

Review

Why do We Know So Much and Yet So Little? A Scoping Review of Willingness to Pay for Human Excreta Derived Material in Agriculture

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Abstract: Challenges associated with rapid population growth, urbanization, and nutrient mining have seen increased global research and development towards ‘waste to wealth’ initiatives, circular economy models, and cradle-to-cradle waste management principles. Closing the nutrient loop through safe recovery and valorization of human excreta for agricultural use may provide a sustainable method of waste management and sanitation. Understanding the market demand is essential for developing viable waste management and sanitation provision business models. The pathways and processes for the safe recovery of nutrients from human excreta are well-documented. However, only anecdotal evidence is available on the willingness to pay for human excreta-derived material in agriculture. This review closes this gap by identifying and synthesizing published evidence on farmers’ willingness to pay for human excreta-derived material for agricultural use. The Scopus and Web of Science search engines were used to search for the literature. The search results were screened, and the data were extracted, charted, and synthesized using the DistillerSR web-based application. The findings show that understanding willingness to pay for human excreta-derived material is still a nascent and emerging research area. Gender, education, and experience are common factors that influence the farmers’ willingness to pay. The findings show that pelletization, fortification, labeling, packaging, and certification are essential attributes in product development. The wide-scale commercialization can be achieved through incorporation of context-specific socioeconomic, religious and cultural influences on the estimation of willingness to pay. Promoting flexible legislation procedures, harmonization of regional legislations, and creating incentives for sustainable waste recovery and reuse may also promote the commercialization of circular nutrient economy initiatives. More empirical studies are required to validate willingness to pay estimates, especially using the best practice for conducting choice experiments.

Keywords: waste to wealth; circular economy; cradle to grave; choice experiment; contingent valuation; willingness to pay

1. Introduction

Decentralized sanitation systems could help to achieve the United Nations Sustainable Development Goals (SDGs) through guaranteeing basic sanitation [1]. The challenges of rapid urbanization, sustainability, and persistent soil nutrient mining have seen an increased call on the global agenda to meet the sanitation needs of the poor. Agricultural intensification and expansion of cities as more native vegetation is

converted for crop production call for more sustainable options for restoring soil health [2–4]. The decline in soil physical and chemical properties to support plant growth results from agricultural intensification, especially in Sub-Saharan Africa [5]. The long-term trials in India show the fall in crop yield to be associated with increased chemical fertilizer application [6]. The increased research interest in circular economy research fortifies this growing attention for sustainable waste recovery and reuse [7–16].

SDG Goal 6 emphasizes clean water and sanitation, while Goal 12 calls for responsible production and consumption in a way that minimizes waste [17]. Providing improved sanitation technologies is directly related to SDG Goal 6, and the recovery of nutrients from waste for agricultural use links to the minimization of waste (Goal 12). The creation of sustainable and cheaper alternative fertilizer sources to close the nutrient loop could also help to improve agricultural production. Understanding the demand for nutrients recovered from human waste through the elicitation of farmers' willingness to pay (WTP) may assist in the development of inclusive business models for private sector participation and partnerships with public utilities in line with SDG Goal 17 [17]. It is through these linkages with the global agenda that most researchers and partners in the waste management and sanitation value chain have started paying attention to identifying sustainable viable and business cases and models within the resource recovery and reuse service chain [18–20].

The provision of sanitation services is commonly the mandate of the public sector. The failure of local municipalities to meet sanitation requirements due to overstretched budgets, corruption, mismanagement of public funds, and poor governance of public affairs has created the need for alternative, inclusive business models within the sanitation sector. Developing inclusive business strategies within the sanitation sector is in line with the Growing Inclusive Markets initiative of the United Nations Development Program, which emphasizes a human development framework, home grown solutions, and inclusive partnerships [21,22]. Inclusion of the private sector enterprises should emphasize not only the financial viability of business cases but also economic and environmental viability as this is often critical for public institutions. A win-win situation could result where the private enterprises can generate profits while the public sector can meet sanitation, waste management, and cost recovery objectives without straining the waste sink services of the environment.

The United Nations Population Fund (UNFPA) estimates show that more than half of the global population live in urban areas [23]. The rapid population growth and urbanization create increasing pressure on urban municipalities to meet sanitation requirements [23]. The United Nations Human Settlements Programme (UN-Habitat) opines that population growth, better socioeconomic activities, socio-cultural interactions, and humanitarian activities in urban areas continue to attract migrants from the rural areas [24]. Overpopulation and expansion of urban areas lead to the proliferation of informal settlements where basic amenities such as clean water and sanitation are non-existent and expensive to construct [25]. Consequently, informal settlements and peri-urban dwellers often resort to unplanned waste management and disposal practices such as open defecation [26].

Urbanization and rising incomes often lead to nutrition transition. Nutrition transition is the increased demand for nutrient-dense diets and is linked to population growth, economic development, rising incomes, and urbanization, which exacerbate the mining of agricultural nutrients [27,28]. Nutrition transition creates massive nutrient sinks in urban areas [28]. The consumption of food produced in rural and peri-urban agriculture by urban consumers takes with itself nutrients from the soil. The almost constant mass balance of nutrients in the body means that virtually all nutrients are excreted as urine and fecal matter [29,30]. An estimate of 3.4 kg of nitrogen (N), 0.5 kg of phosphorus (P), and 1.6 kg of potassium (K) are excreted as waste per person annually [30]. The ecological balance can be maintained if these nutrients are recovered and returned to the soil, and this is not often the case because the philosophy within which the centralized sanitation systems are constructed did not consider waste as a resource [31]. The global trend is that only 50% of the soil nutrients mined from the soil are returned, posing some severe agricultural production bottlenecks due to soil nutrient depletion and consequently reducing water productivity [32].

A paradigm shift in thinking towards a circular economy may provide a new way of redefining human excreta as ‘wealth’ rather than ‘waste’ [31]). Globally, full resource recovery and reuse present 41 million tons of nutrients, making up 28% of the present world N, P, K utilization [33]). Furthermore, the depletion of non-renewable nutrient sources (‘peak phosphorus’) also contributes to this paradigm shift in thinking towards the circular economy models (Cordell and White, 2011). Long-term agronomic trials with human excreta show significant phosphorus recovery when compared to cattle manure and inorganic fertilizers [34,35]. The findings of agronomic trials demonstrate the effectiveness of human excreta-derived fertilizers in improving soil physiochemical properties and crop yields [36]. Human excreta-derived material (HEDM) improves soil physiochemical properties, namely, soil hydraulic conductivity, pH, electrical conductivity, and cation exchange capacity (CEC) [31]. Recycled organic waste reduces greenhouse gas (GHG) emissions compared to inorganic fertilizers [37].

More recently, there has been another shift in scientific research towards the development of technologies that can recover safer and acceptable excreta fertilizer for agricultural use [31]. The pathways and processes for the safe recovery of micronutrients and macronutrients for use in agriculture have been extensively discussed in the literature focusing on the elimination of pathogens, organic pollutants, and heavy metals [38–40]. The maturity and potential for wide-scale commercialization of the recovery and reuse processes and pathways are discussed in the literature [41–43]. The wet chemical extraction of P from mono-incinerated sewage sludge ash using phosphoric acid (RecoPhos[®]) and P crystallization of digester supernatant (AirPrex[®] and Ostara[®]) are among the mature technologies [38,41]. The use of urine harvested from source-separated sanitation technologies eliminates pathogen, heavy metal, and organic pollutant concerns in the end-product. The SaNiPhos[®] in the Netherlands, which uses source-separated urine to produce struvite and ammonium sulfate at full-scale commercially, is an excellent example of such mature recovery technologies [44]. Storage, composting, and anaerobic digestion are among the technologies with the highest readiness level [43]. Other technologies with great potential for nutrient recovery include nitrified urine concentrate production, black soldier fly larva production, and Latrine Dehydration and Pasteurization (LaDePa) of screened ventilated improved pit latrine sludge [45–47].

The market or demand segment remains the most understudied, especially the pecuniary and non-pecuniary factors that affect the acceptance of the waste-derived products [48]. Drechsel et al. [20] opined that failure of resource recovery and reuse projects to cover operational costs is related to the complexity of the technologies selected, high maintenance costs, and failure to understand the product markets. Developing viable business models for resource recovery and reuse has become imperative for policy decision making [20]. This review provides a synopsis of the state of published knowledge in understanding the HEDM market demand and farmers’ WTP. Establishing the monetary value that farmers are willing to pay for different product attributes is vital to evaluate whether the estimated price covers the cost of providing the product and its attributes [48,49].

A scoping review methodology offers a way of compiling and synthesizing research evidence in a systematic and reproducible manner [50]. The review provides a picture of the state of research evidence by characterizing and synthesizing the previous empirical evidence. There is a growing body of literature on understanding the attitudes and perceptions of farmers on HEDM but little on their WTP. This review is the first study to employ the scoping review method in understanding the state of knowledge and research evidence of the WTP for HEDM. Providing this research evidence may inform future research directions on knowledge gaps, study design improvements, sample sizes, attribute quality and levels, and the number of alternatives, among other design issues. Moreover, consolidating the WTP estimates from different studies may provide valuable information required by policymakers for improved decision making on the viability of waste management and sanitation provision.

2. Methods

A scoping review methodology proposed by Arksey and O’Malley [50] provided a rigorous and comprehensive methodology for synthesizing research evidence. The methodology offers a

flexible but reproducible guide on search terms that allows for a comprehensive literature review process [50]. This study follows the proposed five stages, which include: defining the research objective, search strategy, study selection, synthesizing, and reporting the findings [50]. The application of the method in other research areas includes compiling the state of research evidence in public health [51–53], public health and sanitation [54,55], epidemiology [56], environmental health [57], consumer health [58], and in the investigation of social determinants of the rural labor force [59] and dental health care [60].

2.1. Research Question

This review employed the population, interventions, comparatives, outcomes, and study design (PICOS) methodology in specifying the research objective [61]. The population was specified as users of HEDM in agriculture, such as rural, peri-urban, and urban farmers. The intervention was the agricultural use of the HEDM in comparison with conventional inorganic fertilizers and animal manure. The outcome was defined as the WTP for HEDM by farmers or other users. The study designs were categorized into quantitative, qualitative, and mixed methods.

2.2. Identification of Relevant Studies, Data Sources, and Search Strategy

The study involved performing the primary search in all databases in Web of Science (WoS Core Collection, KCI Korean Journal Database, MEDLINE, Russian Science Citation Index, and SciELO Citation Index) and Scopus electronic databases. Web of Science was selected as it provides a greater depth of citation coverage in the areas of Sciences and Social Sciences [58]. Title-Abstract-Keyword search was performed in Scopus while Topic search was employed in all databases of Web of Science. The review was limited to peer-reviewed articles published in the English language by 8 April 2019. The time limitation allowed for this review to extract all studies conducted on WTP of HEDM for agricultural use thus far. By employing several search terms, synonyms, and Boolean operators, this review provided a structured, exhaustive, and comprehensive search (Table 1). The snowballing technique was also employed to back-search and handpick references of the articles included in other electronic databases such as Google Scholar because electronic databases may vary in their abstracting, indexing, depth, and breadth of information [50].

Table 1. Search Queries.

Database	Search Strategy	Search Results
Scopus	TITLE-ABS-KEY ("human manure" OR "fecal sludge" OR "human waste" OR "humanure" OR "solid waste" OR fec * OR fec * OR "human excreta" OR "human excreta derived material") AND ("Willingness to pay" OR "Contingent valuation" OR "Discrete choice Experiment" OR "Choice experiment")	325 document results
Web of Science	TOPIC ("human manure" OR "fecal sludge" OR "human waste" OR "humanure" OR "solid waste" OR fec * OR fec * OR "human excreta" OR "human excreta derived material") AND ("Willingness to pay" OR "Contingent valuation" OR "Discrete choice Experiment" OR "Choice experiment")	321 document results
Top of Form		

* operator in the search syntax refers to Boolean for the shortest word to be retrieved from the search.

2.3. Study Selection

All peer-reviewed articles or references from WoS and Scopus were exported to the DistillerSR Evidence Partners Incorporated web-based application. The duplicate detection function in DistillerSR was used to quarantine duplicates before conducting the initial screening. The DistillerSR application allows for data extraction from included articles based on study characteristics. This application has been employed in other studies [54,57].

2.4. Screening and Eligibility Criteria

The study screened the remaining unique articles for relevance using title screening. Studies that passed the inclusion criteria were further screened using abstract and full-text screening. Only the articles that were relevant after the full-text screening were considered for data extraction. The references of the included articles were scanned for potential references that might not have been indexed and archived in WoS and Scopus databases. The data from these articles were also added to the included articles for data extraction. These additional studies identified through handpicking or snowball technique were searched in Google Scholar. The articles considered for inclusion were those that investigated the WTP for HEDM, which is a unique fertilizer product when compared to other organic fertilizer sources available to agricultural producers (Table 2).

Table 2. Inclusion and Exclusion Criteria.

Article Inclusion Criterion		Article Exclusion Criterion	
√	The study investigated WTP for HEDM	×	The study described WTP for other products but human excreta and or HEDM
√	The study was written and published in the English language	×	The study was published in other languages and not in the English language
√	The study was published in a peer-reviewed journal	×	The study was not published in a peer-reviewed journal, such as articles published in predatory journals, conference proceedings, working papers, abstracts and books
√	The study was an original paper with original results	×	The study was a review article without original results
√	The study contained enough details to evaluate the methodology.	×	The study had insufficient details to evaluate the methodology
√	The full text of the article could be retrieved	×	The full text of the article could not be retrieved for evaluation

2.5. Data Extraction

The review implemented a descriptive-analytical approach to extract information from the articles that passed the inclusion criteria following the framework of the traditional narrative review [50,54]. The data extracted included the name of the author, publication year, location, study participants, type of HEDM investigated, study design, analytical framework, sample size, and WTP attributes and estimates reported. Systematic reviews are supposed to assess the strength of research evidence. This study, therefore, extracted variables that may offer quality assessment from the included studies. Variables such as whether the articles assessed the validity and reliability of the survey instrument, sample size calculation, the econometric model estimated, the goodness of fit tests, HEDM attributes, the mean WTP estimated, and the factors influencing farmers' WTP were also extracted for analysis.

2.6. Synthesizing and Reporting

This review was summarized into specific themes that emerged from the included articles. The summarizing stage included supporting research evidence from grey literature, which was essential to support the claim that more work is needed in this research area in terms of understanding the consumer demand and the market value of HEDM. The additional benefit is especially in identifying future research directions and knowledge gaps, which form the rationale for conducting scoping reviews.

3. Results

3.1. Search and Article Screening Results

A total of 647 articles were exported to the DistillerSR web-based application for screening. A total of 174 duplicate articles were quarantined using the duplicate detection function leaving 473 unique articles. A total of 344 articles were excluded using title screening. The remaining 129 articles were

excluded following abstract and full-text screening. Only two articles were considered for data extraction. Three additional references were identified through handpicking and snowballing for data extraction (Figure 1).

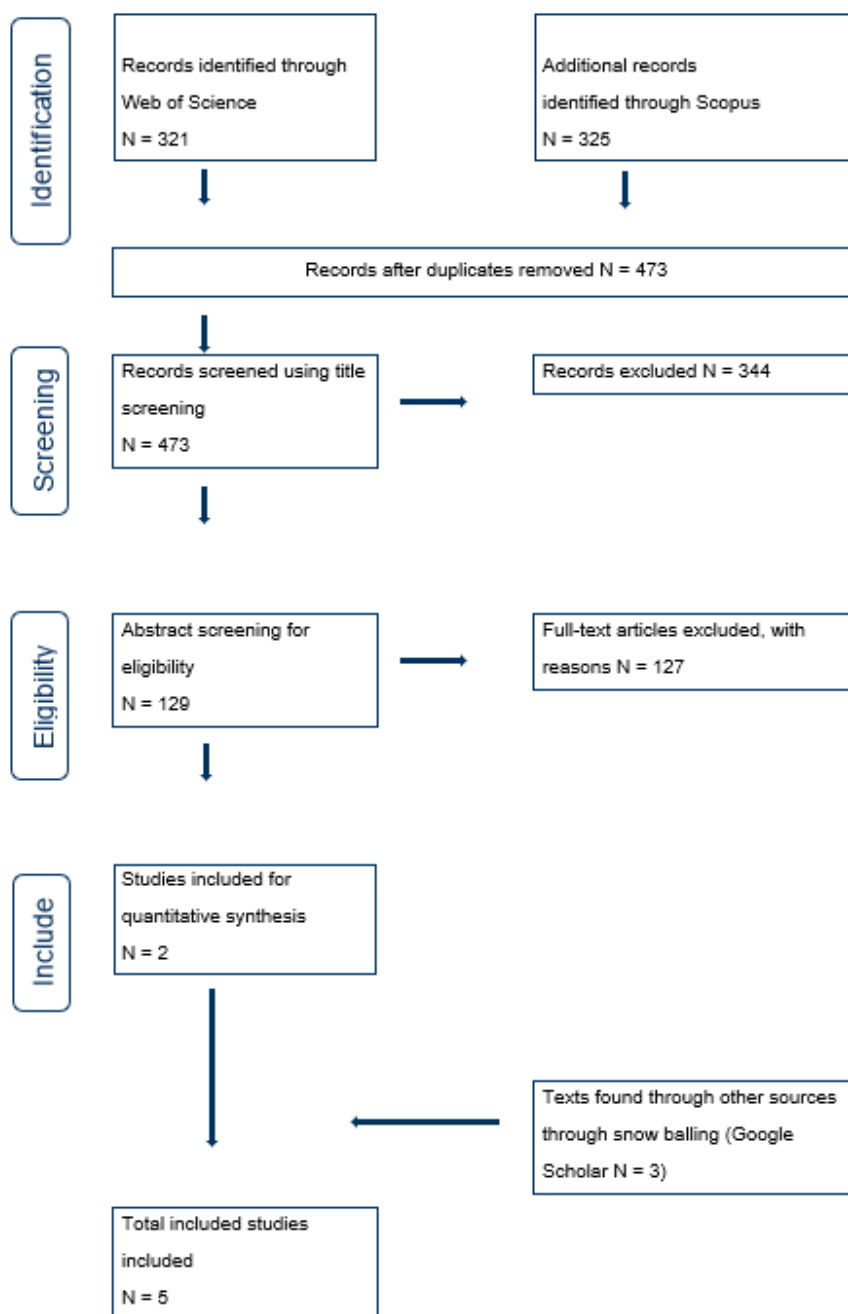


Figure 1. Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) flow chart.

3.2. Characteristics of Articles Included

Out of the five published studies conducted on the WTP of farmers for HEDM, three were from Uganda, while the remaining two were from Ghana and Vietnam. Out of the five publications, the first publication was conducted in the year 2006, followed by another one in 2014. The remaining three studies were conducted in 2017

The participants in all the studies were farmers. The types of HEDM analyzed in the studies include fortified and pelletized municipality solid waste, which was co-composted with human excreta [49].

Fortified excreta pellets involve the enrichment of composted excreta with inorganic fertilizers or struvite to enhance its value (marketability and competitive advantage) and reduce bulkiness while allowing usability for different crops [62]. Pre-gelatinized cassava starch and clay binders may be used to reduce nitrogen loss through volatilization [49,62,63]. Another study estimated the WTP for municipal solid compost, which was co-composted with human excreta but not enriched with inorganic fertilizer [48]. Other types of HEDM investigated include pelletized human excreta-derived fertilizer [64] and fecal compost [65]. Pelletization of compost enhances product structure, increases the bulk density, reduces costs associated with handling, transport, storage, and application while homogenizing and concentrating nutrients in manure [49,66,67]. The fifth study investigated WTP for human excreta-derived organic biomass liquid fertilizer treated using auto-thermal thermophilic aerobic treatment [68]. The auto-thermal thermophilic aerobic treatment uses aeration flow and batch flow manipulation to regulate the solid-retention-time and digester temperature required for sludge pasteurization [69].

This review also extracted data on the type of research design and the technique used to elicit the WTP for HEDM. The results show that all the studies included collected cross-sectional data. The methods used to elicit WTP included the contingent valuation method (CVM) [48,64,68]. The remaining two studies used the choice experiment (CE) method [49,65]. The sample sizes ranged from a minimum of 200 farmers to a maximum of 700 farmers. None of the included studies gave information on the sample size determination in terms of the population heterogeneity and the power tests. Recommendations for sample size calculation consider the number of choice tasks, alternatives and the largest number of levels for main effects, and the largest product of any two attributes for interaction effects [70,71]. Researchers may also use the rule of thumb of over 100 respondents for choice experiment surveys as proposed by [72] or use power test recommendations proposed by [73].

The survey instruments used in the included articles were checked for validity and reliability. None of the studies reported any ex-ante validity and reliability checks to the survey instruments. However, one of the studies reported piloting the survey instrument to a few unspecified numbers of farmers. Typically, formal tests are required in cross-sectional survey instruments reported, such as the Cohen's kappa index or the Cronbach's alpha test for reliability [74].

The data analysis methods used show that all five studies used different empirical models. (Tables 3 and 4). A mix of models including the conditional logit (CL) model, random parameters logit (RPL) model, and latent class model (LCM) were used in estimating WTP for HEDM in Ghana [49]. In another similar study that used the CE elicitation technique, the basic and hybrid CL models were used to elicit WTP for HEDM [65]. The studies that elicit WTP using CVM used the tobit model [64], the probit model [48], and the log-logistic model [68]. Based on these empirical models, the review further extracted data on the WTP estimates. The CVM model results showed the WTP estimates ranging from a minimum of 0.4 US cents per kilogram (kg) of organic biomass liquid fertilizer [68] to 19 US cents per kg of pelletized human fecal matter [64]. The mean WTP estimate for municipal compost with human excreta was estimated to be 3 US cents per kg [48].

Table 3. Characteristics of Articles Included.

Author (Year)	Country of Study	Target Group	Study Design	Sample Size	Human Excreta-Derived Fertilizer	Validity Reported?	Reliability Reported?
(Danso et al., 2017)	Uganda	Farmers	Choice Experiment	300	Fortified Pelletized Municipality Solid Waste and Human Excreta	No	No
(Kuwornu et al., 2017)	Ghana	Farmers	Contingent Valuation	461	Pelletized feces	No	No
(Danso et al., 2006)	Ghana	Farmers	Contingent Valuation	700	Co-compost	No	No
(Agyekum et al., 2014)	Ghana	Farmers	Choice Experiment	200	Composted feces	No	No
(Hong et al., 2017)	Vietnam	Farmers	Contingent Valuation	530	Organic Biomass Liquid Fertilizer	No	No

Table 4. Characteristics of Articles Continued.

Author (Year)	Econometric Model	Log Likelihood	Attributes	Mean WTP Estimate USD/kg
(Danso et al., 2017)	Conditional Logit Model	−2134.551	Fortification	0.09
	Random Parameters Logit Model	−1910.586	Pelletization	0.13
	Latent Class Model	−2245.083	Certification	0.40
(Kuwornu et al., 2017)	Tobit Model	−1770.300	-	0.19 (Pelletized feces)
(Danso et al., 2006)	Probit Model	(8.9; 645.7; 745.13) [†]	-	0.03 [‡] (Co-compost)
(Agyekum et al., 2014)	Basic and Hybrid Conditional Logit Model	−305.827	Packaging	0.01
		−296.676	Labeling	0.01
(Hong et al., 2017)	Log-logistic Model	−293.400	-	0.004 (Organic Biomass Liquid Fertilizer)

[†] Pearson's goodness of fit was used for three cities. [‡] WTP value was estimated as average for the three cities for different crops.

Farmers were willing to pay 1 US cent for a labeled and 1 US cent for a packaged kg of composted feces [65]. The fortified HEDM had a marginal WTP of 9 US cents per kg below the market price as compensation for fortification, 13 US cents per kg above the market price for pelletization, and 40 US cents above the market price per kg for certification [49]. The reported WTP estimates for certification were found to be 67 times above the cost of providing a certified product while being 0.57 times lower than the cost of providing a pelletized product [49]).

3.3. Factors Influencing WTP for HEDM

Various factors were discussed that influenced the WTP for HEDM in the five included studies. The variables used in different econometric models were extracted and tabulated (Table 5). The results show that gender, education, and experience are the most common factors that influence farmer WTP for HEDM reported in all the five studies. The next common factors include age, household size, and income, which were reported in four studies. Awareness of the HEDM was the third most common variable in three of the studies. Farm size and perception of the use of HEDM were reported in two out of five studies. The remaining factors include product quality, religion, training, and membership of a farmer-based organization, which were reported each in one study. For the two CE studies, one used price, fortification, certification, and palletization as the HEDM attributes [49]. The other CE study used price packaging and labeling as HEDM attributes [65].

The effect of the socioeconomic and demographic variables on the WTP in the CE studies differed depending on which attribute it was interacted with. For instance, a negative effect on WTP was reported when gender was interacted with pelletization and certification, but a positive and significant effect was reported when gender was interacted with fortification [49]. The results may imply that women are more risk-averse and therefore prefer a certified product compared to men. Women may prefer a product that is easier to handle, as it reduces drudgery. However, men and more experienced farmers were found to prefer a more valuable fortified compost compared to women. However, education had a negative effect on all three interactions and with packaging and labeling, implying that educated farmers may find less value in all the improved compost attributes [49,65]. Larger households were also willing to use HEDM in the two CE studies, which is very intuitive because of the availability of labor [49,65]). Household income was reported to have a positive effect on WTP when interacted with packaging and labeling [65]. The finding shows that low resourced farmers could still accept HEDM even if it were to be sold in bulk without packaging and labeling. However, resourced farmers would prefer a packaged and labeled compost for ease of handling. The results also show that older farmers have lower WTP than younger farmers, which is the usual case in most examples of adoption of new technologies in agriculture [65].

Table 5. Factors Influencing WTP for HEDM.

Danso et al., 2017	Kurwону et al., 2017	Danso et al., 2006	Agyekum et al., 2014	Hong et al., 2017
† Price (–)	† Unit cost of current fertilizer (+)		† Price (+)	† Bid coefficient (–)
† Fortification (–)	† Household head (+)		† Packaging (+)	
† Certification (+)	Own land		Labeling	
† Pelletization (+)	No of 50 kg	† Location (+)		Farm size
† Gender (+/–)	Gender	Gender	† Gender (+)	Gender
	Age (years)	† Age (years) (+/–)	† Age (years) (–)	Age (years)
† Household size (+)	† Household size (+)	HH dependency	† Household size (+)	Household size
† Education (–)	Education	† Education (+/–)	† Education (–)	Education
† Experience (+/–)	Experience	† Experience (+)	Experience	† Experience (+)
	Farm income	† Farm income (–)	† Disposable income (+)	† Household income (+)
† Religion (+/–)	Awareness		† Awareness (+)	† Awareness (+)
Farm size	Farm size [†]			† Training (+)
† Product quality (+/–) perception	† Used Organic (–)	† Soil input (+/–)		
† Water holding capacity (+/–)	FBO member			
† Product reservation perception (+/–)		† Perception (+/–)		
† Product use perception (+)				

[†] significant effect of WTP (+ or – sign indicates the direction of the relationship and +/- indicates negative or positive effect depending on which attribute was interacted with.

In the three studies that used the CVM method, the effects of the socioeconomic and demographic factors are straightforward as there are no interaction terms. While two studies found no effect of income on WTP [64,68], the other study reported a positive effect of income on WTP [48]. The effect of education was also not significant in the two studies [64,68], but was reported to have a positive effect in Kumasi and a negative effect in Tamale in Ghana. Experience had a positive effect in the two studies [48,64], but no effect in another study [64]. Awareness had a positive effect on the WTP for packaging [65] in Tamale but no effect in Kumasi and Accra [48] and Ghana [64].

4. Discussion

4.1. *Why do We Know So Much and Yet So Little about the Market Demand for HEDM?*

Incubation studies, tunnel experiments, and field trials have demonstrated positive impacts of HEDM on soil physio-chemical properties and crop productivity [36]. Specific findings from long-term agronomic trials demonstrate significant nutrient recovery, of phosphorus in particular, compared to its recovery from cattle manure and conventional fertilizers [34,35]. Other experiments show improvement in soil physical and chemical properties [31] and a considerable reduction in greenhouse gas emissions [37]. For these and many other reasons (such as rapid urbanization, population growth, and nutrient mining), there has been a recent shift in scientific research towards understanding and development of technologies to safely recover socially acceptable and stabilized material from human excreta waste streams for agricultural use [31]. The technologies range from those developed for the safe recovery of agricultural products from human excreta: struvite precipitation and nitrified urine concentrate [45]; biochar pyrolysis [75–77]; residue derived from black soldier fly larva [78–81]; latrine dehydration and pasteurization [46,47]; composting, co-composting and vermicomposting [43,82–86].

The pathways and processes for the safe recovery of micronutrients and macronutrients for use in agriculture have been extensively discussed in the literature focusing on the elimination of organic pollutants and heavy metals [38–40], technology maturity and potential for wide-scale commercialization [41–43,87,88]. The chemical extraction of P from incineration ash using phosphoric acid (RecoPhos[®]) and the P precipitation/crystallization of digester supernatant (AirPrex[®] and Ostara[®]) and co-composting are among the full-scale and mature technologies with the highest readiness level [38,41,43]. Although composting has been identified as a low-cost technology [89], evidence from Northern Europe shows contradicting results with farmers citing market, financial, institutional, technological, and behavioral factors as potential barriers to wide-scale acceptance of composting [90].

The concerns about product homogeneity and quality, especially heavy metals and organic pollutants, can potentially reduce the market demand and acceptance of the products. The use of urine derived from source-separated sanitation technologies eliminates pathogen, heavy metal, and organic pollutant concerns in the end-product. The SaNiPhos[®] in the Netherlands, for instance, uses source-separated urine to commercially produce struvite and ammonium sulfate at full scale [44]. The partnership between SaNiPhos[®] and the MSD pharmaceutical company, albeit at the pilot level, has seen the recovery of the hormones for use in developing fertility medicines [91].

The scoping review of the literature at the time of this writing shows that 22 studies have been published to understand the attitudes and perceptions of farmers on the HEDM for use in agriculture [88,92–98]. These studies reported health risk perception as the main barrier to the use of HEDM in agriculture [95,99–104]. The cost-effectiveness of HEDM for use in agriculture has also been empirically demonstrated in the literature [105].

With so much known about HEDM, one wonders why there are only five published studies on estimating the market demand for human excreta in peer-reviewed journals. The ‘peak phosphorus’ phenomenon, where phosphorus is rapidly approaching global economic depletion, shows the importance of incorporating the demand for recycled fertilizer options into product development. Understanding factors that influence how much farmers are willing to pay and accurately estimating

the amount they are willing to pay may provide the vital information required to put HEDM on the market. We suggest that the product heterogeneity resulting from the nascence of the commercialization of HEDM and the infancy of the regulatory environment may explain this dearth of information in scientific/academic publications. However, while the technologies to recover a more consistent product are being explored, it is imperative to explore the market demand if the green fertilizers and other HEDM are to cross the ‘innovation chasm’ or what is often stylized as ‘bridging the valley of death’ [106,107]. We discuss these among other issues hindering wide-scale commercialization in the following sections.

4.2. Product Attributes

The product attributes that have been suggested in the two studies that used CE to elicit farmers’ WTP for HEDM include pelletization, fortification, labeling, packaging, and certification, which should be considered strongly in product development. Pelletization is an attribute that improves the product structure while making it easy to apply HEDM in the crop field [49]. Fortification with other HEDM such as struvite, urine, and inorganic fertilizer may increase the competitiveness of the product on the market by reducing its bulkiness while adding to its value. A combination of fast- and slow-release nutrients can be added to the soil while improving the soil organic matter content. Packaging and labeling are essential for ease of handling and may provide an opportunity to specify information such as the composition of nutrients and application rates [65]. It is highly recommended that the labeling and packaging of HEDM should follow the country-specific legislation and regulations, including global policies where export markets are the target.

The results of the five reviewed studies show that the WTP for the attributes covers the cost of production, which presents a significant opportunity for product design, placement, and marketing of HEDM. However, this depends so much on the creation of an enabling regulatory environment. A review of the legislation regulating the use of HEDM shows that the United States legislation is guided by Part 503 of the Environment Protection Agency (EPA) under Section 405 of the Clean Water Act [108]. In Europe, the Fertilisers Regulation, Reg. (EC) 2003/2003, and the Animal Byproducts Regulation (ABP), Reg. (EC) 1069/2009 guide the use of sludge as fertilizer [109]. Additional clearance is required for use as organic fertilizer under the Organic Products Regulation, Reg. (EC) 834/2007 [110], and the production, labeling, and control of organic products, Reg. (EC) 889/2008 [111] while the Sewage Sludge Directive Dir. 86/278/EEC [112] regulates sewage sludge. Harmonization of fragmented policies to include all fertilizer categories such as HEDM for EC certification and generic rather than the piecemeal application of mutual recognition could offer an excellent enabling policy environment for commercialization and product standardization within the European market. However, current legislation on the EC status does not have provisions for waste-derived material as fertilizer source as well as heavy metal limits for HEDM [113]. Compost and other materials from waste streams do not need registration according to the European Chemicals Regulation (REACH; Reg. 1907/2006) [113].

In South Africa, the Department of Water and Sanitation regulates treatment and application of sludge on agricultural land in consultation with various departments such as the Department of Environmental Affairs) (e.g., Act No. 39 of 2004), the Department of Agriculture, Forestry and Fisheries (DAFF) (e.g., Act No. 36 of 1947) and the Department of Health (e.g., Act No. 85 of 1993) [114]. A positive environmental impact assessment (Record of Decision) from the Department of Environmental Affairs is required for the Department of Water and Sanitation to issue a license [115]. In terms of Act 36 of 1947, sludge can be classified as an organic fertilizer [115]. The Act 36 of 1947, however, prohibits the use of insect-processed animal protein (PAP) as animal feeds intended for commercial purposes [114]. Use of PAP in aquaculture is allowed in North Korea and Europe while use in poultry is allowed in Canada and also considered as animal feed in South Korea and the United States [116,117]. The Global Good Agricultural Practice (GAP) also limits the commercialization of the use of human excreta on certified farms for horticultural exporters [118]. The specifications of the Global GAP create a barrier for the use of

HEDM among horticultural exporters in Kenya [87,119]. In most countries where legislation and policies are missing, the global good agricultural practices take precedence to local legislations.

Transportation costs [49] and financial support [120] are among the other factors that can limit the commercialization and scaling-up of HEDM. Conditional cash transfers as financial incentives can potentially increase the bulking of treatment material to reduce collection logistics, although designing effective payment vehicles with minimum regressive welfare distribution is still a question for empirical and development research in recycling systems [121]. Using clustered or nucleated settlements and densely populated centers such as shopping centers, hospitals, and universities for on-site treatment centers can potentially cut transport costs while ensuring consistent availability of raw materials. However, this remains an area for future research. Inclusive business models such as the community-based approaches to total sanitation and community-led total sanitation may have the potential to achieve both waste management, resource recovery, and sanitation provision objectives [122]. Examples include the Menengai Waste Recycling Management Group, Nakuru Waste Collectors and Recyclers Management Cooperative Society in Kenya [33,123], the Sustainable Organic Integrated Livelihoods in Haiti, the X-Runner in Peru, and the Clean Team in Ghana and SANERGY in Kenya [18].

4.3. Best Practice for Conducting Stated Preference Studies

The results of the studies show that there is indeed a high demand for HEDM by the farmers. However, the WTP estimates differed from one study to another, and the factors influencing WTP showed inconclusive results as they also differed from one study to another. The study results did not show consensus on the significance, direction, and magnitude of factors influencing WTP, such as socioeconomic and demographic factors. This study proposes possible explanations for this outcome. Various efforts have been made in the literature to raise the quality and promote best practices of stated preference studies [124,125]. In more recent work, several recommendations have been proposed and grouped into several categories, namely: survey development and implementation, value elicitation, data analysis, validity assessment, and study reporting [124]. The goal of survey development and implementation is and should be to maximize the validity and reliability of parameter estimates. The pretesting of survey instruments is critical for content validity. However, the decision to choose between the attribute or non-attribute approaches depends on the type of goods or policy being evaluated [124].

The validity and reliability of the data collection instruments were not reported in any of the studies. In conducting cross-sectional studies, it is crucial to ensure that the survey instruments are valid and reliable. Different types of validity exist in the literature (such as face, content, construct, and criterion validity) [74]. Subjecting survey instruments to pilot studies and then testing validity using either the Cohen's kappa index, Lawshe's content validity ratio, factor analysis, and expert opinions may allow for more valid survey tools [74]. Reliability, on the other hand, may also be measured using Cronbach's alpha in exploratory analysis before conducting a survey. The validity of choice experiments can be enhanced by accurate attribute framing, through the provision of information cues, varying monetary attributes, consultation with key informants, such as scientists, policymakers, and through conducting focus group discussions [126].

The design of the choice experiment is also critical in stated preference approaches. Experimental designs need to be explicit regarding the statistical power [73], information order or scope effects in CV [127], attribute nonattendance [128,129], omitted attributes, bid amount effects, and the effects of the selected optimization criteria [124]. Regarding statistical power, none of the included studies included a formal calculation of sample size or power test. The standard rules for sample size calculation consider the number of choice tasks, alternatives, and the largest number of levels for main effects and product of any two attributes [70,71]. Researchers may also use the rule of thumb of over 100 respondents for choice experiment surveys [72]. The number of choice tasks can also be formally calculated as the minimum number divisible by all the attribute levels [130].

The welfare measure to use between the equivalence variation and the compensating variation is tantamount to the willingness to accept and willingness to pay for welfare changes [131,132]. The selection of welfare measures should be considered taking cognizance of the underlying theoretical approach and the empirical difficulties associated with the willingness to accept or pay [124]. Other recommendations include the response options in a CV payment vehicle and how the study makes use of various design elements and auxiliary questions to increase and evaluate the validity, such as the use of cheap talk scripts and certainty scales to improve incentive compatibility and consequentiality [124]. As such, elicitation methods should minimize strategic responses and inconsistent response behaviors. Incentive compatibility theoretically pushes the respondent to truthfully reveal their preference as the dominant strategy [133,134]. Design elements such as the randomization of questions order across respondents, task complexity, and sequencing effects, for instance, scope effects and use of visible choice sets, may improve the validity of the studies.

Researchers conducting choice experiments need to make assumptions about the decision makers' behavior, and as such, utility-maximizing behavior that is generated from random utility maximization models is commonly assumed to reflect this behavior [135]. The included studies used orthogonal fractional factorial designs, which have the advantage of producing unconfounded estimates because of the enforced statistical attribute independence of the design [136]. However, in practice, socioeconomic and demographic variables may exhibit some correlation with the main effects, as seen when examining the asymptotic variance-covariance design matrix. Correlations may also occur between socioeconomic and demographic variables and attributes as they do not vary across individuals [137]. There may also exist unrealistic and behaviorally implausible choice tasks, where new information may not be gained. The non-linearity of choice models and cognitive burden (task complexity) may also arise from having too many choice sets per respondent [137].

Full factorial designs used in the studies included are entirely orthogonal in both the main and higher-order interactions. Fractional factorial designs assume that the preference distribution is identically and independently distributed (IID), and that higher-order interactions are zero and that there is attribute-level balance [138,139]. Orthogonal designs also make an additional assumption that there is no confounding, and therefore, the main effects can be determined stochastically and independently. This assumption is called the independence of irrelevant alternatives (IIA). The assumptions of orthogonality fail to fulfill this linear independence assumption for nonlinear discrete choice models. As a result, desirable design properties such as statistical efficiency, utility balance, attribute balance, task complexity, and response efficiency are sought after in trying to maximize the information gained from each choice made by the respondent. [130]. Optimal designs help to achieve this by maximizing the negative inverse of the Fisher information matrix (calculated as the second derivative of the log-likelihood function) which is the covariance matrix of the parameter estimates [137].

The Fisher information is applied to experimental design because of its reciprocity with the asymptotic variance-covariance matrix. Maximizing the Fisher information (dispersion matrix) is equivalent to minimizing the variance or confounding. A statistically efficient design, therefore, produces smaller confidence ellipsoids around the parameter estimates for a given sample size. Minimizing the D-error can be achieved using several algorithms, for instance, the classical Fedorov algorithm or its modification. The information matrix, however, relies on the parameter distribution of the assumed model. Therefore, the efficiency of the model to be estimated depends on the accuracy of information priors using Bayesian efficient designs [140,141]. The research evidence in this area concludes that efficient design may outperform both orthogonal and D-optimal designs [130,141,142], albeit with sensitivity to the specification of the prior distribution. The guidelines on specifying priors include literature reviews, expert judgment, context analysis, focus group discussions, and pilot surveys [130,143].

None of the included studies discussed the bias that might result from choice inconsistency. The most common definition of choice consistency in the DCE literature is to make identical choices when faced with identical choice tasks as opined in the axioms for revealed preference [136]. Non-satiation is essential for removing circular indifference curves, which indeed may be rational

for certain bundles with bliss points [136]. The satisfaction of the non-satiation or dominance axiom of revealed preference, however, is not crucial for rationality according to economic theory. Tests for non-satiation in DCEs involve investigating whether individuals chose dominated options [136]. When dealing with lexicographic preferences, non-satiation or attribute dominance, the researcher must decide on the theoretical approach on which to explain the respondent's choice rule. Lexicographic preferences satisfy the axioms of the preference-based consumer theory, namely, completeness, transitivity, strong monotonicity, and strict convexity. However, such preference patterns fail to satisfy the continuity assumption, which is essential for the existence of utility functions [136]. Researchers should, therefore, be cautious when concluding the irrationality of lexicographic choice rules as what may appear irrational using the standard preference-based approaches could be explained as rational using an alternative approach to consumer theory, such as the theories of choice under uncertainty.

Lancsar and Louviere (2006) also noted that the use of fractional factorial designs and linearly additive utility functions, or orthogonal main effects only designs might prevent studies from observing a full pattern of responses that would be possible with a full factorial design. This may label some decision rules as irrational when there are no full degrees of freedom to conclude the presence of dominance and lexicographic preferences [136]. The fact that the choice tasks are repeated in choice experiments means that respondents can learn through institutional learning or reconsider initial choices through value learning, which can magnify the scale parameters [144,145]. Throwing away such observations may reduce the degrees of freedom required to accurately estimate parameters for a given sample size [136]. However, such behavior may be rational and accurately captured in the random utility error term based on random utility theory [136,146].

The studies used different elicitation methods, which may potentially lead to different conclusions. The choice of the correct elicitation method between CVM and CE has raised debate over the past few decades [147–150]. The models used in the analysis may also differ depending on the type of data and research objectives. While the CVM estimates the WTP of moving from one holistic non-marketed good to a new alternative by altering the attributes, CE approaches attach the value of individual attributes by providing different options, altering the number of attributes and levels within each bundle which is not possible in CVM [149]. Moreover, including the price attribute in different choice sets helps to estimate how much value people attach to each attribute level [149]. However, the use of CVM to elicit WTP has been found to have a practical advantage of reducing cognitive burden primarily where a large number of attributes and levels are used to achieve design efficiency, which is often the case with most CE methods [151]. The CE estimates are also sensitive to the nature of the study design, choice of attributes, number of attribute levels, and the method of representing choices to participants [151].

A systematic review of the literature in the fields of environmental, health, and agricultural economics showed that CE methods have become more popular than CVM [148]. Although the overall objective is the same, CE presents several advantages over CVM, which has led to its growing popularity. The first and apparent reason is that it allows for the estimation of both mean WTP and marginal WTP for different attributes [148]. The CE methodology also reduces ethical protesting and strategic response when compared to CVM while providing information that allows for an in-depth understanding of trade-offs between attributes [151,152]. While CVM is suited for the overall holistic policy or product package, the CE approach is more suited to cases where individual attributes make up the product [149]. The CVM and CE welfare estimates have been analyzed in the literature [148], [149,151]. The CE method has been found to perform better than CVM in terms of precision of welfare estimates as measured by error variance of parameter estimates relative to the mean [152].

Lastly, the choice and specification of the empirical models also varied from one study to the other. Focusing the attention on the CE studies, the conditional logit model, random parameters model, and latent class model were used to estimate WTP for HEDM. Agyekum et al. [65] employed the basic and hybrid conditional logit model, which does not incorporate preference and scale heterogeneity. The conditional logit model assumes that the error terms are independently and

identically distributed (IID) and that preferences are homogeneous, leading to independence of irrelevant alternatives (IIA) assumption [49,153]. Under real-world situations, preferences or tastes for observed attributes do vary from farmer to farmer. Danso et al. [49] applied the mixed logit or RPL models, which relaxes this assumption and allows for correlation induced by the scale and behavioral heterogeneity. However, the source of this heterogeneity (tastes and scale) is empirically impossible to disentangle with the RPL model [154]. Running a restricted generalized multinomial logit (GMNL) and the RPL may allow the researchers to make a nearly weak conclusion about the structure of heterogeneity. It is, therefore, advisable to use WTP-space models when estimating welfare estimates, which provides a way of directly estimating WTP without imposing normal distribution assumptions on the price coefficient [154].

4.4. Implications for Policy-Making and Development Practice

While the importance of accurately estimating WTP has been clarified in this short review, the evaluation of development initiatives in developing countries has taken a different approach. The precision of WTP estimates is demanded when performing project evaluation procedures such as cost-benefit analysis and other related welfare analysis. The standard in most project evaluation procedures in developing countries has been to avoid conducting WTP studies. The possible reasons for this practice include the monetary costs of conducting such studies and both the seemingly pedantic nature, empirical demands, and the level of expertise required to apply the best practice when conducting WTP studies, including those explained in this review. There has been a general inclination towards the benefit-transfer approach whenever attempts are made to incorporate non-market social and environmental impacts in project evaluation. The social/environmental cost-benefit analysis often used in project evaluation is sensitive to the accuracy of the WTP estimates used when calculating the gross value-added of a development initiative or project. The metrics used, namely, the net present values, benefit-cost ratios, modified internal rate of return, and the economic rate of return, are sensitive to the accuracy of the WTP estimates or other inferred alternatives from the benefit transfer approach. Regardless of whichever value is used, it is essential to consider incorporating social and environmental gains from recovery and reuse initiatives in cost-benefit analysis of development initiatives. Some circular economy initiatives may appear not feasible financially but could justify 'viability gap funding' when social and environmental benefits are incorporated in feasibility studies.

It is very crucial to understand how the recovery of human excreta for agricultural use links with the current nexus thinking, especially during implementing on-the-ground project initiatives in developing countries. The human excreta-agriculture-development nexus thinking allows for the co-optimization of sanitation initiatives by cheaply recovering agricultural products from human excreta that would otherwise be left to pollute the environment [155]. There is also an increase in agricultural production either from using cheaper fertilizer alternatives such as human excreta-derived material, improved soil physical and chemical properties, that in turn increase soil-water productivity. Recovery and reuse of human excreta (including wastewater) in agriculture is at the center of the water-energy-food nexus and the water-soil-waste nexus, which addresses the linkages between the environmental resources to address sustainable management [155]. The water-energy-food nexus aims to reduce trade-offs and create synergies, increase water, energy, and food security, sustain ecosystem services, combat resource scarcity, and reduce poverty through enhanced policy coherence. The water-energy-food nexus approach also provides an integrated framework for dealing with complex natural and human systems [156]. The nexus approach, thus, provides a cross-sectoral conceptual and analytical framework for sustainable management of scarce resources in light of complex challenges posed by rapid population growth, climate change, and land degradation [157]. The cross-sectoral approach, therefore, helps to manage and mitigate complex cross-sectoral trade-offs and synergies that were otherwise difficult to solve using sectoral approaches [158]. Recent interest in the approach has been suggested to result from the adverse effects of climate change on water-energy-food security, its transdisciplinary approach, and the recent emphasis on sustainability especially waste reuse [159].

The expansion of the water-energy-food nexus to incorporate the 3R (reduce, reuse, and recycle or resource, recovery, and reuse) concepts is in sync with the transition towards a circular economy [160]. The circular economy allows for more integrated resource management as it balances both economic development and environmental protection. Adding the waste or material flow component to the water-energy-food nexus has very significant effects on food production through nutrient recycling, water harvesting to recharge aquifers, and recovery of renewable energy from biomass, while reducing natural resource depletion [161]. The water-soil-waste nexus adds the waste dimension to increase resource effectiveness and efficiency by moving from a sectoral to a resource-based approach [155]. Increased resource-use efficiency can improve crop yields from the use of human excreta-derived material and water efficiency through recovery and reuse of wastewater for irrigation. Indirect socio-economic and developmental benefits include improved food security, energy security, and public health. Environmental gains may also occur from recovery and reuse of human excreta by extending the lifetime of landfills, thereby sustaining the waste-sink ecosystem services. Extending the lifespan of landfills may also save costs for the local municipalities in developing countries that currently face substantial budgetary constraints and sanitation backlogs. Other indirect benefits include reduced greenhouse gas emissions, such as methane and carbon dioxide.

To strengthen and sustain the livelihoods of the communities, especially in developing countries, therefore, requires integrated approaches that incorporate green-nexus-circular thinking and indigenous knowledge systems to contextualize development initiatives. Appreciating the micro-diversity, idiosyncrasies, and uniqueness of local elements by understanding the indigenous knowledge systems is imperative for adaptation [162]. The rationale behind this thinking rests on the complexity of the rural livelihood strategies and the importance of adaptive project management. Community-based adaptation is one such integrated approach that focuses on socio-economic and political dimensions of poverty and vulnerability, including the physical dimension of climate risks [163]. Community-based adaptation considers climate risk among a range of physical and socio-economic challenges that communities face to inform interventions. By doing so, the community-based adaptation simultaneously factors in both socio-economic and environmental drivers by incorporating an element of 'deliberate social learning' from both the community, scientific, and development practitioners to enhance risk assessment and upscaling of interventions while challenging the traditional top-down approach [163]. The implementation of the community-based adaptation approach requires an understanding of what adaptive entails, especially in the context of project management in developing countries. This study recommends that circular nutrient economy initiatives be conceptualized and implemented within transdisciplinary and related frameworks such as the nexus thinking, the green village concept, and other cross-sectoral integrated resource management frameworks. Investing in initiatives that promote social acceptance while promoting an enabling policy environment for circular economy initiatives remains a crucial area for future research and policymaking.

5. Limitations and Future Research Directions

While this study provides pertinent information on understanding the demand for HEDM by farmers, there are a few caveats that need to be mentioned. Firstly, to offer quality checks, we limited this review to only published peer-reviewed studies. Thus, some vital information found in grey literature, which includes academic theses, project reports, and conference proceedings, may have been excluded. Secondly, this review was limited to articles published in the English language and excluded other peer-reviewed articles published in other languages. Therefore, the assumption drawn from this study is that a similar publication trend exists in all the other languages. Thirdly, there were only five published articles on WTP for HEDM. A clearer picture would have been drawn if more studies had been conducted in this research area. Future research should consider results from this review as an essential point of departure for conducting further empirical studies in this area.

This study confirmed that the market demand segment of the recovery and reuse of human excreta-derived material is a nascent but important area of research. The findings of this review are not

surprising, given the technocentric nature of this research area. Most circular economy research, in general, focuses on the production/supply side with little attention paid to the demand side. The lack of understanding of the consumption patterns, the social dimensions of end-users, and how they can be transformed is one of the barriers to the success of most circular economy projects [120]. The demonstration of the knowledge, attitudes, and perceptions of farmers is imperative for the social acceptance of the new fertilizer alternatives given their contextual differences. However, even more critical is establishing the monetary value that farmers attach to pertinent attributes of the human waste-derived products to evaluate whether the estimated price covers the cost of providing the product in its acceptable form.

The findings of this study also demonstrate the contextual differences in the results of the included articles, especially the effects of socio-economic, cultural, and religious factors on the value that farmers attach to the attributes of human excreta-derived products. It is, therefore, difficult to draw conclusive evidence from the included studies due to the dearth of published research in this area. Alternatively, the inconsistency in the results could be a result of the different methodological approaches implemented by the five studies, as discussed in the sections above. The different conclusions drawn from the studies included in this review may also reflect contextual differences. The latter point may justify the importance of conducting WTP studies whenever estimates are required for decision-making and evaluation procedures. Thus, reliance on the benefit-transfer approach in such instances may provide misleading results and misguided decision making. More importantly, the findings of this review demonstrate that farmers are willing to pay for the new fertilizer alternatives derived from human excreta. The differences in the WTP estimates and factors influencing WTP remain an important area for future research to validate the findings of this review. Improving the methodological approaches using best practice for conducting willingness to pay studies in future research may help to draw conclusive evidence on the WTP estimates and the factors affecting the willingness to pay for human excreta-derived material in agriculture.

6. Conclusions

This review synthesized knowledge on the extent of published research evidence on farmers' WTP for HEDM. The results of this study show that the area of understanding WTP for HEDM is a very nascent research area. While many studies have been conducted on HEDM, little is known about its demand and farmers' willingness to pay. More research should be conducted in this research area. While this review provided useful information on the factors influencing WTP for HEDM, several methodological issues were identified. These include failure of included studies to check data collection instruments for validity and reliability, model selection considering the scale, and taste heterogeneity, among other issues. Incorporating these issues may provide more accurate estimates while providing more consistent information on the direction and magnitude of factors influencing WTP for HEDM.

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