Farmers' Perception, Willingness and Capacity in Utilization of Household Sewage Sludge as Organic Resources for Peri-Urban Agriculture around Jos Nigeria

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***Abstract*—**Peri-urban agriculture in Jos Nigeria serves as a major means of livelihood for both urban and peri-urban poor, and constitutes huge commercial inclination with a target market that has spanned beyond Plateau State. Yet, the sustainability of this sector is threatened by intensive application of urban refuse ash contaminated with heavy metals, as a result of the highly heterogeneous materials used in ash production. Hence, this research aimed to understand the current fertilizer employed by farmers, their perception and acceptability in utilization of household sewage sludge for agricultural purposes and their capacity in mitigating risks associated with such practice. Mixed methods approach was adopted, and data collection tools used include survey questionnaire, focus group discussion with farmers, participants and field observation. The study identified that farmers maintain a complex mixture of organic and chemical fertilizers, with mixture composition that is dependent on fertilizer availability and affordability. Also, farmers have decreased the rate of utilization of urban refuse ash due to labor and increased logistic cost and are keen to utilize household sewage sludge for soil fertility improvement but are mainly constrained by accessibility of this waste product. Nevertheless, farmers near to sewage disposal points have commenced utilization of household sewage sludge for improving soil fertility. Farmers were knowledgeable on composting but find their strategic method of dewatering and sun drying more convenient. Irrigation farmers were not enthusiastic for treatment, as they desired both water and sludge. Secondly, household sewage sludge observed in the field is heterogeneous due to nearness between its disposal point and that of urban refuse, which raises concern for possible cross-contamination of pollutants and also portrays lack of extension guidance as regards to treatment and management of household sewage sludge for agricultural purposes. Hence, farmers concerns need to be addressed, particularly in providing extension advice and establishment of decentralized household sewage sludge collection centers, for continuous availability of liquid and concentrated sludge. Urgent need is also required for the Federal Government of Nigeria to increase commitment towards empowering her subsidiaries for efficient discharge of corporate responsibilities.

***Keywords*—**Ash, farmers, household, peri-urban, refuse, sewage, sludge, urban.

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I. Introduction

CONTINUOUS global population increase towards the urban and peri-urban [1], with a subsequent increase in household sewage sludge, has raised concerns on what could be its best method of disposal. Currently, the most common methods of disposal include, dumping in the sea, incineration, land filling and field application as organic manure for agricultural purposes [2], [3]. Reports from several researchers have enumerated series of soil fertility benefits associated with sewage sludge. These include as source of nutrients like nitrogen, phosphorus, potassium and other micro elements needed for plant growth [4], increase in soil microbial population and their activities [5], improves physico-chemical and biological properties of soils [6], and hence, have classed field application of sewage sludge as organic manure for agricultural purposes as among the most efficient disposal methods. Added to this, farmers mostly in developing countries are intensifying the use of this approach for crop production, irrespective of several reports of health and environmental risk associated with such practice [5], [7], [8]; mainly from the perspective of the heavy metals and pathogens present, which also varies in amount based on factors like type of sewage collection systems, the source of sewage sludge, types and level of industrial activities within which the sludge is generated and the method of treatment applied before field application for agricultural purposes.

Nigeria, on the other hand, has a long record of overwhelming sewage management problems. The ancient method of human waste disposal such as open defecation in bushes, bucket latrines and pits toilet are still being used, mostly in rural and peri-urban areas [9]. This is worsened by the increase in population in urban areas, thus exceeding the capability of most cities to provide efficient collection systems for disposal of sewage sludge. Therefore, the Nigerian community, mostly in the urban areas has resorted to the use of independent septic tank and pit latrines for household sewage collection [10], which when filled, are collected by scavengers paid by the household to evacuate the sludge and the contents are either discharged in the river, water canal or buried in insubstantial pits and trenches [9]. Furthermore, peri-urban agriculture in Jos Nigeria constitutes huge commercial inclination with a target market that has spanned across and beyond Plateau State [11]. Yet, the sustainability of this sector is threatened by soil nutrients predominantly employed by peri-urban farmers. This was as a result of a reduction in chemical fertilizer subsidies by the Nigerian government in the 1990s with subsequent fertilizer scarcity and hikes in prices, which led to excessive use of urban refuse ash to enhance soil fertility. The urban refuse used was reported to be highly heterogeneous, thus increasing concern for health and environmental risks associated with such practices [11], [12]. In addition to this, a report of soil analysis conducted on several case study farms where ash was intensively used for soil amendment, showed high concentration of lead on soil and crops above the WHO/FAO maximum acceptable limit [13], and therefore, recommended both implementation of precautionary measures to mitigate pollution and exploration of other organic resources.

In this study, we report the findings on the current trend of fertilizers used by peri-urban farmers for improving soil fertility, farmer's perceptions, awareness and acceptability associated with the utilization of household sewage sludge for improving soil fertility around Jos Plateau and their capacity in mitigating any associated health and environmental challenges.

II. Materials and Method

A. Description of Study Area

1) Location and Extent

This study was carried out in Jos North, which is among the three local government areas that make up Jos Plateau, in Plateau State North Central Nigeria. Jos Plateau has an estimated population of about 1,000,000 people as at the 2006 population census. Among the three local governments that constitute Jos Plateau, Jos North has the most commercial activities in the state, with high level of peri-urban agriculture, constitute the state capital (Jos city) and 22 large communities situated on a total land area of only 291 km^2 and a population of close to half a million people [14]. Jos Plateau is situated on a highland area of about 8600 km^2 with latitudes of 9° 50' N and 10° 05' N and Longitudes 8° 50' E and 8° 55' E and an average elevation of 1,300 meters above mean sea level [15].

2) Climate

The city has a mild climatic condition due to periodic movement of the Inter-Tropical Convergence Zone (ITCZ), which has given rise to three distinctive sequences of seasons. That is a cool dry season that commences from October to February, a hot season from March to April and a wet season between May and September [15]. The monthly mean temperature ranges from 20.2°C to 24.3°C, mean annual rainfall is 1413 mm characterized by an estimation of 200-300 mm monthly mean rainfall between May and September, while the pick period (July) is characterized by mean monthly rainfall of about 321 mm [17].

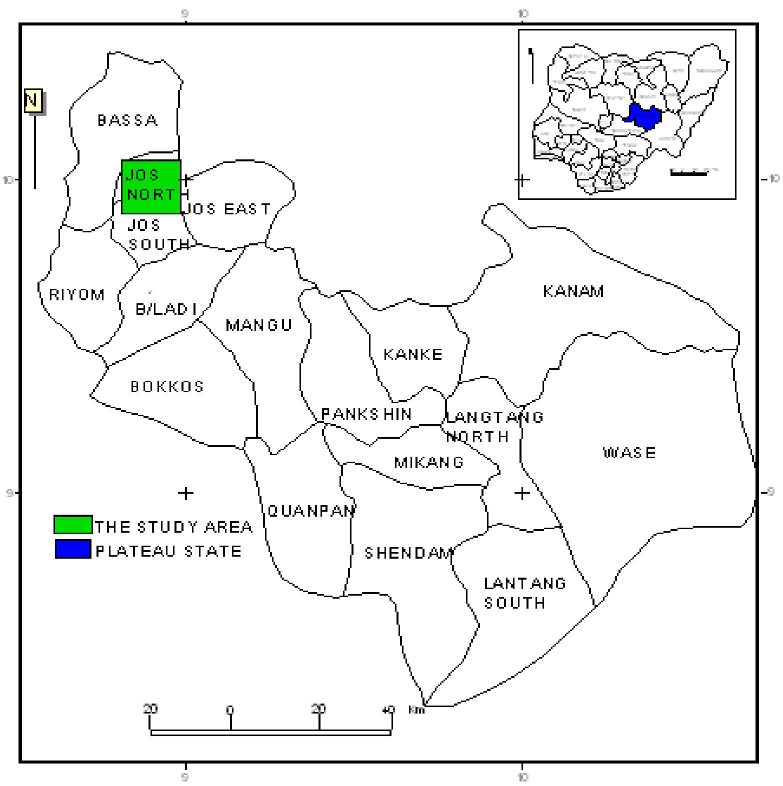

Fig. 1 Map of Plateau State showing the study area and other local governments. Source: James, D. G. & Edafetano C. A., 2010 [16]

B. Study Design

This study employed face-to-face survey method, field observation and focus group discussions, which led to the adoption of the mixed methods approach, so as to achieve both exploratory and representative study, through qualitative and quantitative methods [18]-[20].

1) Sampling Strategy

This study employed probability sampling in the selection of the sample population and non-probability sampling in the selection of the sample area. Hence, five different locations (Zaria Road, Mistali, Delimi, Gengere and Naraguta) were purposively identified as the sample area, based on their increased peri-urban agricultural activities, accessibility and close proximity to Jos city, while farmer's individual farms within the identified locations were categorized into plots from which sample populations were systematically drawn. Farmer's plots were mapped as the sampling frame and every occupant of the third plot was drawn into the sample population, which led to the successful administration of 141 semi-structured questionnaires across the entire sample area.

2) Focus Group Discussion

We grouped farmers according to the type of fertilizers used for soil fertility improvement. These groups were categorized into three i.e. the chemical group which symbolizes farmers that used either single or a mix of different chemical fertilizers, organic group for farmers that either use single or a mix of different organic fertilizers, and the chemical plus organic group for farmers that mixed different chemical and organic fertilizers. Hence, each farmer was systematically drawn from each group making it three farmers per location, with a total of 15 farmers invited for the focus group discussions.

3) Method of Statistical Analysis

Statistical tools chosen for the analysis of the data collected was dependent on the nature of data collected [21]. Hence, data collected were subjected to descriptive statistical analysis, using SPSS statistical tools.

III. Results and Discussions

A. Participants Demographic Results

Participants' demographics vary across all sample areas as a result of the uniqueness of each area. An instance is in Delimi, which is a Muslim dominated area and the entire sample population from this area were males. Surprisingly, 100% of females in the entire sample population were Christians. In the survey of 2017, the entire sample population showed that 56.8% were illiterate, which is more than 15% increase when compared to the 48% reported in 2004 by [22]. Also, we observed that literacy level increased with the rise in the number of young and middle-aged farmers, most of whom were part-time farmers. This thus led to an inference that education serves as an exit strategy from farming practice as the more educated farmers become the more likely they are to get a white collar job, which in turn decreased the number of educated farmers participating in full-time farming practices.

B. Fertilizer Types Currently Used by Farmers

The statistical results from Delimi (Table I), Gengere (Table II), Naraguta (Table IV) and Zaria road (Table V) showed similar patterns, as farmers in these locations were highly inclined to the use of chemical fertilizers followed by animal manure for enhancing soil fertility. These fertilizers were either used independently or as a mixture with other fertilizers. In Mistali (Table III), farmers intensively used household sewage sludge either as a mixture with other fertilizers or independently, for enhancing soil fertility.

TABLE I
FERTILIZERS USED BY FARMERS IN DELIMI

Fertilizer types	Frequency	Percentage (%)
Chemical fertilizer	12	46.2
Urban refuse ash + Animal manure	5	19.2
Animal Manure	4	15.5
Chemical fertilizer + Urban refuse ash + Animal manure	2	7.7
Chemical fertilizer + Animal manure	1	3.8
Chemical fertilizer + Household sewage sludge	1	3.8
Urban refuse ash	1	3.8
Total	26	100

TABLE II
FERTILIZERS USED BY FARMERS IN GENGERE

Fertilizer types	Frequency	Percentage (%)
Chemical fertilizer + Animal manure	12	48.0
Chemical fertilizer + Household sewage sludge	7	28.0
Chemical fertilizer	2	8.0
Chemical fertilizer + Urban refuse ash + Household sewage sludge + Animal manure	2	8.0
Chemical fertilizer + Urban refuse ash + Animal manure	1	4.0
Urban refuse ash + Animal manure	1	4.0
Total	25	100

TABLE III
FERTILIZERS USED BY FARMERS IN MISTALI

Fertilizer types	Frequency	Percentage (%)
Chemical fertilizer + Animal Manure	12	40.0
Chemical fertilizer + Household sewage sludge	9	30.0
Household sewage sludge	5	16.7
Urban refuse ash + Household sewage sludge	2	6.7
Chemical fertilizer + Urban refuse ash + Household sewage sludge + Animal manure	2	6.6
Total	30	100

TABLE IV
FERTILIZERS USED BY FARMERS IN NARAGUTA

Fertilizer types	Frequency	Percentage (%)
Chemical fertilizer	8	30.8
Animal manure	7	26.9
Chemical fertilizer + Urban refuse ash + Household sewage sludge	4	15.6
Chemical fertilizer + Animal manure	3	11.5
Urban refuse ash + Animal manure	2	7.6
Urban refuse ash	1	3.8
Chemical fertilizer + Urban refuse ash + Animal manure	1	3.8
Total	26	100

TABLE V
FERTILIZERS USED BY FARMERS IN ZARIA ROAD

Fertilizer types	Frequency	Percentage (%)
Chemical fertilizer + Animal Manure	16	47.1
Chemical fertilizer	7	20.6
Chemical fertilizer + Urban refuse ash + Animal manure	5	14.7
Urban refuse ash	3	8.8
Animal manure	2	5.9
Chemical fertilizer + Urban refuse ash + Household sewage sludge + Animal manure	1	2.9
Total	34	100

1) Focus Group Discussion on Fertilizer Types Used by Farmers

We deduced from the focus group discussion that farmers do not know the specific amount of nutrient applied, rather that farmers maintain a complex mixture of fertilizers to improve soil fertility and this could cause over application or under application of soil nutrients. The discussion also revealed that farmers determine which fertilizer mixture is efficient through empirical knowledge acquired from long-term experimentation, crops and soil responses to the fertilizer applied. Farmers also revealed that better produce could be achieved when fertilizers are mixed, mostly the combination of organic and inorganic fertilizers rather than when used independently. This thus explained why the majority of farmers embraced complex fertilizer mixture for soil fertility improvement. Furthermore, the discussion revealed the reason for the pattern observed in Mistali, where farmers preferentially use household sewage sludge either independently or mix it with other fertilizers. This transition is because farmers in Mistali do not pay for the delivery of household sewage sludge, as this location is in close proximity to household sewage sludge disposal points and the household from which the sewage is evacuated makes the payment. This made household sewage sludge easily accessible and affordable for farmers in this location. On the contrary, urban refuse from which ash is predominantly produced is readily available but the cost of transporting it to farms to produce ash is a challenge. Most times, farmers contributed among themselves for a truck load of urban refuse to be delivered to them but the increased heterogeneity of urban refuse with materials that are not easily combustible makes it difficult to produce enough ash. To augment this, farmers have added farm debris like maize haylage during ash production but had achieved insignificant result. This therefore had drastically decreased the level in which farmers utilized urban refuse ash for soil fertility improvement. Also, the use of urban refuse ash shares some consensus with that of chemical fertilizer in terms of accessibility and affordability. This is because farmers complained a decrease in the efficacy of available chemical fertilizers and increase in price of desired chemical fertilizers and this has made most of the farmers that rely on chemical fertilizers to consistently crave for fertilizer subsidy from the government. Therefore, it became evident through observation that fertilizer affordability and accessibility played a significant role in determining the fertilizer mixture composition used by farmers, rather than the best mixture identified from a long-term experimentation.

Fig. 2 (a) Maize haylage to be incorporated into ash production

Fig. 2 (b) Truck load of urban refuse being delivered to farmers

Fig. 2 (c) Urban refuse showing high level of heterogeneity

Fig. 2 (d) Household sewage sludge disposal point

C. Farmers' Perception, Awareness and Acceptability Associated with the Utilization of household Sewage Sludge for Soil Fertility Improvement

The outcome from the entire sample population revealed that more than 70% of the sample population had a positive perception on the utilization of household sewage for soil fertility improvement (Table VI); they are aware of its use for soil fertility purposes (Table VII) and are willing to utilize household sewage sludge (Table VIII).

TABLE VI
FARMERS' PERCEPTION ON THE USE OF HOUSEHOLD SEWAGE SLUDGE FOR SOIL FERTILITY IMPROVEMENT

Perception	Frequency	Percentage (%)
Positive perception	101	71.6
Negative perception	19	13.5
Neutral perception	21	14.9
Total	141	100

TABLE VII
FARMERS' AWARENESS ON THE USE OF HOUSEHOLD SEWAGE SLUDGE FOR SOIL FERTILITY IMPROVEMENT

Awareness	Frequency	Percentage (%)
Strongly aware	37	26.2.
Aware	70	49.6
Cannot say	28	19.9
Unaware	2	1.4
Strongly unaware	4	2.8
Total	141	100

TABLE VIII
FARMERS' WILLINGNESS TO USE HOUSEHOLD SEWAGE SLUDGE FOR SOIL FERTILITY IMPROVEMENT

Willingness	Frequency	Percentage (%)
Strongly willing	72	51.1
Willing	32	22.7
Cannot say	21	14.9
Unwilling	10	7.1
Strongly unwilling	6	4.3
Total	141	100

The information gathered is striking as it contradicts farmers' responses in Section III.*B*. In totality, four groups of fertilizers identified to be used by farmers for soil fertility improvement were mentioned 62 times in the statistical data collected (Tables I-V). Among the 62 times these fertilizers were mentioned, chemical fertilizers were mentioned 20 times, animal manure 18 times, urban refuse ash 15 times, while household sewage sludge was only mentioned nine times. Therefore, it became necessary for further investigation using focus group discussions.

1) Findings from Focus Group Discussions

The discussions showed that farmers were faced with constraints that have denied them their desire to utilize household sewage sludge for soil fertility improvement and some identified constraints are briefly described below:

Inaccessibility of household sewage sludge was the major constraints identified by farmers. In accordance to this, a farmer who has practiced farming for close to 15 years stated that:

> "I have never used it, but it appears to be effective based on other farmer's opinions. The challenge with using it is that it is expensive to hire a truck to convey sewage unless you have close access to the point of disposal. It could be difficult to access by people whose farm or house are far away from the disposal point".

Another constraint observed was treatment and storage difficulty during rainy season. As disclosed by farmers, their preferable methods of treatment are drying under the sun and composting. Another farmer hinted as follows:

> "Household sewage sludge is a good manure, but my challenge is it's difficult to access and treat, mostly during the rainy season. This is because rain can easily wash it away from the disposal point before farmers can even have access".

Pollution and possible infection were among the identified constraints. We gathered from the discussion that possible pollution and infection due to inadequate extension advice on how to treat household sewage sludge and lack of personal protective equipment that farmers can use during collection from the disposal site is a constraint. In consensus, most farmers craved for government intervention through the establishment of sewage collection centers to enable continuous access, while a few requested that the government or private organization should intervene through sludge availability and treatment.

Poor public acceptance was also among the identified constraints by farmers. Hence, farmers were keen on how their buyers will perceive the use of household sewage sludge as manure for growing crop produce and this in turn deterred their desire to use household sewage sludge for soil fertility improvement. One participant in his contribution stated as follows:

> "Sewage sludge is not publicly accepted and might cause diseases to people and I doubt if I can support people to use it as a fertilizer".

D. Farmers' Capacity in Treatment of Household Sewage Sludge before Field Application

The survey revealed that composting techniques are not new to peri-urban farmers around Jos Plateau as more than 75% of farmers revealed to have basic composting skills and are willing to compost household sewage sludge before field application (Tables IX and X).

TABLE IX
FARMERS' SKILLFULNESS IN COMPOSTING TECHNIQUES

Skillfulness	Frequency	Percentage (%)
Strongly skillful	27	19.1
Skillful	83	58.9
Cannot say	29	20.6
Unskillful	2	1.4
Total	141	100

Based on this premise, we further investigated farmers' responses through field observation to acquire practical understanding of farmers composting skills, using the sample area (Mistali) highly inclined to this practice as a reference point.

TABLE X
FARMERS' WILLINGNESS TO COMPOST HOUSEHOLD SEWAGE SLUDGE BEFORE USE

Willingness	Frequency	Percentage (%)
Strongly willing	42	29.8
Willing	68	48.2
Cannot say	29	20.6
Unwilling	2	1.4
Total	141	100

1) Observation from the Field

We observed from the field that farmers have acquired simplified treatment method for household sewage sludge, while others indulged in utilization of household sewage sludge without treatment. Farmers that practiced irrigation farming utilized household sewage sludge without treatment, as they desired both the concentrated sludge and the associated water. Nevertheless, there has not been any record of crop failure by farmers. Rather, farmers revealed improved yield through this practice. This could be attributed to the exit of tin mining companies in late-20th century as result of oil boom of the 1970s in the eastern region of Nigeria, which channeled all attention to the oil sector [23] and drastically reduced the level of industrial activities in Jos Plateau with subsequent little or no generation of sewage sludge contaminated with heavy metals. Another attribution could be associated with decentralized sewage collection systems that constituted household septic tanks and pit latrines as the major source of sewage sludge in Jos Plateau. Added to this, farmers through experimentation have learnt to apply household sewage 2-3 months prior to harvesting period and this could contribute to minimization of possible pathogenic and enteropathogenic contamination through natural processes. Secondly, farmers that practiced rain fed agriculture used deep pits and shallow trenches to collect and dewater sludge before further treatment. Irrespective of farmers heightened willingness to compost household sewage sludge (Table X), field observation showed that a substantial percentage of farmers prefer sun-drying before field application or storage for future use as they complained that composting is labor-intensive and decreased the quantity of the sludge, while only few farmers engaged in composting before field application or sundried after composting to store for future use. In consensus, both parties revealed increased yield as a result of application of household sewage sludge, which implies that household sewage sludge from Jos Plateau only requires fundamental treatment for pathogens before utilization as organic resources for agricultural purposes.

We also observed that the household sewage sludge in the field is heterogeneous as a result of close proximity between household sewage sludge disposal points and that of urban refuse from which ash is being produced; hence, causing migration of other particles from urban refuse heap to sewage sludge with possible cross-contamination. Based on this, we inferred that irrespective of the farmer's empirical knowledge, most times they lack formal understanding of their actions, which implies poor extension guidance and low literacy/education level among farmers.

Fig. 3 (a) Household sewage sludge disposed directly into maize field without treatment

Fig. 3 (b) Household sewage sludge disposal pit

Fig. 3 (c) Trench for dewatering/separation of water from concentrated household sewage sludge

Fig. 3 (d) Concentrated household sewage sludge after dewatering

Fig. 3 (e) Dried sludge to be used for soil amendment

Fig. 3 (f) Dried and bagged household sewage sludge for future soil amendment purposes

Fig. 4 Household sewage disposal point in close proximity to urban refuse disposal point

IV. Conclusions

In conclusion, farmers maintain a complex mixture of organic and inorganic fertilizers which could cause over application or under application of required nutrients, due to lack of formal knowledge of the nutrient composition of respective fertilizers. Furthermore, the composition of fertilizer mixture is dependent on its accessibility and affordability rather than knowledge of which fertilizer combinations work best, and this has caused a trade-off between the desired and used fertilizer. Also, farmers have decreased the use of urban refuse ash due to labor and logistic issues but are gradually transiting to the utilization of household sewage sludge for soil fertility improvement mostly in areas where farmer's plots/houses are in close proximity to a sewage sludge disposal point. Farmers were aware of sewage sludge benefits and uses for agricultural purposes, had positive perceptions about such practice and were willing to utilize it, but were constrained by inaccessibility, possible infection, treatment difficulty during rainy seasons, poor public acceptance, and craved for establishment of several disposal points by the government for continuous accessibility followed by increased public awareness by the government through adequate extension services. The contradiction as regards to farmers heightened composting skills, willingness to compost and preferred method of dewatering and sun-drying observed in the field reinforces the importance of field observation as most times, farmers respond differently during survey interview but act differently in the field, as a result of the needs and challenges faced there. Also, field observation disclosed that farmer's ingenuity today might be problematic tomorrow if not properly checked. An evidence to this is the close proximity between disposal point for household sewage sludge used by farmers as a manure for improving soil fertility and urban refuse from which ash were produced for the purpose of enhancing the soil. This not only increased the heterogeneity of sewage sludge due to migration of particles from refuse heap to sewage sludge but also heightens the urgency needed to integrate farmers empirical knowledge with scientific knowledge through adequate extension services that are practically oriented and embrace the bottom-up approach, coupled with further studies, to ascertain the impact of this practice as regards to the associated health and environmental risks.

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