Measuring Soil Recovery after Coal Minesite Rehabilitation

By Dwi Setyawan

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Measuring Soil Recovery after Coal Minesite Rehabilitation in South Sumatra

Dwi Setyawan*[1*], Adipati Napoleon[1], Herlina Hanum[2]

[1]Soil Science Department, Faculty of Agriculture, Universitas Sriwijaya, Indralaya 30662, Indonesia,

[2]Mathematics Department, Faculty of Mathematics and Sciences, Universitas Sriwijaya, Indralaya 30662, Indonesia,

Abstract: Soil recovery in minesites is a complex process and needs various methods to measure the progress. This study integrated static closed-chamber technique together with several soil variables. Soil respiration used 20 ml of 0.25 M KOH and measured with a portable EC-meter. Land reclamation was located in Banko Barat, Tanjung Enim, South Sumatra, which has been revegetated in 1997, 2000, 2007 and 2013. Revegetation patterns have remained relatively the same. Types of plants are generally Acacia, Eucalyptus, Albizia with some local species including mahogany. Post-mining land showed a trend to improve with age reclamation by soil respiration rate. The old location (1997) has a hourly rate of 500 mg CO_2/m^2. A warmer temperature may lead to higher hourly rate in recently planted 2013 site (680 mg CO_2/m^2). Soil organic carbon increased significantly (5.41 ± 3.64 %) while soil pH was still acidic (3.61 ± 0.42). Soil recovery may be related to increasing soil respiration, organic carbon, and soil pH. Plant selection is important to ensure future success of site rehabilitation.

Keywords: Coal mine, In-situ method, Plant selection, Soil respiration.

e-mail: dsetyawan@unsri.ac.id*

1. INTRODUCTION

Minesite rehabilitation creates a new environment that in turn will serve as a nieche for returning habitants. However, the way to achieve such conditions is not easy. Many factors get involved to ensure its future successful story. Local experience and knowledge also determine the continuity of rehabilitated ecosystems. Most commonly used is replanting the mined land with various plant species, particularly those indigenous to the locality. Planted trees are expected to return soil biomass that subsequently beneficial for soil biota. Therefore, measuring changes in soil surface may be utilised as a surrogate to measuring the developmet of soil ecology in minesites.

One of the key measurement is *in-situ* soil respiration. In general soil respiration is the process of evolution of CO_2 from the soil into the atmosphere, mainly generated by micro-organisms in the soil and plant roots. This is influenced not only by biological factors (vegetation, micro-organisms, etc.) and environmental factors (temperature, humidity, pH, etc.), but also more powerful by man-made factors. Reference [1] examined the relationship between soil respiration with the latitude and temperature using the measured data of forest vegetation in different parts of the world. Soil respiration rate decreases in exponential with increasing latitude while increases with increasing temperature. The relationship between soil respiration and temperature, the Q10 (Van Hoff law) was 1.57 on a global scale.

Respiration measurement for *in-situ* is often translated as CO_2 flux. Respiration can be attributed to soil health status. The rate of soil respiration can be measured in static and dynamic system. Sophisticated measurement techniques generally use infrared gas analyzer (IRGA). This technique is still relatively expensive.

Revegetation of disturbed sites using a mixture of a large number of plant species is a common practice. Plant species for site rehabilitation may be indigenous to the locality or introduced, as for example the rehabilitation of a gold mine spoil [2], bauxite mines [3,4], and a lignite mine [5]. Various cultural practices are usually employed.

In contrast, natural (spontaneous) rehabilitation may also provide quite satisfactory remediation of disturbed sites although establishment of plant cover by this method may take a considerably longer period and outcomes may not be easily predicted due to exposure to risk of failure during the long slow development [6]. Reference [7] reviewed disturbed sites around the world and found that natural rehabilitation induces a more stable landscape, owing partly to less compaction by machinery and provides more favorable niches for species diversity on abandoned sites.

Another issue in minesites rehabilitation is how to monitor progress. Procedures to be used in monitoring should be practical, quick, unambiguous, and repetitive. Landscape Function Analysis (LFA) technique was originally developed the for rangelands in Australia [8], but now it has been revised for use on minesites [9]. Although the analysis is quite reliable, examples of its application to minesites are still limited, and more fieldwork is required to validate the technique.

Soil development on disturbed sites is often initiated by surface stabilization which is partly due to binding of soil particles by fine roots of annual species, together with growth of lichens and mosses which may lead to biocrust (cryptogam) formation. Protection against rain-splash erosion is necessary to minimize losses of soil particles, nutrients, viable seeds and water. The protection may come from rock fragment, logs and branches, or low shrubs and perennial grasses (i.e. less than 0.5 m height).

Soil conditions on disturbed sites change with time at a variable rate. The improvement of conditions can be expressed by a substantial increase in the nutrient pool (e.g. total nitrogen, available phosphorus), or by other soil indicators. Changes in these soil properties can be related to soil surface and landscape attributes. Therefore, an assessment of soil surface conditions is an important step in describing the extent of soil recovery that might have occurred at disturbed sites. Various methods have been developed as tools for assessing ecosystem recovery and soil conditions after disturbance. Various parameters are used by each method as indicators of soil and habitat recovery including ants [10], avifauna [11], amphibians and invertebrates [12], and soil surface conditions [8]. Despite a wide range of parameters used in the analysis, interpretation and prediction of site evolution, the common ground is to assess whether the present landscape condition is progressing toward a sustainable ecosystem. Re-establishment of a sustainable ecosystem needs vegetative diversity and productivity that are suitable for the prescribed final use. This requirement is equally applicable for mine site and agricultural land.

This research focused on the development of soil-based indicator to measure soil recovery in coal mine sites after several years of reclamation and revegetation.

2. EXPERIMENTAL DETAILS

A. Research Site

The research was conducted at coal post-mining land in Banko Barat site of Tanjung Enim mining concession (operated by PT Tambang Bukit Asam Tbk) in 2014, and continues in 2016. The reclamation sites included the planting year of 1997, 2000, 2007 and 2013. These sites had been prepared in slightly different ways. The old sites of 1997 and 2000 were planted with mixed local tree species including sengon (*Albizia chinensis*), laban (*Vitex pubescens*), pulai (*Alstonia scholaris*), trembesi (*Samanea saman*), *Acacia mangium*, and merbau (*Instia palembanica*). The 2007 site is typically planted with kayu putih *(Melaleuca leucadendra).* While in the newest site of 2013 the common species is sengon buto (*Enterolobium cyclocarpum*)

B. Soil Respiration Measurement

The basic research protocol is as follows. The ground condition is graded qualitatively especially litter or organic matter content. Transect lines are established and soils surface condition are observe and recorded following the procedure of landscape function analysis [8].

Main outcomes include the amount of CO_2 captured in a solution of 0.25 M KOH (as absorbent) after incubation for several hours. The solution is measured for salinity using EC meters previously standardised. The method was adopted from [13], a technique called inverted box.

In each area to be studied some ground conditions are chosen to estimate the range of soil conditions. The initial assessment includes litter cover (organic matter), plant conditions, and soil development. Furthermore inverted chamber (in the form of ring diameter 20 cm) mounted on the ground, inserted 3-4 cm into the soils. Plastic vials are placed in the chamber then filled up with 20 ml of 0.25 M KOH solution. Ring is then closed, and the time is recorded. After several hours the closed ring is opened, KOH solution is transferred into a container (tube) and directly measured for salinity (EC) with portable EC meter that has been calibrated previously.

The rate of soil respiration was estimated by measuring the electrical conductivity (EC) of alkali solution. The measurement results are calibrated using a curve EC that also read newly created KOH solution and saturated KOH CO_2. For a ring with diameter of 20 cm and 20 ml of 0.25 M KOH, soil respiration can be calculated by the following (1) (modified from [9].

$$Rate = \frac{110(x_2-x)}{x_2-x_1} x \frac{10000}{314} x \frac{1}{t} \qquad (1)$$

Where

Rate of respiration in mg CO_2/m^2/hour; x = sample EC (mS/cm), x_1 = EC of CO_2-saturated KOH, x_2 = EC of fresh KOH, t = time of measurement (hour)

C. Soil Sample Analysis

Five soil samples were also collected from individual sites in conjunction with soil respiration. We analysed for soil pH (glass electrode, 1:2.5 solution), soil organic carbon (wet destruction following Walkley-Black method), and soil bulk density (ring and gravimetric method).

In addition, aseptic soil samples were also collected and later analysed for total soil microbes. One gram of soil sample wwas diluted in 99 ml of aquadest, later diluted several time as required in nutrient agar, and finally the formed colony was counted.

3. RESULTS AND DISCUSSION

A. Soil Properties

Organic carbon content from surface soil of the research sites increases with time of revegetation (Table I). Litter fall from higher trees has contributed to significant increase in soil organic carbon (SOC). In many cases of soil reclamation SOC is a good and reliable indicator of soil recovery. For example, the study of soil recovery after gold mining in Kelian of East Kalimantan demonstrated a strong relation between SOC and soil index [14]. The increase of SOC is closely related to soil bulk density. The remaining acidic condition of all sites reflects the quality of returned waste materials for land rehabilitation.

TABLE I. SELECTED SOIL PROPERTIES OF COAL MINE SITES

Reclamation site	Soil pH	Organic carbon (g/kg)	Bulk density (g/cm3)
1997	3.28	65.3	0.88
2000	3.53	35.6	1.21
2007	4.00	41.5	1.14
2013	3.64	9.0	1.45

B. Soil Microbe and Respiration

Revegetation induced a significant increase in total soil microbes (Tabel II). In this case, the microbes are distinguished between bacteria and fungi. The higher respiration rate for the newly planted is more likely induced by warmer temperature due to less plant canopy. Assuming soil respiration is mainly produced by soil microbes, the high value of measurement for short time (1-2 hours) in 2013 site is believed due to higher soil temperature,

TABLE II. SOIL MICROBES AND RESPIRATION OF COAL MINE SITES

Reclamation site	Total soil microbes (cfu/gram)	Respration rate (mg CO2/m2/hour)
1997	7.73E+11	505
2000	3.24E+11	477
2007	3.06E+11	488
2013	2.41E+11	769

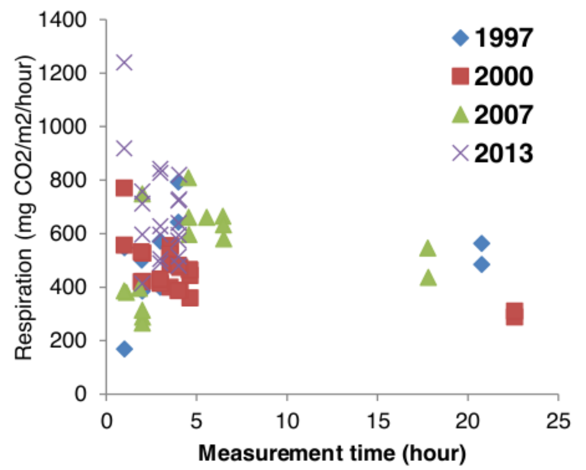

Fig.1. Respiration rate with time representing four sites

Soil respiration rate on each of reclaimed land has a common pattern. However, the trends are slightly different (Fig.1). Surprisingly, the newly planted site in 2013 produced an active respiration, while for the older sites the trends are slowing down. Many environmental factors influence soil respiration. Soil respiration may be treated as CO_2 flux. It is generally divided into autotrophic and heterotrophic respiration. The autotrophic example is the respiration of roots and soil microbes being closely associated with the rate of photosynthesis. While CO_2 in heterotrophic respiration is derived from the metabolism of soil microorganisms and soil fauna. Heterotrophic respiration is the process of respiration closely linked with changes in temperature [15].

4. CONCLUSION

Soil recovery in coal mine sites is considerably satisfactory with time of reclamation. There is significant increase in soil organic carbon and total soil microbe. This improving condition however is not followed by reducing of soil acidity. Long-term changes is anticipated by soil resiration data. Plant species selection and site prepartion should be reviewed regularly to ensure the achievement of sustainability threshold.

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