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Farmer attitudes and perceptions to the re–use of fertiliser products from resource–oriented sanitation systems – The case of Vellore, South India

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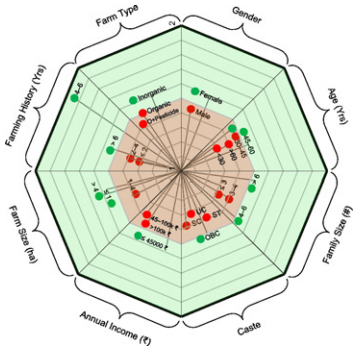
HIGHLIGHTS

- Deconstructed factors that encourage/discourage, negative/positive views on excreta reuse
- *Not-in-my-circle* syndrome on urine reuse: less negative attitude towards neighbours
- Cultivators prefer dry fertilisers manufactured from urine than liquid urine.
- While *faecophobia* exists study shows it would be erroneous to overestimate its extent.
- Aspects like 'trust' must be identified in eco-sanitation planning & implementation.

GRAPHICAL ABSTRACT



Overall attitude to human urine recycling among farmers in Vellore divided as per their socio-demographic variables; green depicts region of positive attitude while red depicts negative attitude.

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ABSTRACT

Relatively little research has been conducted to date on farmer attitudes towards the use of fertilisers from resource–oriented sanitation systems. This study employed a psycho–sociological approach to identify factors that encourage, or discourage, negative and positive attitudes to human waste recycling among farmers in southern India. A survey involving face–to–face interviews was performed with 120 randomly sampled farmers, taking into account the following factors: gender, age, religion, caste, type of farming, farm size, annual income and farming history. Variations in variables (χ^2 and ANOVA) were considered statistically significant if p–value was <0.05. When asked whether they thought human wastes could be used as fertiliser, of the farmers who expressed an opinion 59% were positive to re–use of urine and 46% to re–use of human faeces. Farmers in Vellore appeared to display what we term, a '*not–in–my–circle*' syndrome, as they would prefer their neighbours to use human urine rather than their friends, family and colleagues. The main factors that motivated farmers to respond positively to re–use of urine were improved soil quality and potential cost savings from reduced use of chemical fertilisers. Fear of crop die–off, fear of being ridiculed and uncertainty over consumer marketplace behaviour were significant factors among farmers with a negative attitude. Furthermore, the survey responses indicated that besides socio–demographic factors, other factors such as '*trust*' might have to be taken into consideration when planning and implementing nutrient recycling programmes. Early dialogue, continuous interaction and integration of user stakeholders (producers and consumers) in conceptualisation, design and implementation of nutrient recycling programmes are essential to ensure future success and wider adoption.

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Nomenclature

Caste	A determinant of socio–economic inequality in India. The official classification defines four major categories: Scheduled Castes (SCs), Scheduled Tribes (STs), Other Backward Classes (OBCs) and others.
CS	Cannot say; farmer response
Dalits	Literal meaning '*broken people*'; self–designated terminology used by, and referring to, so–called 'untouchables' who traditionally occupy the lowest place in the Indian caste hierarchy. 'Scheduled Castes and Scheduled Tribes' is the official term used by the Government of India to refer to *Dalits*; the Indian Constitution (Scheduled Castes) Order of 1950 lists 1108 castes across 29 states in its First Schedule, while the Constitution (Scheduled Tribes) Order of 1950 lists 744 tribes across 22 states in its First Schedule
GHG	greenhouse gas
HRW	Human Rights Watch
NSSO	National Sample Survey Organisation
N	no; farmer response
n	number of survey respondents
OBC	Other Backward Classes; defined by the Indian Constitution as socially and educationally backward classes; the Indian Ministry of Social Justice and Empowerment maintains a dynamic list of OBCs
SC	Scheduled Caste
ST	Scheduled Tribe
WHO	World Health Organisation
Y	Yes; farmer response

1. Introduction

Resource–oriented sanitation, or sustainable sanitation, has been advocated as an approach to promote circularity in the flow of (waste) resources from the built to the natural environment (Esrey, 2001; Langergraber and Muellegger, 2005; Werner et al., 2009). It seeks to promote closed–loop methodology that enables separation of human wastes at source (households) and re–channels them back to agricultural areas for use as crop fertilisers (Esrey et al., 2001; Ganesapillai et al., 2015). The emergence of new sanitation systems such as urine diversion toilets provides an elegant way to separate, collect and concentrate useful products (nutrients) from the non–desirable components (pathogens, micropollutants, heavy metals). Since the early 1990s, resource–oriented sanitation and its underlying principles have been implemented as pilot projects in diverse geographical settings, including emerging economies like India (Winblad and Simpson–Hébert, 2004; Langergraber and Muellegger, 2005). In a study comparing the nutrient composition of various potential fertiliser products from sanitation against their suitability for crop production, Winker et al. (2009) found that urine was the 'most promising' and 'well investigated' product derived from such systems. In India, however, synthetic fertilisers are subsidised by the government, while the use of urine is not recognised by the Fertiliser (Control) Order (1985) issued by the Ministry of Agriculture, which regulates the price, quality and quantity of fertilisers used in India.

Over the past 25 years, there has been a gradual increase in the proportion of the population with access to improved sanitation facilitates in India. However, while global access to improved sanitation increased from 53 to 67.5% between 1990 and 2015, access to sanitation in India only increased from 19 to 40% in the same period (WHO, 2013). Development of sanitation systems thus continues of be of great significance for developing countries such as India, where it is necessary to increase the provisioning of sanitation. In such development work, there is an opportunity to follow the principles of resource–oriented sanitation, which not only promotes sanitation but also the associated sectors of hygiene, water and agriculture. Given their high rate of economic growth and socio–economic development (Leimbach et al., 2015), emerging economies appear to be prime candidates for implementing and proliferating sustainable sanitation practices.

Certainly, technology and innovation have already had far–reaching implications on, among others, societal functions, human behaviour, cultural practices, policy formulations and governance, economies, markets and the environment. Over time, the heuristics of past technological transitions and conceptualisation of approaches that guide sustainable innovations have evolved considerably. These shifts that technologies initiate are now recognised as socio–technical transitions, emphasising their embedding within wider socio–economic systems (Rip and Kemp, 1998). However in most, if not all transitions, the strategic positioning of stakeholders to a proposed technology features strongly in determining its adoption and influences the timing, extent, swiftness and magnitude of its diffusion (Geels, 2002).

In a sustainable sanitation cycle, nutrient mobilisation can be perceived to begin with consumers in their households, where source–separation provides an elegant approach to re–direct nutrients to agriculture. Within agriculture, farmers immobilise these nutrients during crop fertilisation and production, through which the nutrients ultimately end up in food for consumers. Hence, in case of sustainable sanitation, two *system user stakeholders* are:

a. *Consumers* – stakeholders that need to be motivated to use urine–diverting toilets and consume urine–fertilised food. Consumers are vital, since the initiation of a closed–loop sanitation cycle through source–separation begins in households.
b. *Producers (Farmers)* – stakeholders among whom interest, motivation and acceptance of source–separated human wastes as a fertiliser must be created, developed and sustained over time.

According to Tanner (1995), every societal group approaches and manages its excrement based on codes of social conduct that vary with demographic, cultural and socio–economical characteristics. However, relatively little research has been devoted to recording farmers' perceptions, attitudes and willingness to transition to use of these alternative fertilisers. In a recent review on the subject, Lienert (2013) points to the dearth of sociological research in urine recycling. She remarks, '*I know of four questionnaire surveys addressed to the general public and four to the farmers that elicited their acceptance of reusing human urine in agriculture*' (Chapter 14, p. 202). A number of studies published following Lienert's review seek to provide a socio–technological perspective on consumer attitudes over the design and use of urine–diverting toilets. These include Pahl–Wostl et al. (2003) (Switzerland); Cordova and Knuth (2005) (Mexico), Lienert and Larsen (2006) (Switzerland); Lienert and Larsen (2009) (EU review); Lamichhane and Babcock (2013) (Hawaii); Mugivhisa and Olowoyo (2015) (South Africa); Ishii and Boyer (2016) (USA). The surveys conducted to date describing farmer attitudes have been carried out in Ghana (Mariwah and Drangert, 2011), South Africa (Andersson, 2015) and Switzerland (Lienert et al., 2003). To the best of our knowledge, no psycho–sociological study on *farmer* attitudes to the issue has been performed in India. A survey of Indian farmers was performed by Rahman and Chariar (2015), but their investigation dealt only with regional levels of acceptance/willingness among Indian farmers, without delving into the reasons for the existence of such attitudes. Psycho––sociological studies involve empirical qualitative research on subjects/respondents who may not be fully knowledgeable actors and who have conscious/unconscious defences that influence their responses to perceptive questions (Clarke and Hoggett, 2009). The aim in such studies is to analyse social patterns, behaviour and transformations by internalising sociological factors that may affect participant responses.

The aim in the present study was to identify and analyse the factors that encourage, or discourage, negative and positive attitudes to human waste recycling among farmers in Vellore district, India. The study was exploratory in nature and the farmers were not provided with any information packs beforehand. Furthermore, the survey questions were tailored in an attempt to uncover internalising factors (conscious/unconscious) such as association to a particular societal stratum (caste), traditional practices (use of cow urine), relatability and intellectual identification (with friends, family, neighbours). Vellore lies between 12°15′ and 3°15′ N and 78°20′ and 79°50′ E, and encompasses an area of 6077 km^2 (Fig. 1). According to the latest population census, the district is home to 3,936,331 people, 56.7% of whom live in rural areas (Census of India, 2011). The population is predominantly Hindu (88%), with nearly one–quarter of the population made up of *Dalits*[*] or Scheduled Castes and Scheduled Tribes. With a gross sown area of 1974.5 km^2, the economy in Vellore is primarily agrarian; there are 153,211 cultivators and 254,999 agricultural labourers, plus 21,897 marginal cultivators and 136,956 marginal agricultural labourers. In the present study, 120 farmers were randomly sampled from the district farm register and interviewed in order to determine their perceptions of human waste recycling. It is acknowledged that the scope of the study and any results thereof may be considered representative of farmers in Vellore district, but not of Indian farmers in general.

2. Methodology

The geographical scope of the study was restricted to the administrative boundaries of Vellore district, in the southern Indian state of Tamil Nadu (Fig. 1). Since only <5.5% households in Vellore district own a computer and even fewer (<2.3% of these) have access to the internet (Census of India, 2011), it was decided to conduct the survey in face–to–face interviews, where the interviewer recorded the responses of farmers to a set of pre–designed questions. Ten interviewers with a good command of the local language and dialects were trained between November 2015 and January 2016 in the concept of sustainable sanitation and human waste recycling. The 120 farmers included in the survey were selected through simple random sampling (SRS) of the district farm register. The sample size was chosen by considering a population size of 153,211 farmers (Census of India, 2011), with 95% confidence interval and <10% margin of error. Prior to the interviews, all respondents were informed about the purpose of the survey and assured that it was voluntary and completely anonymous. Written consent was obtained from all respondents regarding use of the survey data in the present study.

The questionnaire comprised a series of 22 sequential, closed–ended questions with multiple choice answers divided into three main sections. The purpose of *Section I* (questions 1–7) was to establish the socio–economic and cultural profile of the respondents, *Section II* (questions 8–13) sought details of their farms and the type of farming they pursued and *Section III* (questions 14–22) looked for insights into the respondents' perceptions, attitudes, inclinations and willingness to shift to use of human excreta–based fertilisers (Supplementary information, p. S17).

In randomised face–to–face interviews, there is always room for respondents to become uncooperative and sceptical (Kuk, 1990), as they are required to answer either 'yes' or 'no' and hence take a stand. Bearing in mind the socio–cultural and psychological sensitivities of people towards excreta, 10 pre–test surveys were carried out to identify sensitive questions (*Section III*). Based on the results, the questionnaire was re–organised and refined. To have a more respondent–friendly survey and reduce non–response, respondents were also asked to provide opinions from someone else's point of view (that of neighbours, relatives, friends, colleagues) before providing their own. The pre–test survey revealed difficulties in obtaining responses to questions on which respondents had little or no information. Although central tendency bias was avoided by providing close–ended 'yes' or 'no' choices, an option of 'cannot say' or 'no opinion' was provided for certain questions in *Section III*, since no information package or material was given to respondents prior to the survey.

To analyse the survey data, all positive responses (yes) were assigned a numerical value of 2 and all negative responses (no) were assigned a value of 1. The mean ($1 \le \mu \le 2$) represented the probability of the response being positive (yes). The response 'cannot say' was also assigned a numerical value of 1, since it is not indicative of a positive response/attitude and the objective of the survey was to assess the general attitude (positive or negative) to the use of human excreta for crop production. The data were analysed to determine whether the respondents' perceptions and attitudes to human waste recycling differed according to their socio–demographic variables. Chi–squared tests (χ^2) and one–way analysis of variance (ANOVA) were used to estimate variations in demographic variables with two and more than three categories, respectively (Tables S1–S6). Level of statistical significance was set at $p < 0.05$. Evaluating the responses to the questions in *Section III* against the demographic variables was necessary since the analysis did not end with mere determination of the level of acceptance of human waste recycling. In this study, it was considered equally important to gain insights into why the farmers with positive attitudes had such attitudes in the first place and of course, to understand the factors inhibiting acceptance of waste recycling among respondents with a negative or non–positive attitude. All statistical analyses were carried out using R, version 3.3.0 RC. Graphical illustrations were made using the ggplot2 (V 2.1.0).

3. Results

3.1. Initial screening and sample socio–demography

A total of 98 of the 120 farmers selected for the survey provided full socio–demographic data and responded to all questions up to question 20 (response rate = 82%). However, only 62 of the 120 farmers completed the entire survey (response rate 52%); 62 answered questions 20.1 and 20.2 while 68 chose to answer questions 21 and 22. A relatively good response rate was observed in comparison to surveys conducted elsewhere (Mariwah and Drangert, 2011; Lamichhane and Babcock, 2013; Ishii and Boyer, 2016), partly due to the survey being administered in face–to–face interviews.

Of the 98 respondents who provided full socio–demographic data, 80 were male and 18 female (Table 1). This disproportionate gender segmentation can be attributed to the rural societal structure in the region, in which men are considered the head of the household and the decision makers and are in charge of the income–generating operation of crop production. In contrast, the women's role is confined to either cultivating vegetable crops for household consumption or selling a small portion of the produce at a local farmer's market (Rengasamy et al., 2002, p. 27). Majority of the 98 farmers (78%) had been on their farms for more than six years and 72% of the farms were home to 3–6 people. Less than 7% of the farmers belonged to the age category <30 years, reflecting the ongoing demographic crisis in Indian agriculture in which young people are increasingly less inclined to look to farming for their livelihood (Sharma, 2007; Rajan, 2013). Less than 9% belonged to the upper caste, with Other Backward Classes (OBCs), Scheduled Castes (SCs) and Scheduled Tribes (STs) accounting for 83% of respondents. The OBCs also accounted for 75% of all landholdings with size < 1 ha.

Income levels were found to be predominantly low and low to medium (<₹100,000 per annum; 2016 exchange rate: 1 US$ = ~₹67). These incomes corresponded well to the size of the holdings; 75% of the farmers with low income and 67% of those with medium income farmed <2 ha (Table 1). A significant proportion of the farmers surveyed

[*] See Nomenclature.

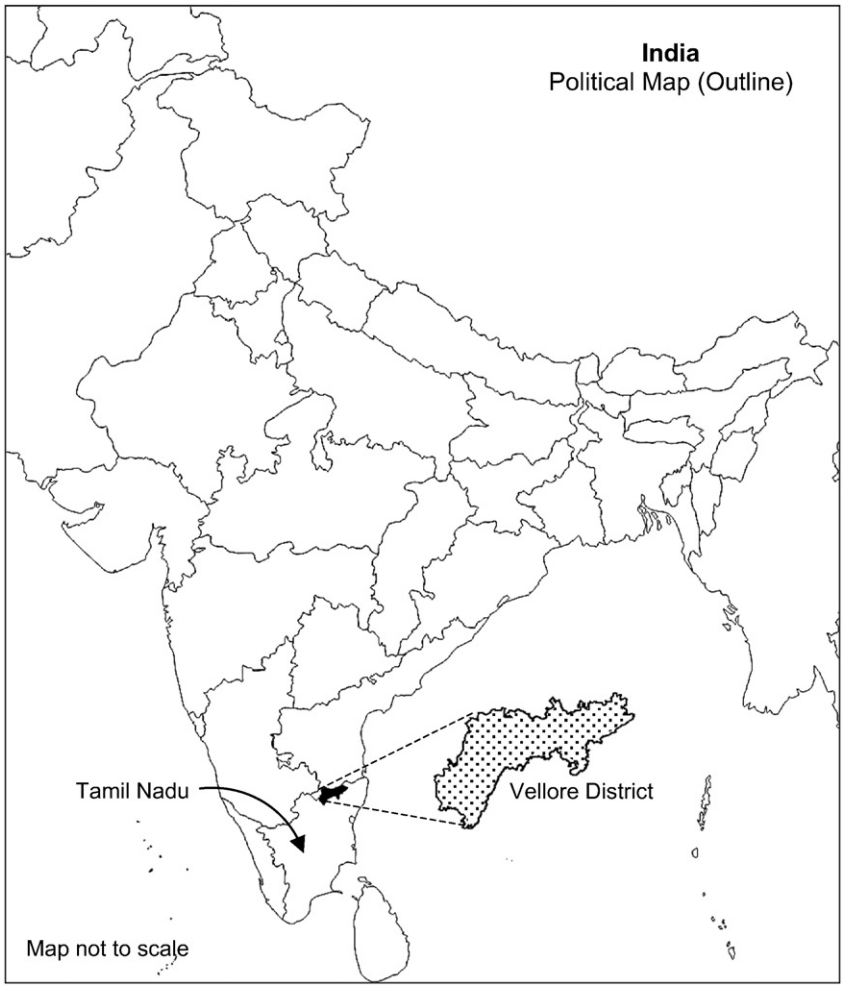

Fig. 1. Location of the study area (Vellore district, Tamil Nadu) in India.

(27%) did not wish to disclose their income. Of these, 73% stated that their farm size was <2 ha, while 15% reported that they owned >4 ha. The reluctance to disclose income could have been either because the income levels were low and low to medium (among those with <1 ha) or that they were high (among those with >4 ha). All except one farmer stated that they followed Hinduism, a proportion representative of the religious demographics in Tamil Nadu.

In Vellore, there is diversity in the types of crops cultivated. They include rice, sugarcane, coconut, groundnut, vegetables, maize and black gram. Thirty–five of the farmers surveyed followed monoculture cropping, 28 followed multiple cropping and a further 17 practised crop rotation. Moreover, 13% of the farmers considered themselves 'purely organic', while the majority (60%) considered themselves organic apart from the use of chemical pesticides. In terms of fertiliser use, 74% stated their requirements as being small and small to medium. As is common practice on most Indian farms, 95% of all respondents used animal manure for fertilising their soils.

3.2. Respondent groups with positive and negative attitudes to urine recycling

To distinguish positive and negative attitudes to re–use of human urine in agriculture, the numerical transformations of farmer responses to questions 19–21 were assessed for each demographic variable. A mean response of >1.5 was taken to represent a positive attitude, while a mean response of <1.5 represented a negative attitude (Table 2). The demographic variables scoring a mean response of >1.5, i.e. reflecting a positive attitude, were: female, age between 30 and 60 years, belonging to Other Backward Classes, annual income ≤₹45,000, farming ≤1 ha of land, and practising inorganic farming for at least 4 years. In contrast, a negative attitude to urine recycling was associated with: male respondent, age < 30 or >60 years, belonging to Scheduled Caste, tribes or upper caste, annual income exceeding ₹45,000 and farming 1–4 ha of land for <4 years (Fig. 2(a)).

Calculation of the mean response value for the respondent groups with positive and negative attitudes revealed that farmers with an overall positive attitude were willing to fertilise their own crops with urine, even though they did not believe that urine could be used as a fertiliser (Fig. 2(b)). However, a strong preference for dry fertiliser products manufactured from urine was seen in the positive group, but not in the negative group. Moreover, the negative group was negative overall to all aspects of using human urine as a fertiliser.

On dividing the responses according to the different demographic variables, it was found that the inorganic farmers behaved significantly different from the rest, in that a majority of them would buy dry urine fertiliser (84%). However, among these, 68% would buy such a fertiliser only if it were cheaper or similar in price to their current product (Fig. S2). Similar preferences, especially in terms of fertiliser form (solid/liquid), have been observed by Lienert et al. (2003) among integrated production (IP) and vegetable farmers in Switzerland who also purchase additional fertilisers, like the inorganic farmers participating in this study. Among the remaining 62 respondents, 44% said they would buy dry urine fertiliser only if it cost less than they currently pay for fertiliser, 15% stated they would buy it if it cost the same as their current fertiliser and 41% said they would buy it irrespective of the cost (Fig. S2). Most of the farmers who did not have opinions on urine re–use remarked that

Table 1
Socio–demographic characteristics of the survey respondents.

Variable	*N*
Gender	
Male	80
Female	18
Age (years)	
<30	7
30–45	27
45–60	40
>60	24
Family size	
≤3	14
3–4	32
4–6	39
>6	13
Caste	
Scheduled Caste, SC	11
Scheduled Tribe, ST	4
Other Backward Class, OBC	67
Upper caste	9
Do not know	1
Do not wish to disclose	6
Annual income (₹)	
≤45,000	39
45,000–100,000	30
>100.000	3
Do not wish to disclose	26
Farm size (ha)	
≤1	47
1–2	22
2–4	16
>4	12
Farming history (years)	
≤2	6
2–4	13
4–6	3
>6	76
Farm type	
Organic	13
Inorganic	26
Organic + pesticides	59

they would have to see a demonstrated benefit in terms of crop productivity equivalent to at least that of animal manure for them to consider using urine.

3.3. Factors that shaped positive and negative attitudes to urine recycling

The farmers were also asked two different sets of additional questions in order to investigate why they considered using human urine to be a good (four statements) or bad idea (seven statements). The main factors that motivated the farmers to respond positively to the possibility of using human urine were soil quality and potential gains from reduced chemical fertiliser use (Fig. 3): 83% of the farmers surveyed believed that using urine would improve their soil quality, while 75% were of the opinion that using urine would reduce their need for chemical fertilisers, which currently adds to their cost of production. Despite having little information on urine sanitisation and its concentrations of micropollutants and pharmaceuticals, 78% of the respondents considered urine to be a 'safe' fertiliser. Health risks associated with urine handling and re–use may not have been a major concern for these Vellore farmers, but crop productivity certainly was, with 39% of farmers not being aware of the agronomic potential of urine as a fertiliser, while an additional 8% thought crop productivity might not increase with the application of human urine, but that they might still use it.

Concerns about crop die–off were expressed by those farmers who considered using human urine as a crop fertiliser to be a bad idea. A typical comment was that urine would make the soil "poisonous" and reduce its fertility. These farmers may have been referring to foliar burning which can happen if urine is sprayed directly onto leaves. High ammonia content, high salt concentrations and drying of urine on the leaves can result in reduced productivity and, in extreme cases, crop die–off (Vinnerås et al., 2003). Farmer 12 remarked: "…..urine cannot be sprayed but maybe it can be applied if it is mixed with cow dung". A majority (92%) of the 62 respondents who answered this question stated that their current use of animal manure and/or chemical fertilisers to meet their fertiliser requirements makes urine recycling less attractive. Respondents' opinions on potential changes in the taste of crops and vegetables following urine application were found to differ significantly ($p < 0.01$) by type of farming carried out: 63% of organic farmers believed that the taste would change, while none of the inorganic farmers thought so. In contrast to findings in earlier studies (e.g. Lienert et al., 2003; Nawab et al., 2006; Mariwah and Drangert, 2011), the Vellore farmers surveyed here did not consider bad odour to be a major concern. Moreover, 85% of the farmers with a negative attitude to urine re–use believed that people would mock them and/or make fun of them if they used human urine (Fig. 3). In the survey, this was the second most important factor discouraging respondents from using urine as a fertiliser. However, responses to the last question, on whether the farmers would 'never use urine', revealed that, among all the farmers with a negative attitude ($N = 36$), 31% would still consider using human urine.

3.4. Explanatory factors and aspects influencing farmer attitudes to human waste re–use

In an effort to unlock conscious/unconscious defences that might influence the attitudes of farmers to urine recycling, they were confronted with three additional (indirect) questions concerning: the difference between cow and human urine, the notion of 'relatability' and their views of consumer marketplace behaviour. The mean response of the farmers, segregated into their socio–demographic variables, revealed an overall negative attitude to urine recycling (Table S1).

3.4.1. Farmer perceptions of cow urine and human urine

By tradition, the cow is considered holy in the Hindu religion and is extensively studied and used in the ancient system of Indian medicine, while cow urine routinely finds use as a 'safe' crop fertiliser. On the other hand, the Indian caste–based hierarchy considers most, if not all, activities that deal with human urine, sanitation, cleaning and maintenance of sewers and toilets to be 'polluting labour' that must be designated to *Dalits*, castes also considered 'polluted' or 'untouchable' (Narula, 1999). Hence, to explore the contrast between perceptions over these two different types of urine, the farmers were confronted with a question on whether they considered human urine to be any different from cow urine in terms of fertiliser potential. Based on the responses, 52% of the farmers ($N = 98$) believed that human urine was different from cow urine (Fig. 4). However, there was a statistically significant difference ($p = 0.046$) between the mean responses of the male and female farmers, with 72% of the females considering human urine to be no different than cow urine. In terms of caste affiliation, Scheduled Tribes ($\mu = 2$) and Scheduled Castes ($\mu = 1.64$) cultivators believed that the two urines are different, while the upper castes ($\mu = 1.33$) did not.

3.4.2. 'Not–in–my–circle' syndrome

A majority of the respondents (82%) did not know anyone else that uses or used human urine for crop fertilisation. No statistically significant difference between the mean responses was found for any of the demographic variables except family size (Fig. S3). Only farmers who had been cultivating their land in Vellore for at least six years knew of

Table 2
Attitude of farmers in Vellore to urine recycling (questions 19–21), divided by socio–demographic variables.

Variable	Question 19			Question 20			Question 21			Overall Attitude	
	μ	*p*–value	Attitude	μ	*p*–value	Attitude	μ	*p*–value	Attitude	Variable μ	Variable Attitude
Gender											
Male	1.31	0.0945	–	1.48	0.1839	–	1.61	0.8650	+	1.47	–
Female	1.56		+	1.61		+	1.62		+	1.60	+
Age (years)											
< 30	1.43	0.5990	–	1.29	0.3601	–	1.17	0.0204*	–	1.30	–
30–45	1.44		–	1.41		–	1.65		+	1.50	+/–
45–60	1.30		–	1.55		+	1.74		+	1.53	+
> 60	1.33		–	1.58		+	1.50		+/–	1.47	–
Family Size											
≤ 3	1.36	0.6960	–	1.43	0.8740	–	1.30	0.0597†	–	1.36	–
3–4	1.31		–	1.47		–	1.58		+	1.45	–
4–6	1.38		–	1.54		+	1.71		+	1.54	+
> 6	1.38		–	1.54		+	1.78		+	1.57	+
Caste											
Scheduled Caste, SC	1.45	0.4030	–	1.36	0.2100	–	1.38	0.1050	–	1.40	–
Scheduled Tribe, ST	1.00		–	1.75		+	NA		–	1.38	–
Other Backward Class, OBC	1.37		–	1.55		+	1.68		+	1.53	+
Upper caste	1.44		–	1.33		–	1.29		–	1.35	–
Do not know	1.00		–	2.00		+	2.00		+	1.67	+
Do not wish to disclose	1.17		–	1.17		–	1.60		+	1.31	–
Annual Income (₹)											
≤ 45000	1.41	0.1310	–	1.62	0.3210	+	1.60	0.2630	+	1.54	+
45,000 – 100,000	1.23		–	1.43		–	1.53		+	1.40	–
> 100,000	1.67		+	1.33		–	1.33		–	1.44	–
Do not wish to disclose	1.38		–	1.42		–	1.75		+	1.52	+
Farm Size (ha)											
≤ 1	1.28	0.2981	–	1.60	0.3851	+	1.69	0.1250	+	1.52	+
1–2	1.36		–	1.08		–	1.60		+	1.35	–
2–4	1.38		–	1.38		–	1.36		–	1.37	–
> 4	1.67		+	1.42		–	1.67		+	1.59	+
Farm ing History (years)											
≤ 2	1.17	0.4250	–	1.67	0.1360	+	1.00	0.1521	–	1.28	–
2–4	1.31		–	1.31		–	1.44		–	1.35	–
4–6	1.67		+	2.00		+	2.00		+	1.89	+
> 6	1.37		–	1.50		+/–	1.65		+	1.51	+
Farm type											
Organic	1.31	0.0933	–	1.62	0.3510	+/–	1.50	0.1530	+/–	1.48	–
Inorganic	1.50		+/–	1.58		+	1.76		+	1.61	+
Organic+Pesticides	1.31		–	1.44		–	1.55		+	1.43	–
Mean response: *Negative group*	1.41		–	1.61		+	1.74		+		
Mean *response: Positive group*	1.33		–	1.42		–	1.43		–		

*p<0.05; **p<0.01; ***p<0.001; †p<0.1; (+) positive attitude; (–) negative attitude

other people who had used human urine earlier. Furthermore, none of the Scheduled Tribe or Scheduled Caste farmers knew anyone using human urine. Nonetheless, most of the farmers who did know anyone using human urine as a fertiliser (83%) considered themselves organic farmers.

To analyse the influence of 'relatability' of the respondents with respect to the idea of urine re–use in agriculture, the farmers were asked to compare two hypothetical situations: someone they know, or are related to, such as a friend or a relative (family) starts using human urine and their neighbour starts using human urine. The farmers were expected to react positively, i.e. be open to the idea of urine re–use, or react negatively to it. Interestingly, 92% of the farmers stated they would react negatively if a friend or a relative started using urine as a fertiliser, while only 41% responded negatively to their neighbours using it (Fig. 5). A syndrome that we denoted '*not–in–my–circle*' appeared to have an influence, as farmers would rather see their neighbours use human urine than their friends, family and colleagues. However, even among the farmers with a positive reaction, some remarked that they would not mind their neighbour using urine as long as no foul odours found their way to them. An economic motive for re–use of urine was evident among a few farmers who stated that, if their neighbours used human urine and received good productivity gains from it, they too would give it a try, since it is a "free fertiliser". The responses of organic and inorganic farmers differed significantly ($p = 0.042$), with respondents identifying themselves as organic farmers being open to their neighbours using urine and those identifying themselves as inorganic farmers being resistant.

3.4.3. Marketplace dynamics and its influence on farmer attitudes

In the survey, the farmers were also asked to provide an opinion on whether they thought people in the marketplace would be willing to buy food produced on a farm that used human urine as a fertiliser. This question was intended to identify whether the farmers believed any potential barriers and/or incentives existed among consumers of their produce. Only 25% of the farmers stated that they thought people in the market would buy urine–fertilised produce (Fig. S4), while 34% of

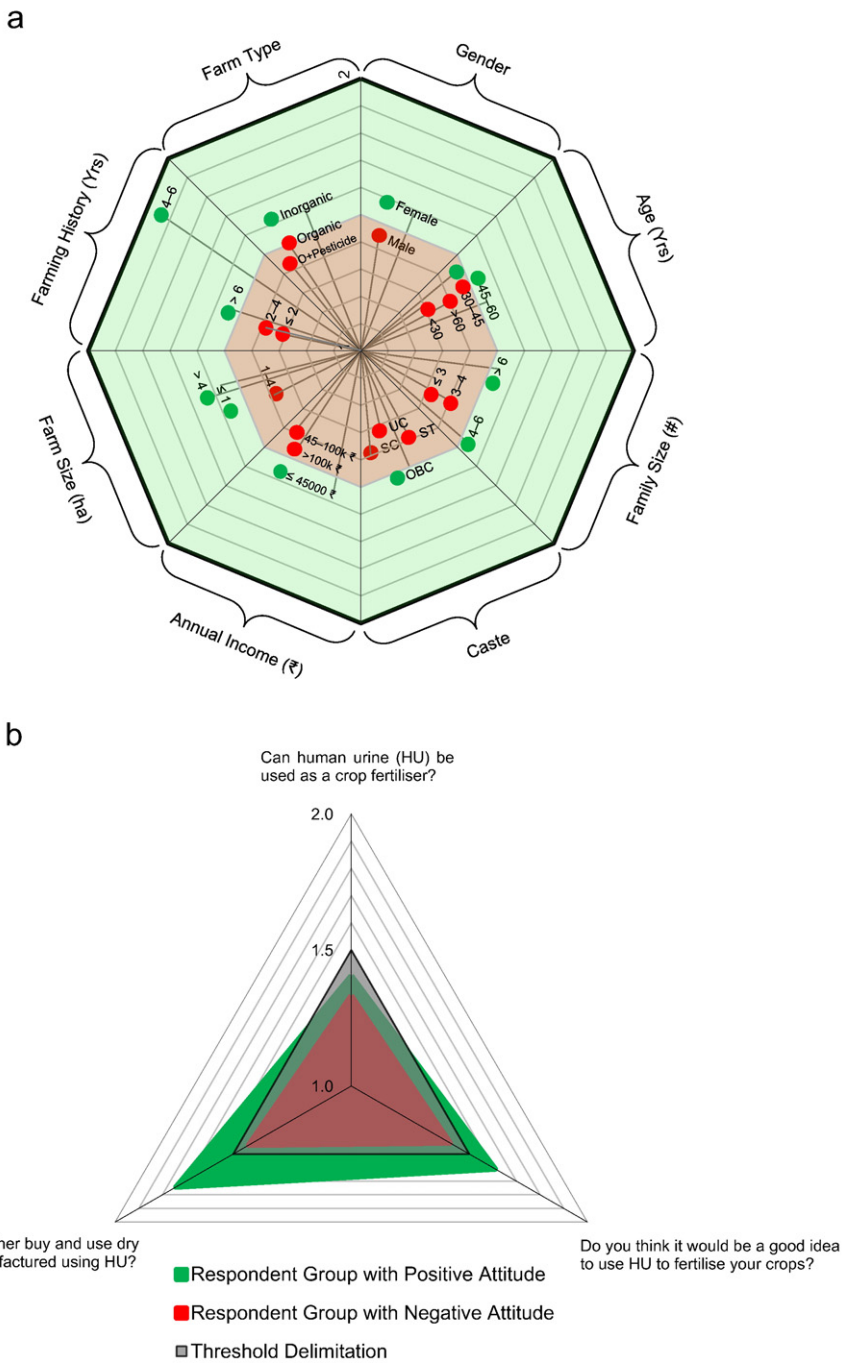

Fig. 2. (a) Overall attitude to human urine recycling among farmers in Vellore, divided according to their socio–demographic variables; green depicts region of positive attitude while red depicts negative attitude. (b) Overall perception in Vellore on urine recycling, divided into groups of farmers with a positive (green) and negative (red) attitude.

the farmers stated that they could not take a stance on this as they felt consumer behaviour was not something they could predict. The mean response of the inorganic farmers was found to differ significantly ($p = 0.034$) from that of the organic farmers. Against what was expected, none of the 'pure organic' farmers thought that people in the market would buy urine–fertilised food, while 48% of the inorganic farmers thought that they would. The comments from the farmers in response to this question were quite interesting. Those who said that consumers would buy urine–fertilised food thought so because: (i) they would not inform their consumers in the first place; (ii) the consumers would think the farmer was lying and buy the food nonetheless; and (iii) some farmers believed that urine–fertilised produce could only be sold at a lower price, which might encourage consumers with low disposable incomes.

3.5. Faecophobia: its existence and extent

Drangert (1998) noted that people's perceptions of urine differ from those on faeces. When asked to provide an opinion on human faeces, 46% of the respondents in the present study stated that it was a good ($N = 23$) or very good idea ($N = 8$) to use it as a fertiliser. Although farmer responses with respect to age did not differ significantly, none of the young farmers thought using faeces was a good idea. Moreover, the 'pure organic' farmers either did not have an opinion or thought it

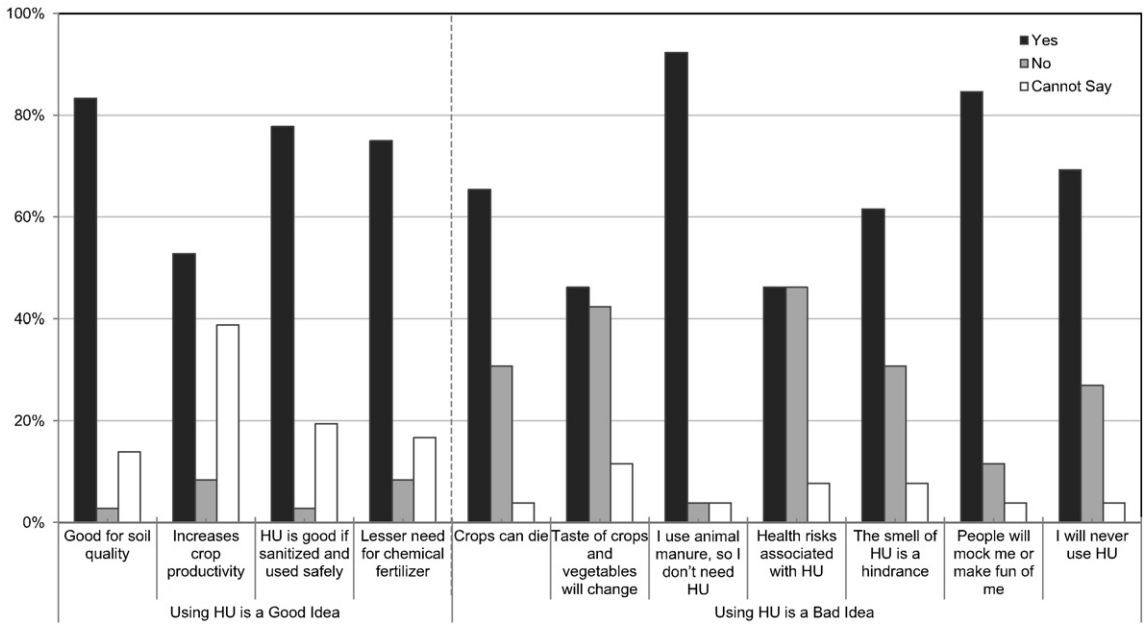

Fig. 3. Factors that encourage/discourage positive and negative attitudes to urine recycling among the 62 respondents who answered this question. Those who thought it was a good idea were asked to take a stance on a number of positive statements on fertilising with human urine (HU), while those who did not think it was a good idea were asked to take a stance on a number of negative statements; the respondents were given the options – yes (black), no (grey) and cannot say (white).

was a bad idea ($p = 0.03$) (Fig. 6). A few respondents remarked that they were aware of the fertilising nature of faeces and that they knew people who are currently using it and/or people who used to apply faeces a few decades ago.

In their analysis of potential obstacles to sustainable sanitation, Winblad and Simpson–Hébert (2004) talk about modern society's fear of human faeces and refer to this as "*faecophobia*". They point to Hinduism as an example to illustrate the fear of faeces, as it is considered

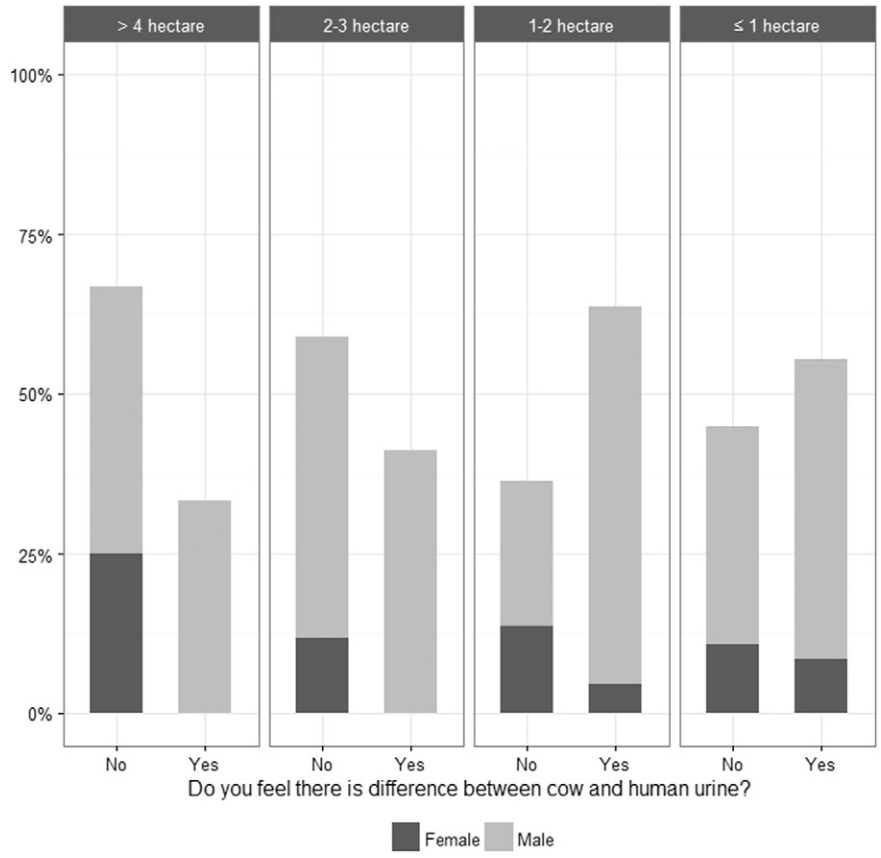

Fig. 4. Graphical representation of respondents' views on whether there is any difference between human and cow urine in terms of fertiliser potential ($p < 0.05$); responses divided by holding size (>4 ha, 2–3 ha, 1–2 ha, ≤1 ha) and by gender (female, male).

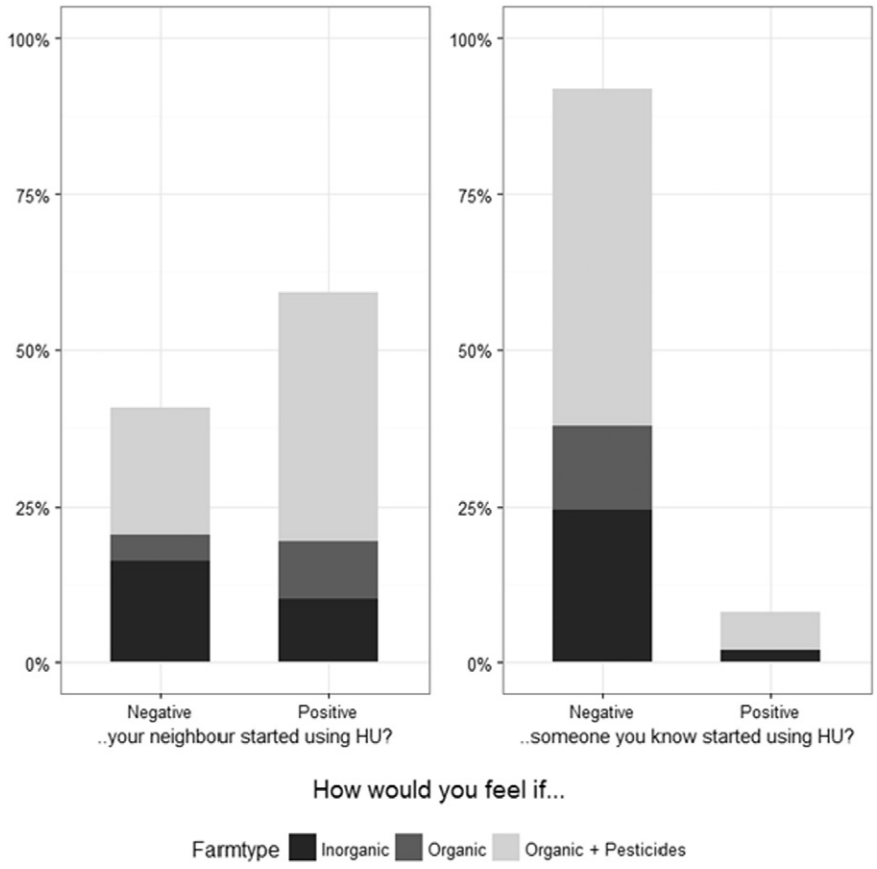

Fig. 5. '*Not–in–my–circle*' syndrome among survey respondents in Vellore, divided by type of farming the respondents reported practising – inorganic (dark grey), organic (medium grey) or organic + pesticides (light grey).

'unclean' by upper caste Hindus. In the present survey, conducted on randomly selected farmers in Vellore, no caste–based difference in attitudes to use of faeces was found. While upper caste farmers in Vellore were essentially against the idea of using faeces (50%), it is important to note that they made up <10% of the survey sample. In India, the upper caste accounts for a large proportion of total landholdings; however, the Other Backward Classes, Scheduled Castes and tribes far outnumber them in terms of total number of farmers and agricultural labourers (Census of India, 2011). According to a National Sample Survey Organisation study conducted in 2006, the Other Backward Classes account for 41% of the total population in India (NSSO, 2007); it is also estimated that they account for around one–third of all landholdings in India (Byres et al., 2013). However, people belonging to the lower castes also work as agricultural labourers and seasonal workers on farms owned by the upper caste (Fuller and Narasimhan, 2014) and hence are likely to determine the use of recycled faeces. Although not tested in this survey, it could be interesting to observe the attitudes of upper caste landowners in India to their agricultural labourers applying and using human wastes on their lands. It would be equally interesting to elicit the willingness of labourers to do so. Making this distinction could possibly result in different answers than those found in this study.

There appears to be some degree of faecophobia in Vellore and, conceivably, this is also the case in other parts of India and the world, judging from studies conducted elsewhere. However, it would be erroneous to overestimate its extent and to simply go on assuming that faecophobia exists in all societies and that people would not be open to the idea of nutrient recycling from faeces. Understanding the origins of such perceptions certainly holds the key to deconstructing the reasons for faecophobia and providing insights to dispel them.

4. Discussion

4.1. Trust as a variable

Demography, culture and tradition significantly shape the approach and management practices that societies adopt to address societal issues such as sanitation. However, besides these factors, there may be other significant factors that have to be taken into consideration when planning and implementing nutrient recycling programmes. In the case of Vellore farmers, for instance, '*trust*' could be a key variable that determines the proliferation potential of human waste recycling. Farmers in that region trust and value the opinions of people they know, people to whom they are related or people with whom they have been socialising and interacting over the years. This information was elicited in the present study, where it was observed that none of the respondents who knew someone using human urine as a fertiliser thought it was a bad idea to use it on their own crops (Table 2; Fig. S3).

In rural India, farmers have been observed to rely on the advice of people they know, family members and, in many cases, helpful neighbouring farmers, rather than 'expert' advice. For example, in a survey of 375 households in Karnataka, Gandhi et al. (2007) observed that even though several farmers had been approached repeatedly by experts in the past, they were more inclined to turn to a friendly neighbour for advice than to rely on expert recommendations. With this in mind, it is likely to be important that safe urine recycling practices are demonstrated by farmers who are already using urine on their land to farmers who are considering using them, in order for any misconceptions such as the 'poisonous' effect of urine on soils to be removed.

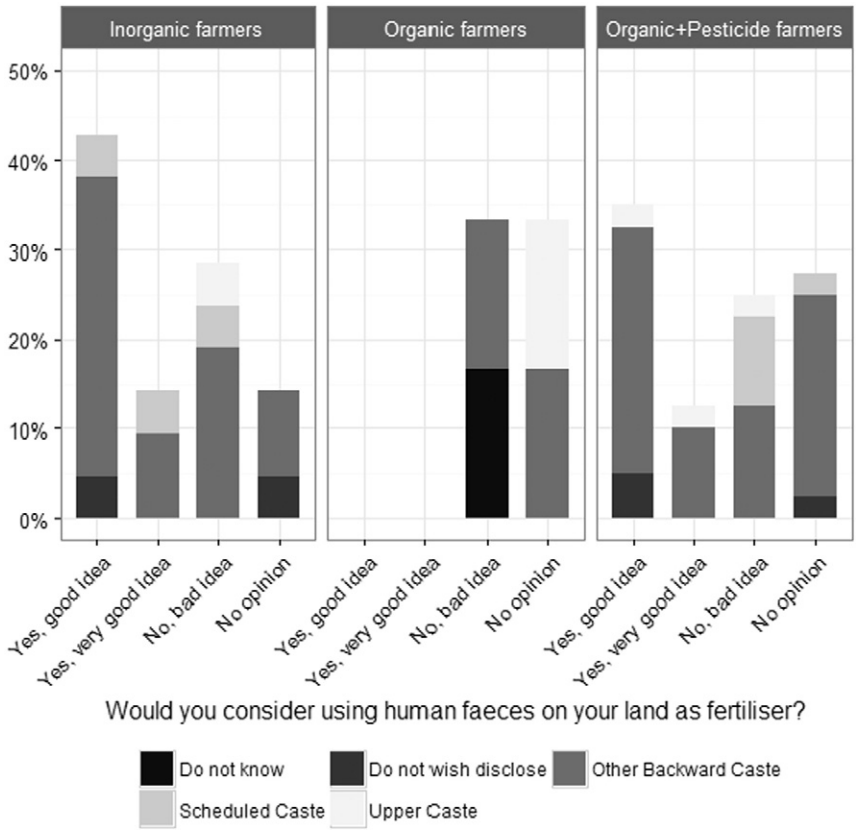

Fig. 6. Graphical representation of whether the respondents would consider using human faeces on their land as fertiliser, divided into the type of farming the respondents identify themselves as practising (inorganic (left panel), organic (middle panel) or organic + pesticides (right panel)) and the caste to which the respondent belongs (do not know (black), do not wish to disclose (dark grey), other backward class (OBC, medium grey), Scheduled Caste (SC, light–medium grey) and upper caste (light grey).

4.2. Producer–consumer dynamics

Previous studies examining the acceptance of No–Mix toilets among consumers in urban, semi–urban and eco–housing settlements have found that there is high acceptance of urine–diverting toilets and re–use of human wastes for food production (Lienert and Larsen, 2006; Lienert and Larsen, 2009; Lamichhane and Babcock, 2013). On the other hand, Lienert et al. (2003) and Lienert (2013) found that farmers were worried about reduced sales and low consumer acceptance of urine–fertilised food. Similar concerns were voiced by farmers in Vellore, as only 25% were of the opinion that consumers would be willing to buy urine–fertilised food. Even among farmers with a positive attitude, many stated that they would not inform their consumers about their practices. Based on the results from earlier studies and the present survey, it would appear that there is a disconnect between producer and consumer. Despite some indications that consumers may be willing to accept new systems of sanitation and fertilisation/food production, there is reluctance among the producers to close this nutrient loop. This could be because they might be unaware of the creation or existence of such willingness among consumers, or because they do not believe in such positive indications. Nevertheless, for urine recycling to become a reality, it will be imperative to demonstrate to farmers that there is willingness among their consumers to buy urine–fertilised food. Only through such integration can urine recycling become attractive enough to encourage both consumers and producers to shift away from their current practices.

4.3. Urine: health risks and awareness

Health risks from human urine was not a crucial factor discouraging farmers in Vellore from using it as a fertiliser (Fig. 3). Moreover, none of the farmers who believed urine poses health risks expanded on why they felt so. In a survey of 125 Swiss farmers, Lienert et al. (2003) reported that 30% raised concerns regarding urinary hormones and pharmaceutical residues. However, environmental awareness is high among Swiss farmers and they have also been made accountable for various environmental problems (eutrophication, land degradation) in the country (Belz, 2004). In contrast, ever since the adoption of the Green Revolution and the goal of modernising and industrialising the agriculture sector, Indian farmers have been predisposed towards chemical fertilisers and pesticides and encouraged to streamline themselves into large–scale irrigation schemes (Frankel, 2015). It is estimated that 11–27% of the potential agricultural output in India is lost to poor soil management practices, over–farming (intensification), over–fertilisation and improper irrigation (Scherr, 1999).

4.4. Caste hierarchy in society and sanitation

In Tamil Nadu and in India as a whole, 'caste traditionalism' plays an important role in determining people's profession. By convention, the upper castes are 'landowners' who never work on the land, as manual labour is considered demeaning and best left to the lower castes (Deliege, 1992). Besides, professions that deal with sanitation management and excreta disposal are discriminated as 'polluting labour' and these activities are traditionally performed by the lowermost sections of Indian society. Centuries of tradition have established not only broad congruence between caste and class (Chakravarti, 2005), but also an inter–generational inheritance of occupations that people can prescribe to. The Supreme Court of India has estimated that 9.6 million dry toilets throughout the country are still being manually cleaned by people belonging to the Scheduled Castes (Human Rights Watch, 2014).

In the present survey, both the upper and lower castes seemed to agree that the use of urine on their farms would put them at risk of

being ridiculed, although the reasons for such beliefs may differ between the castes. It could be so that the position of upper caste farmers in society may create hesitation among them to considering using urine, whereas among farmers belonging to the lower castes a lingering fear of returning to their erstwhile unfavourable positions as manual scavengers and sanitation workers could be the reason for such hesitation.

4.5. Comments on the research methodology

In the research methodology followed in the present study, the response 'cannot say' was assigned a numerical value of '1', since it did not indicate a positive attitude in the respondent to excreta re–use during the period in which the survey was administered. Hence, given the cross–sectional nature of the survey, it is quite probable that the mean response for farmers with a negative attitude may have been over–estimated. While 98 out of the 120 cultivators approached provided all socio–demographic data, there was a large dropout during the survey (36%) when confronted with questions that elicited their attitudes on waste recycling. Analysis of the mean response, i.e. $\mu =$ proportion of farmers who responded to further questions, indicated that all farmers who had spent ≤2 years farming and followed 'pure organic' ($\mu = 1.38$) or 'organic + pesticide' ($\mu = 1.43$) farming on holdings ≤ 1 ha in size were not interested in further questions. Besides, none of the Scheduled Tribe farmers participated further. These aspects must be taken into consideration when conducting future studies on farmer attitudes in India and when attempting to promote waste recycling programmes in such settings.

5. Conclusions

By applying a sociological perspective, this survey of farmers in Vellore (southern India) provided insights that add to the current discourse in environmental psychology, which seeks to understand the factors that encourage or discourage adoption of environmentally friendly technologies. When asked whether they thought human wastes could be used as a fertiliser, 59% of the farmers who took a stance responded positively to the use of urine, while 46% were positive to the use of human faeces.

Interestingly, farmers in Vellore appeared to display what we termed a '*not–in–my–circle*' syndrome, as they would prefer to see their neighbours use human urine rather than their friends, family and colleagues. Improved soil quality and potential cost savings from the reduced use of chemical fertilisers were found to be the main factors that motivated farmers to respond positively to the possibility of using human urine. Moreover, 78% of the respondents who indicated a positive attitude considered urine to be 'safe' fertiliser despite having little or no information about its sanitisation or concentration of micropollutants and pharmaceuticals. The main factors that discouraged urine recycling among the farmers with a negative attitude included crop die–off, the risk of being ridiculed and uncertainty over consumer marketplace behaviour. The survey also indicated that, for farmers to adopt human urine as a fertiliser, they must know someone who uses/used it and/or must be convinced of its crop productivity potential. Any consideration of human waste recycling in Vellore will most likely be shaped by how, and by whom, the concerns of farmers are addressed.

In the present survey, irrespective of how the farmers responded or what position they took on various questions, an interest in human waste recycling and re–use in agriculture was noted. However, early dialogue, continuous interaction and integration of user stakeholders (producers and consumers) in the conceptualisation, design and implementation of nutrient recycling programmes is essential to ensure future success and adoption. This will surely necessitate further psycho–sociological research on the subject. As a recommendation for further research, a study co–investigating consumer and producer attitudes might make further contributions to the discourse surrounding user behaviour regarding environmental sanitation technologies.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at http://dx.doi.org/10.1016/j.scitotenv.2017.01.044.

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