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Soil Variability and Sugarcane (*Saccharum officinarum L.*) Biomass along Ultisol Toposequences

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ABSTRACT
Uniforming sugarcane management without any knowledge of soil variability could result in some parts of a sugarcane field receiving insufficient inputs, while other parts receive an excessive input. The research aimed at assessing the soil variability and sugarcane biomass along Ultisol toposequences in Central Lampung, Indonesia. Two sugarcane catenas and one forest catena were fully described in the fields. Soil horizons are represented by Ap/Ah/M, E, B, Cc and Cg with dominant clay translocation. The gleying symptom was found only in the lower slope to depression. The concretion depths can be used as an erosion indicator if the soil parent material is well characterized. Soil P has a maximum value of Ap horizon and decreases with the depth and no effect of internal erosion in the form of soil P accumulation in subsoils can be observed, except for the colluviated horizon. Kaolinite clay is dominantly found to buffer the changes in pH, except Ap horizon of sugarcane. The organic C depends on the pedogenesis and catena form. Al saturation indicates that the dominant soil weathering is intensive. Al saturation in the Ap horizon (Catena G1; G2) was reduced from 80% to 20–40% caused by liming and fertilization. The catena position was the main factor causing the increasing soil variability, which was responsible for the variability of sugarcane biomass. The sugarcane biomass increased with decreasing slopes. The highest biomass was found in the depression (105 tones/ha) if the sedimentation process is characterized by the formation horizon M and accompanied by the nutrient accumulation from the hilltops.

Keywords: soil variability, sugarcane, biomass, toposequences

INTRODUCTION

The often neglected problem in the sugarcane management in Indonesia is the inability to assess the soil variability associated with managing the productivity of sugarcane production, e.g. land suitability for sugarcane (Armanto *et al.,* 2013; 2017). This implies that the sugarcane productivity depends not only on the conventional way of fertilization, where the fertilizer is evenly distributed for the entire landscape, regardless of the level of soil variability. It impacts the imbalance of soil management (Armanto, 2019), less efficient due to low sugarcane production, high production costs, and land management practices which are not aligned with soil variability (Lofton *et al.,* 2012; Armanto and Wildayana, 2016). Thus, to overcome this problem, it is necessary to assess the soil variability that can be considered as one of the important production factors (Kišš *et al.,* 2019; Hamuna *et al.,* 2019; Jakubis and Jakubisová, 2019), capable of reducing the whole sugarcane production (Dietrich *et al.,* 2017).

The development of sugarcane plantations demands concept application of precise agriculture (precise farming), namely precision of location (Martins *et al.,* 2018; Baranowska *et al.,* 2019), dose, time, data and information as well as technology (Carvalho *et al.,* 2018; Wildayana *et al.,* 2016). Such precise agriculture will lead to the management system based on technology and needed information, which is capable of identifying, analyzing, and site-specific managing of temporal and spatial soil variability, thus the optimal sugarcane productivity can be achieved, which is beneficial, sustainable (Wildayana and Armanto, 2018; Rybak *et al.,* 2019; Kaleta *et al.,* 2019) and does not pollute the environment due to input and agricultural machinery (Li, 2018; Guzeeva, 2019). This concept will be able to identify the level of soil suitability to sugarcane, status of soil fertility, and other soil and water quality parameters (rooting condition, soil acidity, oxygen and water availability, retention and buffering capability as well as topography). The concept ensures that soil variability and sugarcane species can be properly managed to achieve the optimal production based on soil variability and location-specific resources (Zuhdi *et al.,* 2019; Zahri *et al.,* 2018; Šimanský *et al.,* 2019; Paul *et al.,* 2015).

Precise agriculture generally includes three major management components. Firstly, all data and information on productivity and potential trigger factors are collected. Secondly all data and information have to be analyzed to determine whether the sugarcane production is mainly determined by the considered factors. If so, it is thus necessary to take corrective actions. Thirdly, the action selections are done by ensuring that the improved treatments are carried out at the appropriate location and levels in the fields (Aviron *et al.,* 2016; Cunningham *et al.,* 2017; Ferreira *et al.,* 2018).

Precise agricultural applications require analyzing the level of biogeophysical biological variability, both horizontally and vertically. To date, there are very few literature studies that discuss the analysis of soil variability with the productivity of sugarcane in tropical lands. Therefore, various farmers and researchers are always motivated to determine the sugarcane response to the provision of various agricultural inputs (Montanari *et al.,* 2012; Mulyono *et al.,* 2019; Operacz *et al.,* 2019).

The dominant soil variability will determine the sugarcane productivity, including organic matter content, structure, texture, pH, basic saturation, cation exchange capacity (CEC), rainfall and water holding capacity, and other soil properties. Mostly, soil variability at the local level is often caused by small changes in topography that affect the transport, washing and water holding capacity, both vertically and horizontally and in soil profiles.

Uniform soil management, regardless of soil variability can cause some parts of sugarcane fields to receive insufficient input, while others receive excessive agricultural input. Understanding soil variability is critical in implementing site-specific management strategies (precise agriculture). If the cause of such soil variability is accessible or manageable, then the correct decision can be made regarding the type of sugarcane that must be managed, the time to process, and the agricultural input management practices required by sugarcane. The research aimed at assessing soil variability and sugarcane biomass along Ultisol toposequences.

MATERIALS AND METHODS

The research site is located in Central Lampung, around 95 km north of Bandar Lampung Indonesia. The territory stretches from 4°35'-4°50' South Latitude and from 105°-105°30' East Longitude. The study area is located at elevation range of around 5–41 m above sea level. Because of erosion and soil denudation, the slopes are partially leveled. The slope is found around 3–25% with the average value of about 10% (Figure 1 and Figure 2).

The research site is divided into five divisions with the total area of 22,000 ha (around 4,000 ha for each division). The study area lies in Division III and has been cultivated with a monoculture of sugarcane for almost 42 years. The sugarcane is planted as cuttings, is harvested after 8 to 9 months and grows again as ratoon. This system runs through 4 cycles of ratoons (about

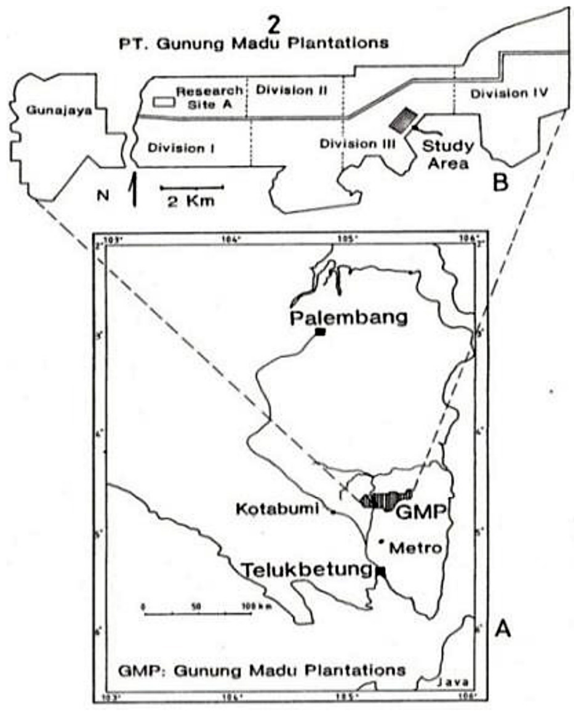


Figure 1. Research site

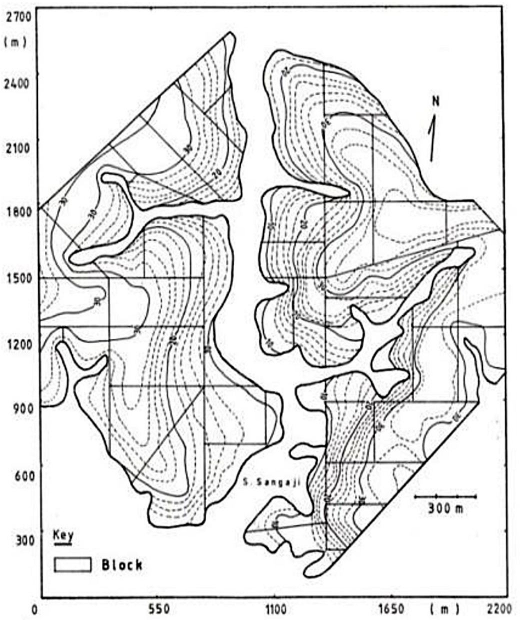


Figure 2. Topographical map

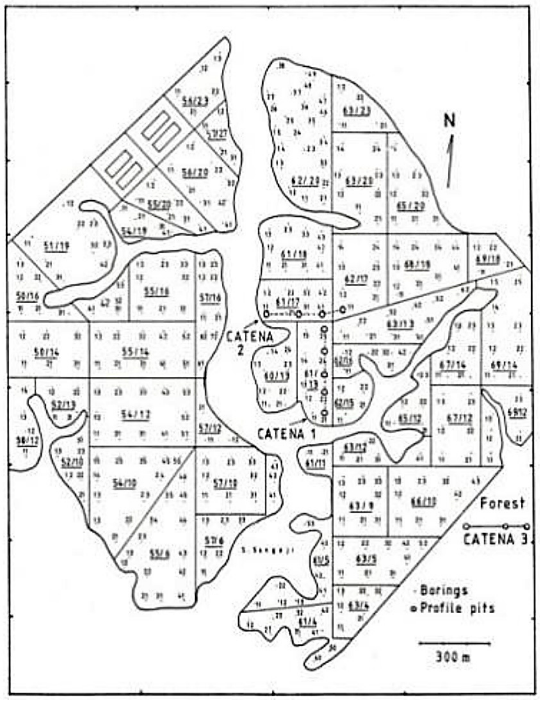


Figure 3. Soil sampling

4 years). Due to intensive management, including a high P-fertilization level (100 kg P/ha·a) and scientific production control, the sugarcane plantation gains a high productivity level even on unfavorable soils.

Soil Sampling Scheme

The soil sampling scheme was performed by soil pits and borings and the intensity of soil sampling is presented in Figure 3. The used maps have scales of 1:5,000 and the survey type was intensively detailed. Remote sensing images help to characterize the boundaries of soil variability on the maps. Most of the considered soils are classified as Ultisols (Soil Survey Staff, 2014).

The selected research locations have soil parent materials of volcanic tuffs. The intensities of soil descriptions were taken from soil pits and soil borings in two phases, namely overall sampling and catenas (Table 1). The overall sampling was done according to the geomorphology of the area. The soil sampling was collected by auger borings at each depth of 15 cm (at depth of 0–15 cm; 20–35 cm; 40–75 cm; and 90–150 cm (around 1,800 soil samples). Due to the high density of the sugarcane canopy and difficulties with the technical field's survey, the soil sampling was done only 20–40 m from the roads. Three catenas with 12 profile descriptions (2 catenas under the sugarcane and 1 catena under the forest) were taken and described (60 soil samples).

Soil Field Descriptions and Analytical Methods

During the field works, the soil descriptions were carried out for 360 profiles in an extended survey area and 12 profiles in the catenas. The field descriptions of pits, borings and landscapes were described generally, including general field description, specific descriptions, soil classification and GPS position.

The major horizons were identified using capital letters indicating master horizons and lower case letters qualifying as suffixes of the master horizons. A combination of capital letters is used for transitional horizons. The moist soil colors and mottles (abundance and size of mottles) were described using standard color notations in the Munsell Soil Color Charts. Concretions depth was determined in the fields by observations of the augering profile. The roots amount was calculated in dm^2. All soil composite samples were collected for soil analyses in laboratory (soil pH, total N, organic Carbon, CEC, base saturation, available P, total P, Exchangeable Al, Al saturation).

Table 1. Intensity of soil sampling schemes

Sampling kind	Σ Borings/pits	Σ Samples
Overall (around 1 boring/ha)	360*	1,800
Catenas (3–5 profiles/ catena)	12	60

Note: * each profile with 5–6 soil samples.

RESULTS AND DISCUSSION

The research results will be discussed in several important aspects, namely catena, selected soil profiles and soil horizons; depth of concretions layers; description of soil characters; and variability of sugarcane biomass.

Catena, Selected Soil Profiles and Soil Horizons

The landscape is represented by three catenas within Division III, which were all classified as very long in slope length and as clay loams in texture. In order to clarify the sketch visualization of catena, the elevation scale comparison was magnified five times higher than the actual elevation scale (Figure 4), while the catena character, forms, processes and pedogenesis dominant soil horizons were summarized in Table 2.

There are five horizons found in the research site, namely the horizons of Ap; E; B; Cc; and Cg; however, the "C-horizons" are deeply weathered too. The clay translocation is relatively dominant, although the B horizons are not indexed by special character (pointed by a t). Commonly, the soils are relatively well-drained at hilltops and poorly-drained in lower position or depression areas. Most horizons showed highly leached as indicated by thick E-horizons that are dominantly from hilltops to lower positions, also at the steep lower slope of Catena G3. The gleying phenomenon did not occur at the sites from hilltop to middle slopes; they are represented by A-B-Cc or A-E-B-Cc horizon combinations. At lower slopes to depressions, soils are characterized by gleying (Bg/Cg-horizons), but this phenomenon is well expressed for Catena G1 only, and fair to weakly developed for Catena G2 and G3.

The Catena G1 with 5 profiles lies in Block 61/13: with a complex relief form and a total slope length of 450 m, its steepness varies from 2–5 % at hilltop, 4–6 % in the upper to middle slopes, 8–10 % in the middle to lower slope, 2–5 % at foot slopes and 1–2 % in depression sites. Thus, it can be understood that the profile P1.1, P1.2 and P1.3 have thick E and B horizon due to the intensive erosion and leaching. At profiles P1.4 and P1.5, M horizon is formed as a result of the accumulation process. The argillic horizons are formed in the profiles due to intensive process of vertical leaching and further weathering. Because of the inhibition of surface runoff in the depression area, gleying occurs in the soil development process.

The Catena G2, located in Block 61/17 and Block 62/17 with 4 profiles, is 350 m long, generally steeper (8–10 % from hilltop to depression) and has an elongated convex to concave form of relief. No leveling is found in this catena. Very near to the concave depression, there is a small river (Sungai). Profile P2.1 located at the hilltop with a slope of 5–8%, P2.2 and P2.3 located in the middle and lower slopes, both have 8–10% slope. P2.4 is located at the foot slope with a slope of 3–5%. The Catena form is convex-concave and flat areas are not found in this Catena. These conditions do not allow forms of accumulation (horizon M) because all the eroded material goes directly into the river and was not formed because the water flowed faster into the river. Dominant horizons are A, E, B, and Cc. At Catena 2, it is very difficult to predict how much erosion will

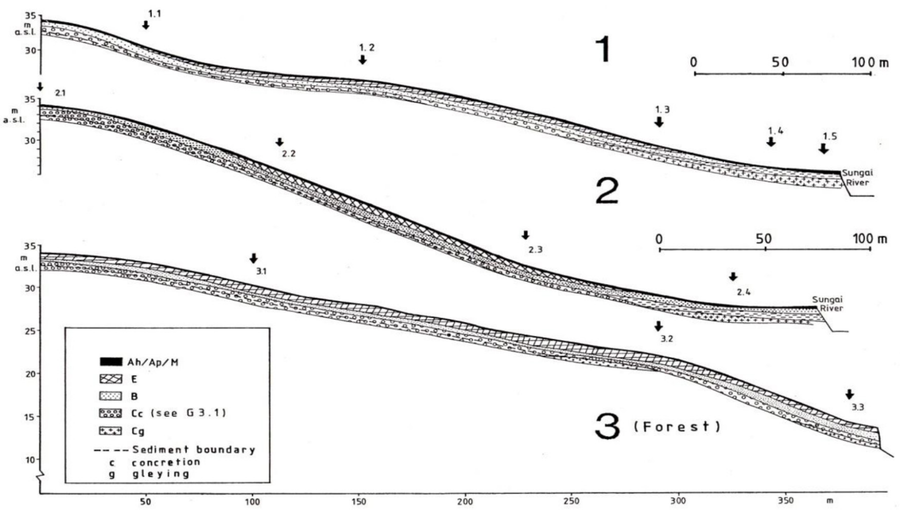


Figure 4. Sketch of the toposequence sampled from hilltop to depression area

Table 2. Catena characters, dominant pedogenesis and soil horizons

Catena Character	Catena Form	Pedogenesis and Dominant soil horizons
Catena 1 (450 m) in Sugarcane plantation	Convex-Concave & Convex-Concave	1) Convex position (Profiles P1.1, P1.2 & P1.3): Horizons A, E, B and Cc, eroded, transported, leached and translocated 2) Flat position (Profile P1.4): Horizon A, E, B & Cc, transported, leached and translocated 3) Concave position (Profile P1.5): Horizon A, M, E, B & Cc, sedimented and translocated
Catena 2 (380 m) in Sugarcane plantation	Convex-Concave	1) Convex position (Profiles P2.1, P2.2 & P2.3): Horizons A, E & B, eroded, transported, leached and translocated 2) Concave position (Profile P2.4): Horizon A, E, Bg & Cg, eroded, transported and translocated
Catena 3 (400 m) in the forest	Convex-concave	1) Convex position (Profiles P3.1 & P3.2): Horizon A, E, B & Cc, leached and translocated 2) Concave position (Profile P3.3): Horizon A, E, B & Cc, leached and translocated

Source: Field survey results (2019).

occur. Landscapes are dominated by such Catena; thus, it will establish an open landscape because more than 90% of eroded material goes directly into the river.

The Catena G3 lies in the secondary forest, has a convex to complex relief form and a slope length of about 400 m with steepness varying between 1–2% (hilltop), 4–6% (middle slope) and 8–12% (foot slope). At the end of Catena G3 there is no river. Theoretically, if sugarcane is cultivated in the Catena, M horizon will be formed at the foot slopes. In fact, on Catena G3, no M horizon is found and character profiles and horizons have the same thickness. This means Catena G3 is stable and erosion can be neglected; therefore, Catena G3 can be utilized as a comparison against the Catena G1 and Catena G2. No gleying formation occurred on Catena G3 because hydrological system is in good condition and is aided by the water cycle in the natural forest vegetation.

Depth of Concretions Layers

The boundary of the younger (quaternary "Lampung tuff") and older (tertiary) volcanic sediments can be used as erosion indicating depth. Since this boundary is difficult to specify exactly, the "concretions depth" was used, which is the upper boundary of concretionary enrichments overlying the tuff boundary. Under forest, this index remained at almost similar depths (80 cm, 79 cm and 83 cm, respectively, see Table 3), but under sugarcane the concretions depths increased down the slope. Thus, the concretions depths under forest can be used as a control to assess the relative profile truncation due to erosion under sugarcane (Figure 4).

On the forest area, the concretions depths were not significantly different and located about the same depth in each profile. However, in the case of sugarcane, the concretions depths were significantly different and increased with decreasing slope. Increasing the concretions depth was significantly different in the depression of Block 60–69 (where Catena G1 was located) because the depression position has thick M horizons (sediment horizon) which buried the previous soil surface. This means that the catena position affects the concretions depth significantly. Therefore, the concretions depths of the forest profile can be used as a control to calculate the thickness of the erosion profile (profile decapitation) due to erosion (Table 3).

Table 3. Average depths of concretions at all research area (cm), N: 355 borings

Catena position	Block 60–69 (Sugarcane)	Block 50–57 (Sugarcane)	Forest area (Uncultivated)
Hilltops	70±27.05[a]	75±35.23[a]	80±26.10[a]
Middle slopes	72±36.14[a]	74±39.28[a]	79±29.85[a]
Lower slopes	96±43.76[b]	95±43.55[b]	77±31.67[a]
Foot slopes	110±48.32[c]	108±52.71[c]	81±37.77[a]
Depressions	125±57.50[d]	110±57.82[c]	83±47.99[a]

Note: Values in the same column and indicated by the similar superscript is not significantly different at the significance level of 5% of T test

Description of Soil Characters

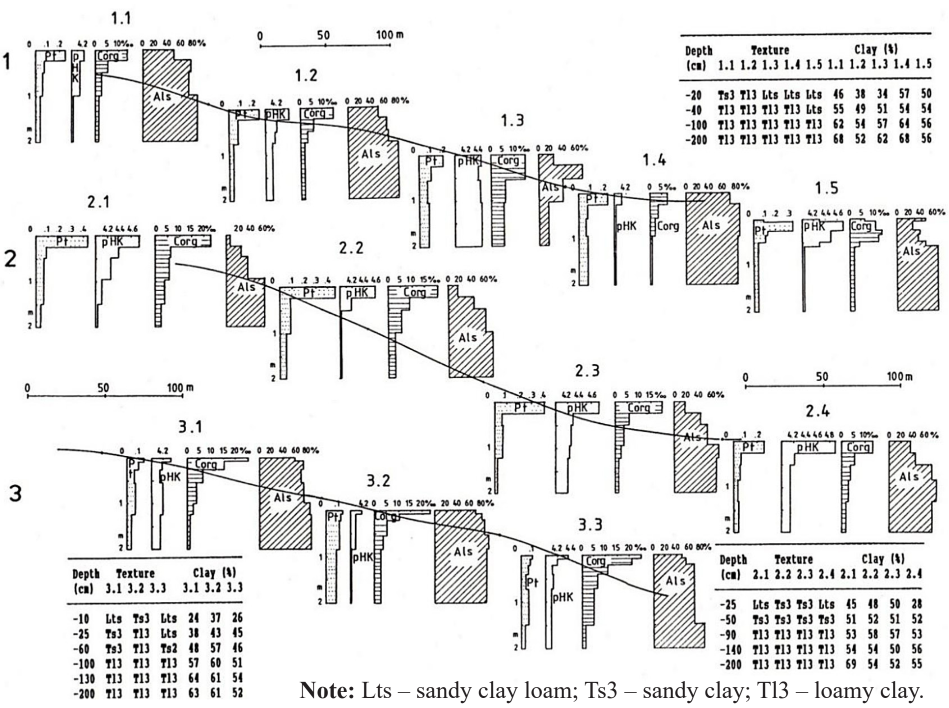
The description of the soil characters are just focused on the content of total P, pH, organic Carbon and Al saturation. They are summarized in the form of a function of depth (Figure 5). Comparing forest and sugarcane soils the acidification effect is revealed alsoas well but the pH-differences are much less pronounced, both between land uses and within the profiles (notice varying pH-scales in Figure 5). The reason must be searched for in the low activity clays with pH-variable charges, which induce a high buffering against pH changes by lime fertilization. Only in Ap horizons, where humus enhances the quality of the exchange complex, may the pH rise to one unit by fertilization, but greater differences within the fields point to a still heterogeneous lime application within the short cultivation period of 40 years. The pH-values tend to follow the distribution of total P (co-variability caused by the joint cultivation effect).

The KCl pH values of the soil in all catena are relatively uniform and relatively acidic to very acidic (pH range 4.2 to 4.8), but on Catena G3, the difference in pH value is not very noticeable at all selected profiles. No different soil pH values were observed at Catena G1 and Catena G2. The identified clay is mostly found as kaolinite clay mineral. This clay mineral has a low charging activity against pH values that contribute to high buffering capacity against pH changes. Only in the Ap Horizons with a lot of humus which is able to improve the exchange complex, can the pH values be improved (two to three units higher).

The Al-saturation changes irregularly in soilscapes of the sugarcane soils indicating uneven fertilization, too. The Al saturation (Al-s) depth functions under forest show the deep-going weathering effects in tropical soils, which still remain in lower horizons of the sugarcane soils. However, the Al-saturation in topsoils was diminished from around 80% to 20–40% on many sites due to fertilization. Al-s may show THE effects of interflow water (see Profile 3.3 in Figure 5), but does not indicate runoff with water erosion.

Organic C shows clearly the effects of erosion, leaching and water stagnation (Figure 5). In Catena G1, organic C increases slightly down slopes (from 1.3% in upper slope to 1.1–1.4% in strong leveling depression). In Catena G2, organic C decreases significantly from hilltop to depression (2.4% in hilltop, 2.1% in middle slope, 1.9% in foot slope and 1.3% in the strongly leached depression. Leaching and extended erosion at lower slopes may be a cause of these phenomena. Under forest, organic C showed similar contents in topsoils from hilltop to depression.

The content of the soil P (total P and available P) tend to follow the spread of soil pH. The available P content increases along with the pH. The available P content of the most dominant profile was found in sugarcane plantations in the



Note: Lts – sandy clay loam; Ts3 – sandy clay; Tl3 – loamy clay.

Figure 5. Depth functions of chemical analyses of the research area

upper layer (54 ppm P_2O_5) as a clear effect of fertilization, followed by forest (17 ppm P_2O_5) and the lowest in the grass field profile (6 ppm P_2O_5). There is only one kind of depth function P which is in all the profiles, i.e. P has a maximum value in the upper layers and decreased dramatically based on the depth. No real effect can be observed as the leaching of accumulated P in the lower layers in all profiles.

In the Ap horizon in Catena G1 and Catena G2 fertilization effect is clearly visible. No internal erosion effect can be observed as the accumulation of Pt in the subsoils layer, except for P1.5 profiles that have colluviated layer (horizon M). The different conditions are found especially in Catena 2. The Ap horizon at the top of the slope (P2.1) until the middle of the slope (P2.3) contains more Pt than the location below the escarpment (P2.4). This condition may be caused by high Pt fixation by Fe (concretion Fe), so that more Pt was found at the top of the slope.

Variability of Sugarcane Biomass

The catena position was the main factor causing the increasing variability of the soil characters. Furthermore, the variability of soil characters was responsible for the variability of sugarcane biomass harvest. The T test results proved that the sugarcane biomass on the Block 60–69 (where Catena G1 located) in the bottom of the slope, foot slope and basin were significantly different compared with those in the top and middle of the slope (Table 4). The highest sugarcane biomass was found in the depression (105 tones/ha), this was caused by the sedimentation process characterized by the formation horizon M and accompanied by the accumulation of nutrients from the top of the slope. However, increasing the harvest of biomass did not make any difference between the slope and the foot of the slope, as shown in Block 50–57; this is due to the position of the foot slopes in Block 50–57 which does not accumulate nutrients and no horizon M is formed due to erosion and intensive leaching process.

There is a variability of sugarcane biomass harvest caused by shape and position on the catena, where its position at the top is convex happening erosion, leaching, transport, translocation, soil nutrient redistribution and more intensive weathering processes. These processes directly affect the character of the soil increased variability. The variability of soil character is the main factor for a great diveristy of sugarcane biomass harvesting.

Table 4. The average sugarcane biomass along soil catena (tones/ha), N: 46 Block

Catena position	Block 60–69 (Sugarcane)	Block 50–57 (Sugarcane)
Hilltops	$73±17.11^a$	$75±20.15^a$
Middle slopes	$75±22.35^a$	$76±26.42^a$
Lower slopes	$85±27.79^b$	$89±31.75^b$
Foot slopes	$94±29.88^c$	$88±34.95^b$
Depressions	$105±32.11^d$	na

Note: Values in the same column and indicated by the similar superscript is not significantly different at the significance level of 5% of T test;
na: not available data.

CONCLUSION

Soil horizons are represented by Ap/Ah/M, E, B, Cc and Cg with dominant clay translocation. The gleying symptom was found only in the lower slope to depression area. Concretion depths can be used as an indicator of the erosion intensity if the soil parent material can be well characterized. Soil P has a total maximum value of Ap horizon and decreases with depth. There was no effect of internal erosion in the form of accumulation of soil P in subsoils layer, except for the colluviated horizon (P1.5). Kaolinite dominated the soil clay type, so it is able to buffer changes in pH, except Ap horizon of sugarcane. The organic C content depends on the pedogenesis and catena form. The Al saturation indicates that the dominant soil weathering is intensive. The Al saturation in the Ap horizon (Catena G1 and G2) was reduced from 80% to 20–40%, caused by liming and fertilization. The catena position was the main factor causing the increasing variability of the soil characters. The variability of soil characters was responsible for the diversity of sugarcane biomass harvest. The sugarcane biomass increased with decreasing slopes. The highest sugarcane biomass was found in the depression (105 tones/ha) if the sedimentation process was characterized by the formation horizon M and accompanied by the accumulation of nutrients from the top of the slope.

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REFERENCES

1. Armanto, M.E. 2019. Comparison of Chemical Properties of Peats under Different Land Uses in South Sumatra, Indonesia. J. Ecol. Eng. 20(5): 184–192.
2. Armanto, M.E., E. Wildayana. 2016. Land Degradation Analysis by Landscape Balance in Lebak Swamp Jakabaring South Sumatra. Journal of Wetlands Environmental Managements. 4(1); 1–6.
3. Armanto, M.E., M.A. Adzemi, E. Wildayana, M.S. Imanudin. 2013. Land Evaluation for Paddy Cultivation in the Reclaimed Tidal Lowland in Delta Saleh South Sumatra, Indonesia. Journal of Sustainability Science and Management. 8(1); 32–42.
4. Armanto, M.E., R.H. Susanto, E. Wildayana. 2017. Functions of Lebak Swamp before and after Landfills in Jakabaring South Sumatra. Sriwijaya Journal of Environment, Vol 2(1); 1–7, February 2017.
5. Aviron, S., S. Poggi, Y.D. Varennes, A. Lefèvre. 2016. Local Landscape Heterogeneity Affects Crop Colonization by Natural Enemies of Pests in Protected Horticultural Cropping Systems. Agriculture, Ecosystems & Environment. Vol 227; 1–10.
6. Baranowska, A., K. Zarzecka, Z. Rudzki. 2019. The Process of Land Consolidation as the Element of Arranging Rural Space on the Example of the Łubka and Zaliszcze Villages. J. Ecol. Eng. 20(1): 9–15
7. Carvalho, A.L.D., J.L.D. Souza, A.C.D.S. Almeida, G.B. Lyra, G.B. Lyra, I. Teodoro, R.A.F. Junior, I.D. Magalhães, L.R. Santos. 2018. Sugarcane Productivity Simulation under Different Planting Times by DSSAT/CANEGRO Model in Alagoas, Brazil. Emirates Journal of Food and Agriculture. 30(3); 190–198.
8. Cunningham, S.C., S.H. Roxburgh, K.I. Paul, A.F. Patti, T.R. Cavagnaro. 2017. Generating Spatially and Statistically Representative Maps of Environmental Variables to Test the Efficiency of Alternative Sampling Protocols. Agriculture, Ecosystems & Environment. 243(1); 103–113.
9. Dietrich, G., M. Sauvadet, S. Recous, M. Redin, I.C. Pfeifer, C.M. Garlet, H. Bazzo, S.J. Giacomini. 2017. Sugarcane Mulch C and N Dynamics during Decomposition under Different Rates of Trash Removal. Agriculture, Ecosystems & Environment. 243; 123–131.
10. Ferreira, D., M. Simoes, F. Reboredo, F. Pessoa, A.S. Almeida, I. Daradzhanska, F. Lidon. 2018. Effects of Climate Change (precipitation Variations), on Rice Crop Yields in Alluvial Plains of the Tejo and Sado Rivers. Emirates Journal of Food and Agriculture. 30(6); 488–495.
11. Guzeeva, S.A. 2019. Influence of Chemical Amelioration of Solonetzic Soils on the Presence of Heavy Metals and Radionuclides in Soil Profile. J. Ecol. Eng. 20(5):179–183.
12. Hamuna, B., R.H.R. Tanjung, A. Alianto. 2019. Assessment of Water Quality and Pollution Index in Coastal Waters of Mimika, Indonesia. J. Ecol. Eng. 20(2): 87–94.
13. Jakubis, M., M. Jakubisová. 2019. Morphogenesis of Torrent Beds in the Watersheds with a Different Geological Bedrock and Geomorphological Rock Value. J. Ecol. Eng. 20(5): 69–77.
14. Kaleta, J.T., A. Puszkarewicz, D. Papciak. 2019. The Influence of the City of Przemyśl on the Quality of Water in the San River. J. Ecol. Eng. 20(1): 76–83
15. Kišš, V., V. Bárek, B. Novotná, L. Tátošová. 2019. Monitoring of the Dendrometric Changes Influenced by Soil Water Content. J. Ecol. Eng. 20(1): 34–38
16. Li, Y. 2018. Brackish Water Irrigation on the Characteristics of Carbon, Nitrogen and Phosphorus Nutrients in the Soil nearby Crop Roots. Emirates Journal of Food and Agriculture. 30(10); 863–872.
17. Lofton, J., B.S. Tubana, Y. Kanke, J. Teboh, H. Viator, M. Dalen. 2012. Estimating Sugarcane Yield Potential Using an In-Season Determination of Normalized Difference Vegetative Index. Sensors 2012. 12(6); 7529–7547.
18. Martins, L.D., F.C. Eugenio, W.N. Rodrigues, M.A. Tomaz, A.R. dos Santos, J.C. Ramalho. 2018. Carbon and Water Footprints in Brazilian Coffee Plantations – the Spatial and Temporal Distribution. Emirates Journal of Food and Agriculture. 30(6); 482–487.
19. Montanari, R., G.S.A. Souza, G.T. Pereira, J. Marques Jr., D.S. Siqueira, G. M. Siqueira. 2012. The Use of Scaled Semivariograms to Plan Soil Sampling in Sugarcane Fields. Precision Agriculture. 13(5); 542–552.
20. Mulyono, A., A. Suriadikusumah, R. Harriyanto, M.R. Djuwansah. 2019. Soil Quality under Agroforestry Trees Pattern in Upper Citarum Watershed, Indonesia. J. Ecol. Eng. 20(1): 203–213
21. Operacz, A., K. Kurek, D. Młyński, P. Piotrbugajski. 2019. Untypical Draining Barriers Efficiency as a Method ff Pollutants Limiting in the Groundwater Reservoir. J. Ecol. Eng. 20(3): 67–76.

22. Paul, K.I., S.H. Roxburgh, J.R. England, R. de Ligt, J.S. Larmour, K. Brooksbank, S. Murphy, P. Ritson, T. Hobbs, T. Lewis, N.D. Preece. 2015. Improved Models for Estimating Temporal Changes in Carbon Sequestration in Above-Ground Biomass of Mixed-Species Environmental Plantings. Forest Ecology and Management. 338; 208–218.
23. Rybak, J., A. Stojanowska, Ł. Winkler. 2019. Analysis of the Vegetation in the Terrain of Closed Industrial Waste Dump in Siechnice (Lower Silesia). J. Ecol. Eng. 20(5): 242–248.
24. Šimanský, V., D. Šrank, J. Jonczak, M. Juriga. 2019. Fertilization and Application of Different Biochar Types and their Mutual Interactions Influencing Changes of Soil Characteristics in Soils of Different Textures. J. Ecol. Eng. 20(5): 149–164.
25. Soil Survey Staff. 2014. Keys to Soil Taxonomy, 12th ed. USDA-Natural Resources Conservation Service, Washington, DC.
26. Wildayana, E., A.S. Busri, M.E. Armanto. 2016. Value Changes of Lebak Swamp Land over Time in Jakabaring South Sumatra. Journal of Wetlands Environmental Managements. 4(1); 46–54.
27. Wildayana, E., M.E. Armanto. 2018. Dynamics of Landuse Changes and General Perception of Farmers on South Sumatra Wetlands. Bulgarian Journal of Agricultural Science. 24(2); 180–188.
28. Zahri, I., D. Adriani, E. Wildayana, Sabaruddin, M.U. Harun. 2018. Comparing Rice Farming Appearance of Different Agroecosystem in South Sumatra, Indonesia. Bulgarian Journal of Agricultural Science. 24(2); 189–198.
29. Zuhdi, M., M.E. Armanto, D. Setiabudidaya, Ngudiantoro, Sungkono. 2019. Exploring Peat Thickness Variability Using VLF Method. J. Ecol. Eng. 20(5): 142–148.