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Effects of urine and hygienized feces on cocoa production in the village of Blanfla (Bouafle, Côte d'Ivoire)

Yapi Ellélé Aimé Marius ✉

National Institute of Public Hygiene (INHP), PO BOX V 14 Abidjan, Côte d'Ivoire

N'Krumah Tanoh Amany Serge Raymond

Peleforo Gon Coulibaly University, Korhogo (Côte d'Ivoire), PO 1328 Korhogo, Côte d'Ivoire

Swiss Center for Scientific Research (CSRS)/Environment - Health Department, 01 PO 1303 Abidjan 01, Côte d'Ivoire

Gnagne Théophile

Faculty of Sciences and Environment Management, Nangui Abrogoua University, Geosciences and Environment Laboratory, 02 PO 801 Abidjan 02, Côte d'Ivoire

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ABSTRACT

Ecological sanitation involves the use of hygienized human excreta as fertilizer in agriculture. This study aimed to establish the effects of hygienized urine and feces on cocoa production in the village of Blanfla in the Bouaflé Department of Côte d'Ivoire. To this end, 539 people from 100 households were trained in the use of urine-diverting dry toilets (UDDTs) and in fertilizing cocoa plantations with hygienized excreta from UDDTs. The study ran from 2014 to 2017, during which time 6 months were spent building the TSDUs and 1.5 months were monitoring their use. For 2 years, three categories of plantations (young, mature and old) with a total surface area of 285 ha were fertilized by the application of almost 445 m³ of urine and 100 tonnes of hygienized feces. The quantity of biofertilizer applied to the three groups of plantations almost doubled the annual cocoa production (RP=1.95). In all three plantation categories, crop production was significantly associated with BF application (r = 0.993; p = 0.007/r = 0.975; p = 0.025) but not with temperature or rainfall. The use of hygienized urine and feces as biofertilizers through the ecological sanitation approach should be popularized, as it increases agricultural productivity and farmer incomes.

Introduction

Ecological sanitation (Ecosan) is a cycle and a sustainable system in which human excreta are treated as a pathogen-free resource for reuse as fertilizer in agriculture. The benefits of this sanitation system include protecting health and the environment, contributing to soil fertility, improving crop production, increasing farmers' income and combating food insecurity (Esrey *et al.*, 1998). This approach complements conventional sanitation, which generates multiple problems, both ecological and sanitary. A great deal of research has been published on ecological sanitation systems around the world (Jönsson *et al.*, 2004; Jensen *et al.*, 2008; Senecal-Smith, 2013). In Africa, since 2002, the Water and Sanitation Agency for Africa (WSA) and numerous scientific works by several authors have promoted this approach (Centre Régional pour l'Eau Potable et l'Assainissement, 2006; Berendes *et al.*, 2015; Mackie *et al.*, 2016). In the specific case of Côte d'Ivoire, studies conducted by a few authors open up more good prospects for ecological sanitation research (Gnagne *et al.*, 2006; Koné *et al.*, 2014; Yapi *et al.*, 2021). Moreover, the international cocoa trade is valued at more than $5 billion, with almost 72% of the world's cocoa supply coming from Africa Caribbean Pacific (ACP) countries, mainly from West Africa (Agritrade, 2012). Within the West African Economic and Monetary Union (WAEMU), Côte d'Ivoire has remained the world's leading producer, with an average quantity of 1.4 million tons over the last ten years, representing just over 32% of the market share. The cocoa sector in

Corresponding author E-mail: yapiellele@yahoo.fr
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Côte d'Ivoire contributes approximately 20% to national wealth formation and is of strategic importance to the country's economic and social development (Banque Centrale des Etats de l'Afrique de l'Ouest, 2014). However, the sustainability of cocoa farming in Côte d'Ivoire is threatened by several constraints, particularly the aging of orchards and the difficulty of renewing them in the face of a lack of forest, declining soil fertility and adverse effects of climate change (Assiri *et al*., 2016). Cocoa yields in Côte d'Ivoire are said to be among the lowest in the world, at approximately 500 kg per hectare, due to aging plantations, pest attacks (Swollen Shoot and Brown Rot) and the crises that have occurred in Côte d'Ivoire since 1999. (Agritade, 2011; Banque Centrale des États de l'Afrique de l'Ouest, 2014).

With its enormous agricultural potential, the Marahoué region in the west-central Côte d'Ivoire recorded cocoa production of almost 47,000 tonnes in 2014 (Agence Ivoirienne de Presse, 2015). However, swollen shoot disease has affected 12% of the country's cocoa plantations for the past ten years, including those in the central-western region, where 8600 ha have been affected in Sinfra and Bouaflé, leading to a 66% drop in production (Commodoafrica, 2013).

Furthermore, the cocoa soils in the Bouaflé region have a low fertility potential (N'guessan *et al*., 2016). Consequently, faced with the degradation of soil fertility and the challenges of plantation regeneration, the option of intensifying cocoa production in Côte d'Ivoire cannot ignore the need to fertilize cocoa soils (Centre National de Recherche Agronomique, 2012). According to studies by Petithuguenin (1998) and Centre d'Etudes et de Prospective (2015), the use of high doses of fertilizer or biostimulant results in high production of cocoa or any other plant. Therefore, to revitalize cocoa farming, combat soil degradation and protect the environment in the Marahoué region, the use of hygienized human excreta as biofertilizer is highly desirable. The aim of this study was therefore to determine the effects of ecological sanitation via the use of hygienized urine and feces on cocoa production in the village of Blanfla in the west-central Côte d'Ivoire.

Material and Methods

Originality of the study

This study is based on the ecological sanitation (Ecosan) approach, in which dry toilets with urine deviation (TSDU) are built as real domestic fertilizer production units. The innovations in this work are technological, socioeconomic, health and sanitary, environmental and agronomic. Technological innovation concerns the TSDU model, which is adapted to local realities and affordable for rural households. The TSDU model has a parallelepiped-shaped pit with a volume of only 0.$^{21\ m^3}$. Its purpose is to receive human excreta and ash in a urine collection device and another stool collection device. Socioeconomic and health innovation has focused on increasing farmers' incomes by improving crop yields through the fertilization of cocoa plantations with hygienized products from the TSDU. According to the results of this study, the reuse of hygienized urine and feces in agriculture is highly advantageous in rural areas because it resolves the issue of chemical fertilizer use, which destroys the natural environment of the soil and damages farmers' health. The technical aspects of the Ecosan approach consisted of the construction of TSDUs and training in the use and maintenance of toilets. Household demand for the construction of toilets was materialized by a toilet acquisition form, which constitutes the willingness and commitment of the household to join the project.

The agronomic component constituted the last link in the Ecosan approach. Hygenized urine was applied at an average rate of 1.5 liters around the base of the cocoa tree within a radius not exceeding 1 meter.

Type of study and sampling time

This was a longitudinal study that took place over a 3-year period from January 2014 to January 2017.

Guidelines reference

To achieve this innovative work, the ATPC-ECOSAN approach was implemented. This consisted of combining ecological sanitation (Ecosan) with Community-Led Total Sanitation (CLTS) to improve toilet coverage in the locality and limit open defecation. While CLTS highlighted the health hazards of open defecation and led to the decision to change behavior by stopping open defecation (Kamal, 2009), the Ecosan approach provided households with improved toilets. This approach emphasizes the advantage of reusing hygienized excreta in agriculture by putting an end to open defecation while presenting the Dry Toilet with Urine Deviation (TSDU) as an "organic fertilizer factory". The implementation of ecological sanitation in the village of Blanfla took into account these technical, sanitary and agronomic components, as recommended in the Ecosan approach toolbox (Centre Régional pour l'Eau Potable et l'Assainissement, 2006). The technical aspects of the Ecosan approach involved the construction of TSDUs through a system of microcredit granted to households (Yapi *et al*., 2018a). The construction of the TSDUs was followed by a process of training and monitoring households for proper use and maintenance to obtain quality sanitation byproducts (urine and feces) for fertilizing cocoa fields. The continuous collection of urine and feces by households in cans and bidurs over two years (July 2014 to July 2016) constituted the production of urine and feces. The sanitary component of the Ecosan approach enables the hygienization of urine and feces, which must be cleared of all pathogenic germs before being spread on cocoa fields to protect farmers' health (Gnagne *et al*., 2006; World Health Organization, 2012; Yapi *et al*., 2018b). Hygienization of the urine involved simple storage of the urine cans in the shade for 45 days, while the feces were composted for 6 months in a pit (Centre Régional pour l'Eau Potable et l'Assainissement, 2006). Monthly monitoring of household hygienization led to the production of biofertilizers without health risks; these biofertilizers are called "ferturine" for urine and "fertifè" for feces. In total, over two years, 442.60 m^3 of hygienized "ferturine" and 99.12 tonnes of "fertifê" (Yapi *et al*., 2018a) produced by households were used to fertilize cocoa plantations.

The agronomic component constituted the last link in the Ecosan approach. Hygenized urine was applied at an average rate of 1.5 liters around the base of the cocoa tree within a radius not exceeding 1 meter. The same technique was used for spreading compost, with an average dose of 1.5 kg. This agronomic valorization of biofertilizers is ideally carried out during the rainy season each month before cocoa tree flowering (Yapi *et al*., 2018a).

Data collection technique

To collect farmer monitoring data on biofertilizer application, elaborate monitoring tools were used to record the date of monitoring, the date of application, the speculation to be fertilized (cocoa), the area of the fertilized field, the age of the plantation, and the quantity of "ferturine" and/or "fertifê" applied. Every month for two years, each farmer was monitored in the cocoa field to ensure that the application technique and the quantity of ferturine and fertifè applied were controlled. The collection of annual cocoa harvest data in the village of Blanfla took place during cross-sectional household surveys with a survey form among the 100 farmers (households) who benefited from the TSDU. The survey covered four years and was spread over two periods. Two years of annual harvest before the application of urine and feces (2013 and 2014) and two years after the application of urine and feces (2015 and 2016). The data collected concerned the area of the plantation, the duration of exploitation of the plantation (the age of the plantation), and the annual cocoa harvest. The cocoa harvests were collected during the 2013, 2014, 2015 and 2016 seasons for small (March to May) and large (October to December) cocoa campaigns. The collection of historical meteorological parameter data was carried out from June 1 to 30, 2017. These data made it possible to determine the effects of biofertilizers and meteorological parameters on cocoa production over the study period. These data concerned the rainfall (precipitation) and average air temperature of the Bouaflé region. The samples were collected annually over the period 2013-2016 (04 years) on a sheet prepared for this purpose, which served as a collection tool.

Study area

This study was carried out in the village of Blanla, located 14 km from the town of Bouaflé, which is the regional capital and is mainly irrigated by an agricultural dam. (Agence Nationale d'Appui au Développement Rural, 2014). The Bouaflé Department comprises 5 subprefectures and covers an area of 3,980 km2 with a population of 300,305 (Institute National de la Statistique, 2021) (Fig. 1-2). It is located between 06°58.717 north latitude and

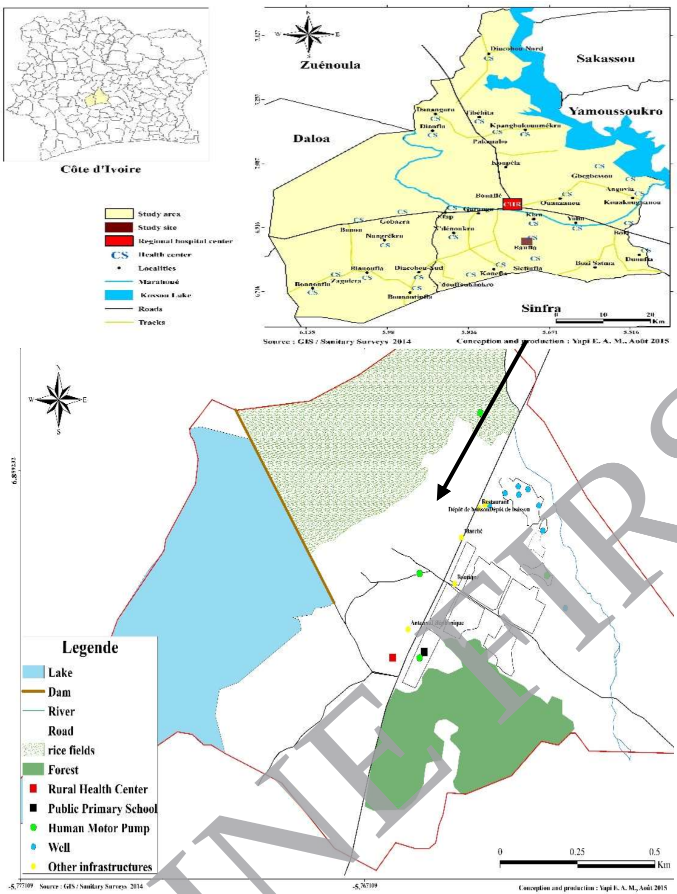

Figure 1: Map of the village of Blanfla in the Department of Bengal (Côte d'Ivoire)

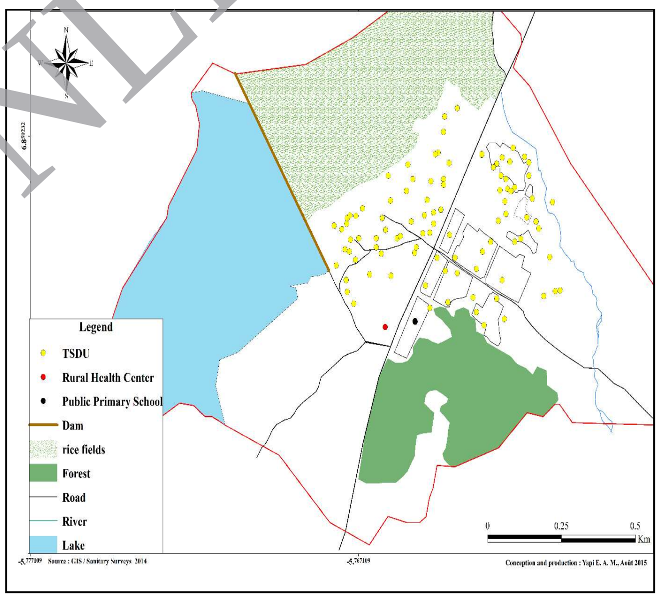

Figure 2: Spatial distribution of TSDUs in the village of Blanfla (Yapi *et al*., 2018a)

005°44.602 west longitude in west-central Côte d'Ivoire, 306 km from Abidjan, the country's economic capital. Bordered by the departments of Zuénoula and Sakassou to the north, Sinfra to the south, the Yamoussoukro district to the east, and Daloa to the west, the landscape of the Bouaflé department is characterized by a wooded savannah and dense forest (Agence Ivoirienne de Presse, 2015). The climate has four seasons, including a long dry season (November to April), a long rainy season (May to July), a short dry season (August - September) and a short rainy season (October). The department is watered by the Bandama River and Lake Kossou.

Selection criteria for the study area The choice of the village of Blanfla as a study area was based on the following criteria: Very few households in Blanfla have improved toilets, and the majority of them practice open defecation;

- There is a high incidence of diseases linked to a lack of hygiene and sanitation (Ministère de la Santé et de la Lutte contre le Sida, 2012; Yapi *et al.*, 2018a).

Selection criteria for the households that participated in the study

The inclusion criteria for households were as follows:

- Agree to participate in the project;
- Pay the membership fee to the microcredit mechanism, which is 2000 FCFA
- Own a cocoa plantation
- Agreeing to apply biofertilizers in cocoa plantations.

Calculation of sample size

A sample of 100 households was identified to participate in this study from January 2014 to January 2017. This sample was determined by the formula (Giezendanner, 2012) $N = (z^2\, p\, (1-p))/d^2$ z = 90% confidence level estimated at 1.645; margin of error d = 7%; p = proportion of improved toilets at 24%; N = 100 households.

Processing and test carried out for data analysis

Excel spreadsheets and IBM SPSS 22.0 software were used for data entry and statistical analysis. The Friedmann test was used for k matched samples to compare agricultural production, yields and quantities of biofertilizer applied between different periods on the same plots. The correlations between production and area and between production and operating time were calculated. Correlations between yield and area and between yield and operating time were also determined. Finally, the correlations between the amount of biofertilizer and the area and between the amount of biofertilizer and the age of the plantation were calculated. Using IBM SPSS 22.0 software, the Pearson correlation coefficient (r) was calculated to establish the correlation between cocoa productivity in the village of Blanfla and various parameters, such as rainfall, temperature, orchard age, amount of urine and amount of fertiferin applied. The tests were significant at the 5% level.

Ethical considerations

Approval was obtained from the Côte d'Ivoire National Ethics and Research Committee under N°74/MSLS/CNER-dkn before the start of the study. Favorable opinions from the various departmental directors of the health, construction, sanitation and agriculture sectors were required for the study. People took part in the study by providing written informed consent on a microcredit registration form. The anonymity of the participants and the confidentiality of the data were rigorously respected.

Results and Discussion

This study was devoted to the valorization of the biofertilizers "ferturine" and "fertifè" (hygienized urine and feces) obtained during the ecological sanitation process. The application of biofertilizers took place on cocoa plantations whose age ranged from youngest to oldest. The results of the impact of biofertilizer application, "ferturine" or "fertifè", on cocoa production are presented in Table 1. From 2015 to 2016, in the presence of biofertilizers, the annual harvests and agricultural yields of young plantations (1 to 10 years), adult plantations (11 to 20 years) and old plantations (more than 20 years) were significantly greater ($p < 0.001$) than the annual harvests and yields in the absence of biofertilizers (from 2013 to 2014). The provision of biofertilizers to cocoa fields improved agricultural production by doubling agricultural yield (RP = 1.96). In addition, the correlations between annual cocoa harvests and the quantities of "ferturine" and "fertifê" plants were significant for the three plantation categories: young, adult and old (Table 2).

Table 1: Annual cocoa harvest in the absence or presence of biofertilizers in the three plantation categories from 2013 to 2016

		ABSENCE OF URINE AND HYGIENIZED FECES						PRESENCE OF URINE AND HYGIENIZED FECES							
		Year 2013	r[d]	p value	Year 2014	r	p value	Year 2015	r	p value	Year 2016	r	p value	PR/ YR[e]	p value
Young Plantations 1 to 10 years old (n = 42; area = 77.5 ha)															
Prod[kg] [a]		15350			15900			23240			30080			1,96	< 0,001
Age[ans]	1 à 10		0,621	0,010		0,642	0,003		0,610	0,015		0,625	0,009		
Area[ha[b]]	77,5		0,786	0,001		0,711	0,001		0,781	0,001		0,809	0,001		
Y[kg/ha][c]		198,06			205,16			299,87			388,12			1,96	< 0,001
Age[ans]	1 à 10		0,554	0,004		0,526	0,002		0,467	0,007		0,390	0,014		
Area[ha]	77,5		0,394	0,357		0,252	0,846		0,234	0,934		0,132	0,571		
Adult plantations from 11 to 20 years old (n = 35; area = 103.5 ha)															
Prod[kg]		24945			24125			35910			48740			1,95	< 0,001
Age[ans]	11 à 20		-0,211	0,874		-0,171	0,799		-0,169	0,810		-0,227	0,759		
Area[ha]	103,5		0,825	0,001		0,824	0,001		0,813	0,001		0,831	0,001		
Y[kg/ha]		241,01			233,09			346,95			470,91			1,95	< 0,001
Age[ans]	11 à 20		0,042	0,961		0,127	0,524		0,123	0,496		0,011	0,827		
Area[ha]	103,5		-0,141	0,445		-0,072	0,807		-0,024	0,978		0,111	0,509		
Old Plantations over 20 years old (n = 23; area = 104 ha)															
Prod[kg]		22300			22450			31860			41050			1,84	< 0,001
Age[ans]	≤ 20		0,296	0,725		0,176	0,168		0,192	0,337		0,327	0,774		
Area[ha]	104		0,574	0,013		0,608	0,001		0,553	0,007		0,608	0,009		
Y[kg/ha]		214,42			215,86			306,46			394,71			1,84	< 0,001
Age[ans]	≤ 20		-0,345	0,884		-0,491	0,143		-0,467	0,305		-0,306	0,822		
Area[ha]	104		-0,533	0,404		-0,428	0,402		-0,512	0,139		-0,445	0,119		

[a] Production per kilogram **[b] hectare** **[c] Yield per hectare** **[d] Pearson correlation**
[e] Production ratio/yield ratio

Table 2: Correlation matrix between precipitation, temperature, plantation age, biofertilizer quantity and cocoa production

CORRELATION YOUNG PLANTATIONS						
	Precipitation	age	Temperature	Young Productivity	urine Quantity	fertifè Quantity
Precipitation	1	0,389	0,788	0,121	0,075	0,113
age		1	0,852	**0,956***	0,948	0,907
Temperature			1	0,660	0,649	0,587
Young Productivity				1	**0,993***	**0,975***
urine Quantity					1	0,943
fertifè Quantity						1
CORRELATION ADULT PLANTATIONS						
	Precipitation	age	Temperature	Adult Productivity	urine Quantity	fertifè Quantity
Precipitation	1	0,389	0,788	0,068	0,072	0,111
age		1	0,852	0,931	0,947	0,915
Temperature			1	0,604	0,651	0,595
Adult Productivity				1	**0,980***	**0,990***
urine Quantity					1	0,944
fertifè Quantity						1
CORRELATION OLD PLANTATIONS						
	Precipitation	age	Temperature	Old Productivity	urine Quantity	fertifè Quantity
Precipitation	1	0,389	0,788	0,099	0,075	0,116
age		1	0,852	0,947	0,948	0,900
Temperature			1	0,638	0,650	0,580
Old Productivity				1	**0,990***	**0,974***
urine Quantity					1	0,933
fertifè Quantity						1

*** Significant correlation**

This would mean that cocoa production depends on the application of biofertilizers. These results could be explained by a lack of nutrients, especially nitrogen and phosphorus, in the cocoa plants. Indeed, the supply of urine and/or feces enriches the soil through the addition of certain elements, and the nitrogen and phosphorus availability of plants improves. The study region is the second largest cocoa-producing region in Côte d'Ivoire, but the aging of orchards and pest attacks have caused a 66% drop in production (Commodoafrica, 2013). Our results are in line with those of Assiri *et al.* (2012), who also showed that fertilizer use improved agricultural productivity and yield. However, the simultaneous use of urine and feces by farmers on plantations did not allow us to assess the effect of each biofertilizer on the annual cocoa harvest separately. The correlations between annual harvests and plantation age and between yields and plantation age are positive and significant for young plantations. However, these correlations were not significant for adult plantations or old plantations (Table 1). This would mean that among young plantations, agricultural production or yield depends on age. This is not the case for adult plantations or old cocoa plantations. These results could be explained by strong physiological growth in young orchards, which could stabilize in adulthood and decline at a very old age (over 20 years). This strong growth of young orchards would therefore lead to a high annual production of these young cocoa trees. The cocoa tree flowers at 3 years of age and produces flowers, fruits and leaves year round. The plant reaches its full yield 6 to 7 years after planting and lives for 40 years. In addition, the yield of a cocoa plantation follows an upward or downward curve over time, with a period of relative stabilization between the two curves (Petithuguenin, 1998; Zuppo, 2012). Our results on cocoa production are in line with those of Banque Centrale des Etats de l'Afrique de l'Ouest (2014), who explained that the aging of orchards makes cocoa trees unproductive and vulnerable to pest attacks. However, a comparative study in the same year between plots fertilized with "ferturine" and/or "fertifè" and unfertilized plots (control plots) could make it possible to measure the imputability of the cocoa tree's age and the effect of biofertilizers on agricultural production. From 2013 to 2016, the correlation between annual harvests and areas was significant for all three categories of young, adult and old plantations (Table 1). The larger the area is, the greater the production in the three plantation groups. In addition, the proportional contribution of biofertilizer quantities on plantation surfaces significantly maintains the correlation between the increase in harvest and the surface area. Our results are in line with the findings of the studies of Petithuguenin (1998) and Centre d'Etudes et de Prospective (2015), which showed that the use of high doses of fertilizer or biostimulants allows high production of cocoa or any other plant with various surfaces. In contrast, the correlation between yield and area was not significant (Table 1) for the three plantation groups (young, adult, old), which indicated that yield did not depend on area. This is confirmed by IOS Partners (2014), who revealed that the absence of a link between yield and area allows Côte d'Ivoire to remain competitive with other producing countries since 2000 in existing areas despite the stagnation of plantation yields. Table 3 shows the quantities of biofertilizers applied by plantation category from 2015 to 2016. The significant difference in biofertilizer application between 2015 and 2016 on young, adult and old plantations shows that agricultural production is greater when households receive a greater quantity of fertilizer. This difference in the amount of biofertilizer applied between the two years could be explained by the greater interest in using biofertilizers given the previous year's results. Households perceived the use of urine and feces in agriculture as a response to their expectations. Our results on urine and fecal use are similar to those of Comoé (2005) and N'da *et al.* (2007), who showed that excreta ensure good agricultural productivity. However, these findings contrast with those of N'goran *et al.* (2010), who showed that only a core group of the community understood the benefits of excreta as biofertilizer in the village of Petit Badien in southern Côte d'Ivoire. From 2015 to 2016, the correlation between the quantities of biofertilizers and area on the one hand and the correlation between the quantities of biofertilizers and the operating time on the other hand are not significant (Table 3). The quantity of biofertilizer used in fields does not depend on the area or duration of use but no longer on the need for fertilizer planting. Indeed, studies by Snoeck *et al.* (2010) and Koko *et al.* (2011) have shown that the quantities of biofertilizer applied by farmers on cocoa farms are not controlled and that an update of fertilizer formulas and doses is needed. In addition, a chemical study of the soil and a soil and climate study related to the aging of cocoa plantations and parasitic attacks would have made it possible to further optimize the results of this study to popularize them. The correlation matrices between precipitation, temperature, plantation age, biofertilizer quantity and cocoa production are shown in Table 2. Regarding the meteorological parameters of rainfall and temperature, the correlations between agricultural productivity and these parameters are nonsignificant ($p > 0.05$). This could be explained by the relatively stable rainfall and low temperature variation over the four years of the study. Ultimately, the urine production for young plantations (1 to 10 years old) was 164.43 m^3 of urine and 58.76 tons of feces, for a total area of 77.5 ha. In adult plantations (11 and 20 years old), there were 152.12 m^3 of urine and 54.92 tons of feces, for a total area of 103.5 ha. Among old cocoa farms (more than 20 years old), 80.50 m^3 of urine and 27.52 tons of feces were estimated to exist for an area of 104 ha. The amount of biofertilizer applied in agriculture doubled the annual cocoa harvest in the village of Blanfla. In view of the results of this study, ecological sanitation can be proposed as an effective measure to combat soil infertility and food insecurity through the absence of defecation in the open air.

Table 3: Quantity of biofertilizers by plantation category in 2015 and 2016

	Year 2015	r[c]	P value	Year 2016	r	P value	PR[d]	P value
Young Plantations 1 to 10 years old (n = 42; area = 77.5 ha)								
Urine [liter]	64390			100045			1,55	0,000
Age [year]		-0,050	0,963		0,047	0,647		
Area [ha[a]]		-0,084	0,673		-0,031	0,688		
Feces [kg[b]]	14048			44720			3,18	0,000
Fertifè [kg]	7024			22360			3,18	0,000
Age [year]		-0,017	0,830		-0,058	0,960		
Area [ha]		-0,090	0,557		-0,123	0,495		
Adult plantations from 11 to 20 years old (n = 35; area = 103.5 ha)								
Urine [liter]	60960			91160			1,49	0,000
Age [year]		0,133	0,318		0,156	0,257		
Area [ha]		0,155	0,272		0,151	0,267		
Feces [kg]	13920			41000			2,95	0,000
Fertifè [kg]	6960			20500			2,95	0,000
Age [year]		0,122	0,361		0,211	0,145		
Area [ha]		0,143	0,314		0,147	0,239		
Old Plantations over 20 years old (n = 23; area = 104 ha)								
Urine [liter]	31665			48830			1,54	0,000
Age [year]		0,255	0,132		0,301	0,160		
Area [ha]		-0,013	0,329		0,090	0,592		
Feces [kg]	6200			21320			3,43	0,000
Fertifè [kg]	3100			10660			3,43	0,000
Age [year]		-0,055	0,212		0,246	0,217		
Area [ha]		-0,420	0,021		0,046	0,555		

[a] hectare **[b] kilogram** **[c] correlation of Pearson** **[d] production ratio**

Conclusion

The CLTS-ECOSAN methodology highlighted the transition from disgust with excreta to people's desire to reuse them in agriculture. The voluntary acquisition of TSDUs through the microcredit mechanism has enabled this type of toilet to be built for the benefit of households who have been trained in its use and maintenance. The production of a large quantity of excreta transformed into biofertilizer after hygienization has almost doubled the annual cocoa harvest in the village of Blanfla. Ecological sanitation can be proposed as an effective measure to combat soil infertility and food insecurity.

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Conflict of interest
The authors declare that they have no conflicts of interest.

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