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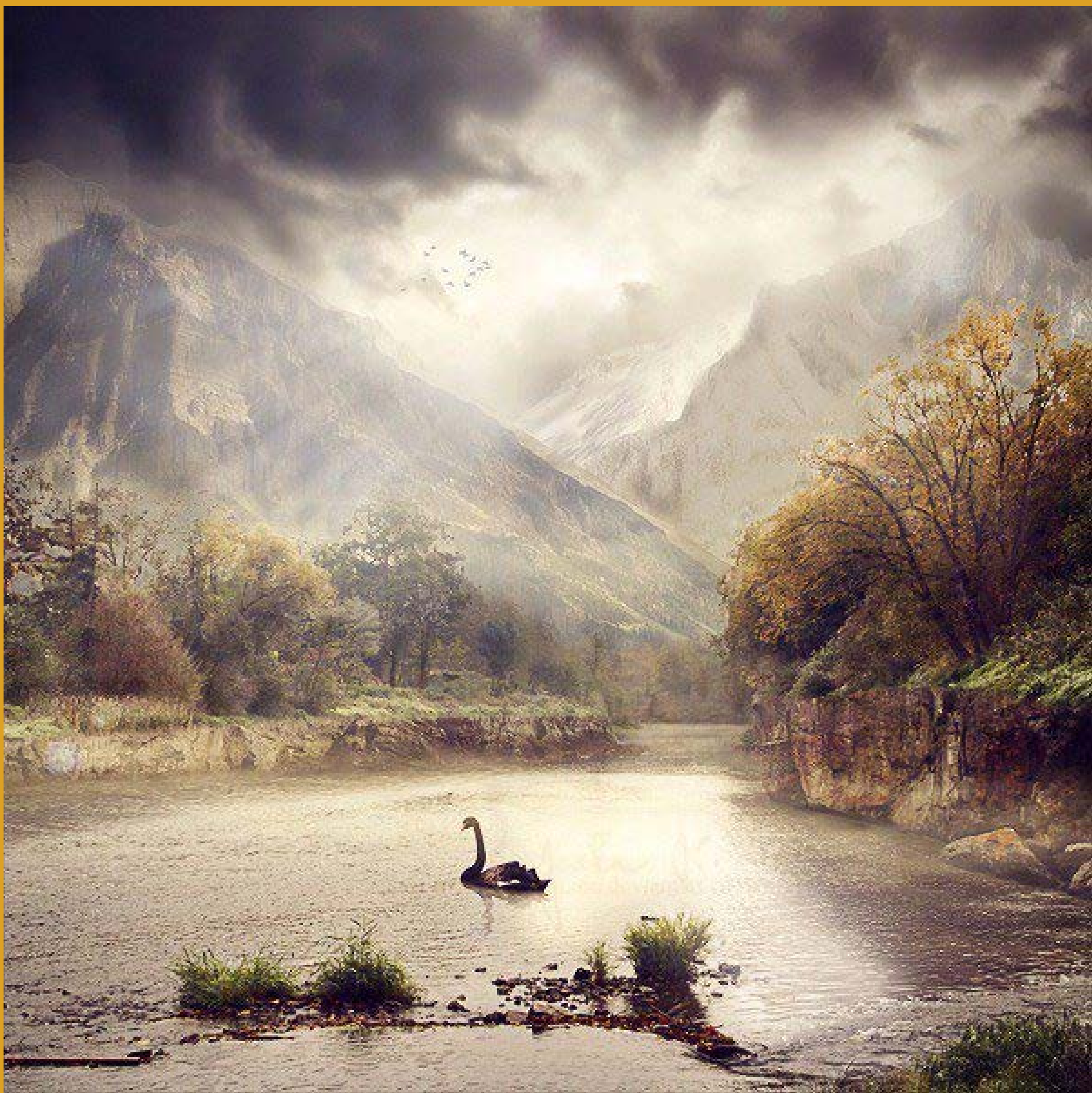

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PALM OIL MILL WASTE IMPORTANCE AND ITS MANAGEMENT IN A SUSTAINABILITY CONTEXT IN SOUTHERN BENIN

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ABSTRACT

Palm oil is one of the most valuable oleaginous trees worldwide. Wastes from palm oil production are used for many purposes (soap, fire starting cake, butter…). While researchers have paid attention to the sustainability of the palm oil mill environment, there have been no studies about the importance of each kind of waste in relation to its sustainability. To analyze these questions, a survey was conducted in Southern Benin with a random sample of 335 palm oil mill owners. An ethnobotanical index was used to evaluate the importance and value of palm oil mill wastes in palm oil production. A double Principal Component Analysis was performed to characterize palm oil mill waste using categories of palm oil production. The study reveals that palm fiber and empty fruit bunches were plays the same social important ($p>0.05$) to mill owners, with the Importance Value at 0.52 and 0.45, respectively. The importance of these wastes varied within palm oil production. The quantity of empty fruit bunches and palm oil mill effluent used depended on the amount generated and use value to mill owners. At the same time, the quantity of fiber used depended only on its use value. When fiber was used for many purposes, the mill owners did not use all the quantity produced. Palm oil mill waste was more valorized in soil fertilization in Ouémé. The discharge of palm oil mill effluent in Plateau, Couffo and Mono contributed more to environmental pollution than palm oil mill solid wastes.

Key words: palm oil mills wastes; importance value; use value; sustainability; environment

Importance et gestion des résidus d'huilerie de palme dans un contexte de durabilité au Sud du Bénin

RÉSUMÉ

Le palmier à huile est l'une des plantes oléagineuses les plus exploitées au monde. Les déchets issus de l'extraction d'huile de palme valorisés à diverses fins font de plus en plus objet de récentes études du fait de leur nature polluante. L'étude, réalisée au Sud Bénin, vise une meilleure compréhension du lien entre l'importance sociale accordée à ces déchets et leur gestion durable. Une enquête semi structurée a été faite auprès de 335 producteurs d'huile de palme. Les indices ethnobotaniques ont été utilisés pour appréhender l'importance et la valeur d'usage des déchets d'huileries de palme selon les zones de production de palmier à huile. L'analyse factorielle a été utilisée pour montrer le lien entre les zones de production du palmier à huile et les usages faites des déchets issus des usines de production d'huile de palme. Les résultats ont montrés que les fibres, les pédoncules et les rafles étaient importants avec 0,52 et 0,45 comme indice d'importance pour les propriétaires d'usines d'huile de palme. L'importance de ces déchets a variée selon les zones de production. Les usines qui arrivaient à valoriser toute la quantité de pédoncules et de rafles étaient celles pour qui ces déchets étaient importants mais elles s'y concentraient pour l'utiliser à peu d'usages possibles. L'utilisation totale des fibres dépendait seulement de la valeur d'usage. Les déchets des huileries de palme étaient utilisés comme fertilisants pour la production de légumes feuilles dans l'Ouémé. Le Plateau, le Couffo et le Mono sont des zones qui contribuaient plus à la pollution environnementale.

Mots clés: déchets d'huilerie de palme; importance; valeur d'usage; durabilité; environnement

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INTRODUCTION

Palm oil has been introduced in Benin since 1800. Despite the problems its production chain has faced over the years, palm oil production promoted by the government (valorized), has remained an important industry (Fournier, 2001; Carrere, 2010; Hodonou, 2010). It plays an important socioeconomic role in households (Quenum, cited by Adegbola *et al.,* 2009). Indeed, the production of palm oil and 'sodabi' (local palm wine) has led to an increased income and social capital (such as social and economic differentiation), with a positive impact on the status of operators and an enhanced livelihood for households. This oil extraction generates fairly large amounts of byproducts, usually referred to as palm oil mill wastes (POMW) like palm oil mill effluent (POME), fiber, and empty fruit bunches (EFB). According to Prasertsan and Prasertsan (2006), during processing in the palm oil mill, more than 70% of the processed fresh fruit bunches (FFB) were left over as palm oil wastes. These wastes have been efficiently used as input (Mensah, 1999). The solid and liquid waste products have been combined for economically useful purposes such as boiler fuel, soap production, fertilizer, composting material, fire starting cake, electricity generation in the mills, pig and cattle food and mushroom production (Law *et al.,* 2007; Yacob *et al.,* 2005; Fournier *et al*, 2002). Wastes produced by mills must be used entirely or become a source of pollution. According to Ahmad *et al.* (2003), wastewater highly polluted by POME causes pollution of waterways due to oxygen depletion and related effects. For example, the biological oxygen demand (BOD) generated by the palm oil industry in Malaysia in 1998 is equivalent to that generated by 38 million people (Bek-Nielsen *et al*., 1999). Ojonoma and Nnennaya (2007) reported that, while palm oil production is highly profitable, the adverse environmental impact from the palm oil industry cannot be ignored. Sustainability and waste management have become important global issues because of climate change. The sustainability of palm oil is thus crucial if this versatile crop is to become the leading vegetable oil in the world (Tan *et al.,* 2009). However, conventional palm oil mills are considerable environmental polluters and do not follow the principles of sustainability (Anonym RSPO, 2005; Anonym Unilever, 2003). In fact, during some field surveys in Ouémé on palm oil production areas in Benin, it was found that some quantities of POMW were still unreasonably discarded even though these wastes were used for many purposes, according to Ahoyo (2008) and Fournier (2002). This study aims to study the palm oil milling sector in Benin and the sustainable management of its wastes. The importance of these wastes and value added by the mills to those involved in palm oil value chains is assessed.

METHODOLOGY

Study site

The study was carried out in Southern Benin and covered the Atlantic, Mono, Couffo, Ouémé and Plateau agro-ecological palm area production (Figure 1). Southern Benin extends from the coast from 6° 25' N to 7°30' N latitude. This part of Benin Republic belongs to the Guinea-Congolese zone. The climate of this part is sub-equatorial with two rainy seasons (March to June, and September to mid-November) and two dry seasons (July to September, and November to March). The annual rainfall varies between 1,100 and 1,400 mm. The average daily temperature ranges from 25 °C to 29 °C and the average daily humidity from 69 % to 97 %. The Guinean zone is the area of deep Lateritic soils of low fertility (700, 000 ha) as well as more fertile alluvial soils and heavy clay soils (360,000 ha) located in the river valleys of Mono, Couffo, Ouémé, and in the Lama depression (Adjanohoun *et al.* 1989).

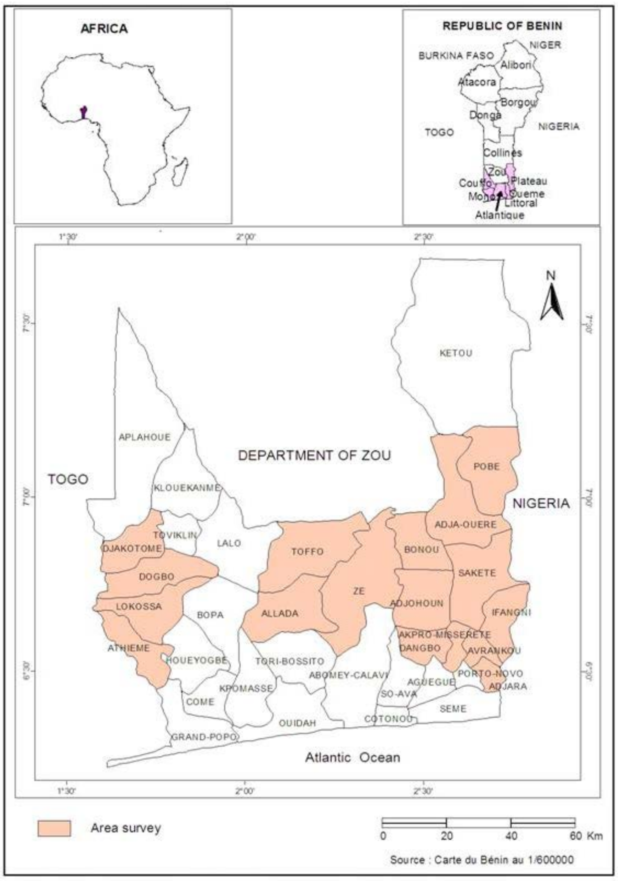


Figure 1. Location of experiment sites

Sampling and Survey

A questionnaire and personal observations were used to achieve research objectives. In each areas production, villages surveyed were chosen according to two criteria: the oil palm fertilizer demand and the presence of local and selected oil palm. The survey was conducted from November 2011 to March 2012 in palm oil mills associated with the palm oil producers of the Communal Union of Palm oil Producers (CUPOP) (UCPPH), a communal palm oil producers group. These palm mills are members of CUPOP or buy their nuts from CUPOP members. This survey also included well known waste management researchers. In each region studied, only districts and villages comprising significant numbers of plantations and mills were selected. Three hundred and thirty five palm oil mills were surveyed randomly (Table I).

Table I. Palm oil mill owners' responses.

Palm area production	Responders	
	Number	Percentage (%)
Atlantique	80	24
Couffo	56	17
Mono	63	19
Oueme	90	27
Plateau	46	14
Total	**335**	**100**

Interviews were focused on the importance of the various palm oil mill wastes to the industry. Each surveyed mill owner was invited to rate the importance of empty fruit bunches (EFB), fiber and palm oil mills effluents (POME). Each responder then evaluated the proportion of wastes utilized and discarded using the matrix method. Each mill owner explained how the utilized waste was used. The results of the interviews were combined with direct observations of the mill environment, particularly where the wastes were packed. The soil profile in one mill was described using the Mensul code to predict the effect of POME accumulation in the soil profile when it was discarded (Figures 4a and 4b). The sustainability was assessed based on converting all POMW into resources, preferably renewable resources with positive impact on the environment.

Data analysis

User Percentage, Importance and Use Values of Palm Oil Mill Wastes

To measure the proportion of interviewees who used palm oil mill wastes, those who considered a waste most important, the average number of uses known for a waste, and the Users percentage (Up), the Importance Value (IV) and the Use Value (UV) of each waste were calculated as follows:

(1) $Up = N_{users}/N$; N_{users} is the number of informants who use a waste

(2) $IV = N_w/N$; N_w is the number of informants who consider a waste w as the most important.

(3) $UV = UV_{iw} / N$ (Phillips and Gentry, 1993);

UV_{iw} = number of uses informant i knows for wastes valorization. N is the total number of informants

Use Diversity Value and Purposes Consensus Value

To evaluate the number of ways a waste is used, how evenly these contribute to its total usage and the degree of consensus among interviewees as to rationale for use, the Use Diversity Value (UD) (4) and Purposes Consensus Value (PC_v) (5) as described by Byg and Balslev (2001) were employed:

(1) $UD_v = 1/\Sigma P_c^2$

P_c is the contribution of use category to the total utility of a waste (the number of times waste w was mentioned within each use category, divided by the total number of reports of use of waste w across all use categories)

(2) $PC_v = \Sigma P_u^2/S$;

P_u is the proportional contribution of use u to the total utility of a waste w (the number of times use u was reported for species s divided by the total number of reports of use of waste w). S is the number of types of uses of a waste.

Statistical analysis

The comparison of proportion test analysis allowed the comparison of palm area production according to user number and the importance values of POMW. The Kruskal-Wallis Rank Sum test in R (Hollander and Wolfe, 1973) was used due to the non-normality of the data obtained. Because of the undistributed normality (Shapiro test of normality) of the EFB, fiber and POME quantities, Mann-Whitney U Test, a non-parametric test, was used to study whether the use of all POMW depended on the quantities produced. The Pearson test was performed to examine the correlation between a pair of three variables for each POMW type, such as the total use of POMW considered, the UV and the IV.

Double Principal Component Analysis (PCA) was performed to explain the relation between palm area production and POMW use categories. All these analyses were made using R software.

RESULTS

Importance of Palm Oil Mill Wastes

Contrary to household wastes and some industrial wastes, palm oil mill wastes are utilized by the mills that generate them. Eighty two point fifty zero nine per cent, ninety six point forty two per cent and seventy seven point ninety

Table II. Waste, usages and relation between groups and use of all waste quantities

Provinces	% Users			Importance Value			Uses Values		
	EFB	FFM	POME	EFB	FFM	POME	EFB	FFM	POME
Plateau	80.4bc	89.1	45.7c	0.39	0.59a	0	1.6	0.5	1.4
Oueme	80 bc	92.2	82.2b	0.53	0.38b	0.04	1.6	1	0.8
Atlantique	72.5 c	100	98.8a	0.41	0.56a	0.03	1.4	1.1	1
Mono	87.3ab	100	55.6c	0.43	0.57a	0	1.7	1.1	0.6
Couffo	94.6a	100	92.9ab	0.46	0.52ab	0.018	2	1.2	0.9
Total	83±8.4	96.3±5.2	74±23.3	0.44±0.06	0.52±0.08	0.02±0.02	1.7±0.2	0.98±0.28	0.94±0.3
p	0.01*	$4E^{-7}$***	$2.5E^{-15}$***	0.44	0.06	0.3	$<2.2E^{-16}$***	$<2.2E^{-16}$***	$<2.2E^{-16}$***

Difference of parameter for each waste among all departments is significant at 5% (*), 1% (**), 0.1% (***)
Values followed by the same letter within a column are not significantly different (P<0.05)

one owners of mills surveyed used respectively EFB, Fiber and POME. So fiber was used more often than EFB and POME. Despite the percentages observed, fiber and EFB were equally important (P>0.05) for mill owners, with 0.52 and 0.45 respectively as the importance value (IV). POME was not important for mill owners (0.02 IV). The importance of these wastes varies within palm oil mills. In Ouémé, EFB was more important than fiber and POME (Table 2). POME did not have any importance in Plateau and Mono palm production mills. While EFB is highly and equally used in all palm area productions, POME was used more often in Atlantic palm oil mills and EFB in Couffo and Mono palm oil mills (Table 2). In all palm oil production, EFB had higher use value than FIBER use value, which was equal to POME use value (Table II). In all palm area production, except in Plateau (UV=0.5), fiber was generally used for one purpose (UV≈1). EFB had a higher use value in Couffo. It is generally used for two purposes, depending on palm area production, except in Atlantic where it is used for one purpose. POME had the least UV in Mono.

Palm Oil Mill Waste Management

Despite the importance and high use values observed in POMW for mills, some mills are unable to use all waste. In that case, they discard the rest. The proportion of mills that discard their wastes is 42.4%, 23.3%, and 36.7% respectively for EFB, fiber and POME. The Mann-Whitney test between POMW quantity generated and total usage showed that the use of all palm oil mill waste does not depend on the quantities of waste generated for EFB and fiber (P>0.05). For POME, the Mann-Whitney test revealed that the total use depends on the quantity produced (P<0.05). The analysis of correlation between total POMW use and the importance of waste types and their use value (Table III) revealed a significant negative correlation between UV and the POMW total use. Thus mill owners who valorized all their wastes had low UV, so wastes were used for few purposes. There is a significant and positive relation between total POMW used and IV for the total EFB used but a negative and non-significant relation for POME according to total fiber used. EFB and total POME use depend highly on their importance to mill owners. When EFB was important, owners used it for few purposes and used all the wastes. When POME was important for mill owners, it was used for many purposes and was not completely valorized. At the same time, total fiber used depended only on UV. When it was used for many purposes, mill owners did not use all the quantity produced.

Palm Oil Mill Waste Use

POMW were used for six purposes in southern Benin: boiler fuel, fire starting cake, soap making, fertilization, mushroom production, and pig feed. The main purpose was boiler fuel (Figure 2). The use of POMW for mushroom production and pig feed was very rare. These uses varied with POMW type. EFB was valued as boiler fuel, fertilizer, and in soap and mushroom production. Fiber was used as boiler fuel, fertilizer and to make fire-starting cake. POME was used to make fire starting cake and rarely to feed pigs or as fertilizer.

Figure 2. Number of reports of different kind of POMW use

EFB Use Diversity Value (UDV) was higher than those of fiber, which was higher than those of POME (Table IV). This means that among all POMW, only EFB was used for many purposes. All mills agreed on the use of POME for making fire-starting cake (PC*v*=0.98). Results analysis confirms that more mills agreed about the use of POME than the use of fiber (PCv of POME=0.32 > PCv of FIBER =0.26). Boiler fuel was more associated with to fiber and EFB use, with the greatest consensus of mills for each waste type. Fuel use was higher with fiber than with EFB. Mills agreed on EFB use as fertilizer more often than fiber and POME. The use of POMW for mushrooms and pig

Table III. Correlations of total POMW uses and their importance and use value

	EFB			FFM			POME		
	UV	IV	Total use	UV	IV	Total use	UV	IV	Total use
UV		- ($1.1E^{-8}$)	- (< $2.2E^{-16}$)		+ (0.88)	- ($2.63E^{-5}$)		+ (< $2.2E^{-16}$)	- (< $2.2E^{-16}$)
IV	- ($1.1E^{-8}$)		+(< $2.2E^{-16}$)	+ (0.88)		+ (0.23)	+ (< $2.2E^{-16}$)		- (< $2.2E^{-16}$)
Total use	- (< $2.2E^{-16}$)	+ (< $2.2E^{-16}$)		- ($2.63E^{-5}$)	+ (0.23)		- (< $2.2E^{-16}$)	- (< $2.2E^{-16}$)	

UV : Waste use value, IV : Importance waste value, (P<0.05)
No relation between wastes importance value and its total use and also between wastes importance and its use value

Table IV. Correlations between total POMW uses and their importance and use value

Factors	Contribution of uses ategory to the total utility			Purpose consensus value		
	EFB	Fiber	POME	EFB	Fiber	POME
Boiler fuel	0.42	0.75	0	0.84	0.85	0
Fire-starting cake	0	0.22	0.94	0	0.25	0.98
Soap	0.41	0	0	0.81	0	0
Fertilizer	0.16	0.01	0.03	0.31	0.02	0.03
Mushrooms	0.01	0	0	0.02	0	0
Pig alimentation	0	0	0.03	0	0	0.03
	Use Diversity Value			Purpose consensus value		
	2.7	1.64	1.13	0.36	0.26	0.32

feed are merely alternatives for some mills.

POMW utilization according to palm area production

It has been observed that POMW use value (UV) varies within palm oil production (Table II). The result of Principal Component Analysis (PCA) on the overall uses of POMW in palm oil production showed that the first two axes explained 89.76% of the observed variation. Therefore, only these axes were used to describe the relationship between POMW uses and their area production. Table V presents the correlation coefficient between POMW uses and the two axes.

Table V. Correlation coefficient between POMW uses and the two axes

	Axis 1	Axis 2
EFB use to soap production	-0.239	-0.103
EFB use as boiler fuel	-0.109	-0.12
EFB use as fertilizer	1.016	0.005
EFB use for mushrooms production	-0.760	0.089
Fiber use as fertilizer	1.130	-0.261
Fiber use as boiler fuel	0.009	-0.153
Fiber use for fire-starting cake	-0.278	0.469
POME use for fire-starting cake	-0.051	0.199
POME use for pig feed	1.469	0.349
POME use as fertilizer	1.363	0.158

The first axis showed a positive relation among POMW use as fertilizers (EFB use as fertilizer, ferti1); fiber use as fertilizer (ferti 2); POME as fertilizer (ferti3); and POME use for pig feed. These factors are negatively linked to EFB use for soap (soap1) or mushroom (mushrooms1) production. For the second axis, the use of fiber or POME for fire starting cake (cake2 and cake3, respectively) was negatively opposite to the use of EFB or fiber as boiler fuel (fuel 1 and fuel 2, respectively). Moreover, Figure 3 shows the projection of the different palm area production into the system axes 1 and 2.

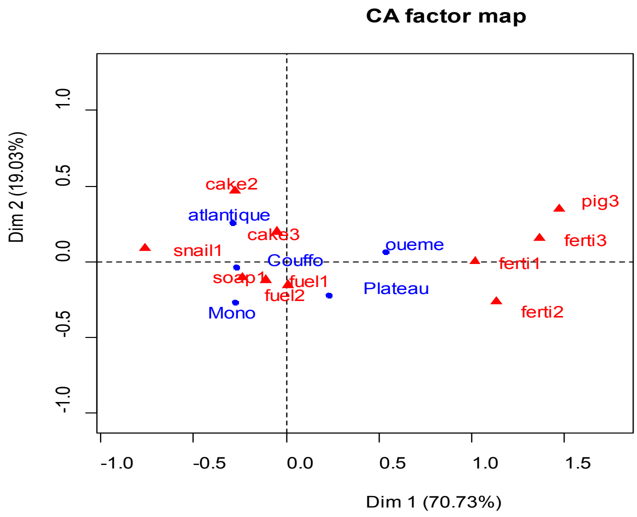


Figure 3. Projection of the different palm area production into the system axis 1 and 2

Indeed, EFB was used for soap production and rarely for mushroom production in Couffo. In this area, mills never used their wastes for fertilization or pig food. In Ouémé, mills utilized all their wastes for soil fertilization and, sometimes, POME for pig feed. Mills of the Plateau palm area production used their wastes in the same manner as those from the Mono palm area production facilities. In these two palm area factories, EFB and fiber were used as boiler fuel. They rarely used POME. In Atlantic, mills used only POME and fiber to produce fire-starting cake. In this area, they don't use POMW for fertilization.

DISCUSSION

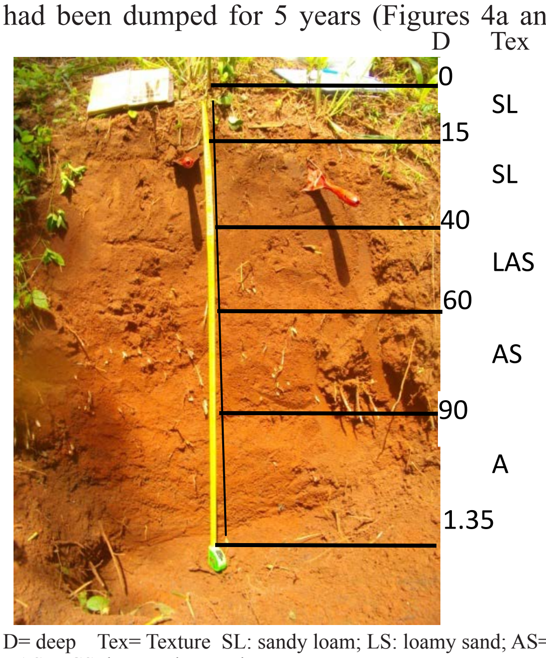
The importance and management of palm oil mill waste

Only EFB and fiber are important for mill owners because they can utilize them for different purposes. POME is not important for mill owners. For these reasons, many mills discard POME. Generally, POME is used for fire-starting cake and pig feed, according to Hodonou (2010) and Ahoyo (2008). Fournier *et al.* (2001) reported that sludge and almond palm oil residue are used for cattle feed. The study shows that management is problematic when POME is produced in quantity. The uses of the waste must be diversified. However, analyses reveal that when POME is important and mill owners try to diversify its usages, they are unable to use all that is generated. Probably they do not choose the best type of utilization, to allow them to use all their waste. In fact, the second use of POME known to mill owners is animal feed. Not every mill feeds animals directly. This is why some mills sold POME to women to make fire-starting cake or lower quality palm oil. According to Binder *et al.* (2002), POME can be used as a soil amendment. The work of Chooi cited by Rupani *et al* (2010) showed that palm oil mill sludge (POMS) can be dried and used as a fertilizer because it higher nutrient value. Except for some in Ouémé, mill owners were unaware of this use.

Fiber was more valued as boiler fuel. It is also mixed with POME to make fire-starting cake. The use of all this waste depends not only on its quantity but how it is valorized; thus this waste must be used for a few purposes. In fact, when one mill owners wanted to valorize POME for many purposes, he ignored the value of other wastes. It was the same case with EFB. These wastes are used for many purposes, principally as boiler fuel and for soap fabrication. The same uses were reported by Beule (2006) in Côte d'Ivoire and Fournier *et al* (2002) in Nigeria. EFB is also used as fertilizer by some mills according to Hamdan *et al.* (1998).

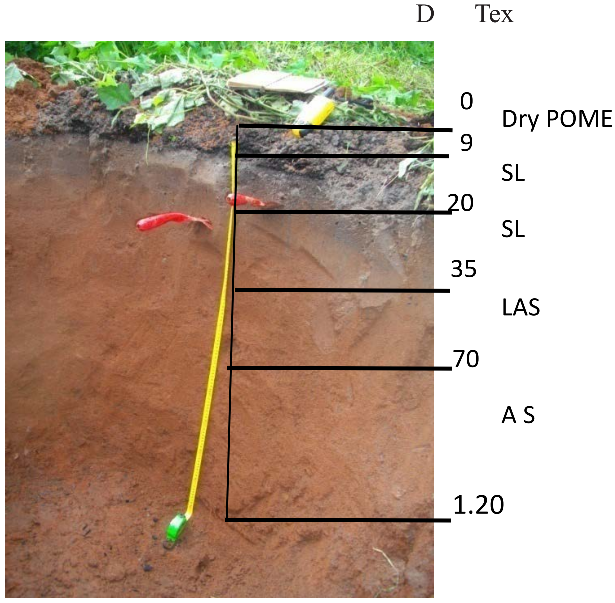
POMW and sustainable environment

Palm oil mills are big polluters according to Schuchardt *et al.* (2007), who affirmed that every ton of crude palm oil produced is responsible for the emission of 46 m^3 (32.9 kg) of methane, corresponding to 384 m^3 (756 kg) of CO_2. Correspondingly, the wastes generated by mills, as all agricultural wastes, have a significant impact on the environment. On the other hand, Sabiiti *et al.* (2011) showed that the impact of agricultural waste on the environment depends not only on the amounts generated, but also on the disposal methods used. Some mills discard all or a part of these wastes and contribute to environmental pollution as confirmed by Schuchardt *et al.* (2007) and Singh *et al.,* (2010). For Maheswaran and Singam (1977), raw POME has Biological Oxygen Demand (BOD) values averaging around 25.0 mg/litre, making it about 100 times more polluting than domestic sewage. Singh *et al* (2010) affirmed that although POME is not toxic because no chemical is added during the oil extraction process, the effluent is considered one of the major sources of aquatic pollution in Malaysia. So it is important to avoid discharging it without treatment. In Plateau, Couffo and Mono, POME was being discarded and not utilized. In fact, mills' owners don't know another POME use except for fire starting cake and pigs feeding. Thus these areas contributed more to environmental pollution by discharging POME. This waste changed the colors of different horizons of the soil profile where POME had been dumped for 5 years (Figures 4a and 4b).



D= deep Tex= Texture SL: sandy loam; LS: loamy sand; AS=CS: Clay sand ; LAS=LCS: loamy clay sand

Figure 4a. Normal soil profile Reddish-brown soil texture SL/LAS/A very porous with a well developed root system until deep, rich in biological activity in the first three horizons



D= deep Tex= Texture SL: sandy loam; LS: loamy sand; AS=CS: Clay sand ; LAS=LCS: loamy clay sand

Figure 4b. Soil profile where POME were throw Reddish-brown soil texture SL/LAS/AS deep, porous with a well developed root system in the first two horizons, rich in biological activity in the first three horizons, deep

In Atlantic, it is used to make fire-starting cake which can reduce the risk of environmental pollution. But when palm oil mills use POME to make fire-starting cake, they remove the sludge from the POME and leave the remainder of water, which infiltrates the groundwater. In Ouémé, very few mills used this waste as fertilizer. This utilization is the best POME management according to scientists. POME is rich in organic matter (Nwoko and Ogunyemi, 2010) and organic nitrogen (Onyia *et al*., 2001) and is the waste most useful in agricultural management (Cayuela *et al*., 2005). This offers an alternative to mill owners, most of whom are farmers confronted with soil degradation and low soil fertility. Despite the advantages of POME, only EFB has been used in agriculture. EFB and fiber are used as boiler fuel, although Their use was prohibited in some countries (Astimar and Wahid, 2006). According to Ezcurra *et al* (2001), the burning of agricultural waste releases pollutants such as carbon monoxide, nitrous oxide, nitrogen dioxide and smoke carbon particles. For Hegg *et al* (1987), these pollutants are accompanied by the formation of ozone and nitric acid, which contributes to acid deposition (Lacaux *et al*, 1992), thereby posing risk to human and ecological health. In all areas of palm oil production, these wastes were being boiled for fuel. To produce traditional soap, mill owners need to burn these wastes. These wastes are also used as fertilizers in Ouémé. This use is more common in Malaysia (Hamdan *et al.* 1998). EFB helps to control weeds, prevent erosion and maintain soil moisture when placed around young palms (Suhaimi and Ong, 2001). There are different kinds of fiber and EFB use. According to some scientists, the best type of utilization of EFB is its composting (Yusri *et al.*, 1995; Thambirajah *et al*., 1995). Composting as well as vermicomposting of these biological wastes can be a good option for sustainable waste management (Rupani *et al*., 2010; Singh *et al*., 2011; Singh *et al*., 2010; Embrandiri *et al*., 2012).

CONCLUSION

Solid POMW management depends on its importance and mill owner knowledge of area production. POMW management in Benin palm oil area production contributes to environmental pollution. EFB and fiber are more important for many mill owners as boiler fuel, which is a source of environmental pollution. Although some part of POME is used as fire starting cake, this type of waste is not important to mill owners and is discarded when the quantity produced is excessive. The best use of these wastes is in agriculture, although only EFB was used in farming. This was probably due to mill owners' ignorance of POMW use in agriculture.

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