Relationship between Soil Health Assessment and the Growth of Lettuce

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ABSTRACT

Soil health is very important point for plant growth which is measured by several indicators. The purposes of the research were to assess and to classify soil health Padang Betuah area of Bengkulu, and to compare between soil health indicators and lettuce plant performance indicators. Soils, consist of mineral and peat soils, were sampled using a soil random sampling technique. Lettuce plants were grown in polybags using sample soils. Both lettuce performance and soil health were assessed by calculating the percentage of total scores of lettuce plant or soil performance indicators which derived from variables observed. Soil variables for field evaluation included color, moisture content, texture, structure, compaction, land slope, organic matter, pH, amount of earthworm, erosion level, LCC (Legume Cover Crop), and vegetation performance. Soil variables for laboratory evaluation were pH, electrical conductivity (EC), total Carbon and Nitrogen, available-Posphorus, cation exchangeable capacity, base saturation, and aluminum saturation. While, the variables for lettuce growth performance included plant height, numbers of leaf, degree of leaf greenness, plant fresh weight, and relative percentage of shoot : root ratio. The results of field and laboratory evaluation showed that soil health were categoried as a healthy soil and moderate healthy soil both for mineral and peat soils, respectively. Furthermore, similar categories were also obtained for evaluation of plant performance categories. No correlation was found between the soil performance indicator category and the lettuce performance category.

INTRODUCTION

Soil is an important factor to increase agricultural production, to keep and to attain water health and quality, as well as a home of various organisms, and as a filter and neutralizer of poisoning substances (NRCS 1996, Riwandi 2007). Therefore, maintaning soil health is very important in order to sustain the soil function.

Soil health is an integration and optimalization among various soil physical, chemical, and biological properties, the condition of which would increase productivity and quality of plant, soil, and environment (Idowu *et al.* 2008; Gugino *et al.* 2007). Soil health is a combination and an optimum of soil properties to increase quality and productivity of soil, plant, and environment. Soil health is the capability of soil to perform the productivity without depleting environment quality in the future.

Soil health assessment is obtained based on soil performance indicators, that is a measureable soil properties and it gives signs that soil does its function naturally. Soil will function as it is whenever the interaction between one property and the others give a mutualistic synergy both to the soil health and quality. For example, soil with an amount of organic matter will be able to ameliorate Al effect by chelating Al to the organic matter (Hocking 2001).

This soil will also serve the essensial elements for plant growth and development, soil moisture content as well as it will creates a healthy environment for plant growth and soil microorganisms. The proper interactions among physical, chemical, and biological properties will perform healthy soil and finally it will provide healthy plants.

The urgency of this research is that soil as natural source has been contaminated with many pollutants because of human activities in agriculture (the usage of syntetic fertilizers and pesticides, and mismanagement of soil). This assumption should be proven. To the farmers, this research was

expected to help them to choose the healthy soil of the agricultural land sites and decide which piece of land the most fit to grow their plants. Growing plants on the healthy soil can decrease production costs and have better harvesting products. The objectives of this research were: 1) to assess soil health using soil performance indicators, 2) to classify soil health, and 3) to correlate between the lettuce plant growth and the soil health.

MATERIALS AND METHODS

Study Site

Research was conducted from April to July 2009 in Padang Betuah, Pondok Kelapa District, Central Bengkulu, Indonesia. To the west of the area is the Ocean of Indonesia, to the east is Pondok Kelapa Village, to the north is Lais District, and to the south is Bengkulu City. The geographical points of the area are in the coordinates of X = 57605 to 59072 and Y = 1096505 to 1095089. It comprised the area of 250 hectares which consisted of 30% mineral and 70% peat soils.

Sampling Methodology

Soil random sampling was used as research design. The lowland area of 210 ha and upland area of 40 ha were sampled in random. The slope area was determined according to slope direction (upper, middle, and lower slopes according to Bureau of Soil Research, Bogor (Balittanah, 2004a,b,c 2005). The number of soil samples to represent the mineral and peat soil were 18 samples. The coordinate points of the soil samples are presented on Table 1.

There were four steps in the soil health assessment. They were soil obervation, scoring for soil performance indicators, laboratory analyses, soil health classification, and bioassay research for lettuce plant.

Step 1. Points for soil sampling on the field were determined according to Table 1. Soil performance indicators were observed and recorded on the Soil Health Assessment Forms. Soils were sampled in the depth of 0 cm to 20 cm using soil auger and were repeated 9 time with interdistance 50 cm. All nine samples were mixed thoroughly in a big bucket, soil was separated from plant fragmentations, stones, and gravels to get a 2 kg soil composite.

Step 2. Scoring to each soil performance indicator on the field according to Table 2 was done by scoring 1 to the lowest soil performance indicator, and scoring 5 to the highest one. Every

Table 1. Coordinate points of sample soils.

Code No.	Coordinate		
	UTM	X	Y
PB3	48M 191182 9595909	57824	1096164
PB4	48M 190962 9596250	57605	1096505
PB5	48M 191096 9596622	57740	1095609
PB13	48M 191718 9595354	58359	1095609
PB14	48M 191462 9595098	58103	1095353
PB16	48M 191242 9595281	57883	1095536
PB9	48M 192019 9594148	58658	1094439
PB1	48M 190808 9595228	57449	1095484
PB10	48M 192432 9594835	59072	1095089
PB11	48M 191926 9595872	58568	1096126
PB12	48M 191423 9595757	58065	1096012
PB15	48M 191293 9594720	57843	1094976
PB17	48M 191352 9596224	57995	1096479
PB18	48M 191841 9596399	58484	1096653
PB2	48M 190936 9595562	57578	1095817
PB6	48M 191955 9594942	58595	1095196
PB7	48M 191768 9594758	58408	1095013
PB8	48M 191687 9594243	58326	1094498

indicator, then, was summed up to get total scores. Classing of soil health was determined according to the total score of the observed point of soil. All those soil properties were scored from 1 (to represent <20%) to 5 (to represent 100%) (OSU Center 2009). In case of any soil property which was not included in that scoring criteria, the score was made and modified according to our reasonable purpose.

Step 3. Analysis of sample soil sample in the laboratory. The soil sample was air dried, grounded on mortal and pestled, and filtered until diameter 0.5 mm with ASTM screen. Soil sample was then ready for analyses. Soil chemical properties consisted of pH (H_2O), electrical conductivity (EC), total C and N, available-P, base saturation (sum of cations of K, Ca, Mg devided by CEC × 100%), and Aluminium saturation (Al devided by CEC × 100%). Every soil chemical property was scored according to criteria from Bureau of Soil Research (Balittanah 2005) and presented in Table 3.

Step 4. Determining soil health class was based on the percentage of total scores of observed point of soil according to Table 4. The soil health was classified as Very Healthy, Healthy, Moderately Healthy, Less Healthy, and Unhealthy.

The pH H_2O (soil : distilled water 1 : 2.5 w/v), was measured by using pH meter (Conway).

Table 2. Assessment criteria and the score for soil performance indicator on field.

Soil Performance Indicator	Very Low (score 1)	Low (score 2)	Moderate (score 3)	High (score 4)	Very High (score 5)
Soil Color	Red	Yellow	Green	Brown	Black
Soil Moisture Content	> 75%	< 25%	75%	50%	25-50%
Slope	> 30%	15-30%	8-15%	3-8%	0-3%
Texture	Sand/clay	Silty sand	Sandy clay	Silty clay	Clay Sapris
Peat Maturity	Fibris	-	Hemis	-	
Soil structure	Very hard	Hard	Less loose	Loose	Very loose
Organic Matter	None	Small amount	Moderate	Large amount	Abundant
pH (H$_2$0)	< 4.5	4.5-5.5	7.6-8.5	5.5-6	6-7.5
Earthworm Population	none	Small amount, faeces, & earthworm holes	moderate, faeces, & earthworm holes	Large amount, faeces, & earthworm holes	Abundant, Faeces, & earthworm holes
LCC	< 45%	45-64%	65-74%	75-99%	100%
Soil Erosion	Big Gully	Small Gully	Gully	Sheet	None
Soil Compaction	Hard, compact, bad root penetration	Hard, compact	Firm, Restricted Root Penetration	Loosely soil	Freely Root penetration
Vegetation Performance	White leaves, stunted, element stress	Stunted, element stress	Plants grow moderately, less element stress	Leaves green, no element stress	Leaves green, normal growth, no element stress

Source: Bierman (2007) modified to fit to local area condition.

Table 3. Assessment criteria and scoring for soil analyses in the laboratory.

Soil Properties	Very Low (score 1)	Low (score 2)	Moderate (score 3)	High (score 4)	Very High (score 5)
C (%)	< 1	1-2	2-3	3-5	> 5
N (%)	< 0.1	0.1-0.2	0.21-0.50	0.51-0.75	> 0.75
P2O5 Bray (ppm P)	< 4	5-7	8-10	11-15	> 15
KTK (cmol(+) kg^{-1})	< 5	5-16	17-24	25-40	> 40
Ca (cmol(+) kg^{-1})	< 2	2-5	6-10	11-20	> 20
Mg(cmol(+) kg^{-1})	< 0.3	0.4-1	1.1-2.0	2.1-8.0	> 8.0
K(cmol(+) kg^{-1})	< 0.1	0.1-0.3	0.4-0.5	0.6-1.0	> 1.0
Bases saturation (%)	< 20	20-40	41-60	61-80	> 80
Al saturation (%)	< 5	5-10	11-20	20-40	> 40
DHL(dS m^{-1})	< 1	1-2	2-3	3-4	> 4

Source: Balittanah (2005).

Electrical Conductivity (EC) was measured by using proportion (soil : distilled water = 1 : 1), was measured by using EC meter (Jenway). Carbon total was measured using Walkley and Black Method. Nitrogen was measured by using Kjeldhal method. Available-P (P$_2$O$_5^-$) was extracted by using Bray 1 method and analysed using UV-Vis Spectrofotometer (PG Instrument Ltd.). Exchanged-base (K-, Ca-, and Mg – exchangeable) was extracted by using 1 *N* Ammonium Acetic pH 7, and exchangeable-K was measured by using Flamephotometer, Calsium (Ca-exc) and

Tabel 4. Assessment criteria indicators for lettuce plant.

Growth Indicators	Score				
	1	2	3	4	5
Plant height (cm)	0-6 cm	7-12 cm	13-18 cm	19-24 cm	25-30 cm
Degree of leaf greenness	0-8	9-16	17-24	25-32	33-40
Shoot/root ratio (% relative)	0-20%	21-40%	41-60%	61-80%	81-100%
Number of leaves	0-2	3-4	5-6	7-8	> 8
Plant fresh weight (g)	0-20 g	21-40 g	41-60 g	61-80 g	> 80 g

Magnesium (Mg-exc) were measured by using a titrated method with 0.005 M EDTA. Aluminium and Hidrogen were extracted with 1 N KCl and measured by using titrated method with 0.1 N H_2SO_4 standard.

Data of soils assessment were plotted and the total scores were used to categorized the soil health into one of the five categories (*e.g.* Unhealthy, Less healthy, Moderate healthy, High healthy, and Very healthy). To compare the soil performance indicators and lettuce plant indicators, data of the two observations were analyzed using t-test 0.05. If the result was significant, it means the assessment method can not be applied so another method should be introduced.

RESULTS AND DISCUSSION

The topography of research area were flat land with total area of 210 ha and light slope with total area of 40 ha. The peat type area covered 70%, whereas mineral type area covered 30%. The land use of flat peat soil area was dominated by paddy. Palm oil plantation was commonly found on slopy mineral soil. The peat soil in this area was unique because it was not influenced by tidewater, mainly consisted of woody remains especially from angiosperm, and originated from the *in situ* formation with topogenic peat as the result of slope effect that supplied mineral soil materials to the peat area. The spread of peat downstream usually reached 10 – 50 km from the sea line (Ritung and Wahyunto 2003).

Table 5 showed that the area was classified as a moderate healthy and a healthy based on the 12 indicators observed in the field. Three soil samples of each mineral soils and peat soils, which represented a moderate healthy and a healthy soil, respectively, were analyzed in the laboratory for soil chemical properties. Result of laboratory analysis were more accurate than field observations but laboratory procedure took a longer time. Field analyses could be reliable method and more

practical especially for farmers. But the farmers should be trained so they get used to assess soil indicator performances.

Soils with category Moderate Healthy were obtained from PB5 and PB12 (mineral soils) and PB6 (peat soil). Healthy soils were PB 7 (mineral) and PB13 as well as PB14 (peat soils). Following field observations and categorization, soil measurement was continued to laboratory analyses. It was an important step since field categorization was greatly depended on the accuracy of person (s) during the observations. Inspite of this fact, both field and laboratory works are interdependent to get the whole picture of soil status.

Table 6 showed that soil chemical properties of the soil samples were categorized as healthy except on bases saturation which showed a very low level. It means the availability of the nutrition elements to plants was low. The unavailability of the elements was due to the low capacity of soil to hold and to exchange the elements. This was indicated by the observed data that the CEC of mineral and peat soils were low. The soil had low pH indicated that it was acid soil, and it was also another factor that imposed the low availability of nutrient elements. Eventhough the C-organic of the peat soil was very high (score 5), it was not strong enough to support the CEC, bases saturation, and to ameliorate high Al saturation.

Table 7 indicated that 3 variables of growth of lettuce plants (plant height, leaf greenness, and number of leaves) were in category healthy, while shoot/root ratio was very low and plants fresh weights were varies. Total categories, lettuce plants were in moderate and healthy categories and this had no correlation to the results from soil performance indicators. It was supported from the t-test showing that it fitted the significance of 95%.

The balance among soil physical, chemical, and biological properties will contribute the assurance of soil health in the future. For that reason, soil health asessment needs some indicators such as physical, chemical, and biologcal properties

Table 5. Soil health categories from Padang Betuah, Pondok Kelapa District, Central Bengkulu.

Code No.	Soil Type	Landuse	Color	Water content	Slope	Texture	Structure	Organic Matter	pH	Earthworm population	Cover crop	Erosion	Soil compaction	Vegetation	Total Score	Percentage	Category
PB1	Mineral	Bush	4	4	3	1	3	5	1	1	1	5	3	5	36	60%	M
PB2	Mineral	Palm oil	4	4	3	1	3	3	1	3	1	5	1	3	32	53%	M
PB3	Mineral	Palm oil	4	5	5	3	3	3	2	1	1	5	3	3	38	63%	H
PB5	Mineral	Palm oil	4	2	5	2	2	3	1	5	1	4	2	1	32	53%	M
PB7	Mineral	Paddy	4	5	4	1	5	2	2	3	1	5	5	3	40	67%	H
PB8	Mineral	Grass	2	2	5	2	2	2	5	1	2	5	2	2	32	53%	M
PB12	Mineral	Bush	4	4	4	2	1	3	2	2	2	4	2	2	32	53%	M
PB17	Mineral	Palm oil	5	3	3	2	5	5	1	1	1	5	5	2	38	63%	H
PB18	Mineral	Palm oil	3	5	5	2	2	2	1	1	2	5	2	2	32	53%	M
PB4	Peat	Palm oil	5	5	5	5	5	5	1	1	2	5	2	5	46	77%	H
PB6	Peat	Palm oil	5	5	5	5	1	5	2	1	1	4	1	1	36	60%	M
PB9	Peat	Bush	4	4	5	5	2	5	2	1	2	5	2	2	39	65%	H
PB10	Peat	Grass	5	5	5	5	1	5	2	1	1	4	2	1	37	62%	H
PB11	Peat	Corn	5	2	5	5	1	5	2	1	1	5	2	1	35	58%	M
PB13	Peat	Bush	5	5	5	2	5	5	1	5	2	5	5	1	46	77%	H
PB14	Peat	Paddy	5	5	5	5	2	5	2	1	1	5	5	5	46	77%	H
PB15	Peat	Paddy	5	5	5	5	1	5	2	1	1	5	4	5	44	73%	H
PB16	Peat	Paddy	5	5	5	5	3	5	2	1	1	5	3	5	49	82%	H

Table 6. Laboratory analyses and scoring of soil properties from Padang Betuah, Pondok Kelapa District, Central Bengkulu.

Code no.	pH (H₂O)	Score pH	EC (dS m⁻¹)	Score EC	C (%)	Score C	N (%)	Score N	P₂O₅ (ppm)	Score P	CEC mg 100g⁻¹	Score CEC	Base-satrn (%)	Score Base	Al satrn (%)	Score Al	Total score	Percentage	Category
PB5	4.3	1	0.079	5	7.40	5	0.64	4	22.85	5	30.35	4	5.67	1	27.48	2	27	68%	H
PB7	5.5	3	0.053	5	5.35	5	0.55	4	7.37	3	17.14	3	8.40	1	22.40	2	26	65%	H
PB12	4.2	1	0.058	5	21.8	5	1.35	5	20.05	5	16.01	3	7.43	1	21.49	2	27	68%	H
PB6	4.2	1	0.056	5	36.3	5	0.37	3	38.28	5	8.54	2	33.14	2	49.77	1	24	60%	M
PB13	4.8	2	0.515	5	20.9	5	0.37	3	1.67	1	39.71	4	7.08	1	9.14	4	25	63%	H
PB14	4.6	2	0.046	5	34.9	5	1.97	5	83.47	5	18.71	3	31.11	2	18.76	3	30	75%	H

Code No.	Soil Type	Land use	Plant height	Score	Leaf greenness	Score	Shoot/Root ratio	Score	Total leaves	Score	Fresh wght	Score	Total Scores	Percentage	Category
PB5	Mineral	Palm oil	16	3	24	3	5	1	12	1	51	5	15	60	M
PB7	Mineral	Paddy	15	3	17	3	5	1	9	1	20	5	13	52	M
PB12	Mineral	Bush	15	3	45	5	6	1	10	1	21	5	16	64	H
PB6	Peat	Palm oil	21	4	22	3	9	1	12	1	42	5	16	64	H
PB13	Peat	Bush	14	3	23	3	4	1	9	1	17	5	13	52	M
PB14	Peat	Paddy	18	3	27	4	8	1	13	1	63	5	17	68	H

Note: M = Moderately Healthy. H = Healthy.

(Monkiedje *et al*. 2006). Eventhough there were 12 soil health indicators used in this research, more indicators were also used by other researchers. Another researcher used 39 soil health indicators consisted of 16 physical indicators, 11 chemical indicators, and 12 biological indicators (Idowu *et al*. 2008). The number of soil indicators used in the asessment depends on the location and level of accuracy in measuring soil health (Kinyangi 2007). Furthermore, it is impossible to choose a single indicator to measure soil health, but it must be chosen some relevant indicators and also having close relationship with the problem of measured soil. For example, the dominant soil health criteria on post-mining areas are soil structure, soil moisture, soil organic matter, soil pH, and number of soil earthworms. On unfertile soil the main criteria are the level of soil elements and soil organic matter. Another example is health-degraded soil which is measured for the level of soil erosion, soil organic matter, soil structure, and soil pH. The soil asessment method used in this research can be applied on every soil type including agricultural land, mineral soil, peat soil, post-mining soil, less fertile soil, marginal soil, degrade soil, and other various soil landuses.

CONCLUSIONS

It can be concluded that the assessment of soil health using soil performance indicator approach, both on field (qualitative, quick, and less accurate) and laboratory approach (quantitative, time consuming, and accurate) was reliable. The categories of Padang Betuah soils were moderate healthy and healthy. The responses of lettuce plants upon the types of soils were 95% in the interval of confidence, but no correlation indicated between soil health performance method and plant performance. It showed that soil health categories based on lettuce growth variables did not correlate to soil health categories based on soil performance indicators. Further research is needed for other different types of soils so that soil health assessment method could be applied on soil types in this area.

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