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Research Article

Assessment of Soil Chemical Properties for Monitoring and Maintenance of Soil Fertility in Probolinggo, Indonesia

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Abstract: Soil is paramount to sustaining living in biomass production, water quality control, climatic mitigation, and biodiversity endurance. Closely associated with sustainable agriculture, it degrades soil in the long run, robbing the soil of its production capacity and food-generating ability. In Probolinggo, a regency in Indonesia, intensifying the use of chemical fertilizers and pesticides yet a declining trend in yield production was discovered. This research analyzed the acid, nitrogen, organic carbon, and nutrients focusing on phosphor, potassium, iron, and manganese contents. Organic carbon/nitrogen ratio, soil organic compound rate, and cation exchange capacity were also discussed in order to illustrate the correlations among chemical substances and their roles in soil and plant maintenance. While such a study has yet to be performed in Probolinggo, the results should show the degree of land deterioration and future attempts at damage control and correction open to facilitate. Employing a simple random method, soil and plant samples were collected from 18 villages in six districts and their chemical contents were compared to the standard set in Government Regulations No 150/2000. The results showed low N-total, P-Bray, P-Olsen, K, C-Organic, and C/N ratio availabilities at 0.18, 13.88, 14.41, 0.37, 1.36, and 7.38 respectively, contrasted to high rates on pH (5.94), Fe (153.46 mg kg^{-1}) and Mn (37.96 mg kg^{-1}). Biomass production is conclusively imperative to fix the land composition and meet the plant nutrient requirements through an organic approach; fertilizers from digester biogas are therefore recommended. This action requires field agricultural advisors to raise awareness of sustainable agriculture.

Keywords: Environmentally Friendly, Organic Approach, Soil Deterioration, Soil Fertility Evaluation, Sustainable Development Goals, Sustainable Farming

1. INTRODUCTION

A natural body as the result of complex biogeochemical and physical processes, soil is imperative in sustaining the living [1, 2]. Not only limited to plant substrate, but its role also expands as far as an exponential part of biodiversity by regulating the water cycle and nutrients [3, 4]. Vastly contributing to the ecosystem, soil is crucial to sustainable development goals (SDGs) concerning biomass production, water quality control, climatic mitigation, and biodiversity endurance [5, 2]. Quality soil holds the potential to solve hunger and poverty issues while retaining robust health [6, 7] key to welfare, making it the most valuable asset of a nation [4].

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While soil health is associated with sustainable agriculture [8, 9], it degrades soil in the long run due to supplying food for the ever-increasing human population [10, 11], robbing the soil of its production capacity and food-generating ability [11, 12]. Agricultural practices deprive soil properties [2, 13] have been reported in Uruguay after an agricultural production period between 2012 and 2014 [14], in Iran after forestland conversion to tea plantation [15], and in Italy where food self-sufficiency plummeted to less than 80 % [12].

Out of various agricultural practices and land exploitations, monocropping is one of the most detrimental methods toward soil quality [16–18]. Another cause is low irrigation water quality [19, 20]. Pesticides are also liable for affecting microorganisms [21, 22], particularly in enzymes entailing carbon, nitrogen, sulphur, and phosphor cycles [23, 24] While fertilizers may be helpful, excessive use of chemical fertilizers reduce soil biodiversity and function [25, 26] by triggering soil acidification and soil crusting that suppress the growth of organic matters [2, 27, 28].

Running soil fertility evaluation (SFE) should be feasible to assess the degree of soil deterioration and its result should help in determining the appropriate biomass treatment for each condition – some countries like Nigeria [29], the Philippines [30], and Indonesia [31, 32] have based their fertilizer application guides on it. Analyzing the chemical properties of soil – e.g. acid, organic carbon, nutrients – is one of the attainable approaches.

Soil deterioration is a serious issue in Indonesia; since the start of modern agricultural practices in the 1970s, biomass-producing areas have been exploited all year long. In addition to monocropping, excessive pesticides on rice production in Java has been reported [33] – a certain site applied up to 24.6 kg of pesticides ha^{-1} yr^{-1} [34], and farmers in another locale violated the recommended amount of chemical pesticides [35]. The preliminary survey in Probolinggo Regency, a regency in the province of East Java, Indonesia, discovered intensifying use of chemical fertilizers and pesticides yet a declining trend in yield production.

Soil quality studies had been performed in a number of areas in Indonesia, among them are of apple plantations [36], cassava fields [37, 38], paddy fields [39, 40] and post-paddy fields [41], oil palm plantations [2, 42–46], rubber [47], sugarcane [48–50], even volcanic soils [51] and drylands [52–54]. A few researchers had also compared different fields at once in Bengkulu [55] and West Java [56]. However, not one of the such studies had been run in Probolinggo Regency. The aforementioned researches mostly put N, P, and K contents as their parameters – only some of them discussed about the C-organic content, pH rate, and micronutrient availability. Further, studies on Mn, Fe, SOC, and CEC contents in Indonesia are scarce. The case in the surveyed area calls for a more thorough soil quality study for biomass production to detect any occurrence of soil deterioration. In addition to the prevalently analyzed factors, the infrequently examined ones are put into consideration. Further, in the soil, the chemicals N, P, and K contained in a number of local commodities are also scrutinized.

2. MATERIALS AND METHODS

2.1 Location

Conducted in Probolinggo Regency, East Java, Indonesia, in 2020, a number of six districts – with three rural villages in each to make 18 in total – were randomly appointed to represent the regency: Krucil District (Krucil Village, Bremi Village, and Betek Village), Tiris District (Ranu Agung Village, Tiris Village, and Andungsari Village), Gading District (Mojolegi Village, Wangkal Village, and Kaliacar Village), Pajarakan District (Karangpranti Village, Pajarakan Kulon Village, and Sukomulyo Village), Krejengan District (Kedung Caluk Village, Sumber Kalimoho Village, Seboro Village), and Kraksan District (Semampir Village, Sidopekso Village, and Kregenan Village) (Figure 1). The GPS details for the six districts are listed in Table 2.

Each district has its type of soil. While Pajarakan is of regosol and alluvial, Kraksaan soil is dominated by alluvial with a small part of andosol. Krejengan has equal portions of regosol and alluvial. Regosol takes most of Gading, leaving a little for andosol. Tiris is mostly regosol with a latosol touch, and Krucil is mostly regosol with bits

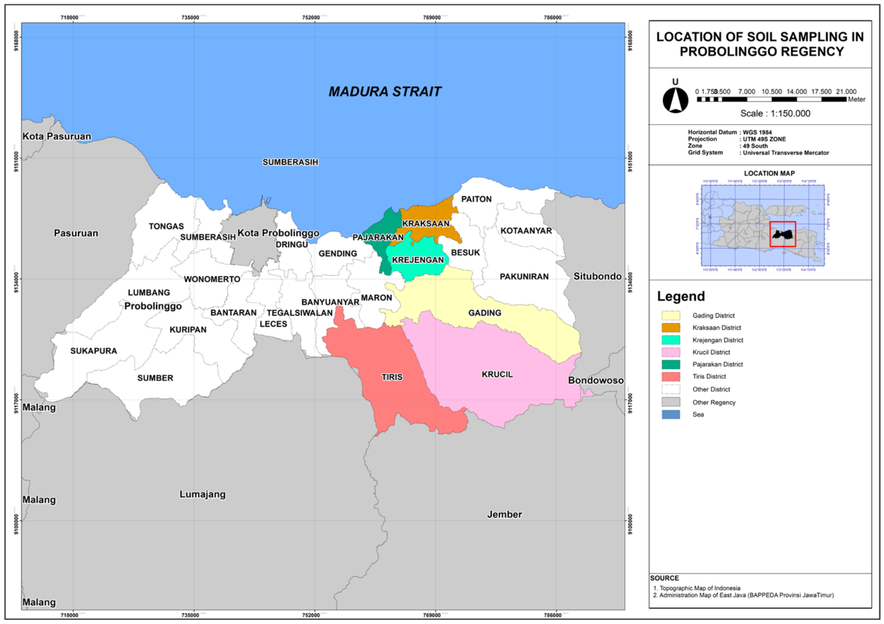

Fig. 1. Location soil sampling (Krucil District, Tiris District, Gading District, Pajarakan District, Krejengan District, and Kraksan District)

of latosol dan andosol.

Average rainfall from 2015 to 2020 at six soil sampling locations as follows: Pajarakan (119 mm), Kraksan (144 mm), Krejengan (155 mm), Gading (108 mm), Tiris (133 mm), and Krucil (78 mm). According to Schmidt-Ferguson, the climate types and Q are Pajarakan (140.00 % - E), Kraksan (120.00 % - E), Krejengan (120.00 % - E), Gading (83.33 % -D), Tiris (133.64 % - E), and Krucil (100.00 % - D). As a complement, cropping system data at six research locations are Pajarakan (1x paddy, corn), Kraksan (1x paddy, corn), Krejengan (1x paddy -100 %, 2x -30 % paddy, corn, soybean), Gading (paddy 1x), Tiris (paddy 1x), and Krucil (paddy 2x).

Referring to Government Regulation No. 150/2000 that the solum critical benchmark is ≤ 20 cm, only six locations are ≥ 50 cm. As no soil crust was encountered, all districts were considered secure at this point. A series of the preliminary survey was conducted to identify soil characteristics in each village. Then, soil and plant samples were gathered for chemical analyses.

2.2 Materials

Soil and plant sample selection were of simple random sampling, taken from three different sites in each village at any time during the research period. Once a plant was chosen, the area around it was leveled and cleaned from grass and rubbles, then dug as deep as 5 cm to 20 cm to take the soil sample. A lead tube was probed into the ground with the help of a wooden block until three-quarters part of it was buried. Another tube was pressed inside the first one at 1 cm deep to compact the dirt and separated it. The tube was then dug out of the ground along with some extra dirt to protect it from direct contact with the shovel. Excessive dirt on the upper end of the tube was carefully leveled and then covered with a plastic lid. The lower end received the same handling. The top lid was then labeled with information on gaining depth, date, and location.

2.3 Methods

Both soil and plant were tested for their acid (pH), organic carbon (C-organic), and nutrient (N, P, and K) contents. Acidity was measured with a pH meter. Organic carbon content was assessed on Walkey and Black method. As for nutrient content, N was calculated by employing the Kjeldahl method and P by Olsen and Bray, while K, Fe, and Mn with Atomic Absorption Spectrophotometry (AAS).

All results were then compared to the parameters set by the Indonesian government as declared in the

Government Regulations No 150/2000 on Land Deterioration Management for Biomass Production [57] – except for Fe which went with the standard set by the Soil Research Center of the Ministry of Agriculture [58] – to determine the land condition as listed in Table 1.

Table 1. Soil fertility scales based on chemical aspects

	Scale		
	Low	**Medium**	**High**
N-total	0.2	0.2 to 0.5	0.5
P-Bray2 (ug g^{-1})	20	20 to 40	40
K (me 100 g^{-1})	0.3	0.3 to 0.6	0.6
Mn (me100 g^{-1})	0.2	0.2 to 0.6	0.6
C-organic (%)	4	4 to10	10
Fe (mg kg^{-1})	3	5	9

Source: [57, 58]

Organic carbon/nitrogen ratio (C/N ratio), soil organic compound (SOC) rate, and cation exchange capacity (CEC) were also discussed to illustrate the correlations among chemical substances and their roles in soil and plant maintenance.

3. RESULTS AND DISCUSSIONS

3.1 Chemical Properties in Soil

The chemical properties in soil represent its ability to provide balanced nutrients for plants. The test results are recorded in Table 2 below.

3.2 Acidity and CEC

Affecting a vast number of biochemical processes in soil, pH is the master variable [59]. With an average of 5.94 in the depth of 0 cm to 25 cm, the general acidity level is within the critical benchmark rates between 4.5 and 8.5. The soil of eight villages came out quite acidic at 5.91, while four villages were neutral to fairly neutral at 7.02. In four villages, the soil conditions were passable despite being acidic at 5.11 since their N, P, K, Mn, and Fe contents were enough to nourish plants.

The fertilizer administration in the study area is deduced to be the reason for low soil pH in some sampling sites. Ammonium fertilizers run through the nitrification process to form nitrate. In such process, the released H^+ ions turn the soil more acidic [59, 60]. Phosphorus and potassium can decrease soil pH after years of use [61]. Years of land use for agriculture typically increases H^+ ions which, consequently, accelerate soil acidification [62]. Plants grown in acidic land are prone to stresses, such as H and Mn poisoning and nutrient deficiency [59].

Acid also affects microbial diversity in soil [63, 64] and its presence indicates nutrient availability [66]. Neutral pH expands CEC, optimizing P and other nutrient contents in soil [6, 22, 66]. Out of all samples, the lowest rate was 10.49 me gr^{-1} while the highest was 55.06 me gr^{-1} – the ones with high CECs were taken after fertilizer application.

3.3 Organic Carbon Content, SOC, and C/N Ratio

While the C-organic should be at least 4 %, the average rate in samples was 1.35 % with the lowest quantity of 0.62 and the highest of 2.67 – these figures characterize badly-damaged soil. This finding corroborates an earlier report that more than 77 % of paddy fields in Java had low organic carbon [26, 67]. That there is inadequate vegetation due to monoculture in the research sites and that farmers barely recover soil biomass are deduced to be the reasons [2, 49, 50].

C-organic content reflects the amount of soil organic compound (SOC), another fertility factor [2, 68] and the most vital component resulting from interactions among producer, decomposer, and mineralogy [60, 70], attributable to its ability to improve soil chemical, physical, and biological characteristics [10, 28].

SOC is the key indicator of soil quality and agricultural sustainability [71]. SOC content relies heavily on nitrogen binding in soil [2, 67]. The SOC test results came out between 1.07 % and 4.62 % for all 18 samples, and seven samples reached the level of as low as 1.65 %. SOC is associated with vegetation type, hydrology, and organic matter.

Referring to the low SOC rate, it is proven that cultivation and land management can cause it, leading to land damage in the long run [71]. Disproportionate use of chemical pesticides and fertilizers suppresses the growth of nutrient-producing biota and, consequently, diminishes

Table 2. Soil chemical properties of 18 villages in six districts in Probolinggo Regency

District	Village	pH H_20	pH KCl.	C-organic (%)	N-total (%)	C/N (%)	SOC (%)	P-Bray (%)	P-Olsen (%)	Available K (%)	CEC me gr^{-1}	Fe mg kg^{-1}	Mn mg kg^{-1}
Pajarakan	Karang Pranti	6.1	5.2	1.22	0.16	8	2.11	22.49	-	0.17	55.06	238.10	36.70
7° 46' 17.458" S								-					
113° 22' 35.044" E	Pajarakan Kulon	6.9	6.2	1.76	0.20	9	3.04	-	5.79	0.29	51.27	92.50	51.27
	Sukomulyo	6.6	5.7	1.14	0.15	8	1.97		7.96	0.17	53.75	265.7	53.75
Kraksaan	Semampir	6.7	6.0	1.39	0.17	8	2.41	-	15.12	0.48	50.18	142.90	28.72
7°45' 30.42"	Sido Pekso	7.9	7.0	1.09	0.14	8	1.89	-	28.77	0.33	43.40	47.60	37.77
S113°23'46.46"E	Kregenan	6.4	5.7	1.13	0.14	8	1.95	16.93	-	0.47	48.12	190.50	47.95
Krejengan	Kedung	6.1	5.2	0.75	0.11	7	1.29	19.59	-	0.60	36.58	263.70	17.58
7° 48' 16.081" S	Caluk	6.5	5.7	0.62	0.12	5	1.07	37.69	-	0.49	39.61	190.50	11.03
113° 25' 5.077" E	Sumberkatimoho								-				
	Sebaroh	5.6	4.9	1.31	0.22	6	2.26	16.22		0.31	38.44	142.90	18.64
Gading 7°50'39.7"	Mojolegi	5.6	4.8	1.57	0.19	8	2.72	13.56	-	0.06	10.49	92.50	31.83
S 113°26'02.2" E	Kaliacar	5.2	4.8	1.39	0.23	6	2.41	8.70	-	0.58	20.99	190.50	42.38
	Wangkal	6.0	5.2	1.47	0.19	8	2.54	3.84	-	0.46	34.37	47.60	17.47
Tiris	Ranu	5.0	4.4	0.94	0.15	6	1.63	9.25	-	0.40	24.19	238.10	58.25
7°94'75402" S 113°	Agung	5.5	4.5	1.41	0.21	7	2.43	8.78	-	0.08	15.12	142.90	22.16
39'4. 2622" E	Andung Sari	4.9	4.4	1.02	0.14	7	1.76	2.95	-	0.60	32.51	95.20	50.93
	Tiris												
Krucil 7°56'35,4"S	Betek	5.2	4.5	1.26	0.15	8	2.18	2.16	-	0.57	26.91	47.60	60.56
113°28'29,8"E	Krucil	5.6	5.0	2.26	0.24	9	3.91	10.97	-	0.28	26.38	190.50	43.39
	Bremi	5.2	4.9	2.67	0.38	7	4.62	21.18	-	0.37	27.10	142.90	52.85
Average		5.94	5.23	1.36	0.18	7.38	2.34	13.88	14.41	0.37	35.25	153.46	37.96
Compare Standards of Table 1				Very low	Low			Very low		Medium		Very high	Very high

SOC [72]. Supporting the finding, applying both chemical and organic fertilizers for years in China is effective in enhancing SOC [63]. Sufficient fertilizer – combined with cattle manure – should encourage SOC content [71] and tackle the issue.

A well-balanced C-organic and nitrogen contents support microorganisms in decomposition [48, 72, 73] and the C/N ratio indicates the speed of the process [2, 74]. From the average ratio of 7.38 %, it is conclusive that the soil is not damaged. However, further treatments should be undergone to prevent it from declining – compost application is needed when the SOC drops to 11 %, and land relaxation is required if it reaches 15 %.

3.4 Nutrient Content

From Table 2, it is derived that N-total values are 0.11 % to 0.38 %, averaging 0.18 %, which is below the standard of 0.2 %. It is similar to the N-total in post-paddy fields in Labuhanbatu, Indonesia [41]. Samples from Sebaroh, Kaliacar, Andung Sari, Krucil, and Bremi Villages are medium, and none are high. The non-existent high N-total value corroborates another soil analysis on several agricultural lands in West Java [56] and adds urgency to the call for management to enhance nitrogen content in agricultural fields throughout Java recommended by a previous study [26, 75]. An essential nutrient for plants [24, 76], nitrogen determines plant growth [32, 77] and therefore significantly influential towards harvest. Nitrogen is assimilated by the plant into amino acid, the main component of protein [78] that is responsible for forming chloroplast, mitochondria, and other structures where biochemical processes in plants occur. Nitrogen is also the key element of nucleic acid, serving as genetic matter, that controls plant growth and sustainability [79]. Nitrogen deprivation leads to stunting in plants [80], so an optimal supply of nitrogen should maximize production [81].

A few features are viewed to be the causes of low N-total content in this study. The fact that tropical lands naturally contain less nitrogen has been proven by contrasting Java with Japan [75] since higher temperature accelerates organic matter decomposition [2, 28]. Improper use of pesticides in agricultural practice not only eradicates nitrogen-generating bacteria [21, 83] but also restrains the work of enzymes in the nitrogen cycle [23, 24].

As for phosphate, the contents of (2.16 to 37.69) ug g^{-1} – averaged at 6.30 ug g^{-1} – are far lower than even the low P-Bray standard of 20 ug g^{-1}. The low P contents in samples are linked to high acidity [32]. Samples from Karang Pranti, Sumber Katimoho, and Bremi are regarded as a medium, and none is high. This outcome validates the report on low P contents in West Java [56], although the same study also informed about the several sites containing high P. It contradicts the high P contents found in post-paddy fields in Labuhanbatu [41] apparently due to much P fertilizers added in every sowing period. Research held in Bogowonto Catchment, Central Java, noted higher P content in agricultural lands than in non-agricultural ones due to human intervention through fertilizers [84].

Another component in nucleic acid forming [79], along with nitrogen, phosphorus is valuable for plants [76] in ensuring sustainability for its roles in cell multiplication, respiration, and photosynthesis. Its importance spreads to energy storage and distribution via adenosine diphosphate (ADP) and adenosine triphosphate (ATP) formation [80, 85]. Energy gained from photosynthesis and carbohydrate metabolism is stored in the form of phosphate compound and later used in growth and reproduction [86], which makes this substance crucial in seed formation and root expansion [87].

The potassium (K) contents in samples span between 0.06 and 0.60, averaged at 0.17, which is below the benchmark of 0.3. Out of all tested villages, nine are medium and one is low and six are very low. A leachable material, K is easy to get washed away. It is often bound to clay and other organic substances, and it mostly gets absorbed when attached to fine soil particles. As such, K is prone to erode to rain or wind exposure [88]. Soil typically erodes more in harder rain [89] and harder wind [90]. The climate of the study area is indicated to be a cause of low K content in some sites. Another consideration is the shallow irrigation canals. Since the deeper a canal is, the more water there will be and the more $K+$ ions will be absorbed [91], adding depth to those canals should help to answer the problem. Furthermore, the low potassium content is observed to be the effect of high CEC, which fortifies soil in keeping the substance within and decelerating its release. Some areas with high K contents are due to agricultural manipulation. However, continuous and excessive use of fertilizers can wane potassium in soil [92].

A macro monovalent compound in soil, K is necessary for plant physiological processes [76] despite being excluded from basic organic compound formation since most enzymes require it as an activator [93], including protein synthesis in producing ATP [80]. K also supports the energy translocating process to various parts of the plant [93], regulates the opening and closing of stomata [80], and even strengthens the plant to resist diseases and stress [94, 95].

Iron contents are recorded at between (47.6 and 265.7) mg kg^{-1}, averaging at 153.45 mg kg^{-1}, which is high above the standard. Three villages are high and 19 are very high. Similarly, manganese contents extend over (11.03 to 60.5) mg kg^{-1}, averaged at 37.95 mg kg^{-1} – five villages are high and 13 are very high. In addition to redox potential and pH content [96], the intensive use of inorganic fertilizers for decades has left residual buildups of Fe and Mn in soil. Mn helps to transport Fe throughout the plant [97] in binding phosphate for growth [98], and only a small amount of < 1 000 mg kg^{-1} is required to activate protein-forming enzymes. While too little Fe and Mn lead to micronutrient deficiency [99, 98], too much of them is malicious for plants [100, 101].

The farmer's behavior in using pesticides is also influential in its production [23, 25]. In regards to controlling pests, diseases, and weeds, pesticides (as well as herbicides) have been reported to add nutrients to the soil, including Fe and Mn [102, 103]. However, their use must be controlled so as not to cause damage to the soil and the environment [21–28, 33, 35]. Several researchers, among others [28, 104], suggest using biomass ash to increase micronutrients, i.e. potassium, calcium, and magnesium. The referring to local wisdom is also recommended by some researchers [24, 83, 105–107], while the application of biological fertilizers is suggested by other researchers [22, 54, 66].

3.5 Chemical Properties in Plants

Ensuring nutrient adequacy in the soil is key to satisfying crops. The contents of N, P, and K towards cassava, coffee, corn, paddy, tobacco, shallot, chili, and melon as local commodities were studied and then administered in Table 3.

The research reveals the N-total values of plants are ranged between 0.81 % and 3.86 %, while P is 0.03 % and 0.64 % and K is 0.4 % and 4.01 %. Conclusively, the dominant weight of the plant biomass is nitrogen, followed by phosphate and calcium respectively.

Comparing the results of the soil test (Table 2) with the plant test (Table 3), it is certain that the N and K contents in the soil are lower than the ones in the plant while the P content is higher. That plant requirement on P is lower than on N and K should be the reason. Furthermore, P is not easily soluble in water, causing it to progress slowly, since most of it is inorganic. Paddy, cassava, corn, tobacco, melon, and chili absorb higher percentages of N and K, draining them from the soil.

This study has revealed the low content of several important substances in soil. Further action should be carried out in Probolinggo Regency by decomposing all organic waste and kitchen waste into organic fertilizer, which result is then returned to agricultural lands. The decomposition of organic matter should be done anaerobically in a communal or household scale digester [108–110]. A biogas digester as such doubles the benefit for society as well as the environment by providing clean, renewable energy [111, 112] and producing two types of organic fertilizers, i.e., liquid and solid. Ideally, this biogas digester should be installed with inlet pipes from excrete disposal to septic tanks in each household [99–101]. Since there is a possibility of decomposition fluctuation due to various feedstocks, several researchers recommended a two-stage digester to overcome the problem [113–115].

Moreover, the farmers in Probolinggo should be educated to prevent excessive land management. Tilling aims to loosen the soil in preparation for seeding [116] so that the plants' roots will be able to penetrate the soil and respire more easily. However, too much handling wears soil organic matter away faster [117]. Land handling limitation in organic agriculture is the potential to improve the total stock of soil organic matter [118].

Table 3. N, P, and K contents in cassava, coffee, corn, paddy, tobacco, shallot, chili, and melon samples in Probolinggo Regency

Location	Commodity	N – Total (%)	P (%)	K (%)
Pajarakan District				
Karang Pranti	Corn	1.62	0.29	3.85
Pajarakan Kulon	Paddy	2.18	0.22	1.89
Sukomulyo	Melon	3.86	0.64	3.53
Kraksaan District				
Semampir	Paddy	0.81	0.11	2.72
Sido Pekso	Tobacco	2.47	0.12	3.19
Kregenan	Tobacco	1.92	0.16	3.20
Krejengan District				
Kedung Caluk	Tobacco	2.56	0.16	4.01
Sumberkatimoho	Shallot	3.37	0.16	2.49
Sebaroh	Paddy	1.07	0.35	1.20
Gading District				
Mojolegi	Paddy	1.24	0.20	0.93
Kaliacar	Chili	3.74	0.21	3.89
Wangkal	Corn	0.82	0.03	0.40
Tiris District				
Ranu Agung	Cassava	3.61	0.25	0.65
Andung Sari	Coffee	2.34	0.16	1.31
Tiris	Cassava	2.09	0.16	1.32
Krucil District				
Betek	Cassava	2.05	0.07	0.65
Krucil	Coffee	2.35	0.11	1.57
Bremi	Cassava	2.31	0.30	2.74

4. CONCLUSION

The low nitrogen and C-organic contents and medium-to-high acidity underline the general deficiency of agricultural lands in Probolinggo Regency. As for nutrients, the low contents of nitrogen, phosphor, and calcium and the high content of manganese depict the imbalance in their soil production and plant consumption. This calls for biomass production to fix the land composition as well as meet the plant nutrient requirements through an organic approach. Involving organic fertilizers is therefore recommended, especially sludge and slurry from anaerobic digestion. Further research to map out land deterioration for biomass production is expected to run in other areas so that proper treatments can be performed in damaged soil and preventive steps can be taken to avoid it from happening. This action requires the role of field agricultural advisors to make people aware of sustainable agriculture.

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6. CONFLICT OF INTEREST

The authors declared no conflict of interest

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