Research Paper

The cultural economy of human waste reuse: perspectives from peri-urban Karnataka, India

Zachary Burt, C. S. Sharada Prasad, Pay Drechsel and Isha Ray

ABSTRACT

Safely managed waste reuse may be a sustainable way to protect human health and livelihoods in agrarian-based countries without adequate sewerage. The safe recovery and reuse of fecal sludge-derived fertilizer (FSF) has become an important policy discussion in low-income economies as a way to manage urban sanitation to benefit peri-urban agriculture. But what drives the user acceptance of composted fecal sludge? We develop a preference-ranking model to understand the attributes of FSF that contribute to its acceptance in Karnataka, India. We use this traditionally economic modeling method to uncover cultural practices and power disparities underlying the waste economy. We model farmowners and farmworkers separately, as the choice to use FSF as an employer versus as an employee is fundamentally different. We find that farmers who are willing to use FSF prefer to conceal its origins from their workers and from their own caste group. This is particularly the case for caste-adhering, vegetarian farmowners. We find that workers are open to using FSF if its attributes resemble cow manure, which they are comfortable handling. The waste economy in rural India remains shaped by caste hierarchies and practices, but these remain unacknowledged in policies promoting sustainable 'business' models for safe reuse. Current efforts under consideration toward formalizing the reuse sector should explicitly acknowledge caste practices in the waste economy, or they may perpetuate the size and scope of the caste-based informal sector.

Key words | caste, fecal sludge, human waste management, preference model, resource recovery and reuse

HIGHLIGHTS

- A discrete choice method is used to uncover preferences and power disparities in the Indian human waste economy.
- Caste-adhering, vegetarian farmowners prefer to conceal the origins of fecal sludge-derived fertilizer (FSF).
- Most workers are open to using FSF if it is dry and not malodorous.
- The formalization of fecal sludge reuse could inadvertently perpetuate caste-based disparities and unsafe waste handling.

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GRAPHICAL ABSTRACT

INTRODUCTION

Safe fecal sludge (FS) management is a necessity for 1.8 billion people in low- and middle-income countries (LMICs) that depend on septic tanks and pits for their sanitation needs (Berendes *et al.* 2017). These systems accumulate FS, which needs to be collected, transported, treated, and disposed of safely. If treated to the necessary standards, FS can be reused as a source of energy and/or nutrients in agriculture instead of being disposed of as waste. At the same time, unregulated reuse carries many risks, such as endangering public health through inadequate safeguards, endangering worker health, and reinforcing the social stigmas associated with the work of human waste management.

In this paper, we estimate the factors influencing the latent demand for FS fertilizer (FSF) among farmowners and farmworkers in Karnataka, India - a significantly agriculture-based country that has made great progress with respect to latrine coverage but much less so with respect to post-latrine waste management (Coffey & Spears 2017; WHO/UNICEF/JMP 2017). In 2017, 93.7% of urban households in India had access to a latrine (WHO/UNICEF/JMP 2017). About half of all urban toilets are connected to a soak pit or a septic tank; however, as of 2019, out of 9,391 towns and cities in India, only 30 have functional FS treatment plants (Rao *et al.* 2020).

The term FSF usually refers to FS that has been treated for safe reuse as fertilizer or other uses. However, there are no studies that have tested the extent to which the FSF available at our study sites were fully or only partially composted; therefore, we use the term FSF to mean at least partially treated waste. Any mention of FS refers to untreated waste. The local term for treated or untreated human waste is *bhangi gobbara*. *Bhangi* is a derogatory term used for a subcommunity among Dalits who occupy the lowest rungs of the Hindu caste ladder. We repudiate the use of derogatory labels for any community, and we use the term in this paper only to reflect the ground realities of FS reuse and, by association, of sanitation work in India.

The literature on safe sanitation and sustainable agriculture has argued that FS should be managed as a resource rather than as waste (Keraita *et al.* 2008; Nikiema *et al.* 2014). The reuse of (treated) human manure for agriculture is actively being debated in India. Researchers have argued that productive waste reuse can generate revenues to partially recover the cost of waste collection and treatment (e.g. Murray & Ray 2010; Nikiema *et al.* 2014). Others have developed innovative business models for waste collection, treatment, and reuse for agriculture or fuels, with estimated demand scenarios and stated willingness-to-pay studies (e.g. Danso *et al.* 2017). For any business models and reuse recommendations to be implemented, however, more needs to be understood about the

preferences, priorities and social relationships that could drive demand for treated FSF. Here, we address this question using qualitative interviews with farmers in Karnataka, and a discrete choice preference-ranking model guided by these interviews.

Reusing human waste in India, a society rooted in a slowly changing caste-based hierarchy comes with special significance attached to those who handle human waste (Teltumbde 2014; Gatade 2015a). Within the caste system, purity and pollution are often defined by scripted and inherited occupations that disallow (or demand) contact with fecal waste (Douglas 1966; Guru 2018). Human waste is handled exclusively by a subsection of Dalits, who occupy the lowest rungs of the Hindu caste ladder, and who are still treated as untouchables by many (Doron & Raja 2015; Coffey *et al.* 2017), though the practice of untouchability is punishable by law. Thus, FS reuse without any social reform may reinforce stigmas and stereotypes associated with caste-related 'untouchability'. Understanding how handling treated waste might exacerbate social exclusion and health disparities needs to become a central part of the discussion on whether and how FS reuse in India should be formalized, regulated, and scaled up. Understanding if and when farm laborers would accept working with human waste, and whether they even have any choice in the matter, is important for workers' health and dignity.

Because concepts of purity and pollution form a central part of Hindu religious beliefs and many elements of the caste system, any comprehensive discussion of FS reuse in India must engage with both ancient systems of oppression and modern efforts toward sustainable agriculture. The objective of our study is therefore to estimate farmowners' preferences for, and to gauge farmworkers' willingness to work with, FSF. If reuse becomes an official policy, composted FSF is the most likely treatment process to be used, since it can provide effective treatment while retaining the chemical components and structural integrity most prized by farmers. In addition to using discrete choice modeling to rank farmowner and farmworker preferences, we use these models to infer the influence of social pressures, caste-adherence, and truth in advertising on the use of FSF.

BACKGROUND

The use of human excreta as fertilizer is an age-old tradition (WHO 2006). Economically developed countries have largely disallowed the practice of using untreated or partially treated human waste in agriculture. In contrast, the reuse of untreated human waste, and specifically wastewater, in LMICs has flourished. Farmers in many countries continue to use wastewater as a source of water and nutrients (Radcliffe 2004). In addition, onsite sanitation systems, in which the toilet empties into a soak pit or septic tank, have grown rapidly in India. As manual emptying has declined as a practice, urban pits and septic tanks are increasingly serviced by vacuum trucks attached to a pump and hose (Van Dijk *et al.* 2014; O'Keefe *et al.* 2015; Sharada Prasad & Ray 2019). These trucks look for places where the sludge can be quickly offloaded, legally or illegally, with the goal of optimizing the number of loads and revenues. They have thus become a new pathway for the old practice of moving human waste from the cities to farmlands to be used as fertilizer.

Research to understand the perceptions of farmers with respect to FS reuse is small but growing. A study from Vietnam found that farmers were enthusiastic about composted FSF if the product was dry and not malodorous (Jensen *et al.* 2008). A study in Ghana on the perceptions of households (but not farmers) toward human excreta as fertilizer found that most respondents thought that fresh excreta should not be reused (Mariwah & Drangert 2011), while farmers across Africa's regions or Sri Lanka reported positive attitudes toward using composted FSF (Cofie *et al.* 2005; Buit & Jansen 2016; Danso *et al.* 2017; Waidyarathne *et al.* 2018; Moya *et al.* 2019).

The reuse of human excreta in irrigation with at best partially treated, diluted wastewater has been estimated at up to 9 million ha in India (Thebo *et al.* 2017). The use of untreated FS is also prevalent, largely through unregulated and informal channels. Aside from the reuse of raw sludge delivered from septic tanks, several FSF entrepreneurs are in business, selling fully or partially composted waste to those farmers who accept its reuse. One recent study on farmers' attitudes toward human waste-based fertilizer products in South India found that more farmers were

receptive to urine reuse over FS reuse (Simha *et al.* 2017). Without treatment and safety regulations, however, informal reuse occurs in the shadows and remains risky for the health of farmers and the environment.

We chose two cities in the state of Karnataka to understand current FS reuse in agriculture: Dharwad (pop: half-million in 2011) and Bangalore (pop: >8 million in 2011). We chose these cities because they both had systems for FSF reuse in their rural periphery, and a significant proportion of their urban populations used onsite systems. In the rest of this paper, we present our exploratory findings on the status of FS reuse in peri-urban Karnataka and on farmowners' and farmworkers' attitudes toward the use of treated human waste-based fertilizers. We conclude with the policy implications of these findings.

METHODS

Initial interviews

We conducted our initial interviews to understand how and where FS reuse (raw or treated) was or was not taking place, and what farmowners' and farmworkers' perceptions of (at least partially treated) FSF might be. These interviews informed our later data collection efforts and helped us to design our stated preference survey. We interviewed 23 farmowners and 38 farmworkers from seven villages surrounding Dharwad and Bangalore. Additionally, we conducted two group interviews with farmowners and three group interviews with farmworkers, all in places at which farmers and farmworkers regularly congregated. As these interviews were, in effect, focus group discussions, their analysis is of a qualitative nature.

Apart from farmowners and workers, two sludge-selling entrepreneurs and seven truck operators who release waste onto farmlands were also interviewed. On 12 occasions, truck operators were accompanied in the act of collecting, transporting, and disposing of FS. The first author also visited farms to observe how the sludge was discharged, stored or applied to farmlands, and the behavior of farmworkers during work, meals, and rest breaks. Taken together, these interviews and observations helped us to understand the practices of and around FS reuse in peri-urban Karnataka, and acted as pilots for the surveys we designed to estimate willingness to use, and to work with, FSF.

Stated preference surveys

To more precisely estimate farmers' perceptions of using FS and gauge farmworkers' willingness to work with FSF, we conducted two stated preference studies, one that looked at farmowner willingness to pay and the other at farmworker willingness to use. To identify and recruit farmowners, we worked from a list from the Revenue Office in Dharwad. Our exploratory work (see the 'Results' section below) had shown that small farmers with the land area under an acre showed no interest in using FSF, so farmers with <1 acre were taken off the list. The final list was stratified by the size of landholding, and each stratum was randomly sampled to arrive at a weighted sample with one-third of all the small farmers, half of all the medium farmers, and two-thirds of the large farmers (>10 acres) in each village; this yielded roughly the same proportion as exists in the larger population of farmers. To identify and recruit farmworkers, we visited the neighborhoods where the workers generally lived. We built up the farmworker sample through snowball sampling; once a farmworker was identified, he or she guided our enumerators to other workers in the village. Snowball sampling carries a risk of selection bias, but this was the only feasible option without a pre-existing sampling frame. Our final sample consisted of 2,306 farmowners and 839 farmworkers.

The stated preference surveys were designed as discrete choice instruments, following established methods in the field (Whittington 1998; Gunatilake *et al.* 2007; Train 2009). Guided by our interviews with farmers, workers, and the two entrepreneurs, we identified six key attributes of FSF: Label, Smell, Health, Wetness, Texture, and Price of the fertilizer (or daily wages for workers, to understand whether they would be more open to using FSF if they were paid more). Each attribute, other than Price, had two levels, one with higher utility than the other. For example, many farmowners believed that packing FSF in bags labeled 'organic' would encourage their workers to handle FSF, whereas labeling it *bhangi gobbara* (or some synonym thereof) would discourage them. Therefore, we had two levels for the attribute Label; both said 'organic manure' but one also said

'bhangi gobbara'. Our choice instrument included two levels (present and absent) for the attribute Smell and two levels (wet and dry) for Wetness (see Supplementary Table S1 and Figure S1 for the full list). The choices also included either cow manure or chemical fertilizers as non-FSF options. Of the 2,306 farmowners, 1,807 completed the entire survey; of the 839 workers, 674 completed it.

We collected separate data (and estimated separate models) for owners and workers because the choice to buy FSF is fundamentally different from the choice to sell one's labor and be asked to use FSF. These surveys were meant to rank attributes of FSF as more or less acceptable; they were not intended to derive demand estimates for FSF. All the surveys and interviews were conducted in Kannada, the primary language in Karnataka.

Discrete choice surveys present respondents with distinct and mutually exclusive 'sets' from which they select a preferred option. We presented farmers and workers with three choice sets, each containing three options, and asked them to choose their favored option from each choice set. Each choice set contained two FSF options with all the FSF attributes (at specified, randomly assigned, levels) (see Supplementary Figure S1 for the full list for an example). The two options, guided by our earlier interviews, were designed such that no one option was deemed 'better' than the other across all attributes. Based on locally prevalent practices, the third option in each choice set was either cow manure or chemical fertilizer, also randomly assigned, at current market prices or at current daily wages (see Supplementary Table S1 for the full list).

Following Train (2009), we employed a multinomial logit specification to model the choices of the respondents and infer how they valued different attributes relative to each other. For a multinomial logit model with a linear-in-parameter model specification, the utility of alternative j over choice set t as perceived by individual n, denoted u_{ntj}, is written:

$$u_{ntj} = \boldsymbol{\beta}' \boldsymbol{x}_{ntj} + \varepsilon_{ntj}$$

where $\boldsymbol{x}_{ntj}$ is a column vector of explanatory variables, such as the attributes of the options presented and the characteristics of the individual; $\boldsymbol{\beta}$ is a column vector of coefficients for these attributes (also known as 'taste parameters'), where each coefficient stands for the relative influence that its associated attribute has on a discrete choice decision; and ε_{ntj} is the stochastic component of the utility. Let y_{ntj} denote the choice indicator, equal to one if individual n chooses alternative j over choice set t, and zero otherwise. Under these assumptions, and assuming further that individuals are utility-maximizing, the probability that individual n chooses a sequence of choices $\boldsymbol{y}_{\vec{n}} = \langle y_{n11}, \ldots, y_{nTJ} \rangle$, where T denotes the number of choice sets faced by a single individual (equal to three in our case) and J denotes the number of options in any one choice set (equal to three in our case), may be given as follows:

$$\Pr_{\boldsymbol{y}}(\boldsymbol{y}_n | \boldsymbol{x}_{ntj}) = \prod_{t=1}^{T} \prod_{j=1}^{J} \left[\frac{\exp(\boldsymbol{\beta}' \boldsymbol{x}_{ntj})}{\sum_{j'=1}^{J} \exp(\boldsymbol{\beta}' \boldsymbol{x}_{ntj'})} \right]^{y_{ntj}}$$

The unknown model parameters ($\boldsymbol{\beta}$), the vector of coefficients for the attributes included in our choice sets, were estimated via maximum-likelihood estimation using the free discrete choice estimation software Biogeme (Bierlaire 2003).

Our study protocol (no. 2014-06-6473) was approved for ethical research practices by UC Berkeley's Office for the Protection of Human Subjects.

RESULTS AND DISCUSSION

Interviews and focus group discussions

Farmers in villages adjacent to Dharwad recounted stories of how, in the past, lower-caste workers collected human excreta from households, hauled it away (see also Sharma 1995), and co-composted human waste and other organic waste into the manure commonly known as *bhangi gobbara* (literally, manure of the *bhangi*). By the mid-1990s, *sarkaari gobbara* (literally, manure of the government, i.e. chemical fertilizer) had become popular; fertilizer companies marketed their products with the help of radio and television. Chemical fertilizers, easy to transport, store and use – and,

according to our respondents, always dry and odor-free – became available throughout the year. Interest in organic manure saw a renewal in the region from the 2000s. But sourcing organic manure had become difficult due to limited supplies. Two villages we visited regularly paid goat herders to camp on their farmland with their goats for few days, so that the land could be fertilized (see also Wade 1988).

The growth of pit latrines in rural India has increased the opportunity to reuse human waste. Truck-based (as opposed to manual) pit emptying has also burgeoned in the last 20 years, but the truck operators we spoke to complained that the disposal of loads of sludge was both difficult and risky (see also Sharada Prasad & Ray 2018). As a result, they have been encouraging farmers whose pits they empty to reuse their own FS. If a truck operator empties the pit of a farmer, he encourages the farmer to compost and reuse the sludge on his own farm, while the driver saves on transport time and costs.

Only seven of out of 23 farmers in our sample had used any form of FS in the past. They used it mainly for mango orchards, banana plantations and sugarcane, and usually right before the monsoon season. Though all seven agreed that using manure could protect the fertility of the soil, they felt that FSF use would reduce but not eliminate the use of chemical fertilizers. *Sarkaari gobbara* was apparently indispensable for obtaining a good yield. As FS was not easy to come by, some of these farmers provided their land for FS offloading and did not charge the truck operator. Others paid the truck operator to discharge the waste on their field, especially if they were not on the regular route. Both farmowners and workers who had used *bhangi gobbara* perceived it to be an organic manure similar to *kottige gobbara* (cow manure). It was more disgusting, certainly, but also more potent (*olle powerru* (good power); *tumba fastu* (very fast)). For yields, it was a 'super hit'.

A primary concern for farmers was that their workers, especially new workers, would not be willing to work with FSF. Three (out of seven) farmers reported mixing dry FSF with cow manure (which workers were comfortable handling) and crop waste to disguise the FS content. Farmowners were also worried that workers would demand higher wages to work with FSF. Larger farmers with mechanized equipment to load, transport, and apply FSF reported that workers had fewer objections to working with *bhangi gobbara* if they used mechanized equipment. A second concern for farmowners, especially those from higher-caste groups, was the social taboo associated with handling human waste. Though these farmers believed that FSF was a good soil amendment, the majority were afraid to use it openly so as not to sully the 'purity' of their lineage.

In our interviews, we found that farmworkers' attitudes toward handling FSF varied from cautious acceptance to resigned acceptance to (rarely) total rejection. Workers who had used untreated FS in the past were inclined to accept FSF as long as it was dry and free of offensive odors. They all thought that chemical fertilizers and cow manure were not smelly; they all believed that cow manure was beneficial. Those who had not used FS said that they might consider working with FSF if they saw other workers from their own (or a higher) caste using it. Others said that they would have to work with human manure if the owner insisted upon it: 'What else can I do when I don't have other options to earn? I have hungry children at home.' In contrast, a small minority refused to work with untreated FS or treated FSF under any circumstance: 'How can you even think of such a disgusting question? … Men don't even wash the bottoms of their own children, they call their wives to do that business. Do you think they will touch someone else's shit?'

Preference modeling

As explained in the "Methods" section, these initial interviews helped us to design discrete choice surveys through which we modeled farmer and worker preferences for the use of FSF. We estimated separate models for chemical fertilizers and cow manure (there was no way to combine them). Both models yielded similar results for Label, Smell, Health, Wetness, Texture, and Price of fertilizer; we are presenting only the cow manure models for simplicity. We estimated separate models for farmowners and workers since they are able to exercise agency in a fundamentally different manner. We also estimated separate models for male and female workers because these two groups face different social pressures and expectations. We found in our interviews that religious or caste identity was not the same as adherence to religious or caste practices; we

included diet in the model estimation for both owners and workers, as diet, such as eating or not eating certain meats, is a significant proxy for adherence.

We estimated the preferences of farmowners across all FSF attributes in Model 1 (see Table 1). Only those choice sets where the third option presented cow manure were included ($n = 1{,}018$). With the exception of price, estimated coefficients for all attributes were significant at the $p < 0.01$ level.

In Model 2, we estimated the differential preferences regarding smell, health risk, and labeling for vegetarians and omnivores. Diet was used as an indicator of caste-adherence; a rich anthropological literature has shown that what foods can and cannot be eaten are foundational to caste boundaries and identities (Appadurai 1981; Gorringe & Karthikeyan 2014). Vegetarianism in Karnataka is usually associated with higher-caste groups (see, e.g., Sathyamala 2019); just under 71% of the farmowners surveyed were

Table 1 | Estimated models for the preferences of farmowners, $n = 3{,}054$ choice sets, for buying fertiliser derived from fecal sludge, compared with preferences for cow manure

	Model 1		Model 2		Model 3	
Attribute	**Value**	***p*-value**	**Value**	***p*-value**	**Value**	***p*-value**
Dry	0.581	< 0.01	0.582	< 0.01	0.579	< 0.01
FSF	− 1.36	< 0.01	− 1.36	< 0.01	− 1.35	< 0.01
Labeled as organic manure	0.228	< 0.01				
Label organic – omnivorous farmer			0.0620	0.58		
Label organic – vegetarian farmer			0.291	< 0.01		
Label organic – has tractor – large area					0.12	0.42
Label organic – has tractor – other area					0.239	0.09
Label organic – no tractor – large area					0.252	0.24
Label organic – no tractor – other area					0.252	< 0.01
No smell	0.478	< 0.01				
No smell – omnivorous farmer			0.433	< 0.01		
No smell – vegetarian farmer			0.494	< 0.01		
No smell – has tractor – large area owned					0.126	0.43
No smell – has tractor – other area					0.228	0.14
No smell – no tractor – large area owned					0.455	0.07
No smell – no tractor – other area					0.648	< 0.01
No health risks	0.558	< 0.01	0.557	< 0.01	0.56	< 0.01
No risk – omnivorous farmer			0.543	< 0.01		
No risk – vegetarian farmer			0.563	< 0.01		
No risk – has tractor – large area owned					0.211	0.18
No risk – has tractor – other area					0.396	0.01
No risk – no tractor – large area owned					0.459	0.05
No risk – no tractor – other area					0.702	< 0.01
Price of FSF	0.107	0.05	0.109	0.04	0.108	0.05
Tea powder texture	0.214	< 0.01	0.21	< 0.01	0.213	< 0.01

Note: We added a dummy variable indicator for FSF to account for any differences between cow manure and FSF not covered in the attributes specified. Out of 2,306 farmowners, only 1,807 participated in the preference modeling study. Each participant was presented with three choice sets (see, e.g., Figure S1). Each choice set had three options to choose. With 1,807 farmowners × 3 choice sets per owner, we get 5,421 choice sets in total. Half of those choice sets ($5{,}421/2 \approx 2{,}710$) had cow manure as the third option, and the other half had chemical fertilizer. We have $n = 3{,}054$ (instead of 2,710) because the cow manure and chemical fertilizer choices were randomly assigned and their allocation was probabilistically but not exactly close to 0.5. Our n was also influenced by the workers who dropped out.

vegetarians and a majority of them were higher-caste, while just over half the surveyed workers were omnivorous. In Model 3, we estimated the differential preferences regarding smell, health risk, and labeling by farmer wealth. Based on the initial interviews, two proxies for farmer wealth, yielding four levels, were used: tractor ownership (has tractor/no tractor) and farm size classification (large area/other area). Tractors also provide a physical barrier between workers and the FSF; we hypothesized that farmowners with tractors might have different preferences when it came to smell, which is strongly tied to a sense of disgust as well as health risk. We tested diet and farmer wealth variables for interactions across all attributes. Only the Label attribute had significantly different coefficient estimates for different diet types; but we present the model for smell, health risk, and labeling.

We observed a strong preference for cow manure over FSF, even when controlling for the included attributes. In Model 1, dry FSF, no health risks, no smell, and tea powder texture were all significantly preferred. The estimated coefficients for these attributes were robust across all three models. We found that landholdings and tractor possession did indeed affect preferences regarding smell; farmers without tractors had a strong preference that smell be absent, especially if they had small-to-medium rather than large landholdings (Table 1). The same pattern was observed for health risk preferences. These proxies of farmer wealth had no impact on preferences with regard to labeling. Labeling as 'organic manure' – without specifying that it was FSF – was preferred across the whole sample in Model 1. In Model 2, we found that all farmers, regardless of diet, were strongly opposed to smell, but the preference for an 'organic' (without *bhangi gobbara*) label was stronger among vegetarian farmowners.

In Models 4 and 5, we estimated the preferences of farmworkers, across all FSF attributes (Table 2). Only those choice sets where Option Three presented cow manure were included, and separate models were estimated for male and female workers. In both models, we interacted diet with labeling and with smell, in order to compare them with the owner models.

The FSF coefficient estimate was not statistically significant for either men or women when compared with cow manure, indicating that a milder preference for cow manure than the owners had expressed. There was no significant effect of wages on willingness to work with FSF. Preferences for an absence of health risks were statistically significant across men and women workers, as they had been for the owners. Vegetarian men and all women had strong preferences for an absence of smell in FSF. As with their employers, omnivorous men and women, when comparing FSF with cow manure, preferred that the term *bhangi gobbara* be excluded from the label. Vegetarian women, however, preferred labeling that included the term *bhangi gobbara*; the labeling preference was in the same direction for vegetarian men, but the coefficient was not statistically significant.

Health impacts were not explicitly measured as part of this study. About 88% of the farmworkers surveyed said that they wore no protective gear when they worked with either manure or chemicals, and no farmowner reported providing safety gear to the workers. Sixty-four percent of the workers surveyed reported minor injuries during their work, mainly

Table 2 | Estimated models for the preferences of male and female workers for working with FSF, compared with cow manure

	Model 4, male workers ($n = 456$ choice sets)		Model 5, female workers ($n = 553$ choice sets)	
Attribute	**Value**	***p*-value**	**Value**	***p*-value**
Dry	0.15	0.31	0.56	<0.01
FSF	−0.07	0.72	−0.28	0.18
No health risks	0.46	<0.01	0.61	<0.01
Tea powder texture	− 0.08	0.57	− 0.35	0.02
Wages	0.69	0.21	0.89	0.09
Labeled as organic manure				
Omnivorous worker	0.43	0.02	0.35	0.05
Vegetarian worker	−0.06	0.78	−0.40	0.04
No smell				
Omnivorous worker	−0.11	0.57	0.66	<0.01
Vegetarian worker	0.57	<0.01	0.63	<0.01

Out of 839 workers (361 males and 478 females) interviewed, 674 (308 males and 366 females) participated in the preference modeling study. Each worker was presented with three choice sets (see, e.g., vpure 1). Each choice set had three options to choose. With 308 male workers × 3 choice sets per worker, we get 924 choice sets in total for males. Half of those choice sets (924/2 = 462) had cow manure as the third option, and the other half had chemical fertilizer. We have *n* as 456 (instead of 462) for males and 553 for females (instead of 549) because cow manure and chemical fertilizer were randomly assigned; the proportions were only probabilistically close to 0.5. Our *n* was also influenced by the workers who dropped out.

scratches and bruises to their hands and feet. In addition, 59% of the workers surveyed carried drinking water in a plastic bottle and drank directly out of it during work, without washing hands. Almost 40% of the workers reported that they did not wash their hands or feet after work due to a lack of water. All the female workers said that they cooked meals for their family and did domestic chores, which commenced as soon as they got home. Given these multiple pathways of exposure, it is not surprising that, across all models with farmers and workers, the preference for FSF with no health risks was strong and statistically significant.

As with farmowners, all farmworkers (674 out of 839 workers) participated in the whole study. The rest dropped out by the time the enumerators reached the 'Preference modeling' section (which was the last section of our survey). We surveyed highly ranked no foul odor and no health risks over other attributes if they were to accept working with FSF. However, controlling for these attributes, and contrary to the fears of their employers, farmworkers expressed only mild preferences for (acceptable) cow manure over FSF. Higher wages were not a driver of higher acceptance of FSF, again contrary to owners' expressed fears.

We found that fertilizer labels that say 'organic', but that do not include any term indicating FS as a component, were preferred by farmers overall, and by vegetarian and small-to-medium farmers, in particular. It seems unlikely that farmowners themselves have an aversion to transparent labeling; rather, our interviews as well as modeling results suggest that they do not want their social peers and/or their workers to know that they are using FSF. For farmers with large landholdings, the increased likelihood of delegation of contact with FSF to farmworkers may attenuate whatever social sanctions might be presented by transparent labeling. The label 'organic' was strongly supported by vegetarian farmers, indicating that caste-adherence (rather than simply caste-position) and its associated 'purity' can be a barrier to overt FSF use. It appears that those who adhere to the social rules associated with higher-caste status, such as not eating meat (Sathyamala 2019), prefer to mislabel the FSF product to protect their social standing.

We found that labeling FSF 'organic', but not FSF (or any synonym for the local term *bhangi gobbara*), was preferred by all omnivorous workers. The most likely interpretation of this combination of stated preferences is that workers do not think that they can avoid handling FSF if their employer demands it, so the more attributes that FSF shares with cow manure, the more acceptable they would find the FSF to be. They may also have believed that any overt association with FSF would have negative consequences for them socially and psychologically (Doron & Jeffrey 2018; Harriss-White 2018).

Vegetarian women workers had a significant preference for transparent labeling: they wanted FSF to be labeled as treated fecal matter. We cannot fully explain this result, and our initial interviews did not lead us to anticipate it. If this is the only group with a strong preference for transparent labeling, it is unlikely to influence any entrepreneurs or businesses that may eventually market FSF at a greater scale. Furthermore, the combined farmer–worker preference for nontransparent labeling suggests that, even if scaled up and regulated, there may be disincentives to provide FSF workers with protective clothing or equipment. These protections are considered unnecessary when working with cow manure in India and could act as visible indicators that the 'organic' manure in use was derived from human sources.

Our findings suggest that transparent labeling in (future) formalized supply chains may encourage informal mechanisms – already well established in many areas – to continue. Given these findings, we are concerned that current efforts made (or under consideration) toward formalizing the sector, which are not grounded in acknowledging the role of caste in the waste economy, could simply perpetuate the size and scope of the caste-based informal sector.

CONCLUSION

Multiple papers and reports (Rao *et al.* 2016) have reported informal FS use in Indian agriculture and have suggested options for safe business opportunities, especially where treatment plants are lacking. This paper contributes to the understanding of the social and cultural drivers of latent demand for FSF and what are considered more or less desirable attributes of FSF, in order to explore the risks of scaling-up reuse within the current hierarchies of caste. We find that latent demand for FSF is shaped by caste practices, labor

practices, and social pressures in the waste reuse economy. Our work supports recent research on India's labor markets, which finds that caste-based occupations and inequalities persist (Lanjouw & Rao 2011; Mosse 2018). Caste-based work is particularly prevalent in the organization of the waste economy (Tam 2013; Singh 2014; Doron & Jeffrey 2018). Without acknowledging these practices, any new reuse policy or business model risks making sanitized, and ultimately untenable, assumptions about the demand for sanitation by-products (Gatade 2015b; O'Reilly *et al.* 2017). Yet official water and sanitation policy documents never refer to the importance of understanding the layers of practices, beliefs, and power disparities that shape waste use practices (see also Kurian 2007). We found the drivers of demand, the interactions between farmers and workers, and the priorities of these various parties, to be unexplored in the existing literature. The social pressures and health risks faced by farm laborers are particularly neglected in FS reuse analyses, though social relations and informal institutions are known to be central to rural livelihoods (de Haan & Zoomers 2005).

We used a combination of qualitative interviews and structured surveys with over 2,000 farmowners to understand the practices of FSF reuse for agriculture in Karnataka. We built a discrete choice (stated preference) model to understand the ranking for each attribute of FSF compared with other attributes, with respect to willingness to use FSF. We found that, across the board, dryness, no smell and no health risks associated with FSF were conducive to the acceptance of FSF (see Table 1); these findings reflect previous work that has found perceptions of cleanliness and aesthetics to be key influences in attitudes toward waste (Ban *et al.* 2010). Our models indicate that farmowner wealth, indicated by large landholdings, hired labor, and tractor ownership, has a mitigating effect on the reluctance to use (treated) fecal waste. We attribute this to the physical barrier between farmers and the FS when there is a tractor on the farm.

Our reliance on preference modeling to estimate the importance of individual product attributes relative to one another – the product in our case being FSF – represents a traditional use of such models. This kind of modeling is used to inform price-setting for many types of hypothetical markets (Gunatilake *et al.* 2007; Train 2009), including as-of-yet unestablished FS management systems (Harder *et al.* 2013; Jenkins *et al.* 2015; Balasubramanya *et al.* 2017). We also use our discrete choice models for a more unusual purpose: we show that they can be used to infer the underlying social relations and caste practices within which FSF use is embedded. These practices include employer's willingness to mislabel a product they and their workers will handle; differences in choice between farmowner and farmworker; and the relationships among FSF acceptance, health concerns, caste-adherence, and the maintenance of caste 'purity'.

In addition, creating hypothetical choice sets allowed us to give voice to workers' preferences for, and to infer the constraints under which they must work with, FSF. Our stated preference models indicate that, for all its sustainability and (possible) revenue generation potential, FSF reuse in Indian agriculture is still undergirded by caste hierarchies and caste practices, reflecting the influence of caste and religion in rural sanitation overall (see Vyas & Spears 2018). Caste-adherence and within-caste social standing emerged as significant predictors of whether farmers would work overtly with FSF, and with the acceptance of FSF as long as the marketing and labeling obfuscated the source. Innovations in treatment technologies, and business models that are being developed without consideration of how stigma and sustainability intersect, could inadvertently continue the caste-based disparities, nontransparent practices, and unsafe waste handling that characterize informal reuse today.

DATA AVAILABILITY STATEMENT

Data cannot be made publicly available; readers should contact the corresponding author for details.

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REFERENCES

Appadurai, A. 1981 gastro-politics in Hindu South Asia. *American Ethnologist* **8** (3), 494–511. https://doi.org/10.1525/ae.1981.8.3.02a00050.

Balasubramanya, S., Evans, B., Hardy, R., Ahmed, R., Habib, A., Asad, N. S. M., Rahman, M., Hasan, M., Dey, D., Fletcher, L., Camargo-Valero, M. A., Chaitanya Rao, K. & Fernando, S. 2017 Towards sustainable sanitation management: establishing the costs and willingness to pay for emptying and transporting sludge in rural districts with high rates of access to latrines. *PLoS One* **12** (3), e0171735. https://doi.org/10.1371/journal.pone.0171735.

Ban, R., Das Gupta, M. & Rao, V. 2010 The political economy of village sanitation in south india: Capture or poor information?. *Journal of Development Studies* **46** (4), 685–700. https://doi.org/10.1080/00220380903002962.

Berendes, D. M., Sumner, T. A. & Brown, J. M. 2017 Safely managed sanitation for all means fecal sludge management for at least 1.8 billion people in low and middle income countries. *Environmental Science and Technology* **51** (5), 3074–3083. https://doi.org/10.1021/acs.est.6b06019.

Bierlaire, M. 2003 BIOGEME: a free package for the estimation of discrete choice models. In: *Proc. 23rd WEDC Conf.*, September 1–5, Durban, South Africa.

Buit, G. & Jansen, K. 2016 Acceptance of human feces-based fertilizers in fecophobic Ghana. *Human Organization* **75** (1), 97–107. https://doi.org/10.17730/0018-7259-75.1.97.

Coffey, D. & Spears, D. 2017 *Where India Goes: Abandoned Toilets, Stunted Development and the Costs of Caste, Kindle Edition*. HarperCollins, New Delhi.

Coffey, D., Spears, D. & Vyas, S. 2017 Switching to sanitation: understanding latrine adoption in a representative panel of rural Indian households. *Social Science and Medicine* **188**, 41–50. https://doi.org/10.1016/j.socscimed.2017.07.001.

Cofie, O. O., Kranjac-Berisavljevic, G. & Drechsel, P. 2005 The use of human waste for peri-urban agriculture in Northern Ghana. *Renewable Agriculture and Food Systems* **20** (02), 73–80. https://doi.org/10.1079/RAF200491.

Danso, G., Otoo, M., Ekere, W., Ddungu, S. & Madurangi, G. 2017 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. *Resources* **6** (3), 31. https://doi.org/10.3390/resources6030031.

de Haan, L. & Zoomers, A. 2005 Exploring the frontier of livelihoods research. *Development and Change* **36** (1), 27–47. https://doi.org/10.1111/j.0012-155X.2005.00401.x.

Doron, A. & Jeffrey, R. 2018 *Waste of a Nation: Garbage and Growth in India*. Harvard University Press, Cambridge, MA.

Doron, A. & Raja, I. 2015 The cultural politics of shit: class, gender and public space in India. *Postcolonial Studies* **18** (2), 189–207. https://doi.org/10.1080/13688790.2015.1065714.

Douglas, M. 1966 *Purity and Danger – An Analysis of Concepts of Pollution and Taboo*. Routledge, New York, NY.

Gatade, S. 2015a Silencing caste, sanitising oppression: understanding swachh bharat abhiyan. *Economic and Political Weekly* **50** (44), 29–35.

Gatade, S. 2015b Silencing caste, sanitising oppression: understanding swachh bharat abhiyan. *Economic and Political Weekly* **50** (44), 29–35.

Gorringe, H. & Karthikeyan, D. 2014 The hidden politics of vegetarianism: caste and The Hindu canteen. *Economic & Political Weekly* **49** (20), 20–22.

Gunatilake, H., Yang, J.-C., Pattanayak, S. & Choe, K. A. 2007 *Good Practices for Estimating Reliable Willingness-to-Pay Values in the Water Supply and Sanitation Sector*. Asian Development Bank, Philippines.

Guru, G. 2018 Caste. In: *The International Encyclopedia of Anthropology*. John Wiley & Sons, Ltd, pp. 1–9. https://doi.org/10.1002/9781118924396.wbiea1898.

Harder, D. S., Sajise, A. J. U. & Galing, E. M. 2013 Willingness to pay for sanitation services in Dagupan City, Philippines. *Journal of Water, Sanitation and Hygiene for Development* **3** (2), 165–180. https://doi.org/10.2166/washdev.2013.064.

Harriss-White, B. 2018 India's informal waste economy and urban informality: An illustrated tour of the epistemological horizon. Work in Progress Paper. https://www.southasia.ox.ac.uk/sites/default/files/southasia/documents/media/bhw_waste_rev_lit_2018.pdf.

Jenkins, M. W., Cumming, O. & Cairncross, S. 2015 Pit latrine emptying behavior and demand for sanitation services in Dar Es Salaam, Tanzania. *International Journal of Environmental Research and Public Health*. https://doi.org/10.3390/ijerph120302588.

Jensen, P. K. M., Phuc, P. D., Knudsen, L. G., Dalsgaard, A. & Konradsen, F. 2008 Hygiene versus fertiliser: the use of human excreta in agriculture – a Vietnamese example. *International Journal of Hygiene and Environmental Health* **211** (3–4), 432–439. https://doi.org/10.1016/j.ijheh.2007.08.011.

Keraita, B., Jimenez, B. & Drechsel, P. 2008 Extent and implications of agricultural reuse of untreated, partly treated and diluted wastewater in developing countries. *Perspectives in Agriculture, Veterinary Science, Nutrition and Natural Resources* **3** (058). https://doi.org/10.1079/PAVSNNR20083058.

Kurian, M. 2007 Governance of water and sanitation services for the peri-urban poor: a framework for understanding and action in metropolitan regions by Adriana Allen, Julio D. Davila and Pascale Hofmann. *Development and Change* **38** (2), 369–371. https://doi.org/10.1111/j.1467-7660.2007.00415_17.x.

Lanjouw, P. & Rao, V. 2011 Revisiting between-group inequality measurement: an application to the dynamics of caste

inequality in two Indian villages. *World Development* **39** (2), 174–187. https://doi.org/10.1016/j.worlddev.2009.11.035.

Mariwah, S. & Drangert, J. O. 2011 Community perceptions of human excreta as fertilizer in peri-urban agriculture in Ghana. *Waste Management and Research* **29** (8), 815–822. https://doi.org/10.1177/0734242X10390073.

Mosse, D. 2018 Caste and development: contemporary perspectives on a structure of discrimination and advantage. In: *World Development*, Vol. 110. Elsevier Ltd, pp. 422–436. https://doi.org/10.1016/j.worlddev.2018.06.003.

Moya, B., Parker, A., Sakrabani, R. & Mesa, B. 2019 Evaluating the efficacy of fertilisers derived from human excreta in agriculture and their perception in Antananarivo, Madagascar. *Waste and Biomass Valorization* **10** (4), 941–952. https://doi.org/10.1007/s12649-017-0113-9.

Murray, A. & Ray, I. 2010 Commentary: back-end users – the unrecognized stakeholders in demand-driven sanitation. *Journal of Planning Education and Research* **30**, 94–102.

Nikiema, J., Cofie, O. & Impraim, R. 2014 *Technological Options for Safe Resource Recovery from Fecal Sludge*. Resource Recovery and Reuse Series 2, Vol. 2. https://doi.org/10.5337/2014.228.

O'Keefe, M., Lüthi, C., Tumwebaze, I. K. & Tobias, R. 2015 Opportunities and limits to market-driven sanitation services: evidence from urban informal settlements in East Africa. *Environment and Urbanization* **27** (2), 421–440. https://doi.org/10.1177/0956247815581758.

O'Reilly, K., Dhanju, R. & Louis, E. 2017 Subjected to sanitation: caste relations and sanitation adoption in rural Tamil Nadu. *Journal of Development Studies* **53** (11), 1915–1928. https://doi.org/10.1080/00220388.2016.1241385.

Radcliffe, J. C. 2004 *Water recycling in Australia: a review undertaken by the Australian academy of technological sciences and engineering*. Australian Academy of Technological Sciences and Engineering, Melbourne, Australia.

Rao, K. C., Velidandla, S., Scott, C. L. & Drechsel, P. 2020 Business models for fecal sludge management in India. In: *Resource Recovery & Reuse Series 6*, Vol. 18, October. IWMI, Colombo, Sri Lanka. https://www.iwmi.cgiar.org/publications/resource-recovery-reuse/series-18/.

Rao, K. C., Kvarnstrom, E., Di Mario, L. & Drechsel, P. 2016 *Business Models for Fecal Sludge Management*. https://doi.org/10.5337/2016.213.

Sathyamala, C. 2019 Meat-eating in India: whose food, whose politics, and whose rights? *Policy Futures in Education* **17** (7), 878–891. https://doi.org/10.1177/1478210318780553.

Sharada Prasad, C. S. & Ray, I. 2018 'It has to be done only at night': human waste disposal in Bengaluru. *Economic & Political Weekly* **53** (21), 13–16.

Sharada Prasad, C. S. & Ray, I. 2019 When the pits fill up: (in) visible flows of waste in urban India. *Journal of Water Sanitation and Hygiene for Development* **9** (2), 338–347. https://doi.org/10.2166/washdev.2019.153.

Sharma, R. 1995 *Bhangi, Scavenger in Indian Society: Marginality, Identity, and Politicization of the Community*. MD Publications, New Delhi.

Simha, P., Lalander, C., Vinnerås, B. & Ganesapillai, M. 2017 Farmer attitudes and perceptions to the re-use of fertiliser products from resource–oriented sanitation systems – the case of Vellore, South India. *Science of the Total Environment* **581–582**, 885–896. https://doi.org/10.1016/j.scitotenv.2017.01.044.

Singh, B. 2014 *Unseen: The Truth About India's Manual Scavengers*. Penguin Books Limited, New Delhi.

Tam, S. 2013 Sewerage's reproduction of caste: the politics of coprology in Ahmedabad, India. *Radical History Review* **2013** (116), 5–30. https://doi.org/10.1215/01636545-1965675.

Teltumbde, A. 2014 No 'Swachh Bharat' without annihilation of caste. *Economic & Political Weekly* **49** (45), 11–12.

Thebo, A. L., Drechsel, P., Lambin, E. F. & Nelson, K. L. 2017 A global, spatially-explicit assessment of irrigated croplands influenced by urban wastewater flows. *Environmental Research Letters* **12** (7). https://doi.org/10.1088/1748-9326/aa75d1.

Train, K. 2009 *Discrete Choice Methods with Simulation*. Cambridge University Press, New York, NY.

Van Dijk, M. P., Etajak, S., Mwalwega, B., Ssempebwa, J., Pieter Van Dijk, M., Etajak, S., Mwalwega, B. & Ssempebwa, J. 2014 Financing sanitation and cost recovery in the slums of Dar es Salaam and Kampala. *Habitat International* **43**, 206–213. https://doi.org/10.1016/j.habitatint.2014.02.003.

Vyas, S. & Spears, D. 2018 Sanitation and religion in South Asia: what accounts for differences across countries? *Journal of Development Studies* **54** (11), 2119–2135. https://doi.org/10.1080/00220388.2018.1469742.

Wade, R. 1988 Why some Indian villages co-operate. *Economic & Political Weekly* **23** (16), 773–776.

Waidyarathne, R. G. I. C., Edirisinge, J. C., Otoo, M. & Weerakkody, W. J. S. K. 2018 An inquiry into farmer perception on fortified compost. In: *17th Agricultural Research Symposium*, pp. 430–434.

Whittington, D. 1998 Administering contingent valuation surveys in developing countries. *World Development* **26** (1), 21–30. https://doi.org/10.1016/S0305-750X(97)00125-3.

WHO 2006 *Guidelines for the Safe Use of Wastewater, Excreta and Greywater*, Vol. IV. https://www.who.int/water_sanitation_health/publications/gsuweg4/en/.

WHO/UNICEF/JMP 2017 *India Country Data – Joint Monitoring Project*. https://washdata.org/data/household#!/ind. (accessed 19 March 2021).

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