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Agro-ecological Valorization of By-Products from ECOSAN Works Carried Out by the PADSER in the Department of Bounkiling

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Abstract— *The present study aims to analyze the potential for valorization of by-products from ECOSAN works in the department of Bounkiling, focusing on their nutrient contents and increasing agricultural yields. The methodology is based on interviews with households using ECOSAN facilities, physico-chemical analyses of by-products, as well as agronomic trials on local crops. The results show that ECOSAN by-products have significant levels of essential nutrients (nitrogen, phosphorus, potassium), favorable to agricultural production. The study showed that urine has a beneficial effect on crops and significantly boosted yields. With eggplant, we obtained the following yields: 16.06T/ha for T0; 31.75T/ha for T1 and 21.37T/ha for T2, which represents an increase of 98.05% and 48.61% compared to T0 and T2 respectively. As for corn, we recorded a T1 yield increase of 4.44T/ha and 3.32T/ha respectively compared to T0 and T2.*

Keywords— *By-products, ECOSAN, urine, yield.*

I. Introduction

The rate of access to sanitation (14%) remains very worrying in the Sedhiou region, particularly in rural areas where it is lower than the national average (17%). The rate of open defecation in the Sedhiou region (11.7%) remains still high, compared to the national average (32.9%).

Efforts are certainly being made by the State of Senegal and its partners, but there is still a great need to be met to reverse the trend and address the notorious disparities, especially in terms of access to sanitation that the region knows.

The PADSER is part of the continuity of actions already undertaken by previous sanitation programs (PEPAM/BADII, USAID/PEPAM, ATPC/UNICEF) and the USAID/PEPAM program in the sanitation and hygiene sector for the benefit of the most deprived poor populations in the Sédhiou region.

The PADSER thus contributes to strengthening previous actions financed by the EU in the region of intervention and will complement the component of hydraulic infrastructure development implemented within the framework of projects and programmes already completed or under implementation.

The sustainable management of by-products (urine and faeces) is a major public health, environmental protection and food security issue in rural areas of Senegal. The ECOSAN concept (ecological sanitation) offers an innovative approach based on the separation, treatment and valorization of by-products from sanitation works, including urine and hygienized faeces, as agricultural fertilizers.

In this dynamic, the PADSER through its agronomic component aims to enhance the by-products from works such as the ECOSAN toilets. It is in this context that this study of the agro-ecological valorization of by-products from works carried out by PADSER in the department of Bounkiling to boost and improve agricultural production fits.

II. Materials and Method

2.1 Description of the study area

The Sedhiou region covers an area of 7.330 km 2, or 3.7% of national territory. The department of Bounkiling is the largest with 38.6% of the regional area, followed by Sedhiou and Goudomp with 37.2% and 24.2% respectively. The region has 941 official villages, including 369 in the department of Bounkiling, 298 in that of Goudomp and 274 in that of Sedhiou.

The department of Bounkiling is crossed by the national road No. 4 which separates each of the districts of Boghal, Bona and Diaroumé into two distinct geographical areas:

- in the North the Kabada which is a zone of dense forest and bordering with the Republic of Gambia and,
- in the South the Soncoundou and the Fogny, which is an area traversed by the rivers (Soungrougrou) fed by the Casamance River.

Figure 1: Administrative breakdown of the department of Bounkiling

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The climate is of the Sudano-Guinean type with a dry season that extends from November to May, and another rainy season from June to October with average rainfall of 600 and 1350 mm. Certain areas in the district of Bogal and Diaroumé are difficult to access, especially during the wintering period. We mainly distinguish two types of winds in the year: the Monsoon, a wind blowing from May to June, heralding wintering, and the Harmattan hot and dry wind, blowing from East to West.

The relief is generally flat and remains favourable for the development of agricultural activities in the area. The soils are essentially made up of tropical ferruginous soils, ferralitic soils, and hydro-morphic soils. Ferralitic or lateritic soils have a texture that supports proper forestry, pastoral and hydrological agronomic abilities. They are the domains of wooded areas and cattle courses.

In the area, the vegetation is essentially woody with a sparse afforestation over part of the territory: tree layers, herbaceous and shrubs. The diverse wildlife is composed of reptiles, birds.

2.2 Plant material

The agronomic tests carried out on the by-products from ECOSAN works concern the following speculation: eggplant and corn. Indeed, we chose these types of crops because they are widely practiced in the area and contribute to household self-consumption. The tests are essentially conducted during wintering.

2.3 Use of by-products from ECOSAN works

2.3.1 Background

The use of by-products in agriculture is an old practice:

- in China: composting of human and animal excreta for thousands of years;
- in Japan: recycling of human excreta in agriculture since the 12th century;
- in Sweden: mechanical application of urine in the fields, a very old practice.

2.3.2 Benefits

- the protection of the environment against pollution;
- the improvement of soil fertility;
- the minimization of production costs and therefore the improvement of producer's income;
- the increase in agricultural production;
- the reduction of often costly chemical fertilizers;
- the protection of health and groundwater etc.

2.3.3 Disadvantages

- more complex approach;
- need more time and human resources;
- handling of by-products (urine and faeces) not easy;
- reservations about the use of by-products.

2.3.4 Production of fertilizers (urine)

The production of good fertilizers (non-harmful and of good agronomic value) goes through different stages, notably the collection and processing of by-products.

a) Separate collection of by-products

The first stage of fertilizer production begins with the implementation of a by-product collection system. This production plant is known as the "ECOSAN latrine".

Figure 2: Book "ECOSAN"

The ECOSAN work includes a urine pit where a bottle is positioned for collection.

b) Treatment (hygienization) through closed storage

The way to remove germs from by-products is relatively simple. Indeed, when the urine can is full, it should be well filled and stored for a maximum of 30 days. Thus the urine becomes hygienized and ready to be used in agriculture without incident on human health and the environment.

2.4 Agronomic characteristics of fertilizers

The total production of nutrients from urine, faeces and digestate is a function of human diet. The amount of nutrients that enter the body is what comes out in urine, faeces and digestate. However, the vast majority of nitrogen and potassium leave the body with urine. As for phosphorus, it is more balanced between urine and faeces.

In 2007, Dagerskog calculated the average annual amount of fertilizer produced per person in countries in West Africa estimated at 500l of urine and 50 kg of faeces (figure 3).

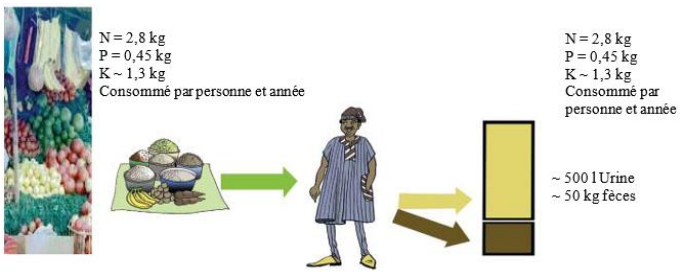

Figure 3: By-products from food consumed

2.5 Method

2.5.1 Experimental device

The fertilizer 'urine' is applied in the following agronomic test fields:

a) Eggplant field

The field has 12 boards, that is to say a block of 3 boards repeated 4 times as follows:

- T0 = control (no fertilizer input);
- T1 = 4 liters of urine + 6 liters of water;
- T2 = mineral fertilizer NPK (10-10-20).

b) Corn field

Each field has 12 boards, that is to say a block of 3 boards repeated 4 times as follows:

- T0 = control (no fertilizer input);
- T1 = 2 liters of urine + 8 liters of water;
- T2 = mineral fertilizer NPK (15-15-15).

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TABLE 1: Beneficiaries of the test fields

N°	Beneficiaries	Localization	Works	Crops	Number of planks	Dimension plank
1	Modou MBOW	Touba Mouride	ECOSAN	Eggplant	12	2m x 6m
2	Mamadou DIAW	Sare Lamine BA	ECOSAN	Corn	12	2m x 10m
3	Ibrahima DIENG	Yaco Wolof	ECOSAN	Corn	12	2m x 10m
4	Ibou SANE	Yaco Wolof	ECOSAN	Eggplant	12	2m x 6m
5	Moussa DIENG	Yaco Wolof	ECOSAN	Corn	12	2m x 10m
6	Yancoba DIABY	Kandialon	ECOSAN	Eggplant	12	2m x 6m

2.5.2 Method of application of the by-product "urine"

For the application of urine, proceed as follows:

- ☞ make the mixture (urine and water);
- ☞ make furrows at least 12cm apart on the plants before adding the mixture;
- ☞ wear gloves, boots and a mask;
- ☞ bring the dose in the grooves uniformly to all the plants concerned;
- ☞ close the furrows.

Figure 4: Applications of urine

Following this, we proceed with the labeling for the identification of treatments and repetitions.

NB: the application of urine is stopped at least 15 days before the start of the harvest.

2.6 Analysis of harvested products

After the harvests, the products were analyzed in order to certify WHO compliance regarding food products. Thus, the harvested products were well packaged and transported by flight and analyzed at the IFAN laboratory at UCAD.

III. Results and Discussions

3.1 Exchanges on agronomic valorization with the beneficiaries

For the smooth running of the very important agronomic component in the PADSER project, we have raised awareness among the populations about the issues, benefits and socio-economic impacts related to the introduction of this practice of agro-ecological valorization of unrecognizable urine in the area. Among the expected impacts, one can cite the increase in yields, the local availability of high-value fertilizers, the reduction of operating costs, the improvement of soil fertility, nature protection, better conservation of agricultural products and the increase in producers' incomes, etc. In this dynamic, we have adopted the participatory involvement of administrative authorities, decentralized services, and local development actors, notably DRDR, SDDR, Sanitation Department, Hygiene Service, Water and Forest Service, NGOs, DAC SEFA and local press. At the end of the meetings, the populations showed great interest in agronomic activities and reiterated their commitment to shelter the demonstration fields with the agro-ecological valorization of by-products from the works carried out by PADSER.

Figure 5: Exchange with the beneficiary populations

3.2 By-product sampling

We visited six (6) ECOSAN works carried out in the area of the PADSER project, of which four (4) have a sufficient quantity of urine for sampling. Thus, we collected them in 500ml bottles. The sampling of by-products is conducted taking into account the research protocol and in collaboration with the local technical services (SDDR and Hygiene Service). The material used consists of a cooler, eight 500ml sterilized flakes, gloves and markers.

3.3 Analysis of by-products after hygienization

After hygienization, the analysis results of by-products are given in the table 3 below.

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TABLE 2: Situation of by-product levies

Visited works	Beneficiaries	Localization	Types of by-products	Availability of the by-product for withdrawals
ECOSAN	Demba SOW	Sare Alpha	Urine	No
ECOSAN	Modou MBOW	Touba Mouride	Urine	Yes
ECOSAN	Mactar KEBE	Touba Mouride	Urine	No
ECOSAN	Ibou SANE	Yaco Wolof	Urine	Yes
ECOSAN	Moussa DIENG	Yaco Wolof	Urine	Yes
ECOSAN	Ibrahima DIENG	Yaco Wolof	Urine	Yes

Figure 6: Urine sampling in the book ECOSAN

TABLE 3: By-product analysis results

By-products	Urine		
Codes	2U	3U	4U
pH	9	7.92	7.90
Conductivity (µS/cm)	18350	24900	23800
Salinity (g/l)	10.7	15.1	14.3
Nitrogen (mg/l)	2400	2500	2300
Phosphorus (mg/l)	1170	720	750
Potassium (mg/l)	880	980	1920

With:

- 2U: Urine collected from Modou MBOW in Touba Mouride
- 3U: Urine collected from Moussa DIENG at Yaco Wolof
- 4U: Urine collected from Ibrahima DIENG at Yaco Wolof

The table shows that by-products are very rich in fertilizers (NPK). Indeed, urine contains a lot of nitrogen with an average of 2400mg/l, the highest value (2500mg/l) is recorded in Moussa DIENG at Yaco Wolof. On the other hand, the concentration of potassium and phosphorus varies from one household to another.

It is important to note that the pH of the basic by-products makes the survival of pathogens unfavorable. Ultimately, the high NPK contents obtained in these by-products will undoubtedly contribute to improving crop yield.

3.4 Effect of the use of by-products on agricultural yield

Experimentation has shown that urine has a beneficial effect on yield as evidenced by the following figures 7 and 8.

According to these figures above, the by-product "urine" clearly had an effect on eggplant and corn. The yields obtained with T1 application (urine) are higher than the yields recorded in T0 (without intake) and T1 (mineral fertilizer). The urine by-product, very rich in nutrients, contains a high nitrogen content (more than 2000mg/l) thus promoting better plant growth. Compared to the T2 application, we note a yield increase of 10.32T or 48.61% for eggplant and 3.32T or 68.31% for corn. Compared to the T0 application, we record an increase of 15.72T or 98.05% for eggplant and 4.44T or 118.98% for corn.

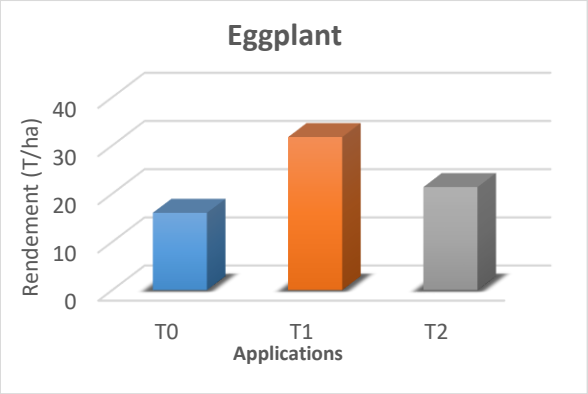

Figure 7: Yields obtained with eggplant

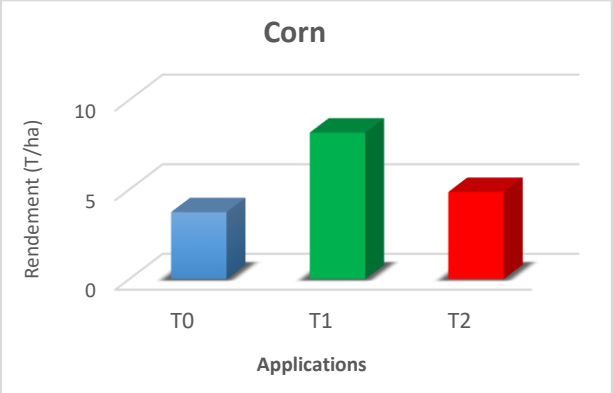

Figure 8: Yields obtained with corn

3.5 Analysis result of the harvested products

The analysis of the urine-based fertilized product revealed no danger to the health of consumers as shown in the following table:

TABLE 4: Result of the analysis of harvested products

Parameters	Eggplant	Corn	Norms
Fecal coliforms	0.00E + 00	3.33E + 03	$*10^5$
Fecal streptococci	0.00E + 00	3.33E + 03	$*10^5$
Eggs of parasites	Absence	Absence	-

*Normative reference of the microbiological criteria for human foods (Regulation EC No. 2073/2005).

According to Table 4, the results of the analysis of harvested products show that only corn has fecal coliform and fecal streptococcal contamination. However, the levels of contamination observed, compared to the standards laid down by the Normative Reference of microbiological criteria for human foods (Regulation EC No. 2073/2005), reveal that the concentrations found are lower than the limits. Regarding parasitological contamination, no sample is contaminated. Ultimately, the food harvested and derived from by-product fertilization meets WHO standards and is safe for consumption.

IV. CONCLUSION

The study reveals that the agro-ecological valorization of by-products from ECOSAN works carried out by the PADSER

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in the department of Bounkiling represents a sustainable opportunity to strengthen sanitation, reduce the use of chemical fertilizers and promote circular agriculture. Indeed, the use of by-products contributes to improving crop yields while respecting agro-ecological practices. The experiment conducted showed that urine is very rich in fertilizing elements (NPK) necessary for crops and boosted crop yield: eggplant and corn. The results obtained showed that the best yields are noted in application T1 (urine), followed by T2 (mineral fertilizer). The lowest yields are recorded in T0 (without input). In addition, the results of the analysis of the harvested products attest that they comply with WHO standards and are safe for human and environmental health.

However, the application of by-products such as urine or faeces remains unrecognizable for most producers. More particularly in Senegal, the introduction of such a practice requires greater awareness to overcome potential reservations often noted by ignorance and imperatively involves the involvement of different decentralized services like the participatory approach accomplished within the framework of the PADSER project. However, the valorization of by-products remains limited by socio-cultural constraints, a lack of user training and the insufficiency of technical support systems. In addition, it would be important to extend into other agro-ecological zones with new speculations.

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