



(RESEARCH ARTICLE)



Humic balance of a rice plot located on the South Iazafo Plain, Vavatenina district, Analanjirofo region - Madagascar: Study of possible humic recovery through the contribution of leaf compost from the distillation activity of essential oils from the leaves of cloves about 20-40 years old

Christian Pierre Ratsimbazafy ^{1,*}, Ignace Rakotoarivonizaka ² and Rijalalaina Rakotosaona ²

¹ Center for Organic Valorization of Ambohimahaso of the Iazafo-Compost Company.

² Chemical Engineering Laboratory of the Polytechnic School of Antananarivo (ESPA)

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Abstract

Knowing the initial state of the soil, especially the amount of organic matter contained in the soil, is the basis of effective fertilization. A soil with too little organic matter will be difficult to cultivate, mainly because of problems of soil structure loss. Humus plays a central role in the quality of soils and the maintenance of their key functions. If the level of organic matter decreases further, soil fertility may be called into question.

Therefore, this study consists of evaluating the stock of humus in a private paddy field located in the South Iazafo plain and considering the possible recovery in the event of a proven deficiency.

The soil examination carried out on this private plot indeed shows the lack of organic matter (barely 2%). Consequently, a humus recovery in order to reach an optimal threshold of 3% ideal for rice cultivation will therefore be deemed necessary. This need for humus is amply compensated by the organic supply in the form of leaf molds from the residues of the essential oil distillation activity of clove leaves, around 20 to 40 years old. Note that this type of organic amendment is very abundant in the neighboring areas of the said Iazafo plain. Their agronomic enhancement is essential in order to promote agricultural yield, in particular paddy yield in this rice-growing area which is unfortunately constantly shrinking

Keywords: Leaves molds; Humus; Humic balance; Organic amendement; Matrangy

1. Introduction

Maintaining an ideal OM (Organic Matter) rate and thus generating a good stock of humus in his soils is a wise and prudent objective that each producer must pursue if he wishes to avoid crop accidents and protect the future of his soils [5]. A low OM content has many disadvantages for soils, among others: low water retention capacity, poor structural stability, lower CEC, reduced biological activity, etc. [2]. In other words, low OM levels inevitably lead to loss of soil fertility. Indeed, organic matter plays an important role in the physical, chemical and biological functions of the soil. It improves the consistency of structural elements, promotes useful water retention, participates in the reversible storage of nutritional elements, limits the development of certain pathogens, increases soil aeration. In order to optimize the paddy yield of the aforementioned rice plot located in the Iazafo South plain, a humic balance assessment study is required in order to plan the possible doses of adjustments in the OM rate of the plot in case of proven deficit in OM. Even if the balance is close to equilibrium (loss = gain) and in order not to impoverish the soil in the long term, it is still

* Corresponding author: Christian Pierre ratsimbazafy
Center for Organic Valorization of Ambohimahaso of the IAZAFO-COMPOST Company.

wise to increase the stock of OM at an optimal rate in order to ensure the efficiency of different cultivation practices and of maintaining good soil functioning [3,6]. Moreover, this is the ultimate goal of our approach. The humic balance relates the gains (humus) minus the losses (mineralization) as a function of time. In a way, it is the forecast of the evolution of the rate of rebuilding and destruction of stocks of organic matter in the soil. This approach requires: prior knowledge of the soil characteristics of the plot studied, in particular estimated knowledge of the quantity of humus present in the soil of the plot, estimation of the loss of humus by mineralization annually, estimation of the humus in the event of organic restitution linked to crop residues on the plot (gain by humifying crop residues), of the amendment value or humogenic potential of the organic amendment used for the recovery of the OM rate in the soil to an optimal rate coveted, etc. Our choice of organic matter intake is particularly focused on the original leaf compost of stills from the distillation of essential oils from clove leaves, because the district in question (Vavatenina) or even all six (06) districts of the Analanjirifo Region are home to many deposits of this type of Organic Residue Product (ORP) originating from the activity of distilling essential oils from clove leaves. Some sites are home to very old leaf mold deposits, sometimes reaching 40 years of age or even older for some sites. As for our choice of rice field plot located in the Izafo plain, it is above all justified by the extent of the said plain with a total estimated area of nearly 8.612Ha [7], on the one hand, and the low level of paddy production in this plain, rarely exceeding 2,5T / ha, on the other hand. This low level of paddy productivity is undoubtedly linked to the gradual depletion of soil OM, probably due to inappropriate agricultural practice based in particular on overburned shifting agriculture and without organic restitution. In addition, the plot in question has never experienced any regular organic input or crop rotation and is mostly usually devoid of cover crops in the absence of rice cultivation, whereas these cover crops are responsible for elevation of CEC.

2. Material and methods

2.1. Organic waste product

Leaves, about 20-40 years old, collected at the Ambodimanga II distillation site, Maromitety rural commune, Vavatenina district, Analanjirifo region (Madagascar). These leaf molds come from the natural decomposition without human intervention of the leaf residues stripped of essential oils and voluntarily abandoned (without any upgrading project until now) by the operators-distillers all around the distillation site after each full distillation operation of 24 hours and this for about forty years or even more for some sites. Thanks to the pedoclimatic conditions of the Analanjirifo Region (hot and humid), these leaf residues decompose spontaneously and over time, they will give rise to potting soil rich in stable organic matter or pre-humified or even humified (very stable). The agronomic characteristics of this ORP are given in the following table 1.

Table 1 Main physico-chemical and biochemical characteristics of Ambodimanga II leaves mold

Criteria	Parameters	Unit	Results
Agronomics	Dry matter (DM)	% RM	61,74
	Total Organic Matter (TOM)	% DM	74,84
	Total Organic carbon (TOC)	% DM	42,62
	Total Nitrogen Kjeldahl (NTK)	% RM	1,87
	C/N	-	14,11
	Conductivity	$\mu\text{S}\cdot\text{cm}^{-1}$ à 20°C	691
	pH	pH unit	6,1
Humigen Potential	Organic compounds insoluble in neutral detergent or NDF	% OM	80
	Organic compounds insoluble in acidic detergent or ADF	% OM	70
	Sulfuric lignin ADL	% OM	42
	Soluble organic compounds "SOL"	% OM	20
	Hemicellulose "HEM"	% OM	10
	Cellulose "CEL"	% OM	28
	Lignin and cutin "LIC"	% OM	42
	Potential carbon mineralization at 03 days Ct3	% TOC	1
	Organic Matter Stability Index (OMSI)	% OM	76

The humus yield or humogenic potential is an estimate of the quantity of stable humus provided by a given organic amendment [2]. The following formula gives us directly the humogenic potential of an organic amendment from the knowledge of its OMSI (Organic Matter Stability Index) value.

$$\text{Humogenic potential of the product (kg/t)} = \text{OM content of the product (kg / t)} \times \text{OMSI (\%)} \quad (1)$$

Therefore, the humogenic potential of the soils in question = 74, 84% x 76% = 568,83kg/t of dry product. So one ton of dry soil potentially provides nearly 568.83kg of humus. Expressed as a target product, the humogenic potential gives here = ((74, 84% x 61, 74) / 100) x 76% = 351, 20 kg/t of raw product.

2.2. Experimental approaches

2.2.1. Pedological analysis of Izafo soil

Our approach consists in identifying beforehand the pedological characteristics of the soil of the plot studied. Thus, the priority soil analysis to be carried out within the framework of this study includes the following determinations: the particle size analysis in order to know the textural class of the plot studied, the water pH, the Cation Exchange Capacity (CEC), the rate of organic matter (OM), the bulk density. Indeed, the granulometric analysis, supplemented by other analyzes of soil characterization in particular (pH, organic matter, CEC, apparent density), and field observations (stoniness, exploitable depth), allows to characterize soil and understand how it works [8].

Knowing the results of particle size analysis and the rate of organic matter allows us to know the textural class of the soil and above all allows us to calculate the secondary mineralization coefficient (K2) of the soil humus reserve of the plot in correlation with the climate factor (mean annual temperature). We also assess any gains in humus via humification (K1) of crop residues at the level of the plot studied. We also perform the determination of calcium carbonate (CaCO₃) in the plot given that the calculation of the coefficient (K2) requires prior knowledge of the limestone content (more precisely total limestone). Moreover, determining the level of organic matter in the context of this study requires the decarbonation operation beforehand.

The organic matter content is deduced from the measurement result of the soil organic carbon, the value of which is multiplied by a conventional coefficient of 1, 72. Organic carbon is determined by the standardized method (NF ISO 14235) based on sulfochromic oxidation of carbon followed by determination by colorimetry [9].

The particle size analysis is carried out according to the standard NF X31-107 method, also called the pipette method [10]. After destruction of the organic matter in liquid environment (previously quantified using the method described above), the sample is allowed to "settle". According to the principle of Stokes' Law, the falling speed of particles depends on their size. Fine fractions (clay and fine silt) are determined after pipetting at given depths and times in the sample, while coarse fractions such as coarse sands, fine sands and coarse silts are obtained after sieving. The sum of these 5 mineral particle size fractions is equal to 100%.

The carbonate content (CaCO₃, in% of DM at 105 ° C) is determined by volumetric method (ISO 10693 standard). Carbonates are destroyed by attack with hydrochloric acid yielding CO₂ measured with a Shreiber apparatus. The volume of CO₂ produced is compared to that produced by pure calcium carbonate [11].

The current water pH or acidity is measured in a soil suspension with a soil / water ratio of 1/5 determined according to standard NF ISO 10390. The water pH is considered to be that of the roots and micro-organisms, that is, that is to say that of the rhizospheric environment [12].

The CEC corresponds to the maximum quantity of cations of any kind that can retain 100 g of soil. This data is therefore essential for an optimal advice of manure [1].

The CEC is determined according to the Metson method as described in the AFNOR NF X31-130 standard. This method involves moving all the cations adsorbed to the CEC exchange sites, then saturating these sites with a single cation (ammonium -NH₄⁺). The ammonium is in turn displaced, then determined by automatic spectrophotometry. The number of CEC exchange sites exactly matches the number of ammonium ions assayed. The result is expressed in the number of charges per 100g of soil (milliequivalents per 100g or meq / 100g) [13].

The apparent density is determined according to the standardized method NF X 31-501 also called the cylinder method [14]. This method uses undisturbed samples, knowing the constant dry weight of the samples at 105 ° C and the volume

of the sample cylinders used. The apparent density of the soil reflects the overall state of compaction of the soil material and indirectly, the total porosity [15].

2.2.2. Calculation of annual humic balance

After having examined through the various physico-chemical analyzes the state of physical fertility (structural and calcium state) as well as the state of chemical fertility, organic state (particularly humic reserve) and state of reserve in exchangeable mineral elements through the knowing the value of the CEC, we proceed to the calculation of the humic balance of the said plot. According to Georges Collaud, (2014) and Eleonore Bouvier, (2012), the humic balance calculation is then done in five (05) very distinct steps in this case [2, 5]:

Step 1: Calculation of mass of fine soil according to the formula:

Mass of fine soil = volume of soil (m³) x apparent density (t/m³) x content of fine soil (%) (2)

Step 2: Estimate the stock of soil humus. The estimate of the stock of soil humus is obtained from the following formula:

$$\text{Current stock of humus} = \text{mass of fine soil (t/ha)} \times \text{OM (\%)} \quad (3)$$

Step 3: Estimation of the annual humus loss. To calculate the annual mineralization of soil humus (humus losses), the mineralization coefficient K₂ was determined from a model which takes into account the total clay and limestone levels of the soil of the plot, as well as the annual average air temperature. This formula for calculating the annual mineralization of soil K₂ humus is as follows [2]:

$$K_2 = \frac{(0,6t^\circ - 3)}{(1 + 0,05A)(100 + 0,15 \text{ CaCO}_3)} \quad (4)$$

With:

t°: annual average temperature = 24,1 ° C for Vavatenina district, Analanjirifo region

A: clay content in %.

CaCO₃: CaCO₃ content in ‰.

The K₂ coefficient essentially depends on the type of soil and the climatic conditions: the hotter the soil, the greater the losses [5]. These are reduced if the soil is clayey and to a lesser extent if it is limestone.

Therefore the annual loss of humus will be calculated by the following formula:

$$\text{Annual humus loss} = \text{current stock of humus (t/ha)} \times K_2 (\%) \quad (5)$$

Step 4: Estimate the gains in humus by humifying the crop residues. The plot in question has an annual organic restitution; these crop residues make a positive contribution to maintaining the stock of soil humus. Their importance depends on their nature and quantity produced and left on the ground per hectare. These crop residues are rice straws also called stubble not collected during the previous harvesting season, locally called “matrangy”.

Therefore, the annual humus gains of the plot are calculated using the following formula:

$$\text{Humus gain by stubble} = \text{DM quantity (t/ha) of stubble} \times K_1 (\%) \quad (6)$$

With K₁: Iso-humic coefficient of crop residues (humus restored by rice stubble).

This coefficient represents the amount of stable humus formed per kg of dry organic matter incorporated into the soil, that is to say, percentage of organic matter (OM) provided by an amendment, remaining in the soil after one year, and which thus feeds the stock of stable OM (humus).

It should be noted that the coefficient K1 of plant residues (rice straw) adopted within the framework of this study corresponds to that of the Hénin & Dupuis model. For rice straw or stubble K1 = 15% [5, 16]

Step 5: Determine the need for humus in the event of a negative balance sheet or in the event of a possible need for recovery. It is determined by the general formula:

$$\text{Humus requirement} = \text{Losses} - \text{Gains} + \text{Recovery} \quad (7)$$

To determine the dose of product to add, it is necessary to be aware of the characteristics of the product chosen and therefore systematically refer to the "product sheets" with an agronomic profile or directly to the analyzes of the organic amendment if these are available. The humic value of the organic amendment used is already known (mentioned in Table 01 above)

3. Results and discussion

3.3. Soil analysis of the Izafo rice plot

Table 2 below summarizes the results of physicochemical analyzes carried out on the Izafo plot.

Table 2 Soil analysis result

Parameters										
Granulometry (%)						Agronomics				
Clay	Fine silt	Coarse silt	Sable fin	Fine sand	Pebbles	Total limestone CaCO ₃ (%)	pH	MOT (%)	CEC (meq /100)	Density Related in t/m ³
40	14	20	10	16	5	2,6	6	2	9	1,45

According to this analysis and by referring to the texture triangle of the GSPAP (Group of Studies of Problems of Applied Pedology) [17], the soil sample taken from the Izafo plain was as clay texture "A", that is, fine texture rich in clay. Its organic matter content here 2% is considered low, especially since this soil will be used for the cultivation of rice later. In addition, by applying the organic matter / clay ratio (R_{mo} / A), we obtain a value of 5 while the pedological optimum starts at 17 [6], so the rate of OM of the Izafo soils should therefore be higher than 6%. At the same time, various research studies have shown that the higher the clay content in the soil, the more the desirable organic matter rate increases [2]. For some authors, the normal OM rate in the soil to allow good productivity should be between 3 to 8% [4, 2, 3]. In this case, it will then be necessary to consider the recovery of the rate of organic matter in the soil via organic inputs in order to optimize the soil fertility of this Izafo plot. In the context of this study, we are content to just increase this OM rate from 2% to an optimum of 3%.

The CEC = 9 meq / 100 which is still qualified as "average" indicates in some ways the low content of exchangeable cationic elements (Ca²⁺, Mg²⁺, K⁺, Na⁺) in the soil [8]. This CEC is "average" or even at the limit of the qualification of "small" because the organic matter content of the soil is considered insufficient. The more OM there is, the higher the CEC [18]. And this justifies the acidic character of the soil of this plot with a water pH = 6 (acid).

3.4. Humic balance calculation

Step 1: Mass of fine soil

The mass of fine soil over one hectare and over a worked depth of 20cm is = 10.000m² x 0.2 m x 1,45 x 0.95 = 2.755t/ha. Indeed, the fine soil content here is 95% because the soil contains 5% pebbles and the density of the soil 1,45t/m³.

The plot studied is therefore considered to be soil with a low pebble load [17, 19, 20].

Step 2: Estimate the stock of humus

Humus is assimilated to the organic matter determined by soil analysis. The reasoning is therefore based on a rate of OM given by the soil analysis.

Organic matter rate measured is 2%, so the quantity of humus and/or the current stock of humus over a depth of 20 cm in a hectare = $2.755\text{t/ha} \times 2\% = 55,1\text{t/ha}$

Step 3: Estimation of the annual humus loss

Using the formula according to equation (4) above, the mineralization coefficient $K_2 = 2, 74\%$.

This means that almost 2.74% of the organic matter in fine soil of the ground is mineralized each year. So the annual loss of humus under the effect of secondary mineralization is $55,1\text{t/ha} \times 2, 74\% = 1,50\text{t/ha}$.

Step 4: Evaluation of humus gains

The plot in question is indeed experiencing organic restitution by humification of crop residues (straw and rice stubble) not collected during the previous harvest season.

The quantity is estimated on average around 1.500kg DM / ha from the usual paddy yield of 2,5t / ha. It should be noted that the plot studied only had one rice growing season per year, locally called "vary taona", usually transplanted towards the end of July and harvested towards the end of November until December or even the month of January of the following year. By applying formula (6), the gain in humus = (quantity of rice stubble / ha x K_1 (%)) is as follows: crop residues annually provide nearly 1.500 kg of DM / ha x 0, 15 = 225kg/ha/year. So a significant gain in humus.

Step 5: Final assessment

That is to say, the need for humus to compensate for the loss of mineralized humus annually added to the dose of the desired recovery (3%) while obviously taking into account any gains in humus by crop residues such as indicated in formula (7) above.

The humus loss to be compensated annually is 1,50t/ha, that is to say loss of organic matter by secondary mineralization. In this case, it will be necessary to add $1, 50 / (0,4621 \times 0, 76) = 4,27\text{t}$ of raw soil/ha.

It is always a good idea to maintain or increase the level of humus in the soil. As part of this study, we recommend correcting the OM rate in the soil of the plot to an optimum rate of 3%. In this case, the increase in the desired OM rate = $3\% - 2\% = 1\%$.

The corresponding humus recovery therefore amounts to $2.755 \text{ t/ha} \times 1\% = 27, 55 \text{ t/ha}$

In this case the amount of intake in organic amendment is $27,55 \text{ t/ha} / (0,4621 \times 0, 76) = 78,44\text{t/ha}$

The total humus requirement or more precisely the humus recovery dose for this plot then amounts to $78, 44 \text{ t/ha} + 4,27 \text{ t/ha} = 82,71 \text{ t / ha}$.

Thus, Table 3 below then recapitulates the various humic recovery operations envisaged for the Iazafo rice plot.

Table 3 Summary table of humus requirements.

Organic contribution	Need to compensate for the annual loss of humus (t / ha)	Need to correct the rate of OM 2% to an optimum rate of 3% (t / ha)	Annual gain in organic matter from crop residues (t / ha)	Contribution of soil to cover the total need for humus (t / ha)
40-year-old leaf mold	4.7	78.44	0.22	82.48

It will therefore be necessary to add 4,27 t/ha of organic amendment to be able to compensate for the loss of humus annually by secondary mineralization and nearly 78,44t / ha of organic amendment in order to raise or correct the current organic matter rate from 2% to 3%, that is to say an increase of 1%.

By taking into account the gain in humus of the test plot, the final recovery dose then amounts to: $82,71t - 0,22t = 82,48t/ha$.

However, with a view to better preservation of the environment and above all in order to respect the annual and ten-year flows of metallic trace elements (MTEs) and Organic Trace Compounds (OTCs) likely to be generated during spraying in the field of this compost, it is advisable to spread out the contributions in thirds of the dose spread over 3 years, that is to say to divide this dose of $82,48t/ha$ into 3 applications at a rate of a dose of $27,33t/year$ spread over 3 consecutive years.

4. Conclusion

The objective of establishing a humus balance for a given plot is to compare the gains and losses of humus of this plot over a defined depth. The humic balance carried out on a private plot of Iazafo indeed shows a negative balance with an annual loss of stable organic matter of nearly $1,5t/year$ while the gain in the form of organic restitution is only $0,22t/year$.

In order not to impoverish this soil in the long term, the producer must intervene to increase organic restitution. The soil supply needed to compensate for this loss is then nearly $4t/ha/year$, that is to say the annual supply dose to balance the humic balance of the said plot.

In contrast, the final input quantity is estimated at $82t/year$ to restore the current organic matter rate from 2% to a level of 3%. In this case, an additional study should be carried out, in particular to check whether the calculated dose meets the product's safety criteria relating to Trace Metal Elements (TME) and Trace Organic Compounds (TOC).

This type of calculation is of course theoretical, the evolutionary dynamics of soils and organic matter being complicated to model. Be that as it may, the interest is to have a basis for thinking about losses and OM entries on your plots.

Compliance with ethical standards

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