Real Time Simulation of the Number of Microbial Populations for Fertility Optimization in Inseptisol Soils Using Smart Biosoidam Technology

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ABSTRACT

This research was conducted on inseptisol soils, especially for vegetable plantations, aimed to determine the ability of the soil layer to distribute nutrients and restore soil health and fertility due to the use of chemical fertilizers and pesticides. Through microbial activity that is controlled by spreading through a horizontal biohole, this study observes in real time through a micro controller the changes in soil acidity, infiltration rate, electrolyte conductivity levels and porosity levels through soil infiltration rates.

Through simulations with the variable microbial population, it can be seen the level of EC and other parameters against the time of observation in real time. From the observations of graphs and EC standards, it can be seen that the ability of the soil. Until day 45 the soil fertility level has not reached=1500 uS/cm with a microbial population=10^3/cfu. Support the planting schedule both during the vegetative growth period and during the generative growth period, so that we will know when the right time to do is: Soil recovery, initial planting and when the tubers/flowers/fruit begin to be conditioned. until cooked based on nutrient values observed through sensors that convert analogue parameters by the micro controller into digital information transmitted by Wi-Fi in real time.

The initial condition before simulating the soil fertility value with the Electrolyte Conductivity (EC) parameter is 744 uS/cm, the simulation results are: Simulation A: To start the growth period (vegetative) is achieved on the 15th day with a EC E=1050 uS/cm and in the generative period it is reached on the 23th day with a EC=1518 uS/cm. Simulation B: To start the growth period (vegetative) is achieved on the 22th day with a EC=1008 uS/cm and at the generative period it is reached on the 38nd day with a EC=1539 uS/cm . Simulation C: to start the growth period (vegetative) is achieved on day 37 with a EC=1025 uS/cm and during the generative period it cannot be observed because on observation until day 45 the electrolyte conductivity has not reach=1500 uS/cm.

Keywords: Biohole; Microbial; Alluvial; Micro controller; Soil acidity; Infiltration; Electrolyte conductivity; Biosoildam

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INTRODUCTION

The potential of alluvial land is very large for agricultural business, but the structure of this soil layer is also easily damaged if managed incorrectly. The ability of farmers also needs to be improved, especially in understanding the characteristics of this soil. So that with Biosoildam technology it will save fertilizer use and increase crop production while preserving natural resources through soil and water conservation.

The current decline in carrying land capacity continues to expand (environment degradation). One of the main contributing factors is the decrease in the soil fertility, health and absorption (infiltration rate), triggered by excessive use of inorganic fertilizers (pesticides) (Widiasmadi N, 2020). To restore the land's capacity quickly and measurably and to restore soil productivity as well, infiltration is not enough. Biological agents (bio fertilizer) are needed to support soil and water conservation. However, so far, there has not been any periodical and continuous/real-time measurement of the monitoring and assessment system of agricultural cultivation. Thus, accurate information on a soil parameter in achieving a harvest target is needed.

Infiltration is the process of water flowing into the soil which generally comes from rainfall, while the infiltration rate is the amount of water that enters the soil per unit time. This process is a very important part of the hydrological cycle which can affect the amount of water that is on the surface of the soil. Water on the surface soil will enter the soil and then flow into the river (Sunjoto S, 2011). Not all surface water flows into the soil, but some portion of the water remains in topsoil to be further evaporated back into the atmosphere through the soil surface or soil evaporation (Suripin IR, 2004).

Infiltration capacity is the ability of the soil to absorb large amounts of water into the ground and influenced by the microorganism activities in the soil (Widiasmadi N, 2020). The large infiltration capacity can reduce surface runoff. The reduced soil pores, generally caused by soil compacting, can cause a decreased infiltration. This condition is also affected by the soil contamination (Widiasmadi N, 2020) due to excessive use of chemical fertilizers and pesticides which hardens the soil as well.

Smart-Biosoildam is a Biodam technology development that involves microbial activity in increasing the measured and controlled inflation rate. Biological activities through the role of microbes as agents of biomass decomposition and soil conservation become important information for soil conservation efforts in supporting healthy food security (Widiasmadi N, 2020). Such development has used a microcontroller to effectively monitor the activities of the said agents through the electrolyte conductivity parameter as an analogue input of EC sensors embedded in the soil and further converted to digital information by the microcontroller (Widiasmadi N, 2020).

To control the activities of biological agents, other variables are needed, such as information on pH, humidity (M) and soil temperature (T) obtained from pH sensors, T sensors, M sensors. These sensors are connected to a microcontroller which can be accessed through a pin that functions as a GPIO (General Port Input Output) in the ESP8266 Module so as to provide the additional capability of a WIFI-enabled microcontroller to send all analogue responses to digital in real-time, every second, minute, hour, day and monthly. Furthermore,

we can display this data in info graphics and numeric tables to be stored and processed in the WEB (Wasisto S, 2018).

METHODOLOGY

To maximize yields, optimal soil nutrient content is required ranging from vegetative growth to generative growth so as to save the use of organic fertilizers and other nutrients. This research is to observe the number of microbes that spread radially through the horizontal biohole as the center of microbial distribution which is observed in real time using soil parameter sensors. This research will show soil characteristics in its ability to increase natural fertility and the ability to nourish the soil from toxins that come from water and air pollution.

The study was conducted on alluvial land which for decades has been the source of livelihood for the community of Banteng Village Pangakalan Baru District Bangka Tengah Regency. Land management lacks soil and water conservation. People use chemical fertilizers and pesticides excessively which harden the soil texture, acidify the soil and decrease the yields. Hardened agricultural land also triggers floods, since the soil's ability to absorb decreases. This research that took place from Mei-September 2020, intends to restore the carrying capacity of the land.

Tools and materials used in research are: Mikrokontroler Arduino UNO,Wifi ESP8266, Soil parameter sensor : Temperature (T) DS18B20, humidity (M) V1.2, Electrolit Conductivity (EC) G14 PE, Acidity pH) Tipe SEN0161-V2 , LCD module HD44780 controller, biohole as injector for biosoildam, bio fertilizer mikrobia alfafaa MA-11, red union straw as microbia nest, abney level, double ring infiltrometer (Figure 1 A and B), erlemeyer, penggaris, stop watch, plastic bucket, tally sheet, measurement glass, micro scale, hydrometer dam water (Douglas, M.G. 2018).

Figure 1A: Double ring infiltrometer and sensors

Hammer Erection   Without Leakage   Instal the scale   Watering   Recording of Water Drop

Figure 1B: Installation of double ring infiltrometer

Determining plot and sensor points

To determine plots and sensors, this study uses purposive sampling at various distances: 1.5; 2; 3 metre from the center of Biohole with a diameter of 1 meter as the central radial distribution of the biological agent Microbe Alfaafa MA-11 through the water injection process. Infiltration rate and radial biological agent distribution can be controlled in real-time through measurement sensors with parameters: EC/salt ion (macronutrients), pH, humidity and soil temperature. And as a periodical control, the infiltration rate with a double ring infiltrometer on

the variable distance from the center of the biohole is manually measured. Next, soil samples are also taken to analyse their characteristics, such as soil texture, organic material content and bulk density (MG Douglas, 2018).

Data processing

Catalysis discharge: Smart biosoildam innovation uses runoff discharge as a media for biological agent's distribution through the inlet/inflow (Biohole) as a centre for the microbial populations distribution with water. The runoff discharge calculation as a basis for the Inflow Biosoildam formula requires the following stages:

• Conducting a rainfall analysis

• Calculating the catchment area, and

• Analysing the soil/rock layers.

Biosoildam structure can be made with holes in the soil layer without or using water pipes/reinforced concrete pipes (RCP) with perforated layer that will let microbes to spread radially. We can calculate the discharge entering biohole as a function of the catchment characteristic with a rational formula:

$$Q=0,278 \; CIA \qquad (1)$$

Where C is the runoff coefficient value, I is the precipitation and A is the area (Sunjoto S, 1998). Based on this formula, the Table presents the results of runoff discharge (Table 1).

Table 1: Microbes analysis

No	Population analysis	Result
1	Total of Micobes	$18,48 \times 108$cfu
2	Selulotik Micobes	$1,39 \times 108$cfu
3	Proteolitik Micobes	$1,32 \times 108$cfu
4	Amilolitik Micobes	$7,72 \times 108$cfu
5	N Fixtation Micobes	$2,2 \times 108$cfu
6	Phosfat Micobes	$1,44 \times 108$cfu
7	Acidity	3,89
8	Ure-Amonium-Nitrat Decomposer	Positive
9	Patogenity for plants	Negative
10	Contaminant E-Coli and Salmonella	Negative
11	Hg	2,71 ppb
12	Cd	<0,01 mg/l
13	Pb	<0,01 mg/l
14	As	<0,01 ppm

Infiltration: Infiltration is the process by which water on the ground surface enters the soil. It is commonly used in both hydrology and soil sciences. The infiltration capacity is defined as the maximum rate of infiltration. It is most often measured in meters per day but can also be measured in other units of distance over time if necessary. The infiltration capacity decreases as the soil moisture content of soils surface layers increases. If the precipitation rate exceeds the infiltration rate, runoff will usually occur unless there is some physical barrier. Infiltrometers, permeameters and rainfall simulators are all devices that can be used to measure infiltration rates. Infiltration is caused by multiple factors including; gravity, capillary forces, adsorption and osmosis. Many soil characteristics can also play a role in determining the rate at which infiltration occurs.

The spread of microbes as a biomass decomposing agent can be controlled through the calculation of the infiltration rate at point radius

from Biohole as the centre of the spread of microbes by using the Horton method. Horton observed that infiltration starts from a standard value f_o and exponentially decreases to a constant condition f_c. One of the earliest infiltration equations developed by Horton is:

$$f(t) = f_c + (f_o - f_c)e - kt \qquad (2)$$

where-

k is a constant reduction to the dimension [T-1] or a constant decreasing infiltration rate.

f_o is an infiltration rate capacity at the beginning of the measurement.

f_c is a constant infiltration capacity that depends on the soil type.

The f_o and f_c parameters are obtained from the field measurement using a double-ring infiltrometer. The fo and fc parameters are the functions of soil type and cover. Sandy or gravel soils have high values, while bare clay soils have little value, and for grassy land surfaces, the value increases (Widiasmadi N, 2019).

$$\text{Infiltration rate} = (\Delta H/t \times 60) \qquad (3)$$

Where-

ΔH=height decrease (cm) within a certain time interval, T=the time interval required by water in ΔH to enter the ground (minutes) (Huang Z, *et al.*, 2011). This observation takes place every 3 days for one month.

Soil characteristics: The porosity of soils is critical in determine the infiltration capacity. Soils that have smaller pore sizes, such as clay, have lower infiltration capacity and slower infiltration rates than soils that have large pore size, such as sands. One exception to this rule is when clay is present in dry conditions. In this case, the soil can develop a large crack which leads to higher infiltration capacity.

Soil compaction is also impacts infiltration capacity. Compaction of soils results in decreased porosity within the soils, which decreases infiltration capacity.

Hydrophobic soils can develop after wildfires have happened, which can greatly diminish or completely prevent infiltration from occurring.

Soil moisture content: Soil that is already saturated has no more capacity to hold more water, therefore infiltration capacity has been reached and the rate cannot increase past this point. This leads to much more surface runoff. When soil is partially saturated then infiltration can occur at a moderate rate and fully unsaturated soils have the highest infiltration capacity.

Organic materials in soils (including plants and animals) all increase the infiltration capacity. Vegetation contains roots that extent into the soil which create cracks and fissures in the soil, allowing for more rapid infiltration and increased capacity. Vegetation can also reduce surface compaction of the soil which again allows for increased infiltration. When no vegetation is present infiltration rates can be very low, which can lead to excessive runoff and increased erosion levels. Similarly to vegetation, animals that burrow in the soil also create cracks in the soil structure (Laflen JM, *et al.*, 2000).

Microbial population: This analysis uses MA-11 biological agents that have been tested by the Microbiology Laboratorium of Gadjah Mada University based on Ministerial Regulation standards: No 70/Permentan/SR.140/10 2011 includes its application in Biosoildam is concentrating the microbes into "population media", as a source of soil conditioner for increasing infiltration rates and restoring natural fertility.

Microcontroller against nutrient content, acidity, temperature and soil moisture: Indications of microbial activity on fertility can be controlled through acidity. The number of nutrients contained in the soil is an indicator of the level of soil fertility due to the activity of biological agents in decomposing biomass. Important factors that influence the absorption of nutrients (EC) by plant roots are the degrees of soil acidity (soil pH), temperature (T) and humidity (M). Soil Acidity level (pH) greatly influences the plant's growth rate and development (Boardman CR, *et al.*, 1966).

Microbial activity as a contributor to soil nutrition from the biomass decomposition results can be controlled through the salinity level of the nutrient solution expressed through conductivity as well as other parameters as analogue inputs. Conductivity can be measured using EC, Electroconductivity or Electrical (or Electro) Conductivity (EC) is the nutrients density in solution. The more concentrated the solution is, the greater the delivery of electric current from the cation (+) and anion (-) to the anode and cathode of the EC meter. Thus, it results in the higher EC. The measurement unit of EC is mS/cm (millisiemens) (Lafle JM, *et al.*, 2011).

This study uses an Arduino Uno microcontroller which has 14 digital pins, of which there are 6 pins used as Pulse Width Modulation or PWM outputs, namely the pins D.3, D.5, D.6, D.9, D.10, D.11, and 6 analogue input pins for these soil parameter elements, namely EC, T, pH, M. Analogue input on Arduino Uno uses C language and for programming uses a compatible software for all types of Arduino (Greengard S, 2017). Arduino Uno microcontroller can facilitate communication between Arduino Uno with computers including smartphones. This microcontroller provides USART (Universal Synchronous and Asynchronous Serial Receiver and Transmitter) facilities located at the D.0 (Rx) pin and the D.1 (Tx) pin.

This research uses the ESP8266 data transmission system with the firmware and the AT Command set that can be programmed with Arduino. The ESP8266 module is an on-chip system that can be connected to a WIFI network. Besides, several pins function as GPIO (General Port Input Output) to access these ground parameter sensors that are connected to Arduino, so that the system can connect to Wi-Fi (Schwab K, 2018). Thus, we can process analogue inputs of various soil parameters into digital information and process them via the web.

RESULTS AND DISCUSSION

Rainfall design and Frequency Duration Intensity (FDI)

The rainfall design intensity was determined using rainfall data from Pangka Pinang in 2010-2018 statistical analysis was performed to determine the distribution type used, which in this study was the Log Person III's. Distribution checking on whether rain opportunities can be accepted or not is calculated using the chi square test and the kolmogorov smirnov test. Next, the design rainfall intensity is calculated using the mononobe formula.

Discharge Plan

The discharge plan as a MA-11 microbial catalyst uses the rainfall intensity for 1 hour since it is estimated that the most predominant rainfall duration in the area studied is 1 hour. The runoff coefficient for various surface flow coefficients is 0.70-0.95 (Suripin IR, 2004), while in this study we use the smallest flow coefficient value, which is 0.70. The discharge plan has various catchment areas, between 9 m^2 to 110 m^2 with a proportional relationship. The larger the plot, the greater the plan discharge generated as a biohole inflow.

The depth of biohole in the study area in the 25-year return period ranges from 0.80 m to 1.50 m. The absorption volume will determine the maximum capacity of water contained in Biohole. The greater the volume of biohole is, the greater the water container is.

Horizontal biohole design

Biohole walls use natural walls with a 0.25 m diameter and a 0.4 m depth or the storage area of 36 m². Organic material (solid pressed padi straw waste) is used as a place for microbial populations/microbial sources. The top is coated with a 5 cm thick rock which acts as an energy-breaking medium. Thus, when filled with organic material water, it remains stable to maintain the radial spread of microbes (Widiasmadi N, 2020).

The Biohole volume capacity for that dimension is 0.125 m³, with a catchment of 36 m² and the 25 year-discharge=0.0000841 m³/sec and will be fully filled in about 15 to 20 minutes. This figure considers natural resources in the form of rainfall intensity of the study area which adjusted to the spread of microbes. Therefore, the water-emptying phase and the microbial population formulation phase can take place optimally (Figure 2).
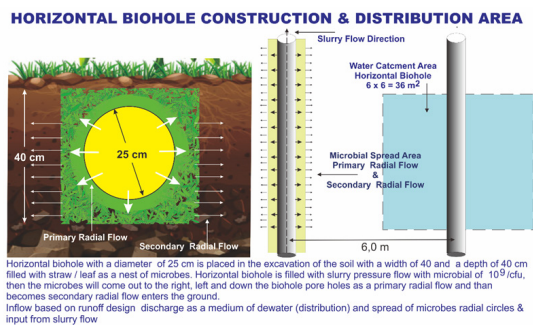

Figure 2: Distribution and biohole structure

Soil coating effect on biohole

If land is covered by impermeable surfaces, such as pavement, infiltration cannot occur as the water cannot infiltrate through an impermeable surface. This relationship also leads to increased runoff. Areas that are impermeable often have storm drains which drain directly into water bodies, which means no infiltration occurs.

Vegetative cover of the land also impacts the infiltration capacity. Vegetative cover can lead to more interception of precipitation, which can decrease intensity leading to less runoff, and more interception. Increased abundance of vegetation also leads to higher levels of evapotranspiration which can decrease the amount of infiltration rate. Debris from vegetation such as leaf cover can also increase infiltration rate by protecting the soils from intense precipitation events.

Geomorphology of agricultural land and its surroundings is in the form of inseptisol lands (Figure 3). Soil consists of horizons that lie above the source rock formed from the interaction of various soil-forming factors such as climate, organisms, parent material and relief that occurs all the time. Different processes in soil formation will produce different soils that can be observed from soil morphological properties.

Figure 3: Inseptisol soil layers

Inceptisols are young soil and begin to develop. Its profile has a horizon formation is rather slow as a result of alteration of the parent material. The horizons are not shows the results of intensive weathering. The horizons of accumulation of clays and iron oxides and aluminium are clearly not present in this soil.

Its profile is more developed than that of entisol. The lands that were once classified as brown forest, andosols and brown soil can be incorporated into Inceptisols. Most Inceptisols have cambic.

Inceptisol soil characteristics are:

1. Has a rather thick soil solum, which is 1-2 meters

2. The colour is black or grey to dark brown

3. The textures are dust, dusty loam, loam

4. The soil structure is crumb, loose consistency, pH 5.0-0.7

5. Organic material content is quite high, 10%-30%

6. Nutrient content: medium to high

7. Soil productivity: moderate to high.

Inceptisols may be also found on alluvial deposits where temporary flooding alters the soil profile due to the deposition of soil particles on the soil surface and the soil profile becomes saturated. For example, Inceptisols in the southern Mississippi River Valley are developed on alluvial deposits. Virtually many pedogenic processes are active to some extent in Inceptisol profiles but none predominates. The genesis of Inceptisols includes multiple pathways depending on the processes occurring on a given landscape and geographic area. Environmental factors can slow down weathering (e.g. low temperatures, low precipitation, or resistant parent material) and soil development to form other soil orders is retarded or even inhibited.

Biological properties are still have parent material so there are still many microorganisms decomposition plant residue Soil There are still many parent materials including plant litter. There are still main ingredients so there are still many microorganisms decompose the rest of the plant.

Chemical properties are pH close to neutral or higher (pH <4 soil problems) Base saturation less than 50% at a depth of 1.8 m COLE between 0.07 and 0.09 BO high (1.64%-7.78%) (. P content low potential to high and very low potential K to moderate. Potential P content is generally higher than the potential K, both the upper and lower layers. Cation Exchange Capacity (CEC) is medium to high in all layers. Low to high alkaline saturation (KB). It is generally concluded that the natural fertility of Inceptisol varies from low to high. Physical properties are Most of the inceptisols exhibit texture class clay with fairly high clay content (35%-78%) however some include fine clay with a clay content lower (18%-35%). This soil type is widely distributed in the Bangka Island.

Inseptisol soil fertility simulation based on the number of microbial populations with (Figure 4).
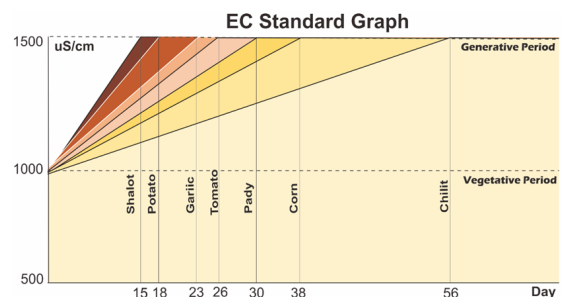

Figure 4: EC standard graph

- Variable 1=Microbial Population 10^8/cfu.

- Variable 2=Microbial Population 10^5/cfu.

- Variable 3=Microbial Population 10^3/cfu.

The initial nutrient content prior to the simulation using the Electrolyte Conductivity (EC) parameter is 744 uS/cm. Soil nutrient conditions will be improved based on total organic farming standards, namely plant growth (vegetative period) which requires soil nutrients at least 1000 uS/cm and fertilization period (generative period) which requires soil nutrients at least 1500 uS/cm (Figure 5).
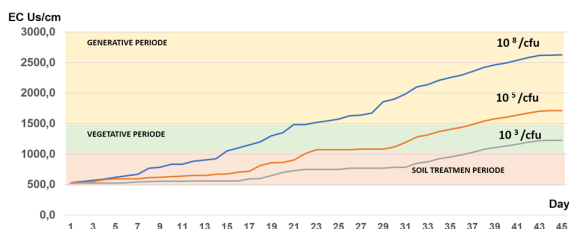

Figure 5: Graph of EC *Vs.* time

Simulation results based on the variable number of microbial populations are produced:

1. Simulation A: To start the growth period (vegetative) is achieved on the 15th day with a fertility rate (Electrolyte Conductivity)=1050 uS/cm and in the generative period it is reached on the 23th day with a fertility level (Electrolyte Conductivity)=1518 uS/cm . This activity is stimulated by microbes with a population=108/cfu. So that the time needed to reach optimal nutrient levels is 9 days.

2. Simulation B: To start the growth period (vegetative) is achieved on the 22th day with a fertility rate (Electrolyte Conductivity)=1008 uS/cm and at the generative period it is reached on the 38nd day with a fertility rate (Electrolyte Conductivity)=1539 uS/cm. This activity is stimulated by microbes with a population=105/cfu. So the time needed to reach optimal nutrient levels is 15 days

3. Simulation C: to start the growth period (vegetative) is achieved on day 37 with a fertility rate (Electrolyte Conductivity)=1025 uS/cm and during the generative period it cannot be observed because on observation until day 45 the electrolyte conductivity has not reach=1500 uS/cm. This activity is stimulated by microbes with a population=10^3/cfu.

4. The soil parameters mentioned above can be controlled against the level of the infiltration rate (Figure 6), where the infiltration rate graph shows a constant value at a level of 70 to 100 cm/hour which is reached after the 30th day. While the EC value in stable conditions is achieved on day 30 with a value between 350-100 uS/cm. So that the activity of biological agents on Andosol soil with the infiltration level will be optimal on day 35.
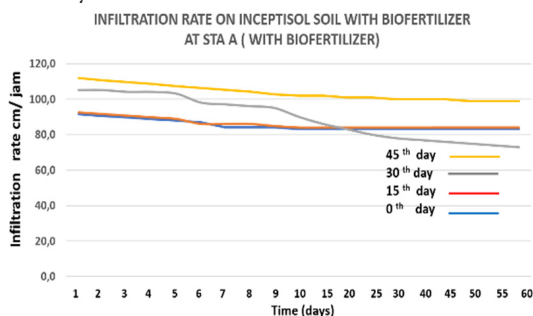

Figure 6: Graph of infiltration rate

CONCLUSION

- In simulations with a microbial population of 108/cfu, it is quite effective to apply to Inceptisol soil because the increase in the minimum nutrients needed in the growth period can be achieved within 15 days and the availability of nutrients in the generative period is obtained at 23 days because the available nutrient values are according to the standard that is 1500 uS/cm.

- In simulations with a microbial population of 105/cfu, it is still quite effective but has been applied for a long time to Inceptisol soils because the increase in the minimum required nutrients in the growth period can be achieved within 22 days and nutrient availability in the generative period is reached at 1539 uS/cm at day 38.

- In simulations with a microbial population of 10^3/cfu, it is still effective but long enough to be applied to Inseptisol soil because the minimum increase in nutrients required during the growth period can be achieved within 37 days but nutrient availability in the generative period is only achieved at a relatively small figure of 1225 uS/cm so that it is not optimal.

- Land Inseptisol is quite effective for short-term or seasonal crops such as horticulture, rice, etc. However, if applied for the long term or annual crops such as Cacao, Coffee, Rubber etc., the microbial population needs to be increased.

- Soil and water conservation activities in the land of inceptisols are very suitable, because in the long term microbial activity is capable of symbiosis with soil gromosol to increase soil fertility, oxygen and groundwater content from infiltration and intermediate flow into groundwater reserves.

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