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AGRICULTURAL RECYCLING OF FISH FARMING SLUDGE FROM EXCAVATED PONDS IN RAMAL DO BANCO, RIO PRETO DA EVA, AMAZONAS

RECICLAGEM AGRÍCOLA DE LODO DE PISCICULTURA DE TANQUE ESCAVADO NO RAMAL DO BANCO EM RIO PRETO DA EVA, AMAZONAS

RECICLAJE AGRÍCOLA DEL LODO DE PISCICULTURA DE TANQUE EXCAVADO EN EL RAMAL DO BANCO EN RIO PRETO DA EVA, AMAZONAS

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ABSTRACT
The generation and recycling of waste are major challenges for humanity. This is the case of fish farming sludge from excavated ponds, composed of a mixture of sediment from applied inputs and fish feces combined with the pond bottom soil. The accumulation of sludge in ponds due to poor maintenance of water oxygenation can create environmental liabilities on properties. This issue was identified in Ramal do Banco in 2019, and based on the observations, the possibility of using the accumulated sludge as a soil conditioner for cultivated land was considered. This practice would replace the unregulated disposal methods currently used in the area. In this context, this study aimed to: i) characterize the type of agriculture practiced and the current use of fish farming sludge in that community; ii) describe the methods and results of extension activities carried out there, and establish recommendations for recycling fish farming sludge from excavated ponds in the cultivation of tall or staked plant species in Ramal do Banco, Rio Preto da Eva, Amazonas. The agriculture practiced in Ramal do Banco is both commercial and subsistence-based and includes a wide variety of species suitable for recycling fish farming sludge produced in the community. According to the analyzed attributes, the fish farming sludge has the physical, chemical, and biological quality required for recycling in agricultural soils. Therefore, doses and methods for recycling fish farming sludge in the cultivated species of Ramal do Banco were calculated and will be included in an agricultural recycling manual to be published in 2025.

Keywords: Fish Farming Sludge. Agricultural Recycling. Regional Fish. Production. Amazon.

RESUMO
A geração e reciclagem de resíduos são desafios para a humanidade. Este é o caso dos lodos de piscicultura de tanques escavados, constituídos pela soma dos sedimentos de insumos aplicados e fezes de peixes com o solo do fundo dos tanques (pond bottom soil). O

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acúmulo de lodo nos tanques pela falta de manutenção da oxigenação da água pode gerar passivo ambiental nas propriedades. Este problema foi identificado no Ramal do Banco em 2019 e, com base no que se observou, pensou-se na possibilidade de uso do lodo acumulado como condicionador do solo cultivado. Essa prática substituiria a prática sem critério de destinação final do lodo adotada na localidade. Neste contexto objetivamos com este trabalho: i) caracterizar a agricultura praticada e o uso atual de lodo de piscicultura naquela comunidade; ii) descrever métodos e resultados de ações de extensão lá realizadas bem como estabelecer recomendações de reciclagem do lodo de piscicultura de tanque escavado no cultivo de espécies de porte alto ou tutoradas no Ramal do Banco em Rio Preto da Eva, Amazonas. A agricultura praticada no Ramal do Banco é comercial e de subsistência, e contempla grande diversidade de espécies para a reciclagem do lodo de piscicultura gerado na comunidade. De acordo com os atributos analisados, o lodo de piscicultura possui qualidade física, química e biológica para reciclagem no solo agrícola. Por isso, doses e métodos para reciclagem de lodo de piscicultura nas espécies cultivadas no Ramal do Banco foram calculadas e constarão de um manual de reciclagem agrícola do material que será publicado em 2025.

Palavras-chave: Lodo de Piscicultura. Reciclagem Agrícola. Peixes Regionais. Produção. Amazônia.

RESUMEN

La generación y el reciclaje de residuos son desafíos para la humanidad. Este es el caso de los lodos de piscicultura de tanques excavados, compuestos por la mezcla de sedimentos provenientes de los insumos aplicados y las heces de los peces con el suelo del fondo de los tanques (pond bottom soil). La acumulación de lodo en los tanques debido a la falta de mantenimiento de la oxigenación del agua puede generar pasivos ambientales en las propiedades. Este problema fue identificado en el Ramal do Banco en 2019 y, a partir de las observaciones realizadas, se consideró la posibilidad de utilizar el lodo acumulado como acondicionador del suelo cultivado. Esta práctica sustituiría el destino final sin criterio que actualmente se da al lodo en la localidad. En este contexto, los objetivos de este trabajo fueron: i) caracterizar la agricultura practicada y el uso actual del lodo de piscicultura en dicha comunidad; ii) describir los métodos y resultados de las acciones de extensión realizadas, así como establecer recomendaciones para el reciclaje del lodo de piscicultura de tanque excavado en el cultivo de especies de porte alto o tutorizadas en el Ramal do Banco, en Rio Preto da Eva, Amazonas. La agricultura practicada en el Ramal do Banco es tanto comercial como de subsistencia, y abarca una gran diversidad de especies que pueden beneficiarse del reciclaje del lodo de piscicultura generado en la comunidad. De acuerdo con los atributos analizados, el lodo de piscicultura presenta calidad física, química y biológica adecuada para su reciclaje en suelos agrícolas. Por ello, se calcularon las dosis y métodos para el reciclaje del lodo de piscicultura en las especies cultivadas en el Ramal do Banco, los cuales formarán parte de un manual de reciclaje agrícola del material que será publicado en 2025.

Palabras clave: Lodo de Piscicultura. Reciclaje Agrícola. Peces Regionales. Producción. Amazonia.

1 INTRODUCTION

The generation and recycling of waste, considering the risks and hazards for final disposal, represent challenges for humanity (POZZETTI; NEPOMUCENO, 2019). *Pond bottom soil or fish farming sludge*, in turn, are the sum of input sediments applied to the soil at the bottom of the ponds (SHAFI et al., 2021) which have also been considered challenges for sustainability in productive properties. This is especially true when the management of the tanks does not achieve the objective of maintaining the oxygenation of the soil at the bottom of the tanks covered by sediments, which is a fundamental condition for fish farming (SHAFI et al., 2021; BOYD; WOOD; THUNJAI, 2002).

Problems with the improper disposal of fish farming sludge was identified in the community of Ramal do Banco (or, São Francisco de Assis community) in 2019 and, based on reports from producers about the potential to increase the number of fish farmers in the locality, the possibility of using the material as a chemical soil conditioner was considered, used in a palliative way and in substitution of a practice without criteria adopted at the time and that persists to the present day.

Such replacement may be feasible because after the maintenance of the tanks and the reduction of sludge generation has been achieved, its incorporation as a soil conditioner through sustainable procedures has been pointed out as one of the solutions to the problem of accumulated sludge (WANGA et al., 2019; MADARIAGA; MARIN, 2017). The agricultural use of fish farming sludge can thus contribute to the closure of the phosphorus (P) and nitrogen (N) cycle in fish farming (BOYD; WOOD; THUNJAI, 2002). However, despite the high production of the residue, this resource is still little explored, even though it is usable as a supplier of nutrients to cultivated species to reduce the relative cost of production.

Among other final destinations, fish farming sludge has been exploited by the fertilizer industry (MAIGUAL-ENRIQUEZA et al., 2019; HERZEL et al., 2016; HAN et al., 2015; JIANG et al., 2015; YIN; WANG, 2015; MAOZHE et al., 2013). With regard to agricultural recycling, several studies provide a basis for the recycling of these sludges in cultivated soil. Recent studies demonstrate the absence of pesticides and hazardous organic materials and a low content of toxic elements in these sludges, which makes them environmentally safe (YURINA et al., 2020; MANDARIAGA; MARIN, 2017). Therefore, this residual material is considered suitable for recycling in agriculture, which is due to the presence of organic matter and plant macronutrients such as N (6-7%) and P (1.5 -2%), K, Ca, Mg, and small amounts of micronutrients (ROHOLD, 2024; LENZ et al., 2021; BROD et al 2017; SILVA et al., 2013; NEMATI; BAKAR; ABAS, 2009). From a production point of view, several species have shown greater growth and production when treated with these sludges (ALVES et al., 2022; SILVA et al., 2017; THANH et al., 2023).

This text is a report on a *problem-solving investigation* in the context of rural university extension applied to the Community of Ramal do Banco in Rio Preto da Eva, Amazonas. Our objectives with this work were outlined based on the context described above.

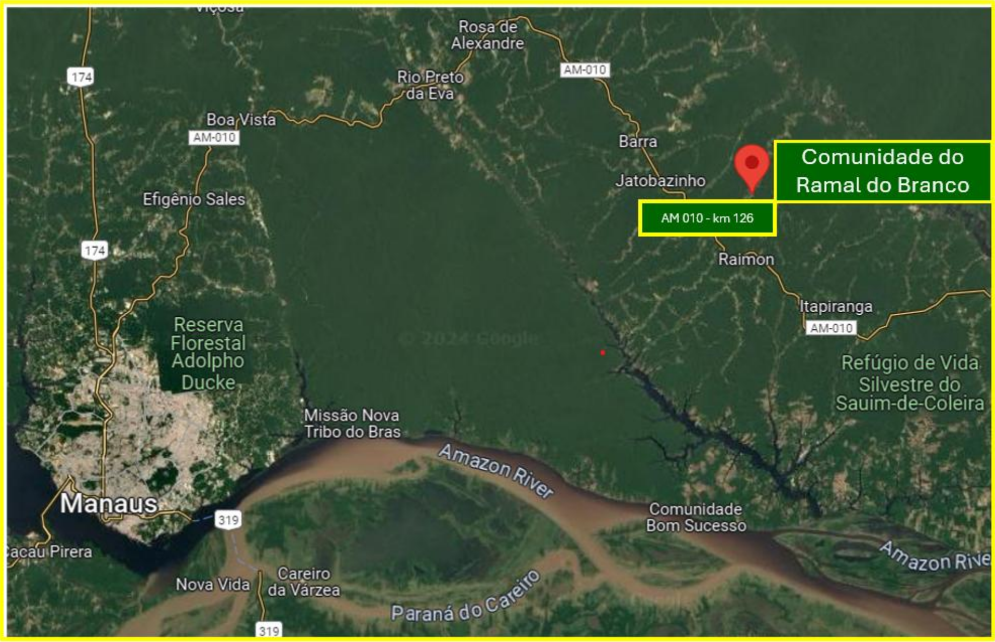
The objective of this work was: i) To characterize the agriculture practiced in the community of Ramal do Banco; ii) Describe university extension actions carried out for sampling and physical, chemical and biological characterization of fish farming sludge for recycling purposes in the species cultivated in that community, and; iii) Based on the results obtained in the extension actions, recommend methods and doses of application of fish farming sludge from excavated tanks for species cultivated in Ramal do Banco, Rio Preto da Eva, Amazonas

2 METHODOLOGY

The activities of this work were developed according to the need for rural extension in the Community of Ramal do Banco, located on the left bank of Highway AM 010, km 126, Rio Preto da Eva (2º 41' 56" S and 59º 42' W), state of Amazonas (Figure 1). A literature review was carried out via the journal portal of the Coordination for the Improvement of Higher Education Personnel/CAPES (www.periodicos.capes.gov.br/) to characterize the species cultivated on a commercial and subsistence scale in that community. Systematized interview according to Marconi; Lakatos (2004) was applied to the producers in order to characterize the current use and the perspective of agricultural recycling of fish farming sludge practiced in the locality.

Figure 1

Location of the São Francisco de Assis Community (Bank Branch), in Rio Preto da Eva, Amazonas



Source: Prepared by the authors, with reproduction of mapped area available at https://www.google.com.br/maps Accessed: November 2025.

Extension actions were carried out from 2019 to 2024 on the property of Mr. Josué Rodrigues de Oliveira, considered a model for the producers of the Bank's Branch, as the management applied to the tanks is what is sought to be applied in the community as a whole. During the actions, the sludge from a tank for the creation of tambaqui (*Colossoma macropomum*) and pirarucu (*Arapaima gigas*) was sampled for physical, chemical and biological characterization for recycling purposes in the soil cultivated in that locality. The biological quality of the sludge was evaluated only in the 2024 action. For this, an area of 0.40 ha of water depth of the tank with greater depth and greater accumulation of sludge (*Pond bottom soil*) was chosen. From this location, 7 simple samples $^{ha-1}$ of the sludge were proportionally and randomly collected by dragging an 18 L plastic bucket. Then, the samples were homogenized and 0.15 kg of sludge was taken from them to compose a representative sample in all the extension actions of the period considered.

Then, the sludge samples were packed in 0.50 m by 0.70 m plastic bags previously identified and prepared for the following analyses: i) percentages of sand, silt and clay and moisture (%) (Embrapa, 2017) (2019, 2022 and 2023); ii) chemical fertility (2019, 2021, 2022, 2023 and 2024): pH $CaCl_2$, Al^{3+} and H+Al (cmol$_c$ dm^{-3}), aluminum saturation (m%), base saturation (V%), organic matter (OM%), cation exchange capacity (CTC$_{pH}$ 7.0 (cmol$_c$ m^{-3}), Ca^{2+} and Mg^{2+} (cmol$_c$ dm^{-3}), K^+ and P (mg dm^{-3}), Cu^{2+}, Fe^{2+}, Mn^{2+} and Zn^{2+} (mg dm^{-3}) (Silva, 2009). O B and SO_4^{2-} (mg dm^{-3}) were analyzed according to Raij et al. (2001); iii) total contents of N, P, K, Ca, Mg, S, B, Cu, Fe, Cu, Mn e Zn, e de As, Ba, Cd, Pb, Cr, Hg, Mo, Ni and Se (BRASIL, 2020; BRAZIL, 2014), by the EPA-3051 digestion method in a microwave oven and determined by ICP-OES (2019, 2023 and 2024), and; iv) in 2024: thermotolerant coliforms (NMP g^{-1}), *Escherichia coli* in total solids (nº g^{-1} of ST) and viable helminth eggs and *Salmonella* spp (NMP 10 $^{g-1}$) (BRASIL, 2020; BRAZIL, 2014). The determination of the fertility classes of *the bottom pond soil* was based on Brasil et al. (2020) and Alvarez et al. (1999). The chemical and biological qualities of the sludge were determined based on the standards of Brazil (2020) and Brazil (2014).

Once the quality of the sludge was determined, methods and doses of fish farming sludge were recommended for recycling in the species cultivated in the community of Ramal do Banco as an alternative to the current management, without criteria and contrasting with the National Solid Waste Policy (Law 12.305/2010), which emphasizes the reduction of environmental liabilities in Brazil. The cycle period of the crops in which the sludge will be recycled was decided based on the growth age at which the plants are already definitively established in the field, or, when they already require greater amounts of nutrients for vegetative growth and/or production (adult plant).

3 FINDINGS

According to Carneiro (2018), and also based on information collected through a systematized questionnaire (Marconi; Lakatos, 2004), the family farmers of the producers' association (ASPRONES) of the Bank's branch cultivate banana trees, dwarf coconut trees, cupuaçu trees and citrus: orange, tangerine, lemon and açaí trees, as well as okra, peppers and chili peppers. Among the producers, there are those who cultivate these species on a commercial scale to generate income. There are also species cultivated for subsistence that, according to the participants of the extension actions, there is interest in expanding to areas for commercial cultivation. They are: peppers, green and sweet sweet sweet pepper trees, burnt yellow pepper (cumari-do-Pará), murupi and chili peppers, black pepper and long pepper, papaya, passion fruit, conilon coffee, guaranazeiro, rubber tree, okra, annatto, acerola, soursop, camucamuzeiro and the coconut tree. Therefore, they were also included among the species for recommendation of recycling of dry and wet sludge, without prejudice to the fertilization recommended in the fertilization and liming manuals for the species.

The problem of final destination in the studied property has been mitigated by its application between the lines of the banana crop. However, the random allocation of uncalculated amounts of sludge on the soil, next to banana plants (mother, daughter and granddaughter), proves to be inadequate. In the places where the newly extracted sludge is allocated from the tanks, large dense clods are formed that persist buried or on the surface of the soil, which can make it difficult to prepare the soil for replanting in the months before the beginning of the rainy season.

High doses can also cause problems in the development of plants in direct contact with the sludge. At the disposal sites, it was observed that banana plants in direct contact with the sludge produced visibly larger fruits, but similar to those found in plants without contact with the material. However, the intermediate leaves of the plants showed symptoms of iron phytotoxicity (Fe^{2+}) similar to those reported by Zaid et al. (2020). Another option adopted by the producer is to keep the excess sludge removed from the tank on the surface of the soil, which can generate significant environmental liabilities over time.

The chemical, physical and biological qualities of the sludge were the basis for calculations of fixed doses of dry and wet sludge for exclusive application on the surface of soils cultivated with tall species and staked vines, so that the residue does not have contact with the plants or with the commercial product. The sludge produced in the Bank's branch is composed, respectively, of 2.1%, 35.7% and 62.9% of sand, silt and clay (EMBRAPA, 2017), being characterized as very clayey according to Santos et al. (2018), with similarity with the granulometry of natural soils. Therefore, the name of *Pond bottom soil* according to BOYD is justified; WOOD; THUNJAI (2002). The average moisture (%) (EMBRAPA, 2017) of the sludge was 94.2%, whose value was used to calculate the wet doses of the sludge for each specific species.

The averages of the acidity attributes of the sludge indicate high acidity (Table 1), but with low levels of Al^{3+}, m% and H+Al in this *Pond bottom soil* (CFSMG, 1999). The CTC is below the minimum limit of soil conditioners according to Brasil (2006). However, the other attributes fall into the medium fertility class, with the exception of the low class of K^+ and the high availability of P and Fe^{2+} (BRASIL et al., 2020; CFSMG, 1999). The mean Fe^{2+} was about 9 times higher than the maximum availability limit, and was classified as very high according to Silva et al. (2020) (Table 1). Therefore, considering the risk of absorption of high amounts and the potential for phytotoxicity, the Fe^{2+} content supported the calculations of the dry and wet mass doses of fish farming sludge for the crops contemplated in this work. Thus, the doses of sludge to be recycled were limited by the content of Fe^{2+} present in the sludge and by the soluble amount of the micronutrient recommended for the crops. In other words, the Fe^{2+} present in the sludge served as a limiting factor for the amounts of sludge to be recycled in the soil.

An analysis based on the total nutrient contents (Table 2) makes it possible to affirm that the sludge generated in the Bank's branch line is agronomically suitable for recycling as a conditioner for soils grown in the Bank's branch. The material has higher amounts of N, P, and S in its composition, in addition to lower levels of other nutrients, as in other results found by other authors (ROHOLD, 2024; YURINA et al., 2020; LENS et al., 2021; BROD et al 2017; MANDARIAGA; MARIN, 2017; SILVA et al., 2013; NEMATI; BAKAR; ABAS, 2009).

Table 1

Chemical quality for agronomic purposes of fish farming sludge from the Bank's branch in Rio Preto da Eva, Amazonas, analyzed as soil

Attribute	2019	2021A	2022	2023/24B	Average	Standard deviation	Fertility Class
pH $CaCl_2$	5,0	5,0	5,0	5,0	5,0	±0,00	Low[C]
Al^{3+} ($cmol_c$ dm^{-3})	0,0	0,02	0,01	0,0	0,008	±0,01	Very low[C]
H+Al ($cmol_c$ dm^{-3})	2,5	2,04	2,02	2,9	2,36	±0,36	Low[C]
m%	0,0	0,35	0,35	0,0	0,17	±0,18	Very lowC
V%	55,81	57,5	58,26	50,22	55,4	±3,15	Average[C]
MO (%)	2,2	1,65	1,67	5,24	2,69	±1,49	Average[C]
CTC (pH 7,0) ($cmol_c$ m^{-3})	5,66	4,87	4,84	5,83	5,3	±0,45	Average[C]
Ca^{2+} ($cmol_c$ dm^{-3})	2,5	2,53	1,70	2,36	2,27	±0,34	Average[C]
Mg^{2+} ($cmol_c$ dm^{-3})	0,55	0,53	1,0	0,44	0,63	±0,22	Average[C]
K^+ (mg dm^{-3})	42	44,0	34,0	39,0	39,7	±3,77	Low[D]
P (mg dm^{-3})	55	58	62,0	79,0	63,5	±9,29	Very high[D]
SO_4^{2-} (mg dm^{-3})	12	15,0	14,0	11,55	13,14	±1,42	High[D]
B (mg dm^{-3})	0,6	0,13	0,17	0,19	0,27	±0,19	Low[D]
Cu^{2+} (mg dm^{-3})	0,41	0,32	0,33	0,53	0,40	±0,08	Low[D]
Fe^{2+} (mg dm^{-3})	401	423	433	366	405,8	±25,70	High[D]
Mn^{2+} (mg dm^{-3})	1,74	2,54	2,82	3,44	2,64	±0,61	Low[D]
Zn^{2+} (mg dm^{-3})	15,51	10,12	9,57	10,44	11,41	±2,39	High[D]

Source: Prepared by the authors (2025). [A]Analyses performed on separate samples preserved after the extension action. [B]Due to force majeure, some analyses were performed in 2023 and others in 2024, keeping the samples frozen; [C]Classification made according to Ribeiro et al. (1999); [D]Classification made according to Silva et al. (2020).

Table 2

Total levels of nutrients and toxic elements (heavy metals) in the fish farming sludge of the Bank's branch in Rio Preto da Eva, Amazonas

Total nutrient	2019	2023/2024A	Average	Standard deviation
N (g kg^{-1})	3,7	7,0	5,35	±2,3
P (g kg^{-1})	1,19	0,6	0,89	±0,41
P (% P_2O_5)	(2,7% P2O5)	(1,4% P2O5)	(2,04% P2O5)	-
K (g kg^{-1})	0,0	<0,1	0,05	±0,07
Ca (g kg^{-1})	0,97	6,7	3,8	±4,05
Mg (g kg^{-1})	0,62	0,5	0,56	±0,08
S (g kg^{-1})	2,13	3,5	2,8	±0,96
B (mg kg^{-1})	4,58	<0,1	2,29	±3,16
Cu (mg kg^{-1})	5,0	0,4	2,7	±3,25
Fe (mg kg^{-1})	8411,7	8000	8206,0	±291,11
Mn (mg kg^{-1})	13,12	3,2	8,16	±7,01
Zn ($^{kg-1}$ mg)	26,37	18,9	22,63	±5.28
Toxic metal[B]	2019	2023/24	Average	Standard deviation
As (mg kg^{-1})	0,01	3,5	1,75	±2,46
Ba (mg kg^{-1})	0,01	-	<0,01	±0,06
Cd (mg kg^{-1})	0,01	<0,1	0,05	±0,06
Pb (mg kg^{-1})	0,01	<0,1	0,05	±0,06
Cr (mg kg^{-1})	0,01	27,3	13,6	±19,29
Hg (mg kg^{-1})	0,01	<0,1	0,05	±0,06
Mo (mg kg^{-1})	0,01	-	<0.01	±0,06
Ni (mg kg^{-1})	0,01	<0,1	0,05	±0,06
Se (mg kg^{-1})	0,01	7,5	3,75	±5,29

Source: Prepared by the authors (2025). [A]Analyses carried out partly in 2023 and partly in 2024 due to force majeure in samples separated and preserved after the end of the extension action; [B]Analyses carried out based on CONAMA resolution nº 498/2020 (BRASIL, 2020).

The average total Fe content reinforces the possibility and need to calculate the sludge doses based on the available content of the micronutrient in the material and, thus, limit the amounts of sludge incorporated into the soil cultivated with the specific species now contemplated for recycling. The total average levels of toxic elements (Table 2) present in the sludge were always below the maximum limits found in Brazil (2020) and Brazil (2014). Therefore, the results also corroborate the quality of the material needed for recycling in the algrícultural soil.

Regarding the biological quality of the sludge produced on the property in Ramal do Banco, the most probable number of thermotolerant coliforms found per gram of sludge (NMP $^{g-1}$) was 296.29. The most probable number of *Salmonella* spp per 10 g of sludge (MPN 10 $^{g-1}$) and *Escherichia coli* (ST nº g^{-1}) showed the absence of pathogens in the material. The 10 g-1 NMP of helminths was 0.19. Thus, these verifications also corroborate the suitability of the material for agricultural recycling since they showed compliance with the values standardized by Brazil (2020) and Brazil (2014).

4 AGRICULTURAL RECYCLING OF FISH FARMING SLUDGE IN THE BANK'S BRANCH LINE

The sludge generated in the representative property of the Bank's Branch has high values of Fe2+ (Table 1) and total Fe (Table 2) in its composition. Given the potential of the Fe2+ form to cause phytotoxicity in cultivated plants (ZAID et al., 2020), the amounts of dry and wet sludge for recycling were calculated to supply the recommended Fe2+ via FTE (fries) for the crops contemplated here (PEREIRA et al., 2014; BRASIL et al., 2020; CFSMG, 1999). That is, the iron content (Fe2+) supplied via FTE to the crops will be replaced by the Fe2+ of a dose, dry or wet mass, of fish farming sludge, thus limiting the amounts of material to be applied to the soil. In this sense, the recycling of sludge in tall crops and staked vines fulfills the objective of replacing the non-criterion mode adopted for its final destination by the producer. This process has the potential to cause a negative impact on the soil-plant system or generate environmental liabilities if not properly recycled in the soil, complicating and burdening the subsequent preparation of agricultural areas for replanting.

Sludge recycling was done for the species reported by Carneiro (2019) and the species discussed with producers throughout the extension actions. They are: i) banana, papaya, passion fruit, with doses calculated for plants aged > 3 months and < 6 months and > 6 months; ii) the açaí trees *Euterpe oleraceae* (BRS Pará) and *Euterpe precatoria* (açaí trees from Amazonas), lemon trees, tangerine trees, orange trees, cupuaçu trees, rubber trees, conilon coffee, guava trees, coconut trees, soursops, camucamuz trees, guarana trees and acerola trees, aged > 3 months and < 1 year and 1 year > years; iii) Capsicum peppers and pepper trees SPP, black pepper, long pepper and annatto with ages > 2 months and < 4 months and > 4 months, and; iv) okra with age ≥ 3 months.

Tables 3 and 4 specify the doses of sludge, dry and wet masses, to be recycled for some crops and, with few subsequent additions of crops contemplated, will be included in a manual for the use of fish farming sludge in the Bank's branch, to be published in 2025. In this manual, emphasis was placed on the recycling of wet sludge, just removed from the tank and prepared for application as described in the future manual. This is due to the labor and manpower required to obtain a sludge particle size close to coarse sand, suitable for surface application of dry sludge to the soil, without pebbles or coarse clods.

Table 3

Dry and wet mass doses of fish farming sludge for arboreal and herbaceous crops in the Bank's Branch

Culture	Dose of FTE BR 12	[2]Quantity of Fe2+	Dry sludge (kg)[3]	Wet sludge (kg)[4]
Banana tree[1] (> 6 months)	80 g plant $^{-1}$	2,4 g plant $^{-1}$	5,9 kg plant $^{-1}$	11,5 kg plant $^{-1}$
Banana tree[1] (>3 months and <6 months)	-	1/2 serving of the plant > 6 months	1/2 serving of the plant > 6 months	1/2 serving of the plant > 6 months
Açaizeiro *E. precatoria* (backyard/forest > 1 year)	10 g plant $^{-1}$	0,3 g plant $^{-1}$	0,74 kg plant $^{-1}$	1,44 kg plant $^{-1}$
Açaizeiro *E. precatoria* (backyard/forest > 3 months and < 1 year)	-	1/2 serving for 1>yearold backyard	1/2 serving for 1>yearold backyard	1/2 serving for Backyard/woods > 1 year
Cupuaçu tree (> 1 year)	10 g plant $^{-1}$	0,3 g plant $^{-1}$	0,74 kg plant $^{-1}$	1,44 kg plant $^{-1}$
Cupuaçueiro (> 3 months < 1 year)	-	1/2 serving for of the plant > 1 year	1/2 serving for of the plant > 1 year	1/2 serving for of the plant > 1 year
Rubber tree (> 1 year)	10 g plant $^{-1}$	0,3 g plant $^{-1}$	0,74 kg plant $^{-1}$	1,44 kg plant $^{-1}$
Rubber tree (> 3 months and < 1 year)	-	1/2 serving for of the plant > 1 year	1/2 serving for of the plant > 1 year	1/2 serving for of the plant > 1 year
Conilon coffee (*C. canefora*) (> 1 year)	50 g plant $^{-1}$	1,5 g plant $^{-1}$	3,7 kg plant $^{-1}$	7,2 kg plant $^{-1}$
Conilon coffee (*C. canefora*) (> 3 months and < 1 year)	-	1/2 serving for of the plant > 1 year	1/2 serving for of the plant > 1 year	1/2 serving for of the plant > 1 year

Source: Prepared by the authors (2025). [1]Recommendation according to Pereira et al. (2014). The other recommendations of FTE BR 12 are in line with Brasil et al. (2020). [2]Amount of Fe^{2+} supplied with FTE BR 12 and sludge doses. [3]Sludge dried after drying for 24 hours in full sun and ground until it can be spread on the soil surface without clods. [4]Wet sludge after removal from the tank, with minimum spreading capacity on the soil surface. [5]Calculated according to the number of plants per hectare. Dose in kg ha^{-1} of sludge will be recalculated per plant by dividing the dose of wet sludge by the number of plants per hectare.

Table 4

Doses of dry and wet mass of fish farming sludge for climbing and shrub crops and in the Bank's Branch

Culture	Dose of FTE BR 12	[2]Quantity of Fe2+	Dry sludge (kg)[3]	Wet sludge (kg)[4]
Guaranazeiro (> 1 year)	30 kg ha^{-1}	0,9 kg ha^{-1}	2218 kg ha^{-1}	4300 kg ha^{-1}
Guaranazeiro (> 3 months < 1 year)	-	½ of the dose for 1>year plant	½ dose for 1>yearold plant	½ dose for 1>yearold plant
Passion fruit (> 6 months)	30 g $plant^{-1}$	0,9 g	2,22 kg $plant^{-1}$	4,3 kg $plant^{-1}$
Passion fruit (> 3 months < 6 months)	-	½ of the dose for 6>month plant	½ of the dose for 6>month plant	½ of the dose for 6>month plant
Bell Peppers & Pepper Trees Capsicum1 (> 4 months)	50 kg ha^{-1}	1,5 kg	3700 kg ha^{-1}	7200 kg ha^{-1}
Bell peppers and pepper trees *Capsicum* spp (> 2 months < 4 months)	-	½ of the dose for 4>month plant	½ of the dose for 4>month plant	½ of the dose for 4>month plant
Black Pepper Tree (>4 months)	30 g $plant^{-1}$	0,9 g $plant^{-1}$	2,22 kg $plant^{-1}$	4,3 kg $plant^{-1}$
Black pepper tree (> 2 months < 4 months)	-	½ of the dose for 4>month plant	½ of the dose for 4>month plant	½ of the dose for 4>month plant
Long pepper tree	30 g $plant^{-1}$	0,9 g $plant^{-1}$	2,22 kg $plant^{-1}$	4,3 kg $plant^{-1}$
Long pepper tree (> 2 months < 4 months)	-	½ of the dose for 4>month plant	½ of the dose for 4>month plant	½ of the dose for 4>month plant
Okra (>3 months only)	50 kg ha^{-1}	1,5 kg	3700 kg ha^{-1}	7200 kg ha^{-1}
Annatto tree (>6 months only)	50 kg ha^{-1}	1,5 kg	3700 kg ha^{-1}	7200 kg ha^{-1}
Annatto tree (>3 months and <6 months only)	-	½ of the dose for 6>month plant	½ of the dose for 6>month plant	½ of the dose for 6>month plant
Acerola (>6 months)	50 kg ha^{-1}	1,5 kg	3700 kg ha^{-1}	7200 kg ha^{-1}
Acerola (>2 months and <6 months only)	50 kg ha^{-1}	1,5 kg	3700 kg ha^{-1}	7200 kg ha^{-1}

Source: Prepared by the authors (2025). [1]Cultures of peppers and green and sweet pepper, yellow and hot pepper (cumari-do-Pará pepper), murupi peppers and chili peppers. [2]Amount of Fe^{2+} supplied with the application of FTE BR 12 and with the doses of dry and wet sludge. [3]Dry sludge after drying (12 hours in full sun, being turned every 3 hours) and complete grinding until it acquires a shape that allows the material to flow (spread) with the appearance of coarse sand, with the absence of coarse clods. [4]Wet sludge after removal from the tank, but which has a capacity for drainage and spreading on the soil surface close to the plants. Note: doses in kg ha^{-1} can be calculated for the individual plant, in kg $plant^{-1}$, dividing the dose by the number of plants per hectare planted.

As in any economic activity, there are risks in this recycling process. These risks are related to the misinterpretation of the recommendations and the application in an unrecommended way. These risks can be minimized if the producer strictly follows the recommendations published here or contained in the manual (to be published in 2025) made by an Agronomist or Agricultural Technician duly knowledgeable about this text in its entirety. It is believed that, due to what is observed at the field level and in the specialized literature, there will be no complications related to the phytotoxicity of iron ($Fe2+$), which appears in high total and available (soluble) quantities in the sludge since its release into the soil requires time and, therefore, its absorption by the plants is gradual. It is also believed that even nutritional disorders in crops are unlikely since the sludge is applied to the soil surface and that this recycling process does not exclude the normal fertilization of each cultivated species. However, occurrences of nutrient deficiency are common in crops due to soil fertility and fertilization management. Therefore, it is recommended that the producer seek the accompaniment of qualified technicians to, together with them, reach more technically economical and appropriate decisions for each specific property.

Fish farming sludge, until there are research results that feed back into the practice in the field, should not be applied in doses higher than those published in this text or recommended in the manual to be published in 2025. The guidelines for preparing the sludge and applying it to the different crops must be followed to the letter. Fish farming sludge should not be applied to crops that are not included in this manual, exceptionally to vegetables or other species cultivated with a growth habit close to the ground. The exception to this rule is okra, whose commercial product emerges in the upper part of the plant in due time, without the risk of contact with recycled fish farming sludge. This is a priority care, even though there is no significant risk of pathological agents, according to the evaluations carried out.

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