Pradesh, *Journal of the Indian Society of Soil Science*, 2015, Vol. 63(3), pp. 245–258, DOI: 10.5958/0974-0228.2015.00034.1.
9. Eruola A.O., Bello N.J., Ufoegbune G.C., Makinde A.A., Effect of mulching on soil temperature and moisture regime on emergence, growth and yield of white yam in a tropical wet-and-dry climate, *International Journal of Agriculture and Forestry*, 2012, Vol. 2(1), pp. 93–100, DOI: 10.5923/j.ijaf.20120201.15.
10. Eviyati, Sulaeman, Analysis of soil, chemical, plants, water, and fertilizer, *Indonesia Centre of Soil Research*, 2009, pp. 1–203.
11. Husain J., Luntungan J.N., Kamagi Y.E.B., Nurdin B., Conservation-based corn farming model in Gorontalo Province. Research Report. *Research, Development and Regional Environmental Impact Control Agency Gorontalo Province*, Gorontalo, 2004.
12. Haridjaja O., Baskoro D.P.T., Setianingsih M., Different levels of field capacity by alhricks, free drainage, and pressure plate methods at different soil texture and relation for sunflower growth (*Helianthus annuus* L.), *Soil Science and Environmental Journal*, 2013, Vol. 15(2), 52 p, DOI: 10.29244/jitl.15.2.52-59.
13. Intara Y.I., Sapei A., Sembiring E.N., Djoefrie M.H.B., Affected of organic matter application at clay and clay loam soil texture on water holding capacity, *Indonesian Agriculture Sciences Journal*, 2011, Vol. 16(2), pp. 130–135.
14. Jambak M.K.F.A., Baskoro D.P.T., Wahjunie E.D., Characteristics of soil physic on soil conservation tillage system (Case study of Cikabayan Research Farm, Bogor), *Soil and Land Bulletin*, 2017, Vol. 1(1), pp. 44–50.
15. Jackson M.L., *Soil chemical analysis*, New Delhi: Prentice Hall of India (Pvt.) Ltd., 1973, 498 p.
16. Kadao S.H., Prasad J., Gajbhlye K.S., Characterization and classification of some typical banana growing soils of Wardha district of Maharashtra,

Agropedology, 2003, Vol. 13(2), pp. 28–34.
17. Ludwig A., Bradford P., David B., Anton W., Vegetation patches and runoff-erosion as interacting ecohydrological processes in semiarid landscapes, *Ecology*, 2007, Vol. 86, pp. 288–297, DOI: 10.1890/03-0569.
18. Mahapatra S.K., Nagdev R., Gopal R., Surya J.N., Meena R.K., Yadav R.P., Singh S.K., Characterization and classification of the soils of Buraka micro-watershed in Haryana for integrated development, *Journal of the Indian Society of Soil Science*, 2019, Vol. 67(2), pp. 137–150, DOI: 10.5958/0974-0228.2019.00015.X.
19. Manik H., Marpaung P., Sabrina T., The level of soil development based on the pattern of clay mineral distribution in Subdistric Lumbanjulu, Distric of Toba Samosir, *Agroteknologi FP USU*, 2017, Vol. 5(2), pp. 422–433.
20. Nasruddin, Hanum H., Study of mulching effects on soil temperature, soil property, and growth of patchouli (*Pogostemon cablin* Benth), *Floratek*, 2015, Vol. 10, pp. 69–78.
21. Niranjana K.V., Ramamurthy V., Hegde R., Srinivas S., Koyal A., Naidu L.G.K., Sarkar D., Characterization, classification and suitability evaluation of banana growing soils of Pulivendla region. Andhra Pradesh, *Journal of the Indian Society of Soil Science*, 2011, Vol. 59(1), pp. 1–5, URL: https://www.indianjournals.com/ijor.aspx?target=ijor:jisss&volume=59&issue=1&article=001.
22. Noor A., Vahlevi J., Fathurrozi., Slope stabilization for erosion control with soil bioengineering using vetiver grass, *Poros Teknik*, 2011, Vol. 3(2), pp. 69–74.
23. Nurdin, *Development, classification and rainfed paddy soils potency derived from lacustrine materials in paguyaman, gorontalo*. MSc Thesis Bogor Agriculture University, 2010a. URL: https://repository.ipb.ac.id/handle/123456789/57081.
24. Nurdin, The morfology, physics and soil chemistry of inceptisol derived from lacustrine paguyaman of gorontalo relating to soil managements, *Jurnal Agroteknotropika*, 2010b, Vol. 1(1), pp. 13–22.
25. Nurdin, Development and rainfed paddy soils potency derived from lacustrine material in paguyaman, Gorontalo, *J. Trop. Soils*, 2011, Vol. 16(3), pp. 267–278, DOI: 10.5400/jts.2011.16.3.267.
26. Nurdin, Combination of soil conservation techniques and its effect on the yield of maize and soil erosion of dry land in biyonga sub-watershed, Gorontalo, *J. Tek. Ling*., 2012, Vol. 13(2), pp. 245–252.
27. Odjugo P.A.O., The effect of tillage systems and mulching on soil microclimate, growth and yield of yellow yam (*Dioscorea cayenensis*) in Midwestern Nigeria, *African Journal of Biotechnology*, 2008, Vol. 7(24), pp. 4500–4507, DOI: 10.4314/ajb.v7i24.59629.

28. Oldeman L.R., Darmiyati S., *An agroclimatic map of Sulawesi scale 1 – 2.500.000*, Center Research for Agriculture, 1977, p. 1.
29. Puslitanak Research Team, *Survey and mapping of semi-detailed soil resources (scale 1 : 50,000) in the North Sulawesi of Paguyaman area for the development of irrigation and sugarcane commodities*. Final report. Book III Attachment of the Land Series. Center for Soil and Agro-climate Research, Agency for Agricultural Research and Development, Indonesian Ministry of Agriculture, Bogor, 1995.
30. Prasetyo B.H., Differentiation in Properties of vertisol from various parent materials, *Indonesian Agriculture Sciences Journal*, 2007, Vol. 9(1), pp. 20–31.
31. Rachman A., Gantzer J., Anderson S.H., Soil hydraulic properties influenced by stiff-stemmed grass hedge systems, *Soil Science Society of America Journal*, 2004, Vol. 68(4), pp. 1386–1393, DOI: 10.2136/sssaj2004.1386.
32. Rachim D.A., *Characterization os soils with low activity clay, and the effect of iron oxides on some soil properties*, PhD thesis, Bogor Agricultural University, 1994, URL: https://repository.ipb.ac.id/handle/123456789/2463?show=full.
33. Rachim D.A., *The foundamentals of soil genesis*. Bogor: Departemen of Soil and Land Resources, Agriculture Faculty of Bogor Agriculture University, 2007, 41p.
34. Rahman A., Geographic information system model for estimating flow coefficient and its relationship with land cover in Riam Kanan River Basin of South Kalimantan Province, *Bumi Lestari*, 2013, Vol. 13(1), p. 1–8.
35. Sys C., Rast E.V., Debaveye J., *Land evaluation*. Part II. Principles in land evaluation and crop production calculations. International Training Centre for Post-Graduate Soil Scientists, University of Ghent, 1991.
36. Sarkar D., Gangipodhyay S.K., Velayutham M., Soil toposequence relationship and classification in lower outlier of Chhotanagpur plateau, *Agropedology*, 2001, Vol. 11, pp. 29–36.
37. Swarnam T.P., Velmurugan A., Rao Y.S., Characterization and classification of some soils from Shahibi basin in parts of Haryana and Delhi, *Agropedology*, 2004, Vol. 14, p. 114–122.
38. Singh C., Singh P., Singh R., *Modern techniques of raising field crops*, New Delhi: Oxford and IBH Publishing Co. Pvt. Ltd., 2004, pp. 1–583.
39. Satish S., Naidu M.V.S., Ramana K.V., Munaswamy V., Reddy G.P., Sudhakar P., Characterization and classification of the soils of Brahmanakotkur watershed in Kurnool district of Andhra Pradesh’, *Journal of the Indian Society of Soil Science*, 2018, Vol. 66(4), pp. 351–361, DOI: 10.5958/0974-0228.2018.00044.0.

40. Sinarta I., Methods of handling landslides with soil nailing’, *Paduraksa*, 2014, Vol. 3(2), pp. 1–16.

41. Sireesha P.V.G., Naidu M.V.S., Clay mineralogy of soils developed from granite-gneiss of Kurnool District in Andhra Pradesh’, *Journal of the Indian Society of Soil Science*, 2015, Vol. 63(1), pp. 16–23, DOI: 10.5958/0974-0228.2015.00003.1.

42. *Soil survey manual*, Soil Science Division Staff, United States Department of Agriculture (USDA), 2017, pp. 1–145, URL: https://www.iec.cat/mapasols/DocuInteres/PDF/Llibre50.pdf.

43. Soil Survey Staff, Keys to soil taxonomy, Soil Conservation Service – NRCS/USDA, 2014, Vol. 12, 360 p.

44. Subardja D., Sudarsono, The influence of land quality on productivity of maize in soils derived from volcanic and sedimentary rocks in the bogor area, *Soil and Climate Journal*, 2005, Vol. 23, pp. 38–46.

45. Suharta N., The characteristic of soil developed from felsic sediments in west kalimantan province and its implication to land management, *Soil and Climate Journal*, 2007, Vol. 25, pp. 11–26.

46. Sukarman S.R., Anda M., Suryani E., *Guidelines for soil observation in the field*, Agricultural Research and Development Agency, Ministry of Agriculture Republic of Indonesia, Bogor, 2017, pp. 1–149.

47. Supriya K., Naidu M.V.S., Kavitha P., Srinivasa M.R., Characterization, classification and evaluation of soils in semi-arid region of Mahanandi Mandal in Kurnool district of Andhra Pradesh’, *Journal of the Indian Society of Soil Science*, 2019, Vol. 67(2), pp. 125–136, DOI: 10.5958/0974-0228.2019.00014.8.

48. Susilawati S., Veronika V., Vetiver grass study as a continuous slope safety, *Civil Engineering Communication Media*, 2016, Vol. 22(2), p. 99, DOI: 10.14710/mkts.v22i2.12886.

49. Suyana J., Sumarno, Supriyono, Lestariningsih N.P., Mulching and strengthening of terraces in three types of plants against surface runoff, erosion, growth and yield of plants in Andisols, *Agrosains*, 2017, Vol. 19(1), p. 15, DOI: 10.20961/agsjpa.v19i1.20924.

50. Vedadri U., Naidu M.V.S., Characterization, classification and evaluation of soils in semi-arid ecosystem of Chillakur mandal in SPSR Nellore district of Andhra Pradesh, *Journal of the Indian Society of Soil Science*, 2018, Vol. 66 (1), pp. 9–19, DOI: 10.5958/0974-0228.2018.00002.6.

51. Walia C.S., Rao Y.S., Characteristics and classification of some soils of Trans-Yamuna plains, *Journal of the Indian Society of Soil Science*, 1997, Vol. 45(1), pp. 156–162.

52. Yasin M.G.H., Langgi W.F., White grain maize as an alternative for staple food, *Iptek Tanaman Pangan*, 2015, Vol. 9(2), pp. 108–117.

53. Yatno E., Mulyanto B., Characteristics of soils formed from schist and their land suitability for cocoa crop in Kolaka and East Kolaka Regencies, Southeast Sulawesi, *Soil and Climate Journal*, 2016, Vol. 39(2), pp. 109–118.
54. Zulkarnain M., Prasetya B., Soemarno, Effects of compost, manure, and custom-bio on soil properties, growth and yield of sugarcane (*Saccharum officinarum* L.) in Entisol Kebun Ngrangkah of Pawon, Kediri, *Indonesian Green Technology Journal*, 2013, Vol. 2(1), pp. 45–52, URL: https://igtj.ub.ac.id/index.php/igtj/article/view/103.

Soils in the Bulia micro watershed of Gorontalo province, Indonesia, and their quality assessment

 Nurdin[1*], M. L. Rayes[2], Soemarno[2], Sudarto[2], E. Listyarini[2], C. Agustina[2], R. Rahman[1], A. Rauf[3], J. Husain[4]

[1]*Department of Agrotechnology, Gorontalo State University, Prof. Dr. Ing. B. J. Habibie Str., Moutong Village, 96554 Bone Bolango, Indonesia.*
**https://orcid.org/0000-0001-5725-5694, e-mail: nurdin@ung.ac.id.*

[2]*Department of Soil Science, Brawijaya University, No. 54 Veteran Str., Lowokwaru, 65145 Malang, Indonesia.*

[3]*Department of Agribussiness, Gorontalo State University, Prof. Dr. Ing. B. J. Habibie Str., Moutong Village, 96554 Bone Bolango, Indonesia.*

[4]*Department of Soil Science, Sam Ratulangi University, No. 1 Kleak Bahu Str., Kleak, 95115 Manado, Indonesia.*

Received 12.07.2021, Revised 24.08.2021, Accepted 20.09.2021

References

Niranjana K.V., Ramamurthy.V., Hegde R., Srinivas S., Koyal A., Naidu L.G.K., Sarkar D., Characterization, classification and suitability evaluation of banana growing soils of Pulivendla region. Andhra Pradesh. *Journal of the Indian Society of Soil Science*, 2011, Vol. 59(1), pp. 1-5. URL: https://www.indianjournals.com/ijor.aspx?target=ijor:jisss&volume=59&issue=1&article=001

Rachim D.A., *Characterization os soils with low activity clay, and the effect of iron oxides on some soil properties*. PhD Dissertation Bogor Agricultural University, 1994. URL: https://repository.ipb.ac.id/handle/123456789/2463?show=full

Rachim D.A., *The foundamentals of soil genesis*. Bogor: Departemen of Soil and Land Resources, Agriculture Faculty of Bogor Agriculture University, 2007, 41p.

PUBLISH

UDC 631.4

DOI: 10.19047/0136-1694-2021-108-104-135

Cite this article as:
Nurdin B.K., Rayes M.L., Soemarno S., Sudarto S., Listyarini E., Agustina C., Rahman R., Rauf A., Husain J., Soils in the Bulia micro watershed of Gorontalo province, Indonesia, and their quality assessment, Dokuchaev Soil Bulletin, 2021, V. 108, pp. 104-135, DOI: 10.19047/0136-1694-2021-108-104-135

Acknowledgments:
We would like to pay our regards to the Faculty of Agriculture, Brawijaya University who has funded this research with a non-tax state revenue grant in accordance with the Budget Implementation List Number: DIPA-042.01.2.400919/2019.

Soils in the Bulia micro watershed of Gorontalo province, Indonesia, and their quality assessment

© 2021 B. K. Nurdin[1*], M. L. Rayes[2], S. Soemarno[2], S. Sudarto[2], E. Listyarini[2], C. Agustina[2], R. Rahman[1], A. Rauf[3], J. Husain[4]

[1]*Department of Agrotechnology, Gorontalo State University,*
No. 6 General Sudirman Str., Wumialo, 96122 Gorontalo, Indonesia, ,
[*]*https://orcid.org/0000-0001-5725-5694, e-mail: nurdin@ung.ac.id.*

[2]*Department of Soil Science, Brawijaya University,*
No. 54 Veteran Str., Lowokwaru, 65145 Malang, Indonesia.

[3]*Department of Agribussiness, Gorontalo State University,*
No. 6 General Sudirman Str., Wumialo, 96122 Gorontalo, Indonesia.

[4]*Department of Soil Science, Sam Ratulangi University,*
No. 1 Kleak Bahu Str., Kleak, 95115 Manado, Indonesia.

Received 12.07.2021, *Revised* 24.08.2021, *Accepted* 20.09.2021

Abstract: Ten representative pedons from the Bulia micro watershed of Gorontalo Province, Indonesia, were characterized and classified to determine its land quality (LQ) class. Angular blocky, sticky, plastic consistencies and a hard consistency prevailed in the soil structure. In the alluvial plains the soil texture is dominated by the clay fraction, while in the hills and volcanic mountains the sand fraction is dominated. The soils in the Bulia micro watershed also have acid to neutral reaction, with the range of very low to high OC (organic carbon) levels, the reserve of exchangeable bases was dominated by Ca^{2+} in two series patterns, namely: $Ca^{2+} > Mg^{+} > Na^{+} > K^{+}$ and Ca^{2+} > Na+ > $Mg^{+} > K^{+}$, cation exchange capacity (CEC) ranged from low to very high, and the base saturation varied from moderate to very high. The alluvial plain is represented by Inceptisol in P1 and Typic Humustepts (P7), also by Oxic Humustepts (P3), then Mollisol on P4 (Typic Argiudolls) and Typic Haplustolls (P6), Alfisol on P5 (Typic Paleustalfs). Entisol on P2 (Typic Ustipsamments) was found in volcanic mountains and P9 (Typic Paleustolls) P8 (Ultic Paleustalfs), P10 (Inceptic Haplustalfs) are typical of volcanic hills. On the alluvial plains the land was categorized as the LQ class II, III and IV, the volcanic mountains were the LQ class IV, while the land on the volcanic hills was categorized as the LQ class VI. River bank erosion on the land river terraces can be held by the manufacture of gabions, talud, cliff reinforcement plants and terraces. The soil temperatures and high clay content can be regulated by mulching and organic materials.

Keywords: Characterization, classification, soils of Indonesia, land quality, the Bulia watershed.

INTRODUCTION

Land is a crucial component of land resources which enables plants growth and food production. Land and plant productivity is primarily determined by soil and other land characteristics related to land quality (Subardja, Sudarsono, 2005). However, an intense tillage during agricultural cultivation and a pressure of the land use when its conservation and sustainability are ignored has resulted into a decrease of land quality. Agricultural production tends to level or even decrease (Nurdin, 2012). Corn is a traditional commercial crop in the province of Gorontalo, Indonesia, which has been intensively and massively cultivated since it was established as a prime commodity in the agropolitan program in 2001. Until 2019, hybrid corn yields in Gorontalo Province reached 1.7 million tons or increased by 9.3% compared to 2018, however, the productivity of maize was still low at only 5.0 tons/ha (BPS Gorontalo Province, 2020). In fact, the potential corn yield in Indonesia can reach 10-11 tons/ha (Yasin et al., 2015), while the achievement of the national productivity in 2018 was only 5.2 tons/ha (Indonesian Ministry of Agriculture, 2019).

The Bulia micro watershed area is a corn production centre that also supports the agricultural area below. The watershed has a vital role because it supplies irrigation water for agriculture and other activities

(Mahapatra et al., 2019). The corn cultivation in this watershed has exceeded the carrying capacity indicated for the corn planting on the slope of >25%, so that the land degradation often occurs. Soil erosion, according to the corn agropolitan program of Gorontalo, reached 1,396 tons/ha/year (Husain et al., 2004). Meanwhile, the corn productivity in this area is only 5.0 tons/ha (BPS Gorontalo Regency, 2020), which could happen due to the fact that the crop was cultivated on a non-suitable land.

Soil characterization is essential because it provides some necessary information about the soil characteristics for growing plants (Devi et al., 2015). For sustainable management of soil resources in agroecological areas we need timely monitoring of significant physical, chemical and biological soil characteristics and responses to the changes in land management (Supriya et al., 2019). These soil characteristics then form the basis for land classification. Combining soil characterization with classification is a powerful tool to develop management strategies for food security and environmental sustainability (Satish et al., 2018). However, the efforts to link land characteristics and classification with a specific land quality are still relatively rare. Land quality is a land ability to perform a specific function before the land is degraded (Beinroth et al., 2001). Understanding soil types and their distribution, its limits and potential is essential for a proper management to increase productivity and yields (Niranjana et al., 2011).

The survey and mapping of soil resources in the Paguyaman watershed were carried out by the Soil and Agro-climate Research Centre of the Indonesian Ministry of Agriculture (Puslittanak Research Team, 1995), however, the mapping scale was 1 : 50,000. In 2010, some research was carried out on the development, classification and potential of the paddy soils on toposequence (Nurdin, 2010), however, it only focused on the rainfed paddy soils, while the dry land was only compared to the locations close to the soil pedon in the rice fields. Considering the high intensity of the land management and the massive corn cultivation in this sub-watershed, this research has become significant.

MATERIALS AND METHODS

Study location

The Bulia micro watershed is a part of the Paguyaman watershed located in the northern part, it covers Mootilango and Boliyohuto District of Gorontalo Regency of Gorontalo Province, Indonesia (Figure 1). Geographically, the research location is between 0°39′123″ and 0°51′321″ N, 122°35′21″ and 122°43′12″ S (Table 1), which is 67 km from Gorontalo City, Indonesia.

Table 1. Site characteristics of the pedons in the Bulia micro watershed

Pedon/ Villages	Location	Elevation (m msl)	Landform	Slope (%)	Drainage
P1, Tolite	0°39′44.80″ N 122°35′27.20″ S	24	Alluvial plain	0–3	Poorly drained
P2, Monggolito	0°40′01.20″ N 122°37′57.20″ S	159	Volcanic mountain	15–30	Well drained
P3, Huyula	0°42′59.9″ N 122°39′43.2″ S	63	Alluvial plain	0–3	Moderately drained
P4, Payu	0°44′04.4″ N 122°37′48.4″ S	53	Alluvial plain	0–3	Moderately drained
P5, Pilomonu	0°43′53.80″ N 122°35′22.60″ S	75	Alluvial plain	0–3	Moderately drained
P6, Karyamukti	0°42′20.50″ N 122°41′05.50″ S	109	Alluvial plain	3–8	Moderately drained
P7, Karyamukti	0°42′10.30″ N 122°41′19.40″ S	114	Alluvial plain	3–8	Moderately drained
P8, Sukamaju	0°44′05″ N 122°40′04″ S	253	Volcanic hill	8–15	Well drained
P9, Payu	0°45′12″ N 122°38′08″ S	285	Volcanic hill	8–15	Well drained
P10, Huyula	0°43′11.10″ N 122°40′31.20″ S	262	Volcanic hill	8–15	Well drained

Overall, the Bulia micro watershed has 21,456.58 ha and consists of upland amounted to 18,993.44 ha (32.59%), and paddy fields amounted to 2,991.15 ha (13.94%). Specifically, the upland agriculture covers the agricultural land areas amounted to 6,993.44 ha (37.87%), settlement areas – 461.59 ha (2.50%), and forest areas amounted to 11,010.40 ha (59.63%). The soils in this area are generally developed from volcanic material in the upper watershed and lacustrine deposits in the middle and the bottom of the watershed. The study area is located in tropical climate with rainy and dry seasons. The average annual rainfall was only 1,478 mm with 1 wet month only and 4 dry months, so it belongs to the E2 agro-climate zone (Oldeman, Darmiyati, 1977). The average annual air temperature reaches 28.19 °C with the maximum temperature of 28.73 °C and the minimum temperature of 27.63°C. Under these conditions, the soil moisture regime is determined ustic and the soil temperature regime – isohyperthermic (Soil Survey Staff, 2014).

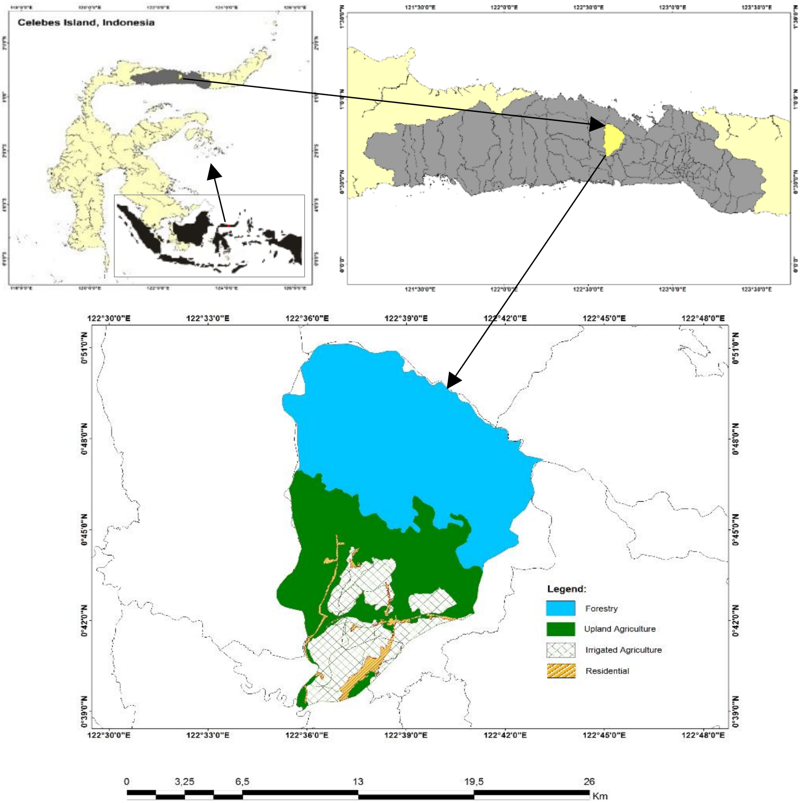


Fig 1. Location Map of the Bulia Micro watershed.

Soil surveying, characterization and classification

Ten representative pedons were selected to conduct the soil survey. The description of soil morphology refers to the Soil Survey Manual (Soil Science Manual, 2017; Sukarman et al., 2017). According to standard procedures, soil samples were taken at each horizon and their physical and chemical properties were analyzed (Jackson, 1973; Eviyati, Sulaeman, 2009). The morphological and the soil properties data obtained during the laboratory analysis are used for the soil characterization together with the climate and the terrain conditions data, according to Sukarman et al. (2017). The soil characteristics are used for soil classification according to the keys to soil taxonomy (Soil Survey Staff, 2014).

Land quality assessment

Land quality (LQ) class assessment follows the method according to Beinroth et al. (2001). This method has been modified based on availability of soil characteristics and classification data without including local population data. Soil pedons (P), which were classified in taxa according to the Soil Taxonomy System (Soil Survey Staff, 2014), were combined with a land unit (LU) basing on the similarity of the criteria in taxa. Soil and pedoclimate information was used to place each LU into I to IX land quality classes with class I having the most appropriate attributes and class IX having the least suitable ones for crop production. The results of the land quality analysis are widely presented and described with the help of Arc GIS.

RESULTS AND DISCUSSION

Morphology and soil physical properties

The results of field studies and the laboratory characterization of ten soil pedons were presented in Table 2, Figure 2. The soils in the study area have been developed as indicated by the horizon structuring (horizons A and B), with the depth of the soil solum varying from shallow to very deep. The soil colour is only of 7.5YR and 10YR hue, where 7.5YR is dominant. P1, P2, P3, P5, P8, P9 and P10 soil colour varies from dark brown, brown to strong brown with hue 7.5YR, ranging from 3 to 5, and chroma – from 1 to 6.

Table 2. Morphological characteristics and soil physical properties in the Bulia micro watershed

Pedon and Horizon	Depth (cm)	Colour Moisture	Struc-tures	Consistence			Sand	Silt	Clay	Texture Class
				w	m	D	%			
P1 (Alluvial Plain)										
Ap	0–23	7.5 YR 4/4	m, 3, abk	s, p	fi	H	9	40	51	Silty Clay
Bw1	23–43	7.5 YR 4/2	m, 3, abk	ss, sp	fi	H	3	46	51	Silty Clay
Bw2	43–75	7.5 YR 4/4	m, 3, abk	ss, sp	fi	H	3	54	43	Silty Clay
Bw3	75–100	7.5 YR 4/2	m, 1, abk	ss, sp	vfi	Vh	3	46	51	Silty Clay
P2 (Volcanic Mountains)										
Ap	0–5	7.5 YR 4/4	f, 1, cr	so, po	fr	L	85	10	5	Loamy sand
Bw1	5–37	7.5 YR 4/4	f, 2, sbk	so, po	fr	L	84	2	14	Loamy sand
Bw2	37–61	7.5 YR 4/4	m, 2, p	so, po	fr	L	75	10	15	Sandy Loam
C	61+	7.5 YR 4/2	m, 3, p	so, po	fr	L	66	15	19	Sandy Loam
P3 (Alluvial Plain)										
Ap	0–14	7.5 YR 3/3	f, 1, cr	ss, sp	fi	H	33	41	26	Loam
Bw1	14–43	7.5 YR 4/4	f, 2, abk	s, p	fi	H	31	37	32	Clay Loam
Bw2	43–68	7.5 YR 4/4	f, 1, abk	ss, sp	fi	H	23	54	23	Silty Loam
Bw3	68+	10 YR 3/6	f, 1, cr	s, p	fi	H	23	48	29	Clay Loam

Pedon and Horizon	Depth (cm)	Colour Moisture	Structures	Consistence			Sand	Silt	Clay	Texture Class
				w	m	D				
P4 (Alluvial Plain)										
Ap	0–14	10 YR 3/3	m, 3, abk	s, p	fi	H	27	26	47	Clay
Bw	14–50	10 YR 4/3	f, 1, abk	s, p	fi	H	32	34	34	Clay Loam
Bt1	50–81	10 YR 3/2	f, 1, abk	ss, sp	fi	H	12	24	64	Clay
Bt2	81+	7.5 YR 4/1	f, 1, abk	s, p	fi	H	16	25	59	Clay
P5 (Alluvial Plain)										
Ap	0–21	7.5 YR 4/4	f, 2, sbk	ss, sp	fi	H	23	43	34	Clay Loam
Bw	21–46	7.5 YR 4/4	f, 2, sbk	ss, sp	fi	H	23	48	29	Clay Loam
Bt1	46–84	7.5 YR 4/3	f, 2, abk	s, p	fi	H	25	35	40	Clay
Bt2	84–117	7.5 YR 4/6	m, 2, p	s, p	fi	H	24	36	40	Clay
Btg	117+	7.5 YR 5/8	m, 1, sbk	ss, sp	fi	H	8	46	46	Silty Clay
P6 (Alluvial Plain)										
Ap	0–12	10 YR 3/3	f, 1, abk	s, p	fi	H	84	15	1	Loamy Sand
Bw1	12–34	10 YR 3/4	f, 1, abk	s, p	fi	H	61	10	29	Sandy Clay Loam
Bw2	34–71	10 YR 4/6	m, 3, abk	ss, sp	fi	H	61	24	15	Sandy Loam
C	71–90	7.5 YR 5/8	f, 1, cr	so, po	fr	L	84	5	11	Loamy Sand

Pedon and Horizon	**Depth (cm)**	**Colour Moisture**	**Struc-tures**	**Consistence**			**Sand**	**Silt**	**Clay**	**Texture Class**
				w	**m**	**D**				
P7 (Alluvial Plain)										
Ap	0–6	7.5 YR 4/6	m, 1, abk	s, p	fi	H	33	11	56	Clay
Bw1	6–17	10 YR 4/6	m, 3, sbk	s, p	fi	H	29	20	51	Clay
Bw2	17–33	10 YR 3/6	m, 1, abk	ss, sp	fi	H	21	20	59	Clay
Bt	33–49	10 YR 3/6	f, 1, p	ss, sp	fi	H	19	15	66	Clay
BC	49+	7.5 YR 4/6	f, 1, abk	ss, sp	fi	H	18	29	53	Clay
P8 (Volcanic Hills)										
Ap	0–7	7.5 YR 3/3	f, 1, abk	ss, sp	fi	H	64	10	26	Sandy Clay Loam
Bw	7–24	7.5 YR 3/3	m, 1, abk	s, p	fi	H	47	24	29	Sandy Clay Loam
Bt1	24–44	7.5 YR 4/6	f, 3, p	s, p	fi	H	45	15	40	Sandy Clay
Bt2	44–63	7.5 YR 5/6	m, 3, abk	s, p	fi	H	42	16	42	Clay
Bt3	63+	7.5 YR 5/6	m, 1, abk	s, p	fi	H	42	6	52	Clay

Pedon and Horizon	Depth (cm)	Colour Moisture	Struc-tures	Consistence			Sand	Silt	Clay	Texture Class
				w	m	D				
P9 (Volcanic Hills)										
Ap	0–16	7.5 YR 3/2	m, 3, abk	vs, vp	vfi	Vh	54	31	15	Sandy Loam
Bw	16–34	7.5 YR 3/3	m, 1, abk	s, p	fi	H	42	24	34	Clay Loam
Bt	34+	7.5 YR 4/4	m, 1, abk	ss. sp	fi	H	50	15	35	Sandy Clay
P10 (Volcanic Hills)										
Ap	0–20	7.5 YR 3/3	m, 3, abk	ss, sp	fi	H	48	26	26	Sandy Clay Loam
Bt1	20–44	7.5 YR 3/4	m, 3, abk	s, p	fi	H	41	15	44	Clay
Bt2	44–76	7.5 YR 4/6	c, 3, sbk	s, p	fi	H	42	14	44	Clay
BC	76+	5 YR 4/6	c, 3, p	vs, vp	vfi	Vh	31	2	67	Clay

Note. Structure: *size*: vf – very fine, f – fine, m – medium, c – coarse; *structureless grade*: l – weak, 2 – moderate, 3 – strong; *type*: cr – crumb, sg – single grain, abk – angular blocky, sbk – sub-angular blocky. Consistence: *dry* (d): s – soft, l – loose, sh – slightly hard, h – hard, vh – very hard, eh – extremely hard; *moist* (m): l – loose, fr – friable, fi – firm, vfi – very firm, efi – extremely firm, *wet* (w): so – non-sticky, ss – slightly sticky, s – sticky, vs – very sticky; po – non-plastic, ps – slightly plastic, p – plastic, vp – very plastic.

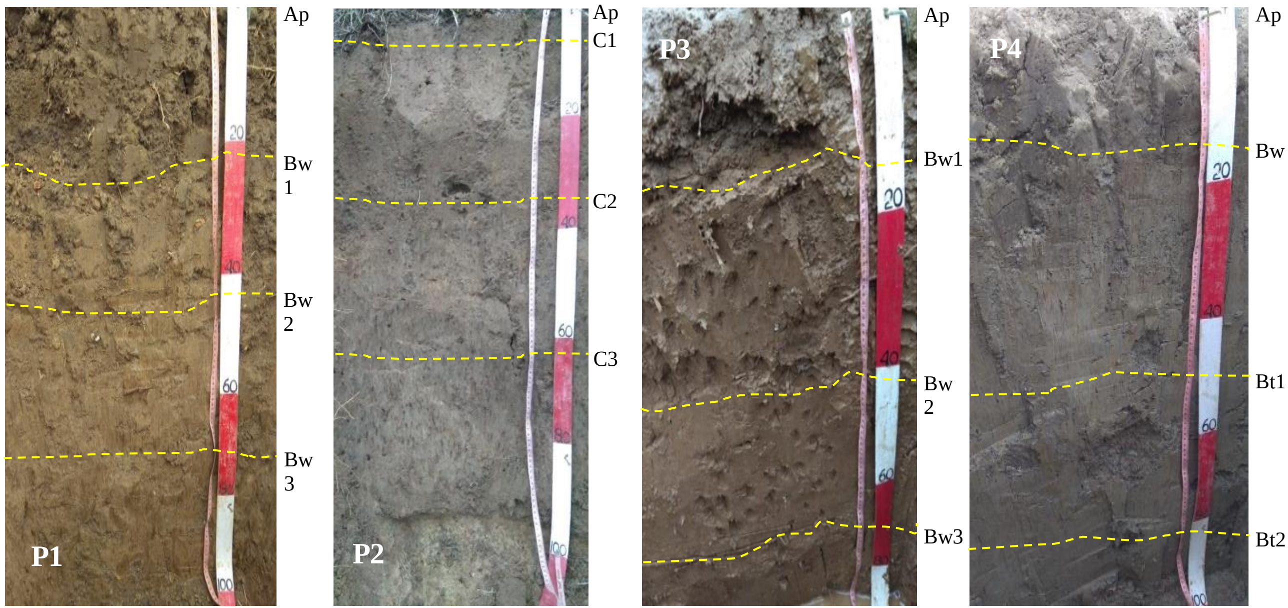


Fig. 2. Soil profile appearance of pedon 1 (P1), 2 (P2), 3 (P3) and pedon 4 (P4).

While in P4, P6 and P7, soil colour varies from very dark grayish brown, dark brown to dark yellowish-brown with hue 10YR, values ranging from 3 to 4, and chroma – from 2 to 6. The colour of soil horizon A is darker than of horizon B due to the fact that the organic matter content in horizon A is higher than in horizon B (Yatno et al., 2015). The higher the organic matter content, the darker the soil colour is (Suharta, 2007). Soil colour seems to be a function of chemical and mineralogical composition (Swarnam et al., 2004; Walia, Rao, 1997), and the soil texture is influenced by topographic position and humidity regimes (Walia, Rao, 1997).

The soil structure varies from crumbs, angular blocky, sub angular blocky to prismatic, with the dominant angular blocky. P1, P3, P4, P6, P7, P8, P9 and P10 were mostly of angular blocky structure with the sizes varying from fine, medium to coarse, with weak and strong structural development. While the soil structures of P2 and P5 varies between crumbs, angular blocky, sub angular blocky and prismatic with the sizes ranging from fine, medium to coarse and the level of the soil structure development varying from weak, moderate to strong. The angular blocky soil structures were strongly associated with higher clay fractions (Devi et al., 2015). Crumbly soil structure indicates newly developed soil (Manik et al., 2017). Intensive soil tillage results in soil structure disturbance (Jambak et al., 2017). The variation of soil structure will be consistently affecting the soil.

The soil consistency in wet conditions varies between non-sticky and non-plastic on Pedon 2, slightly sticky and slightly plastic, sticky and plastic in the horizon on P1, P3, P4, P5, P6, P7, P8, P9 and P10, very sticky and very plastic on the surface horizon (Ap) of P9 and the subsurface horizon (BC) of P10, however, slightly sticky and slightly plastic consistencies prevail. While in moist conditions the consistencies vary from loose, firm to very firm, the firm consistencies are still dominant. P1, P3, P4, P5, P6, P7, P8, P9 and P10 were dominated by hard consistencies, while P2 – by loose ones. There is a very hard consistency in P1 and P10 in the subsurface horizon (Bw and BC), while in the surface horizon (Ap) a very hard consistency can be only found in P9. The consistency in dry conditions varies from loose, hard to very hard, with a dominant hard consistency. P1, P3, P4, P5, P6, P7, P8, P9 and P10 were dominated by a hard consistency, however, in P1 and

P10 in the subsurface horizon (Bw3 and BC) one could notice a very hard consistency, while in P9 precisely a very hard consistency was found on the surface horizon (Ap). Sticky and plastic consistency might form due to a high clay content in the soil (Sarkar et al., 2001); (Kadao et al., 2003), while non-sticky and non-plastic consistency might form due to a very little clay content (Sireesha, Naidu, 2015; Devi et al., 2015).

The soil texture of all pedons varies greatly between sandy clay loam, sandy loam, loamy sand, sandy loam, silty loam, clay loam, silty clay and clay, except for P7 that was of clay texture in all horizons. Wide variations of soil texture may be caused by the variations in parent material, topography, in-situ weathering, translocation of clays by eluviation and soil age (Satish et al., 2018). Apparently, the pedons located in the alluvial group were more dominated by clay fractions, although the distribution patterns were irregular. The distribution of irregular clay fractions was typical for sediment materials (Nurdin, 2010). While a sand fraction dominated the volcanic group, the distribution of sand and clay fractions shows the opposite pattern. A decrease in the sand fraction is due to the clay illuviation and in-situ mineral destruction process, which was characterized by a decline in the absolute amount of sand in the middle of the solum (Rachim, 1994). The texture that is found in the subsurface horizon is caused by higher weathering in the subsurface layer (Dutta, 2009). The clay content in the solum middles (B-illuviation) was higher than in the upper horizon (A-eluviation) and in the lower layer horizon. This indicates the occurrence of a lessivage process with some clay skins seen, so that an argillic horizon was formed in P4, P5, P8, P9 and P10. Although the process of eluviation and illuviation occurred, the pedon remained, but the clay skins were not found, so the cambic and candic horizons were formed.

Soil chemical properties

Soil chemical properties are presented in Table 3. Soil pH varies from acid (pH 5.3) to neutral (pH 7.2). The pedons located on the upper watershed or in volcanic groups (P2, P8, P9 and P10) have a lower pH than the ones located on the lower watershed or in alluvial groups (P1, P3, P4, P5, P6, and P7).

Table 3. Soil chemical properties in the Bulia micro watershed

Pedon and Horizon	Depth (cm)	pH 1:1		OC (%)	Exchangeable cations				CEC	BS (%)
		H_2O	KCl 1N		K	Na	Ca	Mg		
					[cmol(+)kg^{-1}]					
P1 (Alluvial Plains)										
Ap	0–23	6.20	5.40	2.29	0.29	1.88	18.02	1.86	42.40	52.00
Bw1	23–43	6.00	5.20	0.90	0.18	2.01	15.47	2.97	39.19	52.62
Bw2	43–75	6.40	5.50	0.74	0.14	2.19	12.36	2.50	37.85	45.42
Bw3	75–100	6.50	5.60	0.65	0.14	2.23	15.22	3.26	37.58	55.49
P2 (Volcanic Mountains)										
Ap	0–5	6.50	5.60	1.19	0.10	0.34	3.77	0.30	11.13	40.55
Bw1	5–37	6.10	5.20	0.55	0.08	0.34	4.20	0.60	7.75	67.49
Bw2	37–61	6.20	5.30	0.63	0.08	0.35	3.91	0.15	8.87	50.52
C	61+	6.20	5.30	0.56	0.08	0.36	6.51	0.76	12.29	62.79
P3 (Alluvial Plain)										
Ap	0–14	5.60	4.60	0.80	0.05	1.46	4.84	0.61	16.15	43.00
Bw1	14–43	6.00	5.10	0.41	0.09	1.57	7.72	1.70	19.78	56.00
Bw2	43–68	5.80	4.90	0.32	0.05	1.55	8.95	0.91	21.58	53.00
Bw3	> 68	6.20	5.20	0.48	0.05	1.55	10.12	0.76	20.43	61.00
P4 (Alluvial Plains)										
Ap	0–14	6.50	6.10	0.41	0.06	1.49	11.87	0.62	25.55	55.00
Bw	14–50	6.70	6.30	0.96	0.19	1.43	9.71	2.12	21.60	62.00
Bt1	50–81	7.00	6.00	0.41	0.12	1.58	16.54	2.01	35.19	58.00
Bt2	81+	5.80	5.00	0.24	0.09	1.56	13.47	6.66	33.04	66.00

Pedon and Horizon	Depth (cm)	pH 1:1		OC (%)	Exchangeable cations				CEC	BS (%)
		H_2O	KCl 1N		K	Na	Ca	Mg		
					[cmol(+)kg^{-1}]					
P5 (Alluvial Plains)										
Ap	0–21	5.20	4.50	0.08	0.16	2.29	9.39	2.93	28.39	52.00
Bw	21–46	5.10	4.30	0.49	0.20	2.30	8.62	3.08	28.40	50.00
Bt1	46–84	5.70	4.90	0.57	0.12	0.26	7.69	2.00	21.56	47.00
Bt2	84–117	5.10	4.20	0.50	0.17	0.30	10.38	2.05	31.34	41.00
Btg	117+	5.10	4.10	0.42	0.25	0.34	15.37	1.90	38.58	46.00
P6 (Alluvial Plains)										
Ap	0–12	7.20	6.60	0.64	3.56	3.02	2.54	0.91	10.76	93.00
Bw1	12–34	7.10	6.60	0.32	0.28	1.72	6.03	0.30	11.79	71.00
Bw2	34–71	7.00	6.00	0.56	0.16	0.39	7.84	0.15	17.16	50.00
C	71–90	6.80	6.00	0.40	0.12	0.38	6.49	0.15	13.96	51.00
P7 (Alluvial Plains)										
Ap	0–6	6.30	5.40	0.76	0.10	0.42	5.31	2.41	18.31	45.00
Bw1	6–17	6.10	5.10	0.57	0.09	0.39	6.77	2.15	22.99	41.00
Bw2	17–33	5.90	5.00	0.57	0.07	0.44	8.55	4.04	25.45	51.00
Bt	33–49	5.60	4.80	0.33	0.08	0.45	13.64	3.72	29.79	60.00
BC	49+	5.90	5.00	0.41	0.12	2.04	13.16	0.31	33.06	47.00

Pedon and Horizon	Depth (cm)	pH 1:1		OC (%)	Exchangeable cations				CEC	BS (%)
		H_2O	KCl 1N		K	Na	Ca	Mg		
					[cmol(+)kg^{-1}]					
P8 (Volcanic Hills)										
Ap	0–7	6.00	5.20	0.96	0.24	2.09	10.15	0.45	19.40	67.00
Bw	7–24	6.40	5.50	0.80	0.17	2.05	10.30	0.61	21.55	61.00
Bt1	24–44	6.70	5.80	0.48	0.24	2.21	10.07	1.83	26.06	55.00
Bt2	44–63	6.60	5.60	0.49	0.33	2.21	9.47	0.78	26.52	48.00
Bt3	63+	6.60	5.60	0.50	0.49	2.35	13.84	1.27	32.83	55.00
P9 (Volcanic Hills)										
Ap	0–16	5.30	4.50	0.80	0.13	2.15	10.15	0.61	24.80	53.00
Bw	16–34	6.20	5.30	0.57	0.10	2.30	12.44	0.77	29.51	53.00
Bt	34+	6.20	5.20	0.48	0.06	2.25	13.49	0.46	30.54	53.00
P10 (Volcanic Hills)										
Ap	0–20	5.80	4.90	0.72	0.12	0.40	5.90	1.21	18.31	41.69
Bt1	20–44	6.10	5.20	0.64	0.05	0.40	8.23	0.46	18.44	49.59
Bt2	44–76	6.30	5.30	0.48	0.05	0.39	7.26	0.76	19.36	43.66
BC	76+	5.80	5.30	0.33	0.06	0.42	11.28	2.04	25.64	53.82

Note. CEC – cation exchange capacity, OC – organic carbon, BS – base saturation.

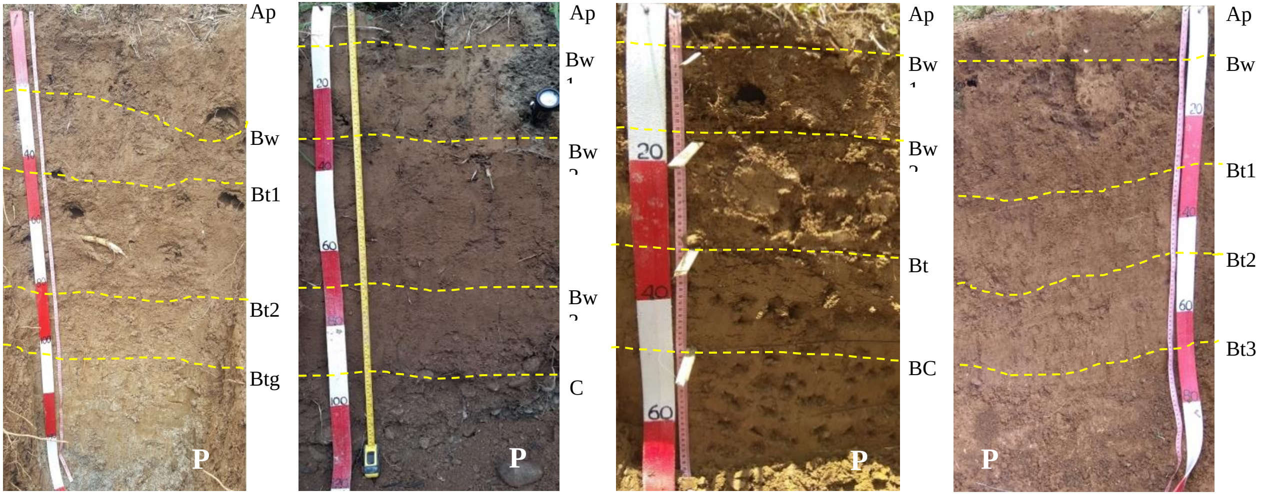


Fig. 3. Soil profile appearance of pedon 5 (P5), 6 (P6), 7 (P7) and pedon 8 (P8).

The pedon in the alluvial group represented a depressed area which is the accumulation of the bases carried by washing water from the hinterland section and the accumulation of more alkaline bases in soils with poorer drainage (Nurdin, 2010a). The pedons in the volcanic group experienced more intensive washing during the rain due to a better soil drainage. The trend of pH increasing with more depth may be explained by the release of organic acids during the decomposition of organic matter, these acids may have lowered the pH at the soil surface (Satish et al., 2018). The pH differences of KCl and the pH of H_2O of all pedons show negative values. This means that all pedons are dominated by negatively charged clay minerals (Suharta, 2007). The acid and slightly acid soil pH values in P1, P3, P5, P9 and P10 indicated that the soil had developed but the level of soil development was not yet advanced, while the neutral soil pH in P2, P4, P6, P7, and P8 shows that the soil is relatively new.

Organic carbon (OC) varies from very low to high (0.08–2.28%). The OC value was high in the surface horizon (Ap), except for P4 and P5. The OC value on the surface is higher due to the accumulation of organic materials, while its low values in P4 and P5 were due to the river flooding. The low OC value was also determined by a faster degradation of the organic material in the tropics and a low addition of farmyard manure (Vedadri, Naidu, 2018). A high OC distribution pattern on the surface and its dramatic decrease in horizon B in accordance with the depth is a general soil development pattern (Prasetyo, 2007).

The reserve (sum) of exchangeable bases vary between very low, low, medium, high and very high. Calcium cation is the dominating one in the exchangeable bases reserve, which ranges from 2.54–18.02 cmol(+)kg^{-1}, while magnesium (Mg^+) ranges from 0.15-6.66 cmol(+)kg^{-1}, sodium (Na^+) ranges from 0.26–3.02 cmol(+)kg^{-1}, potassium (K^+) ranges from 0.05–3.56 cmol(+)kg^{-1}. Based on a number of bases, the P1, P5, P7, and P10 patterns follow the sequence: $Ca^{2+} > Mg^+ > Na^+ > K^+$. This series pattern was the same as Nurdin (2011) and Satish et al. (2018) reported. At the same time P2, P3, P4, P6, P8 and P9 follow the sequence: $Ca^{2+} > Na^+ > Mg^+ > K^+$. A high rate of exchangeable bases in the surface horizon (Ap) results from the fertilization during corn cultivation, while in the lower layer rainfall washing together with good drainage conditions make it possible to wash in the soil solum.

The cation exchange capacity (CEC) varies from low (7.7 cmol(+)kg^{-1}) to very high (42.40 cmol(+)kg^{-1}). The CEC is influenced by the levels of organic carbon and soil minerals (Prasetyo et al., 2007; Suharta, 2007). It seems that CEC in P1, P3, P4, P5, P7, P8, and P9 were more influenced by OC content than by soil minerals. The higher the soil OC, the higher the soil CEC is (Suharta, 2007). While P2, P6 and P10 were thought to be more influenced by soil minerals, these bases can be exchanged and this CEC will eventually affect base saturation. Base saturation (BS) varies from moderate (40.55%) to very high (93%). All pedons generally have a medium and a high BS, except P6, which has a very high BS on the surface horizon (Ap). The variations in BS may be caused by the variations in nature and/or the content of soil colloids, and a relatively high base saturation in the surface layers can be attributed to the recycling of cation base through vegetation (Devi, Kumar, 2010). In addition, if soil has a number of bases which are smaller than CEC, BS tends to be lower, whereas when the soil has a number of bases close to or higher than CEC, BS tends to be higher (Nurdin, 2010b).

Soil classification

Based on morphological and soil characteristics, the pedons are classified according to their family level and the orders of the soils found, namely Entisol, Inceptiol, Mollisol and Alfisol (Table 4, Figure 4). P1 and P7, which are located on a slope of 3% and 5%, are based on the molic epipedon with a 23 cm thickness and a cambic horizon. These pedons did not experience aquatic conditions at the depth of 50 cm from the soil surface (humustept), the soil colour had a value of 4 with a chroma of 2 or less and the soil structure was sub angular blocky. In addition, it had more clay content than the horizons below or above it. Based on these properties, P1 was classified as Typic Humustepts, fine, isohyperthermic.

P2, located on a slope of 15%, is represented by the ochric epipedon with a 5 cm thickness and a candic horizon. In this pedon there was an increase in the percentage of clay in the fine soil fraction with a depth of 15 cm or less in the vertical distance.

Table 4. Soil classification in the Bulia micro watershed

Pedon	Soil Classification					Area	
	Order	**Sub Order**	**Great Group**	**Sub Group**	**Family**	**ha**	**%**
P1	Inceptisol	Ustept	Humustepts	Typic Humustepts	Fine, isohypertermic, Typic Humustepts	596.88	8.53
P2	Entisol	Psamment	Ustipsamme nts	Typic Ustipsamments	Sandy, isohypertermic, Typic Ustipsamments	472.68	6.76
P3	Inceptisol	Ustept	Humustepts	Oxic Humustepts	Fine loamy, isohypertermic, Oxic Humustepts	2,297.78	32.86
P4	Mollisol	Ustoll	Argiustolls	Typic Argiudolls	Fine, isohypertermic, Typic Argiustolls	107.35	1.54
P5	Alfisol	Ustalf	Paleustalfs	Typic Paleustalfs	Fine loamy, isohypertermic, Typic Paleustalfs	1,066.95	15.26
P6	Mollisol	Ustoll	Haplustolls	Typic Haplustolls	Coarse loamy, isohypertermic, Typic Haplustolls	1,026.23	14.67

Pedon	**Soil Classification**					**Area**	
	Order	**Sub Order**	**Great Group**	**Sub Group**	**Family**	**ha**	**%**
P7	Inceptisol	Ustept	Humustepts	Typic Humustepts	Fine, isohypertermic, Typic Humustepts	248.4	3.55
P8	Alfisol	Ustalf	Paleustalfs	Ultic Paleustalfs	Fine loamy, isohypertermic, Ultic Paleustalfs	61.87	0.88
P9	Mollisol	Ustoll	Paleustolls	Typic Paleustolls	Fine loamy, isohypertermic, Typic Paleustolls	48.35	0.69
P10	Alfisol	Ustalf	Haplustalfs	Inceptic Haplustalfs	Fine, isohypertermic, Inceptic Haplustalfs	1,066.95	15.26
Total						6,993.44	100.00

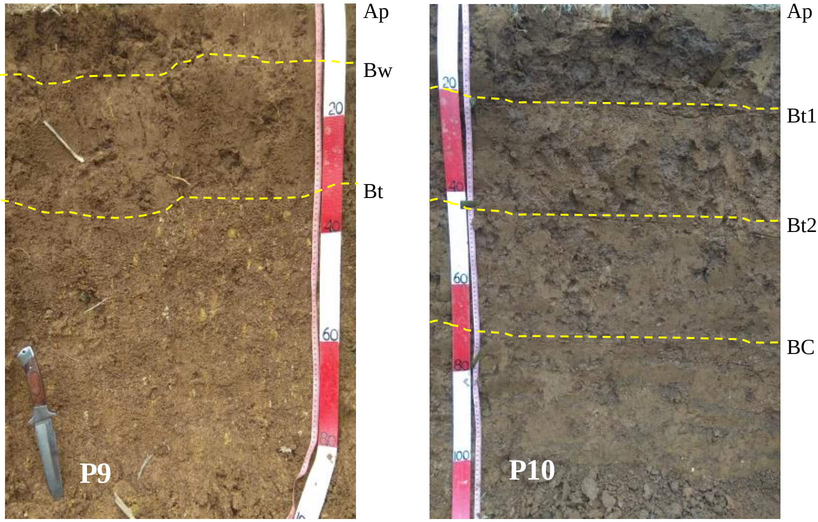


Fig. 4. Soil profile appearance of pedon 9 (P9), and pedon 10 (P10

The clay content was 4% or more (absolute value), which is more than that of the horizon above it, which has a total clay content in the soil fine fraction less than 20%. In addition, it had a loamy sand texture (psamments) and a CEC value (NH_4OAc, pH 7) > 16 cmol(p+)kg^{-1}. Based on these characteristics, P2 was classified as Typic Ustipsamments, sandy, isohyperthermic.

P3 is located on a slope of 1%, represented by the umbric epipedon with a 14 cm thickness and a cambic horizon. This pedon did not experience aquatic conditions at the depth of 50 cm from the soil surface (humustept), the soil colour had a value of 4 with a chroma of 2 or less and the soil structure is sub angular blocky. In addition, it had more clay content than the horizons below or above and its CEC (NH_4OAc 1N) value was 17.96 cmol(+)kg^{-1} only (oxic). Based on these properties, P3 was classified as Oxic Humustepts, fine loamy, isohyperthermic.

P4 is located on a slope of 15%, represented by the molic epipedon (BS 55%) with a 14 cm thickness and an argillic horizon. This pedon had a fine loamy class of particle size with a typical clay coating of the pore walls and the ped surface. In addition, there was 13% (> 8%) of clay on the eluvial horizon and 10YR hue with a chroma ≤ 3, and BS > 75%. Based on these properties, P4 was classified as Typic Argiustolls, fine loamy, isohyperthermic.

P5 is located on a slope of 3%, represented by the ochric epipedon with a 21 cm thickness and an argillic horizon. According to the particle-size classification, this pedon belongs to the fine loam and clay class with an argillic horizon thickness of 25 cm (> 7.5 cm), it also has a typical clay coating of the pore walls and the ped (aggregate) surface. In addition, the clay content in the argillic horizon is 64% or it contains 2.03 times more clay than the eluvial horizon, which was only 34%, and 7.5 YR was typical of all horizons (paleustalf). Based on these properties, P5 was classified as Typic Paleustalfs, fine loamy, isohyperthermic.

P6 is located on a slope of 3%, represented by the molic epipedon (BS 93%) with a 12 cm thickness and a cambic horizon. This pedon had a sandy clay texture and does not have the combination of aquic conditions within 50 cm of the soil surface or artificial drainage (ustoll). The colour value was with a chroma < 6 and it had a sub angular blocky soil structure. In addition, it had more clay content than the below horizons. Based on these properties, P6 was classified as Typic Haplustolls, coarse loamy, isohyperthermic.

P8 is located on a slope of 5%, represented by the molic epipedon with a 7 cm thickness and an argillic horizon. According to the particle-size classification, this pedon belongs to the fine loam and fine clay class with an argillic horizon thickness of 20 cm (> 7.5 cm), also it has a typical clay coating of the pore walls and the ped surface. In addition, the clay content in the argillic horizon is 69% or it contains 2.65 times more clay than the eluvial horizon, which was only 26%, and 7.5YR hue was typical in all horizons (paleustalf), with BS of 61% or > 75% only (ultic). Based on these properties, P8 was classified as Ultic Paleustalfs, fine loamy, isohyperthermic.

P9 is located on an 8% slope, represented by the molic epipedon (BS 53%) with a 7 cm thickness and an argillic horizon. According to the particle-size classification, this pedon belongs to the fine loam class with an argillic horizon thickness of 18 cm (> 7.5 cm), it also has a typical clay coating of the pore walls and the ped surface. In addition, the clay content in the argillic horizon is 69% or it contains 4.60 times more clay than the eluvial horizon, which was only 18%, and 7.5YR hue with a chroma of ≤ 4, and BS of < 75% of all horizons (paleustoll). Based on these properties, P9 was classified as Typic Paleustolls, fine loamy, isohyperthermic.

P10 is located on a slope of 15%, represented by the molic epipedon (BS 57%, 50%) with a 23 cm thickness and an argillic horizon. According to the particle-size classification, this pedon belongs to the fine loam and fine clay class with an argillic horizon thickness of 24 cm (> 7.5 cm), it also has a typical clay coating of the pore walls and the ped surface. In addition, the clay content in the argillic horizon is 88% or it contains 3.38 times more clay than the eluvial horizon, which was only 24%, and 10YR hue with a chroma of ≤ 3, and BS > 75%. Based on these properties, P10 was classified as Inceptic Haplustalfs, fine, isohyperthermic.

Land quality classes

The land quality (LQ) of the Bulia micro watershed was presented in Table 5 and Figure 5. The LQ of class II with the main factor determining the land stress was high temperature and low organic matter. The high temperature factor with an isohyperthermic soil temperature regime as an indicator was found on LU 3 (P3), while the low organic matter factor with an ochric epipedon indicator was only on LU 5 (P5). The LQ of class II is determined as good and this land has few problems for sustainable production, its productivity is generally very high and as a result, the response to management is high (Beinroth et al., 2001). Land management through the addition of organic matter, including green manure, may be adopted along with the recommended fertilizer doses (Sys et al., 1991; Singh et al., 2004; Mahaputra et al., 2019) and mulching to stabilize temperatures and maintain soil moisture (Odjugo, 2008; Eruola et al., 2012; Damaiyanti et al., 2013), which is of great importance. In addition, the use of rice straw mulch and sawdust mulch influences soil properties by decreasing the value of bulk density, increasing soil porosity and soil organic matter (Nasruddin, Hanum, 2015).

Table 5. Land quality classes in the Bulia micro watershed

Land Unit	Land Quality		Land Quality Class	Area	
	Major Land Stress Factor	Determinant of Land Stress		ha	%
3	High temperatures	Isohyperthermic of soil temperature regime	II	2,297.78	32.86
5	Low organic matter	Ochric epipedon	II	1,066.95	15.26
1, 6, 7	Seasonal water excess	Recent terraces	III	1,871.51	26.76
2	Low structural stability and/or crusting	Entisols	IV	472.68	6.76
4	Low structural stability and/or crusting	Clay soils	IV	107.35	1.54
8, 9, 10	Low water holding capacity	Sandy clay loam	VI	1177.17	16.83
Total				3,628.71	51.89

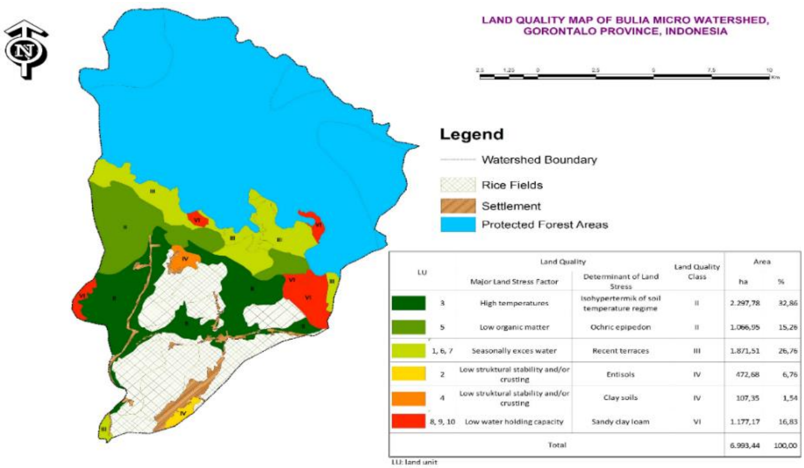


Fig. 5. Land quality map of the Bulia micro watershed.

The LQ of class III with the main factor determining the land stress was a seasonal excess of water. The indicators determining the land stress in class III were new terraces spread over LU 1 (P1), LU 6 (P6) and LU 7 (P7). These new terraces are generally located around the border or river meanders which were prone to erosion and river bank landslides. The LQ of land class III was still considered good and this land has few problems for sustainable production, but has the higher risk of low input of corn production specifically, which results in a response to high management (Beinroth et al., 2001). The land management through the manufacture of gabions and riverbanks (Rahman, 2013), planting river bank reinforcement plants and terraces (Suyana et al., 2017) was of great importance. Bioengineering methods for river bank erosion control commonly used include planting bamboo (Noor et al., 2011). Fine plant roots play a significant role in increasing the shear strength of the soil (Ludwig et al., 2007). The effectiveness of plants in reducing erosion rate is influenced by (1) the canopy or plant canopy, (2) the organic material produced, (3) the root system and the ability of plants to cover the soil (Rachman et al., 2004). Vetiver plants were useful for stabilizing river banks, irrigation canals, river erosion control and coastal embankments, excavation slopes and embankments on highways, sand dunes, erosion on sloped agricultural land (Noor et al., 2011). Vetiver grass, which has strong fibrous roots, holds the ground (Susilawati, Veronika, 2016). Soil nailing was one of the most economical techniques for slopes stabilization of retaining walls because the system works quickly and does not require large space (Sinarta, 2014; Noor et al., 2011).

The LQ of class IV with the main factors determining land stress was low structural stability and/or crusting. These main factors consist of two indicators, namely clay soil and Entisol. The indicator of heavy clay (> 50%) was scattered in LU 4 (P4). This indicator of clay soil was related to soil crusting which was shown by the average sub angular blocky soil structure, and the soil consistency under wet conditions was very sticky and very plastic, while it was very hard under dry conditions. Clay and organic matter are binding agents for aggregates (Rachim, 2007). Apparently, the influence of clay is more dominant than of organic matter as an aggregate binding agent because the OC content was very low. The Entisol indicators were spread on LU 2 (P2) only. Entisol is a soil that is still young and underdeveloped (Rachim, 2007). The results of the morphological analysis of the soil indicated that this Entisol has a granular structure (not solid), fine sized with a weak level of development, therefore the stability was relatively low. In addition, the texture of Entisol was classified as loamy sand with the sand of particle size which makes the soil structure stability relatively low. This class requires major inputs from conservation management; since a lack of plant nutrition is a major obstacle, therefore a plan to use good fertilizers should be adopted (Beinroth et al., 2001). Land management through the addition of organic matter can be applied together with recommended fertilizer doses (Sys et al., 1991; Singh et al., 2004; Mahaputra et al., 2019). Provision of organic matter in soils with clay texture can increase soil water content and available water capacity and reduce soil volume weight (Intara et al., 2011), increase soil porosity (Anastasia et al., 2014), increase N, P, and K uptake and crop yields in Entisol soils (Afandi et al., 2015). Addition of manure, compost and beneficial bacteria technology (custom bio) can reduce soil content weight, soil density, increase aggregate stability, soil porosity and moisture content in Entisol soil (Zulkarnain et al., 2013).

The LQ of class VI with the main factor determining the land stress was low water holding capacity. The indicators of the sandy clay loam texture were spread on LU 8 (P8), LU 9 (P9) and LU 10 (P10). The value of water available on the sandy clay loam texture was only around 20.42 mm (Haridjaja et al., 2013). The available water (pF) under conditions of field capacity (pF 2.0) on LU 8, 9 and LU 10 was indicated as 34 mm, 38 mm, and 37 mm respectively, and at permanent wilting conditions (pF 4.2) 24 mm, 17 mm and only 19 mm respectively, therefore, causing a low water holding capacity. This land should not be used for food production (i. e. corn) because this class requires major inputs from conservation management; since a lack of plant nutrition is a major obstacle, therefore a plan to use good fertilizers should be adopted or this land can be used as a biodiversity zone (Beinroth et al., 2001). However, if this land is used for agricultural cultivation, then the land management should consider the addition of organic matter along with the recommended fertilizer dosage (Sys et al., 1991; Singh et al., 2004; Mahaputra et al., 2019). Provision of organic material in soils with clay texture can increase soil water content and available water capacity and reduce soil volume weight (Intara et al., 2011), increase soil porosity (Anastasia et al., 2014).

CONCLUSIONS

Angular blocky, sticky, plastic consistencies, and hard consistencies prevailed in the soil structure of the Bulia micro watershed of Gorontalo Province, Indonesia. In the alluvial plain, a sand fraction prevailed in Volkan mountains. The soils in the Bulia micro watershed also react acid to neutral, with the range of very low to high OC levels, the reserve of exchangeable bases was dominated by Ca^{2+} in two series patterns, namely: $Ca^{2+} > Mg^{+} > Na^{+} > K^{+}$ and $Ca^{2+} > Na^{+} > Mg^{+} > K^{+}$, CEC ranged from low to very high, and the base saturation varied from moderate to very high. The primary soils found were Entisol on P2 (Typic Ustipsamments), Inceptisol on P1 and P7 (Typic Humustepts), and P3 (Oxic Humustepts), Mollisol on P4 (Typic Argiudolls), P6 (Typic Haplustolls), and P9 (Typic Paleustolls), and Alfisol on P5 (Typic Paleustalfs), P8 (Ultic Paleustalfs) and P10 (Inceptic Haplustalfs). On the alluvial plains the land was categorized as the LQ class II, III and IV, the volcanic mountains were the LQ class IV, while the land on the volcanic hills was categorized as the LQ class VI. River bank erosion on the land river terraces can be held by the manufacture of gabions, talud, cliff reinforcement plants and terraces. The soil temperatures and high clay content can be regulated by mulching and organic materials.

REFERENCES

1. Afandi F.N., Siswanto B., Nuraini Y., Effect of giving various types of organic material on soil chemical properties on the growth and production of sweet potato plants in Entisol Ngrangkah Pawon, Kediri, *Soil and Land Resources*, 2015, Vol. 2(2), pp. 237–244, URL: http://jtsl.ub.ac.id.
2. Anastasia I., Izatti M., Suedy S.W.A., The effect of giving a combination of solid organic fertilizer and liquid organic on soil porosity and spinach plant growth (*Amarantus tricolor* L.), *Biology Journal*, 2014, Vol. 3(2), pp. 1–10.
3. Beinroth F.H., Eswaran H., Reich P.F., Global assessment of land quality, sustaining the global farm, *Selected papers from the 10th International Soil Conservation Organization Meeting*, 2001, pp. 569–574.
4. BPS Gorontalo Province, *Gorontalo province in figure 2020*, BPS

Gorontalo Province, 2020, 1102001.75(75560.2004), pp. 1–535.
5. BPS Gorontalo Regency, Gorontalo regency in figure 2020, BPS Gorontalo Regency, 2020, 1102001.75(75020.2003), pp. 1–262.
6. Dutta M., *Land use planning of Tipukjan watershed of Sivasagar district using GIS and remote sensing technique: Ph.D. Thesis*, Assam Agricultural University, Jorhat, 2009.
7. Damaiyanti D.R.R., Aini N., Koesrihati, The study of organic mulch application on the growth and yield of red pepper (*Capsicum annuum* L.), *Crop Production Journal*, 2013, Vol. 1(2), pp. 25–32.
8. Devi P.A.V., Naidu M.V.S., Rao A.R., Characterization and classification of sugarcane growing soils in southern agro-climatic zone: A case study in eastern mandals of Chittoor district in Andhra Pradesh, *Journal of the Indian Society of Soil Science*, 2015, Vol. 63(3), pp. 245–258, DOI: 10.5958/0974-0228.2015.00034.1.
9. Eruola A.O., Bello N.J., Ufoegbune G.C., Makinde A.A., Effect of mulching on soil temperature and moisture regime on emergence, growth and yield of white yam in a tropical wet-and-dry climate, *International Journal of Agriculture and Forestry*, 2012, Vol. 2(1), pp. 93–100, DOI: 10.5923/j.ijaf.20120201.15.
10. Eviyati, Sulaeman, Analysis of soil, chemical, plants, water, and fertilizer, *Indonesia Centre of Soil Research*, 2009, pp. 1–203.
11. Husain J., Luntungan J.N., Kamagi Y.E.B., Nurdin B., Conservation-based corn farming model in Gorontalo Province. Research Report. *Research, Development and Regional Environmental Impact Control Agency Gorontalo Province*, Gorontalo, 2004.
12. Haridjaja O., Baskoro D.P.T., Setianingsih M., Different levels of field capacity by alhricks, free drainage, and pressure plate methods at different soil texture and relation for sunflower growth (*Helianthus annuus* L.), *Soil Science and Environmental Journal*, 2013, Vol. 15(2), 52 p, DOI: 10.29244/jitl.15.2.52-59.
13. Intara Y.I., Sapei A., Sembiring E.N., Djoefrie M.H.B., Affected of organic matter application at clay and clay loam soil texture on water holding capacity, *Indonesian Agriculture Sciences Journal*, 2011, Vol. 16(2), pp. 130–135.
14. Jambak M.K.F.A., Baskoro D.P.T., Wahjunie E.D., Characteristics of soil physic on soil conservation tillage system (Case study of Cikabayan Research Farm, Bogor), *Soil and Land Bulletin*, 2017, Vol. 1(1), pp. 44–50.
15. Jackson M.L., *Soil chemical analysis*, New Delhi: Prentice Hall of India (Pvt.) Ltd., 1973, 498 p.
16. Kadao S.H., Prasad J., Gajbhlye K.S., Characterization and classification of some typical banana growing soils of Wardha district of Maharashtra,

Agropedology, 2003, Vol. 13(2), pp. 28–34.
17. Ludwig A., Bradford P., David B., Anton W., Vegetation patches and runoff-erosion as interacting ecohydrological processes in semiarid landscapes, *Ecology*, 2007, Vol. 86, pp. 288–297, DOI: 10.1890/03-0569.
18. Mahapatra S.K., Nagdev R., Gopal R., Surya J.N., Meena R.K., Yadav R.P., Singh S.K., Characterization and classification of the soils of Buraka micro-watershed in Haryana for integrated development, *Journal of the Indian Society of Soil Science*, 2019, Vol. 67(2), pp. 137–150, DOI: 10.5958/0974-0228.2019.00015.X.
19. Manik H., Marpaung P., Sabrina T., The level of soil development based on the pattern of clay mineral distribution in Subdistric Lumbanjulu, Distric of Toba Samosir, *Agroteknologi FP USU*, 2017, Vol. 5(2), pp. 422–433.
20. Nasruddin, Hanum H., Study of mulching effects on soil temperature, soil property, and growth of patchouli (*Pogostemon cablin* Benth), *Floratek*, 2015, Vol. 10, pp. 69–78.
21. Noor A., Vahlevi J., Fathurrozi., Slope stabilization for erosion control with soil bioengineering using vetiver grass, *Poros Teknik*, 2011, Vol. 3(2), pp. 69–74.
22. Nurdin, *Development, classification and rainfed paddy soils potency derived from lacustrine materials in paguyaman, gorontalo*. MSc Thesis Bogor Agriculture University, 2010a. URL: https://repository.ipb.ac.id/handle/123456789/57081.
23. Nurdin, The morfology, physics and soil chemistry of inceptisol derived from lacustrine paguyaman of gorontalo relating to soil managements, *Jurnal Agroteknotropika*, 2010b, Vol. 1(1), pp. 13–22.
24. Nurdin, Development and rainfed paddy soils potency derived from lacustrine material in paguyaman, Gorontalo, *J. Trop. Soils*, 2011, Vol. 16(3), pp. 267–278, DOI: 10.5400/jts.2011.16.3.267.
25. Nurdin, Combination of soil conservation techniques and its effect on the yield of maize and soil erosion of dry land in biyonga sub-watershed, Gorontalo, *J. Tek. Ling*., 2012, Vol. 13(2), pp. 245–252.
26. Odjugo P.A.O., The effect of tillage systems and mulching on soil microclimate, growth and yield of yellow yam (*Dioscorea cayenensis*) in Midwestern Nigeria, *African Journal of Biotechnology*, 2008, Vol. 7(24), pp. 4500–4507, DOI: 10.4314/ajb.v7i24.59629.
27. Oldeman L.R., Darmiyati S., *An agroclimatic map of Sulawesi scale 1 - 2.500.000*, Center Research for Agriculture, 1977, p. 1.
28. Puslitanak Research Team, *Survey and mapping of semi-detailed soil resources (scale 1 : 50,000) in the North Sulawesi of Paguyaman area for the development of irrigation and sugarcane commodities*. Final report. Book III Attachment of the Land Series. Center for Soil and Agro-climate Research,

Agency for Agricultural Research and Development, Indonesian Ministry of Agriculture, Bogor, 1995.
29. Prasetyo B.H., Differentiation in Properties of vertisol from various parent materials, *Indonesian Agriculture Sciences Journal*, 2007, Vol. 9(1), pp. 20–31.
30. Rachman A., Gantzer J., Anderson S.H., Soil hydraulic properties influenced by stiff-stemmed grass hedge systems, *Soil Science Society of America Journal*, 2004, Vol. 68(4), pp. 1386–1393, DOI: 10.2136/sssaj2004.1386.
31. Rahman A., Geographic information system model for estimating flow coefficient and its relationship with land cover in Riam Kanan River Basin of South Kalimantan Province, *Bumi Lestari*, 2013, Vol. 13(1), p. 1–8.
32. Sys C., Rast E.V., Debaveye J., *Land evaluation*. Part II. Principles in land evaluation and crop production calculations. International Training Centre for Post-Graduate Soil Scientists, University of Ghent, 1991.
33. Sarkar D., Gangipodhyay S.K., Velayutham M., Soil toposequence relationship and classification in lower outlier of Chhotanagpur plateau, *Agropedology*, 2001, Vol. 11, pp. 29–36.
34. Swarnam T.P., Velmurugan A., Rao Y.S., Characterization and classification of some soils from Shahibi basin in parts of Haryana and Delhi, *Agropedology*, 2004, Vol. 14, p. 114–122.
35. Singh C., Singh P., Singh R., *Modern techniques of raising field crops*, New Delhi: Oxford and IBH Publishing Co. Pvt. Ltd., 2004, pp. 1–583.
36. Satish S., Naidu M.V.S., Ramana K.V., Munaswamy V., Reddy G.P., Sudhakar P., Characterization and classification of the soils of Brahmanakotkur watershed in Kurnool district of Andhra Pradesh', *Journal of the Indian Society of Soil Science*, 2018, Vol. 66(4), pp. 351–361, DOI: 10.5958/0974-0228.2018.00044.0.
37. Sinarta I., Methods of handling landslides with soil nailing', *Paduraksa*, 2014, Vol. 3(2), pp. 1–16.
38. Sireesha P.V.G., Naidu M.V.S., Clay mineralogy of soils developed from granite-gneiss of Kurnool District in Andhra Pradesh', *Journal of the Indian Society of Soil Science*, 2015, Vol. 63(1), pp. 16–23, DOI: 10.5958/0974-0228.2015.00003.1.
39. *Soil survey manual*, Soil Science Division Staff, United States Department of Agriculture (USDA), 2017, pp. 1–145, URL: https://www.iec.cat/mapasols/DocuInteres/PDF/Llibre50.pdf.
40. Keys to soil taxonomy, Soil Survey Staff, Soil Conservation Service – NRCS/USDA, 2014, Vol. 12, 360 p.
41. Subardja D., Sudarsono, The influence of land quality on productivity of maize in soils derived from volcanic and sedimentary rocks in the bogor area,

Soil and Climate Journal, 2005, Vol. 23, pp. 38–46.
42. Suharta N., The characteristic of soil developed from felsic sediments in west kalimantan province and its implication to land management, *Soil and Climate Journal*, 2007, Vol. 25, pp. 11–26.
43. Sukarman S.R., Anda M., Suryani E., *Guidelines for soil observation in the field*, Agricultural Research and Development Agency, Ministry of Agriculture Republic of Indonesia, Bogor, 2017, pp. 1–149.
44. Supriya K., Naidu M.V.S., Kavitha P., Srinivasa M.R., Characterization, classification and evaluation of soils in semi-arid region of Mahanandi Mandal in Kurnool district of Andhra Pradesh', *Journal of the Indian Society of Soil Science*, 2019, Vol. 67(2), pp. 125–136, DOI: 10.5958/0974-0228.2019.00014.8.
45. Susilawati S., Veronika V., Vetiver grass study as a continuous slope safety, *Civil Engineering Communication Media*, 2016, Vol. 22(2), p. 99, DOI: 10.14710/mkts.v22i2.12886.
46. Suyana J., Sumarno, Supriyono, Lestariningsih N.P., Mulching and strengthening of terraces in three types of plants against surface runoff, erosion, growth and yield of plants in Andisols, *Agrosains*, 2017, Vol. 19(1), p. 15, DOI: 10.20961/agsjpa.v19i1.20924.
47. Vedadri U., Naidu M.V.S., Characterization, classification and evaluation of soils in semi-arid ecosystem of Chillakur mandal in SPSR Nellore district of Andhra Pradesh, *Journal of the Indian Society of Soil Science*, 2018, Vol. 66 (1), pp. 9–19, DOI: 10.5958/0974-0228.2018.00002.6.
48. Walia C.S., Rao Y.S., Characteristics and classification of some soils of Trans-Yamuna plains, *Journal of the Indian Society of Soil Science*, 1997, Vol. 45(1), pp. 156–162.
49. Yasin M.G.H., Langgi W.F., White grain maize as an alternative for staple food, *Iptek Tanaman Pangan*, 2015, Vol. 9(2), pp. 108–117.
50. Yatno E., Mulyanto B., Characteristics of soils formed from schist and their land suitability for cocoa crop in Kolaka and East Kolaka Regencies, Southeast Sulawesi, *Soil and Climate Journal*, 2016, Vol. 39(2), pp. 109–118.
51. Zulkarnain M., Prasetya B., Soemarno, Effects of compost, manure, and custom-bio on soil properties, growth and yield of sugarcane (*Saccharum officinarum* L.) in Entisol Kebun Ngrangkah of Pawon, Kediri, *Indonesian Green Technology Journal*, 2013, Vol. 2(1), pp. 45–52, URL: https://igtj.ub.ac.id/index.php/igtj/article/view/103.