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Market Feasibility of Faecal Sludge and Municipal Solid Waste-Based Compost as Measured by Farmers' Willingness-to-Pay for Product Attributes: Evidence from Kampala, Uganda

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Abstract: There is a great potential to close the nutrient recycling loop, support a 'circular economy' and improve cost recovery within the waste sector and to create viable businesses via the conversion of waste to organic fertilizers. Successful commercialization of waste-based organic fertilizer businesses however largely depends on a sound market. We used a choice experiment to estimate farmers' willingness-to-pay (WTP) for faecal sludge and municipal solid waste-based (FSM) compost in Kampala, Uganda and considered three attributes—fortification, pelletization and certification. Our results reveal that farmers are willing to pay for FSM compost and place a higher value on a 'certified' compost product. They are willing to pay US $0.4 per kg above the current market price for a similar certified product, which is 67 times higher than the cost of providing the attribute. Farmers are willing to pay US $0.127 per kg for 'pelletized' FSM compost, which is lower (0.57 times) than the cost of providing the attribute. On the other hand, farmers require US $0.089 per kg as a compensation to use 'fortified' FSM compost. We suggest that future FSM compost businesses focus on a 'certified and pelletized' FSM product as this product type has the highest production cost–WTP differential and for which future businesses can capture the highest percentage of the consumer surplus. The demand for FSM compost indicates the benefits that can accrue to farmers, businesses and the environment from the recycling of organic waste for agriculture.

Keywords: faecal sludge; municipal solid waste; compost; informational attributes; willingness-to-pay; choice experiment; latent class models

1. Introduction

For many years, efficient policies to address waste management challenges on the environment have been on the global agenda. This issue is even more prevalent with the release of the recent United Nations global index in 2015, which places an importance on providing sustainable sanitation services and clean access to water with the intent of improving the environment for current and future generations (agenda 6). Most developing countries have shown limited progress on this indicator [1] and Uganda is no different. Concurrently, opportunities to address the dual challenge of waste management and soil nutrient depletion in developing countries through the safe recovery of nutrients from solid and liquid waste streams for reuse in agriculture is high. Large urban cities in Uganda like Kampala face the challenge of a growing urban population and a resulting exponential increase in waste generation. Limited public funds to support waste management infrastructure and services has resulted in significant environmental pollution as a majority of the generated waste is often disposed of untreated in open spaces, water bodies and/or landfills [2]. The long-term effects of these practices include increased human health risks and generation of significant quantities of greenhouse gas emissions.

Solid waste generation in Kampala is estimated between 0.5 and 1.2 kg per capita per day, of which 74% is organic matter [3,4]. This represents a huge resource for nutrient recovery that is yet to be exploited. The recovery of nutrients from both solid and liquid waste streams is important where soils are poor and the availability of alternative inputs is constrained. However, Uganda is noted as a country with very low fertilizer application rates, compared to other countries in the region. Average annual fertilizer consumption is estimated around 10–20 million kg, which is significantly lower than other comparable African countries [5]. Peri-urban and rural farmers face increasingly limited access to fertilizers because of inefficient distribution networks, resulting in exorbitant market prices; and invariably decreased agricultural productivity. With a foreseeable increasing trend of urban food demand, increasing fertilizer prices and stricter regulations for safeguarding the environment from pollution, initiatives for nutrient recovery from waste will play a key role in the economic development of Uganda.

There is a great potential to close the nutrient recycling loop, support a 'circular economy' and improve cost recovery within the waste sector and to create viable businesses via the conversion of waste to organic fertilizers. The idea of closing the nutrient cycle by using municipal organic waste and faecal sludge for urban and peri-urban agriculture is nothing new. Not only has it been practiced for generations in many countries either formally or informally, it has also been proposed and tried on a small scale as a green solution for modern cities [6]. Over a decade of research by the International Water Management Institute (IWMI), Food and Agriculture Organization (FAO) and International Development Research Centre (IDRC) shows that the use of compost (compost, in this study, is defined as a decomposed organic component of municipal solid waste and/or faecal sludge) can accrue significant benefits to farmers and has the potential to reduce public budget allocations to waste management [7]. Previous studies also show that composting of municipal solid waste is more beneficial than other existing options such as land filling, incineration or open disposal [8,9]. However, very few successful cases have been noted which includes Waste Concern in Bangladesh, Balangoda Municipal Compost Plant in Sri Lanka, Zoomlion in Ghana—and the majority of initiatives in low- and middle-income countries have been recorded as small scale and seldom viable without significant subsidies.

The limited viability of waste-based nutrient recovery initiatives, especially compost businesses, have been particularly linked to gaps in market information. Research has shown that farmers have concerns with low product nutrient content, skin diseases from product use, labor requirements and general mistrust of information on product quality, and these may significantly affect the demand for compost products [6,10,11]. In many situations, farmers' willingness-to-pay (WTP) is either too low or farmers prefer existing substitutes for soil inputs such as cow dung, poultry manure or even dried faecal sludge (faecal sludge consists of human faeces and urine (and flushing water) and has a high concentration of organic matter and nutrients. It is a sludge of variable consistencies collected from on-site sanitation systems, such as latrines, non-sewered public toilets, septic tanks and aqua privies which store blackwater. It comprises varying concentrations of settleable solids as well as of other, non-faecal matter [6]) [10]. The use of these alternatives, however, does not come without its own limitations.

The cost of transporting faecal sludge from Kampala city, for example, to peri-urban and rural areas where large scale farming is more prevalent is significantly high compared to other alternatives like chemical fertilizer. Additionally, the limited awareness about the value and safety of using faecal sludge for enhancing agricultural productivity is prevalent [12]. There are opportunities for pelletizing and blending of faecal sludge and municipal solid waste (MSW) compost with rock-phosphate, urea/struvite or NPK to produce a product with: (a) structure improvement (reduced bulkiness while simplifying crop application—pellets) and (b) higher nutrient content and tailored for specific crops and soils; to enhance its competitive advantage, marketability and field use. The International Water Management Institute has developed such a product called Fortifer, a nitrate fortified and pelletized faecal sludge and MSW-based compost; which addresses the current challenges associated with using 'regular' compost [13]. The main approach is to dry the septage followed by aerobic composting of the dewatered sludge, which sanitizes and reduces its volume. Although faecal sludge can be processed alone, co-composting with another organic waste, such as organic municipal waste is more common, as it improves the composting properties, in particular the carbon–nitrogen ratio and moisture content [14].

The commercialization of such a product in Uganda would particularly make an immense contribution to both the sanitation and agricultural sectors. Revenue generation from the sale of the Fortifer product represents great opportunities for cost-recovery for the sanitation sector [15]; while farmers, on the other hand, have increased access to alternative agricultural inputs at competitive market prices. The successful commercialization of Fortifer, however, requires understanding the dynamics of the market the new product will be sold in. Even more importantly, the question of whether a demand actually exists and the price end-users are willing to pay for the product needs to be examined. In particular, farmers' WTP for the product attributes of Fortifer that give it its competitive advantage in the agricultural fertilizer market needs to be assessed. This paper thus seeks to assess: (a) farmers' WTP for specific attributes of a faecal sludge and municipal solid waste-based (FSM) compost product such as nitrate fortification, pelletization and certification, (b) the effects of socio-economic factors on farmers' WTP for these attributes, using a choice experiment approach, and (c) the implications of cost-price differential on investment feasibility.

There are numerous studies that have estimated farmers' WTP for compost, but the majority have been undertaken in developed countries and very few studies in Africa [16–20]. To the best of our knowledge, this is the first empirical application of a choice experiment approach to estimate farmers' WTP for a compost product in Kampala. The results from this study will provide valuable information for future businesses to guide their investment decisions and the research and development initiatives they pursue before and during the life cycle of their business with the intent of improving the environment. The findings will also be of interest to environmental policy makers in Kampala and to international donors and waste management investors who seek holistic approaches in generating multiple benefits from waste reuse businesses.

2. Materials and Methods

2.1. Theoretical Framework

Stated preferences valuation and conjoint analysis are the most dominant approaches for estimating values for non-market goods and services [21–24]. Most researchers prefer to use these approaches because of their flexibility in design and the relatively low implementation costs. These methods elicit WTP from farmers in a hypothetical and less than realistic environment and are based on either perceived or intended behavior. Critics argue that these approaches are not incentive-compatible as farmers' prevalent decision-making options are not consistent with their preferences for the good in question [25]. Thus, it is not too surprising that research has shown that these elicitation techniques have consistently overestimated consumers' WTP measures [23]. In spite of this bias, these approaches continue to be used because they provide results that are better than other methods and are relatively cost effective to generate. Many studies tend to use elicitation methods, such as contingent valuation, but a choice experiment is appropriate to assess farmers' preferences for FSM compost attributes [26]. The design of choice experiments (CE) can nearly simulate real-world purchasing decisions where, for example, a farmer has to select a product from a set of options [26–28]. Karousakis and Birol (2006) used a CE approach to estimate farmers' demand for recycling services in the United Kingdom and more worldwide applications can be found [29–32]. In particular, Pek and Jamal (2011) used the approach to assess the effectiveness of waste disposal options in Malaysia [33]. The authors found technology-specific and distance factors to be significant determinants in setting equitable solid waste management systems. The underlying theoretical framework for the choice experiments are detailed in Appendix A.

2.2. The Choice Experiment

This study aimed at assessing farmers' preferences for diverse attributes of a faecal sludge and municipal solid waste-based (FSM) compost product (also called Fortifer). The primary step of the research was to select applicable attributes. A review of studies on waste-based organic fertilizer products (compost) helped in identifying these attributes. In collaboration with local research partners and through multiple focus group discussions, the final attributes were selected. Given the difficulties associated with the exact changes in attribute features, the levels of choices were qualitatively presented. The choice profile consisted of attributes from four categories: price, fortification, pelletization and certification. As noted earlier, fortification of the compost product with nutrients presents opportunities to boost the fertilizer value of the product; with pelletization reducing product bulkiness and improving product structure. These product attributes represent opportunities for farmers to increase their productivity, and invariably their incomes. The certification attribute is preliminary noted to be an important factor affecting farmers' WTP and demand for FSM compost given farmers' mixed perceptions on how safe treated faecal sludge is beneficial in agriculture. Local partners provided information on the price levels used in the choice experiment. Additional information on the price levels was obtained through a scoping study. Four levels of prices were chosen in 2014 ranging from USD 0.11/kg (UGX 300/ kg) to USD 0.37/kg (UGX 1000/kg), which reflected the low-end and high-end prices that could be observed in the actual compost market in Kampala, Uganda (Table 1).

Table 1. Attribute levels and descriptions.

Categories	Attribute Levels	Description	Coding
1. Price in USD/kg (UGX/kg)	0.11 (300); 0.22 (600); 0.30 (800); 0.37 (1000)	Refers to the market price of the compost product	Continuous variable
2. Fortification	Yes; No	If present, product indicates that the FSM compost is fortified with nitrate	Dummy variable
3. Pelletization	Yes; No	If present, product indicates that the FSM compost is pelletized, and if not present, the compost is produced in a powdered form (characterized as bulky)	Dummy variable
4. Certification for product quality	Yes; No	If present, product carries a label issued by a trustworthy organization noting that the product was inspected throughout the production process and confirmed to be a safe and high quality product.	Dummy variable

Notes: UGX = Ugandan Shillings. 1 United States dollar is equivalent to UGX 2710 (2014).

It is challenging to implement the full factorial design for all the alternatives considered. Given that there are three attributes each with two levels, one attribute with four levels, we had different treatment combinations $\left(4 \times 2^3\right)^4$. Practically, it is challenging to work with this number of choice sets. A fractional factorial design was used in SAS to obtain eight choice scenarios and D-optimal design that allowed for the estimation of all the main and two-way interaction effects (Table 2). SAS is statistical software developed by the SAS Institute to mine, alter, manage, and retrieve data from a variety of sources and perform statistical and business intelligence analysis. We incorporated eight simulated compost quality scenarios (compost term used for the experiment refers to a faecal sludge and municipal solid waste co-compost) into the farm surveys. The respondents were provided with detailed descriptions of the benefits and costs of compost made from organic waste. The respondents were required to indicate their preferred option on each choice set, which contained alternatives A, B, C and D (status quo) or a neither option. The inclusion of the "opt out" option presents farmers with all the options and provides the opportunity for them to either delay or decline to make a choice if the options presented are not welfare enhancing [34].

Prior to the implementation of the field experiments, a pre-test of the experiment tools was conducted among a small sample of respondents in urban Kampala to ensure the suitability of the choice experiment instrument. The respondents were aware that the different choice sets with specific product attributes represented a specific type of compost product information. During the actual experiment, upon the selection of a respondent, an educational session to describe the general premise of the field experiment was conducted with the experiment participants. The respondents were fully educated on the experimental procedures, the choice sets and the rationale of the choice of attributes. Special attention was paid to the different options defining each choice set and the different levels of the specific attributes.

Table 2. Sample choice set presented to the experiment participants.

Product Attributes	Option A	Option B	Option C	Option D
Fortification	Yes—product fortification	Yes—product fortification	No product fortification	If options A, B, and C were all that was available at my local farm input shop I would not purchase the compost product.
Pelletization	Yes—product pelletization	Yes—product pelletization	No product pelletization	
Certification	Yes—certified product	No product certification	Yes—certified product	
Price (USD/kg)	0.37	0.11	0.30	
I would choose ...	○	○	○	○

The choice experiment survey was conducted in 2014 in Kampala, Uganda. Respondents for this study were sampled from farming households in five distinct districts in Kampala. Representative of (a) urban Kampala was Central division; and (b) peri-urban Kampala: Kawempe, Nakawa, Rubaga and Makindye divisions. A targeted sample size of 300 farmers was proportionally distributed across each district based on the land use (i.e., residential land vs. agricultural land) distribution per district. Respondents from each district for the study were randomly sampled from farming households with and without compost use experience in the different divisions. The farming household heads in the selected sample were provided with different compost types as characterized by the product attributes described in Table 1. The data was coded based on the attribute levels (Table 1). The price attribute was coded as a cardinal variable. The certification and other attributes were coded as dummy variables. The estimated coefficients for these variables indicate farmers' valuation of the change from the status quo level to the higher utility levels.

3. Results and Discussion

3.1. Socio-Demographic Characteristics of Farmers

The surveyed sample consisted of more males than females. The majority of the farmers were within the age bracket of 25–45 years, which corroborates the finding that the productive age group (14–49 years) is the age group that provides labor to the agricultural sector. The majority of the respondents belong to medium and large-sized households. This may be indicative of the use of family labor for agricultural activities. About 43% of the surveyed farmers have secondary education whilst 38% have primary level education. This shows that farmers have a basic education to perform activities such as reading and understanding the instructions on labels and fertilizer application methods. The number of years that the farmers have been engaged in agricultural activities varies significantly from as low as 1 year to 40 years (Table 3). This significant variation also translates to the income earned, ranging from USD 44.28 to approximately USD 1012.00.

Table 3. Socio-demographic characteristics of the farmers (*N* = 275).

Variable	Description	Percentage of Sampled Respondents	Mean (Standard Deviation)	Minimum	Maximum	National Statistics
Gender	Male Female	57.5 42.5				49.25 50.74
Age (years)	<25 26.35 36–45 46–55 56+	15.2 29.7 26.4 17.5 11.2	39.4 (13.2)	17	80	20.6 12.8 8.1 5 8.1
Household size	<2 3–6 7–10 11+	6.3 48.3 33.9 11.4	3.03 (0.93)	1	15	4.7 [1]
Education (in numbers of years)	No formal education Primary education Secondary education Training college Tertiary education	7.3 38.5 43.6 9.1 1.5				18.9 58.4 18.5 n/a 4.3
Farming experience (in number of years)	<5 6–12 13–20 21–30 31+	35.8 30.6 18.1 12.2 3.3	11.3 (9.1)	1	40	n/a
Annual agricultural gross income (USD)	73.8 74.0–184.5 184.8–360.0 370.0–738.0 739.0+	8.8 6.4 8 18.8 58	179.88 (90.35)	44.28	1012.00	113.36 [2]
Farm size (in acres)	Less than 1 1 2	80.00 12.72 5.45	0.44 (0.81)	0	7	1.729

Notes: UGX = Uganda Shillings. 1 United States dollar is equivalent to UGX 2710 (2014); Source: http://www.fao.org/ag/agp/agpc/doc/counprof/uganda.htm; n/a denotes not available. National statistics values represent: [1] average household size and [2] average annual agricultural gross income.

3.2. Factors Affecting Farmers' Fertilizer Purchasing Decisions and Perceptions of FSM Compost

Prior to assessing farmers' perceptions for FSM compost, it is important to evaluate the factors that guide their current purchasing decisions of fertilizers. The survey results indicate that cow dung and poultry manure are the dominant fertilizers for farming activities. Farmers' preference for these inputs are due to: (1) easy access to the inputs and ability to increase crop yields, (2) relatively easy application, (3) comparatively high nutrient value, and (4) scarcity of soil inputs in the community. A five-level Likert scale was used to assess 16 factors with the potential to influence farmers' purchasing decisions. The results suggest price, organic matter content, and water holding capacity as important factors. About half of the farmers were likely to purchase fertilizer if it was recommended by trusted sources and a higher percentage was observed if they knew someone who was currently using it for farming activities.

A five-level Likert scale was similarly used to assess farmers' perceptions of a faecal sludge and municipal solid waste compost (FSM) product. In total, 12 questions were used to evaluate farmers' perceptions, attitudes and knowledge toward the FSM compost. Results suggest that the demand for compost could increase if a relevant and trustworthy government authority provides certification and fortification (Table 4). The results further show that the demand for compost may not necessarily increase if its price is set at the same level as the price of chemical fertilizers. However, farmers stressed that a better strategy would be to reduce the price of the product and implement a penetrative pricing strategy. In support of this strategy, the demand for the product could increase by 50%. Some farmers noted a concern with the use of faecal sludge. It is possible that these negative perceptions could be minimized if farmers are educated on the benefits and risks of using faecal sludge compost for farming. This could be a cost-effective approach, as 20% of the farmers perceive that education on the advantages and disadvantages of the product could potentially increase their demand.

Table 4. Farmers' perception of faecal sludge and municipal solid waste (FSM) compost.

Assessment Questions	Respondents' Assessment of Questions (Likert Scale Ranking) (*N* = 275)				
	Agree	Strongly Agree	Neutral	Disagree	Strongly Disagree
	% of Surveyed Respondents	% of Surveyed Respondents	% of Surveyed Respondents	% of Surveyed Respondents	% of Surveyed Respondents
Have no reservation for using faecal sludge	28.1	9.5	28.5	23.4	10.6
An FSM compost should certified by authorities	41.9	12.8	21.2	18.6	5.47
It is not safe to use pellets made from faecal sludge	20.1	2.5	32.8	37.2	7.3
An FSM compost should be priced the same as chemical fertilizer	39.8	6.6	31.7	19.3	2.5
An FSM compost product should be 20% cheaper than chemical fertilizer	52.2	15.3	14.9	15.6	1.8
An FSM compost product should be 10% cheaper than chemical fertilizer	45.6	13.1	14.9	22.6	3.6
Regardless of the price, I would buy the FSM compost	27.4	4.7	16.1	36.1	15.6
The use of the FSM compost product can generate benefits to the sanitation sector	52.5	15.7	17.2	13.1	1.5
The use of the FSM compost product can generate benefits to the environment	54.4	15.3	16.4	12.7	1.1
The pelletized form of the FSM compost product is better than the powdered form	52.5	17.2	17.5	10.2	2.5

3.3. Choice Modeling Results

We used multinomial logit regression models to estimate the utility functions in Equations (A2) and (A3) in Appendix A, respectively. The log likelihood ratio test was used to select the appropriate model for the analysis [35]. As expected, the results show a significant increase to model fit from the CL model to the RPL model at 1% significance level. In addition, we compared the McFadden R^2 and log-likelihood scores and the results show that RPL model provides better estimates than the CL model. The CL model recorded a McFadden R^2 of 0.056 compared to 0.296 in the RPL model. The RPL model is deemed appropriate to account for preference heterogeneity for FSM compost.

A Principal Component Analysis (PCA) was used to determine the questions that provided a better assessment for farmers' purchasing decisions and perceptions about FSM compost. The PCA shows that factors such as the product quality, the water holding capacity and nutrient contents of the product are the relevant questions to assess farmers' purchasing decisions. Also, the PCA reveals that the ability to use the product if certification was done by a relevant authority, product use without any reservations, certification by trusted authority and benefits to the environment are better determinants of farmers' perceptions about pelletized and certified compost. However, the different CL specifications through likelihood ratio test show that the product quality, water-holding capacity, reservations toward the use of the product and product certification were relevant for the probability of farmers choosing different attributes of FSM compost (Table 5).

Table 5. Definitions of variables used in the econometric analysis.

Variables	Description
Gender	Gender of farmers; dummy variable where male is 1 and 0 is for female; Gender_fort (gender interaction with fortification); gender_pellet (gender interaction with pelletization); gender_cert (gender interaction with certification)
Household size	Household size of farmers; household size_fort (household size interaction with fortification); household size_pellet (household size interaction with pelletization); household size_cert (household size interaction with certification)
Education	Farmers' education in years; education_fort (education interaction with fortification); education_pellet (education interaction with pelletization); education _cert (education interaction with certification)
Experience	Farming experience in years; experience_fort (experience interaction with fortification); experience_pellet (experience interaction with pelletization); experience_cert (experience interaction with certification)
Religion	Religious status of farmers; religion_fort (religion interaction with fortification); religion_pellet (religion interaction with pelletization); Religion_cert (religion interaction with certification)
Product quality	Farmers' perception of the product quality; product quality perception_fort product quality interaction with fortification); Product quality perception_pellet (product quality interaction with pelletization); product quality perception_cert (product quality interaction with certification)
Water holding capacity	Farmers' perception of the water holding capacity of the product; water holding capacity perception_fort (water holding capacity interaction with fortification); water holding capacity perception_pellet (water holding capacity interaction with pelletization); water holding capacity perception_cert(water holding capacity interaction with certification)
Product reservations	Farmers' perception of any reservations toward the use of the product; product reservations perception_fort (reservation interaction with fortification); product reservations perception_pellet (reservation interaction with pelletization); product reservations perception_cert (reservation interaction with certification)
Product use	Farmers' perception on use of the product; product use perception_fort (use interaction with fortification); product use perception_pellet (use interaction with pelletization); product use perception_cert (use interaction with certification attribute)

3.3.1. Random Parameter Logit (RPL) Model Results

The RPL model results indicate that the coefficient on price is negative and highly significant ($p = 0.000$), which holds with prior expectations that price and the probability of compost purchase would be negatively correlated. The sign of the price coefficient indicates that the effect on utility of choosing a choice set with a higher payment is negative. The coefficient of certification and pelletization are significant at 1% level and the signs of these attributes are as expected. Farmers appreciate an FSM compost which is pelletized and are more interested if the product is certified by a relevant government authority. Farmers are willing to pay for certified and pelletized compost while compensations may be required for farmers to use a nitrate-fortified compost (Table 6). Farmers' WTP for pelletized compost is indicative of their need for organic fertilizer alternatives that have better product structure, that is, a compost product with reduced bulkiness that simplifies crop application and its use has lower labor requirements. Their incentive to pay for certification may be indicative of their need of safety assurance from the use of a faecal sludge-based product. Conversely, farmers do not prefer fortified compost. As some farmers in Kampala are already using faecal sludge in different forms, they are aware of the high nutrient level compared to other alternatives such as MSW-based compost. Farmers may view FSM compost as having a sufficient nutrient content level where additional nitrate fortification may not be required. Gender is a significant variable which will affect the probability of choosing high quality compost which is certified and pelletized. With education, however, as the number of years of education increases, the probability of choosing a high quality compost option decreases, ceteris paribus. The model results show that the number of years of farming experience is a significant factor in affecting the probability of choosing fortified and pelletized compost alternatives, but not certified compost. In addition, as household size increases, farmers are willing to pay for certified compost.

Table 6. Estimates of Conditional Logit (CL) model and Random Parameters Logit (RPL) model.

	Basic Model	Extended Model
Model Type	**Random Parameters Logit (RPL)**	**Random Parameters Logit (RPL)**
Variable	**Coefficients (s.e.)**	**Coefficients (s.e.)**
Price	−0.001 (0.000) ***	−0.001 (0.000) ***
Fortification	−0.045 (0.152) ***	−0.779 (0.495) ***
Certification	1.372 (0.108) ***	2.125 (0.477) ***
Pelletization	0.248 (0.088) ***	1.114 (0.370) ***
Gender_fort		0.501 (0.208) **
Gender_pellet		−0.542 (0.197) ***
Gender_cert		−0.622 (0.158) ***
Household size_fort		0.045 (0.028) *
Household size_pellet		0.041 (0.027)
Household size_cert		0.003 (0.022) *
Education_fort		−0.025 (0.128)
Education_pellet		−0.058 (0.120) *
Education_cert		−0.221 (0.096)
Experience_fort		0.009 (0.011) *
Experience_pellet		−0.041 (0.010) ***
Experience_cert		0.002 (0.008)
Religion_fort		0.268 (0.124) **
Religion_pellet		−0.207 (0.120) *
Religion_cert		0.026 (0.094) **
Product quality_fort		0.826 (0.111) ***
Product quality_pellet		−0.527 (0.107) ***
Product quality_cert		−0.235 (0.081) ***
Water holding capacity_fort		−0.001 (0.101)
Water holding capacity_pellet		0.373 (0.097) ***
Water holding capacity_cert		0.147 (0.076) *
Product reservation_fort		0.197 (0.092) **
Product reservation_pellet		−0.072 (0.091)
Product reservation_cert		−0.011 (0.071) **
Product use_fort		0.762 (0.137) ***
Product use_pellet		0.777 (0.131) ***
Product use_cert		0.411 (0.103) ***
Stdev(fort)	2.811 (0.213) ***	1.789 (0.163) ***
Stdev(cert)	1.951 (0.194) ***	1.627 (0.166) ***
Stdev(pellet)	1.489 (0.173) ***	1.202 (0.152) ***
Opt Out		−2.423 (0.325) ***
Log likelihood	−2134.551	−1910.586
AIC	4283	3897
McFadden R^2	0.296	0.365
Number of observations	2400	2400

Notes: parentheses indicate the standard errors of the respective coefficient; * means significant at 10% level, ** significant at 5% level, and *** significant at 1% level; cert, fort and pellet associated with the independent variables denote fortification, pelletization and certification; stdev (fort) denotes standard deviation of the fortification attribute, stdev (pellet) denotes standard deviation of the pelletization attribute and stdev (cert) denotes the standard deviation of the certification attribute.

The RPL model results show that religion positively affects the probability of choosing high quality compost. Results show that farmers' decisions to purchase fortified FSM compost is likely to be affected by the price of other competitive fertilizer products. Conversely, their perception of competitive product quality would negatively affect the probability of choosing either pelletized or certified compost. Farmers' decisions to buy certified FSM compost is likely to be affected by the water holding capacity of the product. These results tend to show the extent to which these attributes are important for the demand for the FSM compost.

3.3.2. Latent Class Model (LCM) Results

In spite of the various advantages of the RPL model, there are some limitations. In particular, the RPL model assumes that preferences are continuously distributed and that it is not possible to identify the sources of heterogeneity. To overcome this limitation, we apply a LCM, which allows parameter estimates to vary among the different classes. The "testing down" approach was adopted where we started from a large number of classes and gradually reduced to a smaller number of classes [36]. In this study, we started with three classes, but the model failed to converge. The model provided the best fit with only two classes. Table 7 reveals a substantial difference between the attributes of the two classes.

The LCM shows the probability that a randomly chosen farmer belongs to a given class is 28% and 72%, respectively. We used the certification coefficient to characterize the farmers into two classes—medium and high value certification farmers. Results for the first class reveal a relatively lower coefficient for certification than the second class. This means that farmers in the second class would suffer a utility loss if they did not have the option of certified compost. We classified farmers in this class as "high" value certification farmers while those in class one are designated as "medium value" certification farmers. The results suggest that farmers in class two place relatively high value on information on whether the product is certified or not. This group is more likely to derive utility from compost when a relevant agency or authority provides information on compost certification. Farmers in class one may be farmers in the study area who are less concerned about the safety aspect (quality) of the compost product and believe that the product is better than chemical fertilizer or any existing soil inputs, all things being equal.

Table 7. Latent Class Model (LCM) results.

Classes	Class 1 (Segment): Medium Certification Conscious Farmers	Class 2 (Segment): High Certification Conscious Farmers
Price	−0.003 (0.001) ***	−0.001 (0.001) ***
Fortification	−4.378 (0.643) ***	0.568 (0.063) ***
Pelletization	0.723 (0.326) **	0.458 (0.056) ***
Certification	0.879 (0.328) ***	1.357 (0.059) ***
Constant	−0.665 (0.873)	−0.422 (0.452)
Gender	0.105 (0.446)	0.595 (0.199) ***
Household size	−0.186 (0.065) ***	−0.184 (0.027) ***
Education	−0.055 (0.319)	−0.093 (0.107)
Experience	0.073 (0.019) ***	0.028 (0.012) **
Religion	−0.658 (0.124)	−0.583 (0.124) ***
Product quality	−0.049 (0.244)	0.049 (0.089)
Product reservation	−0.648 (0.198) ***	−0.451 (0.106) ***
Product use	−0.230 (0.318)	−1.864 (0.952) ***
Class probability	0.28	0.72
Log Likelihood	−2245.08308	
McFadden R^2	0.260	
AIC	4550	

Notes: parentheses indicate the standard errors of the respective coefficient; ** means significant at 5% level, and *** means significant at 1% level.

Results further indicate that education and information on product quality variables are insignificant for both classes. However, the inclusion of household size, farming experience, and farmers' reservation on the use of faecal sludge significantly improved the performance of the model, especially for those in class two. The coefficient on household size in the LCM model reveals that those with smaller household size (less than three) are less likely to belong to the "high value" certified group (class two) relative to class one. Similarly, farmers with a negative perception on the reservation of the use of faecal sludge in compost are more likely to belong to the "high value" certification class than "medium value" certification class.

3.4. Farmers' Marginal Willingness-to-Pay

The results from the RPL models were used to estimate the marginal WTP, which illustrates the amount farmers are willing to pay for an improvement in the attributes. For potential investors, the analysis provides better understanding of the relative importance of attributes to farmers. Table 8 depicts the results from the both the CL and RPL models.

Table 8. Farmers' willingness-to-pay (WTP), mean (95% confidence interval) in USD.

Attributes	Basic Model	Extended Model
	Random Parameter Logit (RPL)	Random Parameter Logit(RPL)
Fortification	−0.014 (0.047) ***	−0.089 (0.039) ***
Pelletization	0.076 (0.027) ***	0.127 (0.032) ***
Certification	0.422 (0.049) ***	0.400 (0.057) ***

Notes: standard deviations calculated through bootstrapping procedure according to Krinsky and Robb in 1986 are given in parentheses; *** means significant at 1% level [37].

The estimates show that farmers are willing to pay USD 0.40 per kg more for 'certified' FSM compost and USD 0.127 per kg for pelletized compost. However, USD 0.089 per kg will be required to compensate farmers to use fortified compost. As noted earlier, farmers view FSM compost as already having a sufficient nutrient content level and are not incentivized to pay for additional nitrate fortification. Overall, the results suggest that farmers prefer FSM compost that is pelletized and certified by a trustworthy and relevant authority. With the LCM, marginal WTP estimations for pelletization and certification attributes reveal farmers valued these attributes and are willing to pay for them. Farmers in segment two are willing to pay more than those in segment one for all the attributes. These farmers accounted for about 70% of the sample. This suggests that most of the farmers in this class valued high quality compost and are willing to pay for information on the certification and pelletization relative to those in segment one. Also, this group valued information on fortification than those in segment one (Table 9).

Table 9. WTP per farmers' segment, mean (95% confidence interval) in USD.

Attributes	Class 1 (Segment): Medium Certification Conscious Farmers	Class 2 (Segment): High Certification Conscious Farmers
Fortification	−0.138 (0.008) ***	0.241(0.031) ***
Pelletization	0.109 (0.041) ***	0.196 (0.034) ***
Certification	0.217 (0.026) ***	0.547 (0.094) ***

Notes: standard deviations calculated through bootstrapping procedure (Krinsky and Robb, 1986) are given in parentheses; *** means significant at 1% level.

Unlike the RPL model, this result suggests that a segment of the farmers may still be interested in fortified compost. This indicates that it may be necessary for investors to focus their marketing strategies on farmers who are likely to belong to segment two than those in segment one. With respect to fortification, different marketing strategies may be needed to target the appropriate farmers.

3.5. Comparison of WTP Estimates with the Cost of Production of FSM Compost

We compared the WTP estimates with the cost of producing these attributes (Table 10). The intent is to assess if future producers will be able to produce FSM compost with these attributes. These estimates were based on the assumption of a plant production level of 350,000kg [38]. The cost of providing the 'certification and pelletization' product attributes, for example, is estimated based on the sum of the costs of providing the individual attributes. The total cost may be lower given increased economies of scale, but here we assume no economies of scale—giving us a more conservative estimate for economic returns. Additionally, it is important to note that the consideration of transportation costs to farmers for accessing the FSM compost may reduce the estimated market demand and invariably the estimated economic return to producers. In this study, we assumed that the farmers will purchase the product from their current fertilizer outlets and will not incur any additional transportation costs when purchasing FSM compost.

From our results, it is observed that the farmers' marginal WTP estimates for certification far exceeds the cost of providing this product attribute; and actually an FSM compost producer will be able to capture a significant share of the consumer surplus as the WTP estimate is almost 67 times higher than the actual cost. At the start-up phase of the business, the FSM compost producer may choose to only charge the exact cost of providing the product and capture some of the consumer surplus at a latter phase. This strategy may be useful for the producer to build a solid customer base or adopt a penetrative pricing mechanism. On the other hand, the results show that farmers' WTP for pelletization is lower than the cost of producing a pelletized FSM compost (0.59 times lower than the cost). Similarly, the marginal WTP for fortification trends in the opposite direction and the cost of producing a 'nitrate fortified' FSM compost is significantly higher than what the farmers are willing to pay. It is clear that future FSM compost producers will have to carefully assess the related costs for producing this product with these select attributes. As the results indicate that the farmers prefer 'certified and pelletized' FSM compost, future businesses can focus on this product type although the cost of pelletization is higher than the farmers' WTP for this attribute. This is because the 'certified and pelletized' FSM compost has the highest cost-WTP differential and for which future businesses can capture the highest percentage of the consumer surplus (WTP is 2.33 times higher than the cost of production); and the surplus of the farmers' WTP for the certification attribute can be used to buffer the cost and WTP differential for providing the pelletization attribute.

Table 10. Comparison of farmers' marginal WTP estimates of FSM compost and the cost of providing select product attributes.

Product Attributes	Marginal WTP Estimates		Cost of Product Attribute	WTP and Cost Percentage Differential
	UGX/kg	**US $/kg**	**US $/kg**	**Based on US $ Values**
1. Certification	1083.94	0.400	0.006	66.67 times more
2. Fortification	−241.41	−0.089	0.150	−0.59 times less
3. Pelletization	344.69	0.127	0.222	0.57 times less
4. Certification & Pelletization	1428.63	0.527	0.228	2.31 times more
5. Certification & Fortification	842.53	0.301	0.156	1.93 times more
6. Certification, Pelletization & Fortification	1187.22	0.431	0.378	1.14 times more

Notes: Exchange rate: UGX 2710 = US $1.

4. Potential Market Outlook of FSM Compost Product

The potential market for FSM compost in Kampala (notable surrounding agricultural districts were considered in the market size estimation, i.e., Luwelo, Mpigi, Mukono and Wakiso in addition to Kampala. The total cultivated area under the 5 districts considered is 130,000 ha (Source: Uganda Census of Agriculture 2008/09 Volume 4)) is noted to be substantial with demand estimated at 26 million kg per year. As noted above, in this study, we assumed that the farmers will purchase the product from their current fertilizer outlets and will not incur any additional transportation costs when purchasing FSM compost. In the instance where the latter is not the case, increased transportation costs borne by the farmers may result in a lower demand. We also assumed an adoption rate of 38%—which was based on the percentage of farmers noted willing to use per purchase FSM compost; and an application rate of 500 kg per ha per year. Chemical fertilizer application rates were used as a basis for the calculation (the average chemical fertilizer applications were estimated at 107.5kg/ha and for FSM compost at five times this estimate) [5]; as it is considered a close competitive product. With the WTP estimates for the product attributes of FSM compost and the potential market demand, it is clear that not only is there an existing market demand for FSM compost by farmers in and around Kampala, but farmers are willing to pay for a certified and pelletized product. This suggests that there are opportunities for business creation around FSM compost.

A potential challenge for future FSM compost producers will be on how to penetrate the concentrated fertilizer market (the fertilizer market is mainly dominated by chemical fertilizers in Uganda) in Uganda. The chemical fertilizer market in Uganda has however not expanded to a significant level due to an ineffective fertilizer policy and market distortions. Limited supply has eventually driven down demand and farmers have resorted to alternative soil nutrient inputs. Additionally, there is neither a large-scale government fertilizer program that provides subsidized chemical fertilizer to farmers nor an active private sector that supplies fertilizers at competitive prices. These market distortions represent a great opportunity for FSM compost producers to take advantage of erratic chemical fertilizer prices and the limited number of actors in the respective market, and capture a share of the fertilizer market. On the other hand, the product mix available of chemical fertilizer products is rather extensive, reflecting the grade (nutrient)-specific requirements of the commercial crop growers. This suggests that FSM compost producers may need to consider at the start-up unique and differentiated formulations tailored to different crops and innovative marketing strategies to mitigate these effects of market competition. Thus, the cost for research and development (sunk cost) and negotiations may be higher in the start-up phase of FSM compost businesses and may lead to lower profits in the short-term.

5. Conclusions

The production of a waste-based agricultural input such as a faecal sludge and municipal solid waste-based (FSM) compost can significantly benefit Uganda's economy. Demand for such a product is not guaranteed even among end-users such as smallholder farmers with limited alternatives. This study applied choice experiment to estimate farmers' WTP for FSM compost and selected product attributes including certification, nitrate fortification and pelletization. Results indicate that farmers are willing to pay for certified and pelletized compost, but compensation may be required for them to use fortified compost. The expressed WTP for certified compost is higher than the cost of producing the attributes. Conversely, the costs of producing the other two attributes are higher than the WTP estimates. While there is the need to develop a product to target farmers who are interested in fortified compost, we suggest that future FSM compost producers focus on a 'certified and pelletized' FSM product as this product type has the highest production cost–WTP differential and for which future businesses can capture the highest percentage of the consumer surplus. Additionally, given that the cost of providing a pelletized FSM compost exceeds the WTP, the surplus of providing the certification attribute can buffer the negative production cost–WTP differential.

While the certification and pelletization attributes are noted to increase the demand for FSM compost, selected demographic and other perception factors such as water holding capacity, farmers' reservation toward the use of the product and product quality are equally noted to be relevant in their purchasing decisions. Future FSM compost businesses will need to account for this in their pricing and marketing strategies to different farmer demographics. From a business perspective, it is pertinent to evaluate the costs of introducing any of these attributes against the benefits, which are measured through the WTP estimates. More detailed financial analysis taking into account the economies of scale will be important in assessing the direct cost implications of producing FSM compost with these product attributes. Strategic partnerships with technology providers, for example, to develop more efficient pelletizing machinery and the resulting effects on business viability should be considered by future FSM compost businesses. Although it may be difficult to obtain, it is important that governmental support via subsid provisions, with the intent of improving the environment through FSM compost businesses be explored. In this context, it may be relevant to focus not only on the private benefits but also on the social and environmental benefits for the full justification of subsidies.

In the context of Uganda, the results from this study provide valuable information for future businesses to guide their investment decisions and the research and development initiatives they pursue before and during the life cycle of their business with the intent of improving the environment. Additionally, the WTP estimates of specific product attributes provide pertinent information to guide businesses on market segmentation and pricing strategies to enable them to not capture the highest percentage of the consumer surplus but also importantly successfully penetrate the fertilizer market.

In southern Ghana, packaging, labeling and other socio-economic factors influenced farmers' preference for feacal sludge compost (16). These factors identified in southern Ghana and others found in Uganda combined with market promotion programs may improve agricultural production and increase organic fertilizer market share.

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Appendix A. Theoretical Framework

The theoretical foundation of the choice experiment is such that a given farmer f obtains utility from choosing alternative, i from a finite set of J alternatives contained in a choice set, C in situation t. The farmer's utility function is comprised of deterministic and stochastic components, but the former depends on the attributes of an alternative. We denote Z_{fit} as the deterministic component and the ε_{fit} as the stochastic component. Formally, we can specify the utility of a farmer of alternative i as:

$$U_{fit} = Z_{fit} + \varepsilon_{fit} \tag{A1}$$

Random utility theory is defined such that farmer f will choose alternative i if $U_{fit} > U_{fjt}\ \forall j \neq i$. Given the choice set, C in situation t, the probability of farmer f choosing alternative i from a set of alternatives J, is estimated as:

$$P_{fit} = \frac{\exp(Z_{fit})}{\sum_{j=1}^{J} \exp(Z_{fjt})} \tag{A2}$$

Equation (A2) is used to estimate farmers' preferences, but it assumes that preferences are homogenous. The Random Parameter Logit (RPL) and Latent Class Models (LCM) are two alternatives increasingly being used to measure heterogeneity in farmers' preferences on informational attributes [39]. The RPL model is flexible because it allows for preference heterogeneity and unlike the logit model does not suffer from the independence of irrelevant alternative (IIA) assumption [40]. For a given sample, the RPL model relaxes the IIA assumption by allowing variation in the taste variables through a specified distribution. We specify the distribution of the random parameters as $f(.)$ and β is a vector of random parameters, which has its own mean and variance, indicating a farmer's preferences, then the RPL model for farmer f choosing alternative i from the choice set, C in situation t is given as [40]:

$$P_{fit} = \int \frac{\exp(Z_{fit})}{\sum_{j=1}^{J} \exp(Z_{fit})} f(\beta) d\beta \tag{A3}$$

It is important to note that when $f(\beta)$ is constant or degenerate, then the RPL model reduces to the standard conditional logit model in equation [39]. It is difficult to estimate the closed form of Equation (A3) and we have to rely on a simulated approach for the probabilities. Halton draws, which provide better coverage of density function and faster convergence were utilized at 1000 draws per iteration in the simulated maximum likelihood estimator [40]. Alternatively, heterogeneity in preferences can be assumed to occur discretely using a LCM where the f farmers are sorted into a number of s latent classes, each comprised of homogenous consumers [41]. In the LCM, $f(\beta)$ is discrete, taking s distinct values [40]. Let $\beta' \chi_{fit}$ represent the deterministic component of the utility in the RPL model. We denote β_s' as the specific parameter for class s and W_{fs} as the probability that farmer f falls into class s. We define Z_f and ϖ_s as a set of observable farmer characteristics that affect the class membership and a vector of parameter for farmers in class s. The probability that farmer f selects option i in a given choice situation t unconditional on the class is represented by:

$$P_{fit} = \sum_{s=1}^{S} \frac{\exp(\beta_s' \chi_{fit})}{\sum_j \exp(\beta_s' \chi_{fjt})} W_{fs} \quad \text{(A1)}$$

Subsequently, the probability that farmer f falls into class s can be modeled as in [28,41]:

$$W_{fs} = \frac{\exp(\varpi_s Z_f)}{\sum_{s=1}^{S} \exp(\varpi_s Z_f)} \quad \text{(A2)}$$

Maximum likelihood approach is used to estimate the LCM; however, it is difficult to estimate the optimal number of segments a priori. The standard procedure is to estimate the model parameters sequentially for an increasing number of segments until an additional segment does not improve the model fit according to specific statistical criteria (e.g., log-likelihood, AIC, and BIC [31]).

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