Psychometric analysis of the ecological dispositions of rural farming communities in South Africa: Implications for human excreta reuse in agriculture

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Abstract

The established link between anthropogenic activities and environmental problems calls for the understanding of public perceptions of the environment. Circular bioeconomy approaches promote sustainable and resilient food systems, and are critical to address soil, human, and environmental health. This study endeavours to understand the ecological worldviews of rural farming communities and implications for human excreta reuse in agriculture. The study adopted the social psychology theory and the new ecological paradigm scale, which measures environmental attitudes. The Cronbach’s alpha factoring indicated high internal consistency and reliability of the questions. The results show that rural farmers are moderately environmentally conscious. The hierarchical regression results show that age, education, and household income negatively influence environmental attitudes. Pro-environmental farmers perceived lower health risk and believed that they were more capable of using human excreta. The study recommends that the reuse of human excreta in agriculture be marketed as a sustainable and environmentally friendly innovation to increase social acceptance by rural farmers in agri-food systems.

Author summary

Understanding how humans relate to their natural environment in a transition to a sustainable world could help to influence their perceptions and behavior towards sustainable production and consumption. The recovery and reuse of human excreta in agriculture could offer cross-sectorial benefits to agriculture, environment, and the sanitation sector. In the current study, we endeavor to understand the environmental worldviews of rural farming communities in South Africa and what implications they could have for the recovery and reuse of human excreta in agriculture. We asked farmers various questions about their perceptions on the limits of the nature to growth, the role of man in
influencing the environment, the balance of nature, and the possibility of the existence of ecological disasters. The results show that rural farmers are moderately conscious of their environmental, and that their demographic and socioeconomic characteristics have influence human-nature relationships. The findings indicate that farmers who are environmentally friendly, are more confident that they could implement sustainable practices such as the use human excreta in agricultural systems. Based on the findings, we recommend that promoting the use of waste-based products in agriculture should emphasize on the sustainability benefits to the entire value chain.

1. Introduction

Agriculture is the main source of food for the rapidly growing global population and is responsible for more than 90% of global water consumption [1–5]. Agriculture also accounts for up to 90% of reactive nitrogen that enters the earth [6,7] and for more than 20% of greenhouse gas emissions [8,9]. The circular bioeconomy approach is essential for promoting sustainable and resilient food systems and is critical for improving soil, as well as human and environmental health [10–12]. The continued loss of natural resources and environmental quality and the advent of potential global catastrophes, such as climate variability and global warming, increase the interest in understanding the nature of society-environment relationships [13]. A circular bioeconomy is important for building resilient and sustainable food systems [14–17]. Conventional agricultural intensification practices have a negative impact on the environment [18–20] and are therefore not sustainable [21]. Sustainable agricultural intensification could help to meet the growing food demand (including water and energy), while replacing the use of external inputs [22]. The United Nations Sustainable Development Goals (SDGs), specifically SDG 2 and SDG 12, emphasise responsible production and consumption, seek to end hunger, and promote sustainable food and nutrition security for the growing global population [23].

The past decade has also seen the emergence of a new and growing field of research called ‘sustainability science’, which is dedicated to understanding human-nature interactions [24,25]. Sustainability science seeks to understand the socio-ecological interaction of human society and its natural environment, and how the relationship influences sustainability, namely intergenerational redistributive justice, poverty, and maintaining the balance of nature [24–26]. The relationship between society and nature has previously been explained by the dominant social paradigm (DSP), which has been criticised for environmental decline [27,28]. The new ecological paradigm (NEP) challenges the DSP to hypothesise five facets, namely limits to growth, anti-anthropocentrism, balance of nature, anti-exemptionalism, and the existence of an ecological catastrophe or eco-crisis [13]. The contribution of anthropogenic activities to issues such as land degradation, environmental pollution, and global warming is well established in the literature, which provides a rationale for understanding the environment-nature relationship [29]. For instance, climate scientists generally agree on anthropogenic global warming [30]. Furthermore, earlier, and new empirical evidence suggests a positive relationship between environmental consciousness and pro-environmental behaviour [31,32].

While the validity of measuring environmental attitudes through the NEP is established [13], understanding how society relates to the environment and its ecosystem services is vital for mainstreaming circular bioeconomy initiatives in specific contexts. In environmental psychology, self-reported environmental attitudes are used as a latent indicator of behavioural intentions of the human concern for their natural environment. Previous psychometric
analyses utilising the NEP scale have reported two-, four-, and five-dimension models as opposed to the hypothesised unidimensionality of the 15-item scale [33]. The explicit measurement technique of a direct self-report method using a questionnaire is the most popular method to measure environmental attitudes [33].

There is however, a dearth of knowledge regarding how rural farmers relate to their agricultural environment. This study endeavoured to close this knowledge gap by investigating the environmental attitudes of rural farming communities and the implications for human excreta reuse in agriculture. The recovery and reuse of human excreta have several benefits as they link with circular bioeconomy and circular sanitation economy in agriculture [14,16,34,35]. The upstream benefits of human excreta recovery and reuse are related to the emptying of full pit latrines, which acts as a way of providing sanitation for communities that mainly depend on on-site sanitation [36,37]. The downstream benefits are related to the reuse of human excreta to build soil organic matter and therefore helping to restore soil health and complement the agronomic efficiency of chemical fertilisers [38–41]. Other benefits of human excreta recycling are associated with waste management, and sustainability issues related to reduction in net emissions, reduction in environmental contaminants, and resource efficiency from the offset use of chemical fertilisers [11,42–44].

Understanding how to raise awareness of environmental impacts is one of the main justifications of understanding environmental worldviews [45]. This study endeavoured to investigate the reliability, validity, and latent structure of the NEP scale as applied to South African rural farmers. The psychometric analysis of environmental attitudes was investigated, firstly, to determine the suitability of the 15-item NEP scale in the African rural farming context, and, secondly, to provide baseline knowledge on the influence of environmental attitudes on pro-environmental behavioural intentions. It is also important to note that both the DSP and the pro-ecological components of the NEP scale were originally based primarily on Western concepts of environmentalism and technology and that the NEP scale does not seem to be valid in all cultural settings. This study therefore endeavoured to validate and at least test the consistency of the NEP when applying it outside of its original context. Understanding how rural African farmers relate to their environment through the identification of demographic and socio-economic farmer characteristics that influence the environmental attitudes may help to mainstream dissemination strategies and promote environmental consciousness.

2. Materials and methods

2.1 Study area and research design

The survey data were collected using a structured questionnaire, which was administered through personal household interviews in the Vulindlela rural farming community (30.1466˚S, 30.6603˚E) in the KwaZulu-Natal province of South Africa. The study was ethically reviewed and granted full ethical approval by the university’s Humanities and Social Sciences Research Ethics Committee (approval number HSSREC/00001499/2020). Informed verbal consent was obtained from the participants before beginning the survey; with participants being provided the freedom to withdraw from the study at any time. Details of the informed consent are provided in the survey instrument, which is available at https://enketo.ona.io/x/#EkSVyazm. Sample power analysis was performed using the G*Power software based on a power of 0.95, alpha of 0.05, and Cohen’s $d$ effect size of 0.15 to provide a sample size of 153, although the total sample size was increased to 341 farmers based on resource availability and to accommodate other choice experiment studies that used the same survey instrument. A multi-stage sampling procedure was used to select two wards that were the farthest from the main city. A systematic random sampling procedure was used to select households where the
sampling interval was calculated to systematically select household units. From each household, the main decision maker or head of the household was selected for the interview. To accommodate non-responses, absentees, or inaccessible households, the closest household was selected and then resampled from the newly selected household.

The Vulindlela Traditional Council consists of nine wards; all under the sole trustee of the king [46,47]. The traditional community provides residence to the more than 150 000 predominantly Zulu-speaking population [46]. A multi-stage sampling procedure was implemented to select 341 farming households to interview. The study implemented two-day training of enumerators to enhance face validity, identify avertable problems, and improve data quality. The elicitation of environmental attitudes using the NEP scale requires enumerators with exceptional language translation skills and a relatively high conceptualisation level, including the ability to have sensitive conversations with rural farmers. A revised, 15 item five-point Likert NEP scale was used to elicit the participants’ environmental attitudes [13,48]

2.2 Data analysis

This study elicited environmental attitudes and general attitudes towards using human excreta-derived material in agriculture from a sample size of 341 rural farmers in South Africa. The study used binary response-type questions, where 2 represents agreement (2 = ‘yes’) and 1 represents disagreement (1 = ‘no’), to give a mean response of $1 \leq \mu \leq 2$ [49]. A mean score of 1.5 was considered neutral, with a mean score above 1.5 indicating a positive attitude. The reason for using single-response, closed-ended yes-no questions was to reduce the cognitive burden on the respondents. Although responses from open-ended qualitative questions may provide a richer dataset, it can be unwieldy to make conclusions from such data. Demographic and socio-economic data such as the age, education, farm experience, income, income sources, gender, religious affiliation, interaction with extension, farm size, and family size of the household head were also collected.

The five-point Likert NEP scale item responses were coded 1 to represent strong disagreement and 5 to represent strong agreement with the question [13]. The seven even-numbered NEP statements where disagreement with each statement represented a pro-environmental/ecological worldview were reverse coded for analysis purposes from the original survey coding to follow the same direction of agreement with the rest of the questions [45,50–52]. The overall NEP rating ($1 \leq \mu \leq 5$) indicated the mean of all responses [52], with 3 being neutral, 1 being strongly anti-ecological, and 5 representing strongly pro-ecological worldviews [53]. The study used Cronbach’s alpha ($\alpha$) to test the participant responses’ internal consistency and the reliability of the NEP statements. Using the results of the exploratory factor analysis, the latent structure and the dimensionality of the NEP scale were evaluated against the five facets, namely reality of limits to growth, anti-anthropocentrism, fragility of nature’s balance, rejection of human exemptionalism (the belief that humans are exempt from environmental forces), and the possibility of an eco-crisis [13,52].

2.3 Segregated environmental attitudes

The study used the theory of planned behaviour to predict the farmers’ behavioural intentions to use human excreta [54,55], which is empirically tested and validated. The assumption is that, if farmers report positive attitudes towards human excreta recycling in their agricultural systems, there should be strong intentions to practise the actual behaviour [50]. The theory has been empirically applied to evaluate various pro-environmental behavioural intentions [56–60]. The farmer characteristics identified include gender (1 = male, 0 = female), age of the household head (in years), years of education, years of farming experience, religious affiliation
(1 = Christianity, 0 = others), and income as categorical variables. Segregated environmental attitudes were analysed using the hierarchical regression models to test the influence of farmers’ demographic and socio-economic characteristics. The latent class-based regression models were used to allow the data dimension reduction of the outcome variable, and to test the hypothesised link between the psychometric NEP scale and the demographic, cultural, socio-logical, and economic farmer-specific variables. The model provides a robust probabilistic approach to capture the unobserved heterogeneity in the response variable [61]. The suitability of factor analysis was examined using a correlation matrix to filter out coefficients less than 0.3 as problematic [62]. The study used the Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy, and Bartlett’s test of sphericity to assess the correlation matrix factorability. Values greater than 0.5 were used as the minimum for the KMO test and values less than 5% for Bartlett’s test [63]. Orthogonal varimax rotation was adopted for easy interpretation of the factor-loading structure. The factors were analysed and saved for use as dependent variables in the regression models. The hierarchical regression analysis requires the dependent variable (attitudinal dimensions) to approximate a normal distribution and to be on a continuous scale [64].

### 2.4 The influence of environmental attitudes on human excreta reuse in agriculture

The segregated attitude scores were evaluated to estimate the effect of environmental world-views on the six dimensions of attitudes inspired by the theory of planned behaviour, namely (i) the attitude score, (ii) the production attitude score, (iii) the consumption attitude score, (iv) the perceived behavioural control, (v) the subjective norms, and (vi) the combined attitude score. The attitude score was computed by taking the mean scores of the following six attitudinal questions, namely (a) are you willing to use co-compost in agriculture, (b) are you willing to use human urine, (c) do you think human excreta should be disposed and never used, (d) would you buy food produced using human excreta, (e) would you eat food produced using co-compost, and (f) would you consume food produced using human urine? The production attitude score was calculated from the mean score of three of the six attitudinal questions above (a, b, and c). The consumption attitude score was computed by taking the mean score of three of the questions above (d, e, and f).

The perceived behavioural control score was calculated based on the mean score of the four question items, namely (i) do you think that you have enough skills to use human excreta in agriculture, (ii) do you think that treating human excreta reduces health risk, (iii) do you think that treated human excreta contain disease-causing agents, and (iv) do you think that pharmaceuticals can still be found in food produced using human excreta? The perceived behavioural control was expected to capture the respondents’ self-evaluation of their confidence or skill (self-efficacy) and their risk-benefit perception. The subjective norms score was calculated by taking the mean score of the following questions: (i) do you think others would use human excreta in agriculture, (ii) do you think others would buy food grown with co-compost, (iii) do you think your family would eat food grown with human excreta, and (iv) do you think relatives, neighbours, or friends would eat food grown using human excreta? The subjective norms were expected to capture the existence of convergent human behaviour and the influence of individual attitudes by the behaviour of others through social learning.

The influence of the environment on behavioural intentions helps to test the attitude-intention hypothesis, namely whether environmental dispositions influence recycling behavioural intentions. The analysis of variance (ANOVA) was used to compare the mean scores of the environmental dispositions. The study used Fisher’s least significant difference (LSD) to report the significant mean group comparisons. The effect of environmental disposition was
evaluated for endorsement of NEP or pro-ecological worldviews ($\mu > 3$), neutral ($\mu = 3$), and the DSP ($\mu < 3$).

3. Results
3.1 Environmental attitudes of farmers

The NEP scale’s reliability was tested, and a Cronbach’s alpha of a respectable 0.76 indicated high internal consistency of the scale (see Table 1). The achievement of internal consistency is a necessary but not sufficient condition for unidimensionality. The mean NEP rating of the dataset was 3.12, which indicates moderate environmental consciousness (see Table 1). Further examination of item mean scores shows that farmers strongly agreed with the ecological crisis and the balance of nature. The results also indicate that rural farmers are anti-anthropocentric; that is, they disagreed with the domination of other species by humans (Items 2 and 12). Rural farmers also disagreed with the exemption of human beings from environmental forces and their capability to adapt (Items 4 and 14).

The dimensionality of the NEP scale revealed three unique constructs (extracted using Kaiser’s rule) against the hypothesised unidimensional constructs or the five facets [13]. Based on Kaiser’s rule, the first component explained 25.42% of the data variation, while the second component explained 14.52% and the third explained 7.34% of the variation in the data. The eigenvalues pattern (3.81, 2.18, 1.10) can be interpreted as suggesting the presence of one main factor that fortifies the strong evidence of internal consistency [13]. The three constructs cumulatively explained 47.28% of the variation in the scale (see Table 2).

The latent structure examination using extracted component loadings greater than 0.3 shows that the first component loaded heavily on nine of the 15 items (see Table 3). Close examination of the first component loading shows two loadings on limits items (Items 1 and 6), two balance of nature items (Items 3 and 8), two ecological crisis items (Items 5 and 15), and two anti-anthropocentrism items (Items 2 and 7), and one anti-exemptionalism item (Item 4) loading of the first factor. The loading structure indicates that all the dimensions or facets loaded on the first factor, which further confirms the unidimensionality assumption.

### Table 1. Exploratory factor analysis of the New Ecological Paradigm (NEP) scale items.

| Item | Item scale | Mean  | Std. dev | Cronbach’s alpha | Five facets |
|------|------------|-------|----------|------------------|-------------|
| 1    | We are approaching the limit of the number of people the earth can support. | 3.57  | 1.01     | 0.74             | Limits      |
| 2    | Humans have the right to modify the natural environment to suit their needs. | 2.32  | 1.00     | 0.76             | Anti-anthro.|
| 3    | When humans interfere with nature, it often produces disastrous consequences. | 3.65  | 0.90     | 0.74             | Balance     |
| 4    | Human intelligence will ensure that we do not make the earth unliveable. | 2.49  | 1.02     | 0.75             | Anti-exempt.|
| 5    | Humans are seriously abusing the environment. | 3.87  | 1.04     | 0.74             | Eco-crisis  |
| 6    | The earth has plenty of natural resources if we just learn how to develop them. | 2.18  | 0.85     | 0.77             | Limits      |
| 7    | Plants and animals have as much right as humans to exist. | 3.63  | 1.14     | 0.76             | Anti-anthro.|
| 8    | The balance of nature is strong enough to cope with the impacts of modern industrial nations. | 2.86  | 0.96     | 0.74             | Balance     |
| 9    | Despite our special abilities, humans are still subject to the laws of nature. | 3.91  | 0.85     | 0.76             | Anti-exempt.|
| 10   | The so-called ‘ecological crisis’ facing humankind is greatly exaggerated. | 3.08  | 1.09     | 0.76             | Eco-crisis  |
| 11   | The earth is like a spaceship with very limited room and resources. | 3.32  | 1.04     | 0.74             | Limits      |
| 12   | Humans were meant to rule over the rest of nature. | 2.14  | 1.04     | 0.76             | Anti-anthro.|
| 13   | The balance of nature is very delicate and it can easily be upset. | 3.57  | 0.82     | 0.74             | Balance     |
| 14   | Humans will eventually learn enough about how nature works to be able to control it. | 2.37  | 0.88     | 0.76             | Anti-exempt.|
| 15   | If things continue on their present course, we will soon experience a major ecological catastrophe. | 3.77  | 0.89     | 0.74             | Eco-crisis  |

Mean NEP rating | 3.12 | 0.47

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The second factor-loading structure has two anti-anthropocentrism items (Items 7 and 12), one of each remaining facet (Items 9, 10, and 11), and no loading on the balance of nature item. The third component heavily loaded on the balance of nature item (Item 13), the anti-exemptionalism item (Item 14), ecological crisis (Item 15), and the limits to growth (Item 11), and did not load on the anti-anthropocentrism dimension. The three discernible dimensions are not unreasonable but indicate sample variations in belief systems and the organisation of items into unique and coherent frameworks [13].

3.2 Segregated environmental attitudes: A measure of construct validity

Segregated environmental attitudes evaluate the influence of the farmers’ demographic and socio-economic characteristics using the latent class models and hierarchical regression. The
NEP scale’s construct validity indicates whether the item scores are related expectedly with individual farmer characteristics, namely age, education, gender, religiosity, and income. Using the mean NEP score as the dependent variable, the age, level of education, and extension officer interaction significantly influenced environmental attitudes. The more sensitive environmental attitudinal dimension was the first component extracted using factor analysis. Age, education, experience in farming, religiosity, extension officer interaction, and household income all significantly influenced the farmers’ environmental disposition. The age variable behaved as expected, where younger farmers endorsed the NEP scale. The rationale is that younger farmers will be willing to try new technologies, instead of older farmers who are firm in their traditions. With a 10% increase in age, the environmental attitude score reduced by 0.2 \( (p < 0.01) \), which validates the construct validity of the NEP score (see Table 4).

The level of education negatively and counterintuitively influenced environmental attitudes. The intuitive results would be that the more educated farmers are, the more likely they are to be exposed to environmental issues and would therefore be more pro-ecological [13]. The study results show that a 10% increase in years of education reduces the mean NEP score by a non-negligible 0.4 units. A shift from the lower-income group to the middle and towards higher income results in a significant reduction of 0.15 score points in the NEP score. The more educated rural farmers are, the less likely they are to care about the environment. This is counterintuitive as empirical evidence from the Global North suggests a positive influence of education on environmental concern [65].

Extension officer interaction and years of farming experience were the only variables that positively affected environmental attitudes as measured by the NEP scale. A change from not interacting with an extension officer to at least one interaction per year shifts the NEP score by a considerable 0.46 score points. A 10% increase in farming experience results in a 0.1 score points increase in the NEP score. Interaction with an extension officer provides new information about changes in the environment; increased frequency of interaction should therefore, as expected, be linked positively to endorsing the NEP scale.

To check for robustness, the results of the exploratory factor analysis were used as dependent variables to identify the influences of farmer characteristics on environmental attitudes. The effect of farming experience is likely to be different from that of the age of the household head. Farming experience indicates the number of years that the farmer has been fully engaged as a farmer. One would expect a more experienced farmer to be in touch with the environment and therefore more environmentally conscious, as indicated by the results. Religiosity (coded

| Dependent variables | Mean NEP score | Component 1 | Component 2 | Component 3 |
|---------------------|---------------|-------------|-------------|-------------|
| Independent variables | Coefficient (std. error) | Coefficient (std. error) | Coefficient (std. error) | Coefficient (std. error) |
| (Constant) | 3.67(0.19)** | 1.50(0.40)** | 0.55(0.32) | 0.75(0.27)** |
| Gender | -0.03(0.06) | 0.02(0.12) | -0.12(0.10) | 0.08(0.08) |
| Age (in years) | -0.01(0.00) | -0.02(0.01)** | 0.01(0.01) | -0.02(0.01)** |
| Years of education | -0.02 (0.01)** | -0.04(0.02)** | -0.02(0.02) | -0.02(0.01) |
| Farming experience (in years) | 0.00(0.00) | 0.01(0.01)** | -0.02(0.00)** | 0.01(0.00)** |
| Religious affiliation | -0.03(0.02) | -0.12(0.05)** | -0.42(0.13)** | -0.20(0.11) |
| Extension officer interaction | 0.22(0.11)** | 0.46(0.22)** | 0.07(0.18) | 0.08(0.16) |
| Annual income | -0.03(0.03) | -0.15(0.05)** | -0.10(0.05) | -0.03(0.05) |

** \( p < 0.05 \)
*** \( p < 0.01 \)

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16. Christianity) also had a significant negative effect on the farmers’ environmental dispositions. Moving from Christianity to other religions increased the likelihood of supporting pro-environmental behavioural intentions. Household income negatively correlated with pro-environmental attitudes and thus with social acceptance of excreta use. The findings for education and household income were particularly in contrast to the findings of similar studies in other populations, in which higher education and income tended to be associated with stronger pro-environmental attitudes and greater acceptance of the agricultural utilisation of human excreta.

3.3 The influence of environmental attitudes on human excreta reuse in agriculture

The general attitudes of rural farmers were positive (1.62), which indicated that 62% of the farmers were willing to use human excreta-based fertilisers. The production attitude score (1.59), consumption attitude score (1.66), and subjective norms (1.59) all indicated willingness to use human excreta in agricultural systems, consume and buy food produced from it, and low restrictions from subjective norms, respectively. The perceived behavioural control (1.43) was negative, which indicated a lack of self-efficacy and perception of health risks (see Table 5). To provide empirical evidence of the influence of ecological dispositions on human excreta recycling behavioural intention, the ANOVA results show that the effect is complex. Environmental attitudes measured using the NEP score significantly affected perceived behavioural control and subjective norms, but not attitudes towards behaviour. Pro-environmental attitudes had a positive and significant effect on perceived behavioural control. The findings indicate that eco-centric farmers, on average, exhibit higher self-confidence (self-efficacy) and lower risk perception in terms of human excreta reuse in agriculture. The attitude-intention hypothesis confirmed the positive influence of environmental attitudes on the behavioural intention to recycle human excreta. However, farmers who endorsed the DSP perceived that subjective norms positively influenced the behavioural intention to recycle human excreta.

4. Discussion

4.1 Understanding environmental attitudes in the context of human excreta reuse in agriculture

The study findings demonstrate that rural farmers in South Africa have moderate eco-centric or pro-ecological attitudes ($\mu = 3.12$). The study also indicates that rural farmers are generally

Table 5. Influence of ecological worldviews on the attitudes towards human excreta reuse using analysis of variance (ANOVA).

| Attitudinal dimensions | Perceived behavioural control | Subjective norms | Attitude score | Combined attitude score | Production attitudes | Consumption attitude |
|-----------------------|------------------------------|------------------|---------------|------------------------|---------------------|---------------------|
| Variables             | N                            | Mean P           | Mean P        | Mean P                 | Mean P              | Mean P              | Mean P              |
| LSD tests             | NEP > DSP = 0.05             | DSP > NEP = 0.13 |
| DSP                   | 119                          | 1.40 0.01**      | 1.67 0.01***  | 1.67 0.28              | 1.54 0.25           | 1.63 0.18           | 1.71 0.22           |
| Neutral               | 21                           | 1.37             | 1.58          | 1.58                   | 1.48               | 1.49               | 1.67               |
| NEP                   | 201                          | 1.45             | 1.54          | 1.60                   | 1.50               | 1.58               | 1.63               |
| Total                 | 1.43                         | 1.59             | 1.62          | 1.51                   | 1.59               | 1.66               |

**p < 0.05
***p < 0.01 N: Number of observations

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positive in almost all dimensions of the attitudes except the perceived behavioural control, which indicated lack of self-efficacy and the strong influence of risk perception in terms of using human excreta in agriculture. The relatively high scoring of the ecological crisis and the balance of nature dimensions may indicate the influence of environmental publicity and the possibility that farmers are currently experiencing the impacts of climate variability or other environmental catastrophes. The results also suggest that rural farmers are anti-anthropocentric and anti-exemptionalistic, which makes it easier for sustainable production systems to appeal to their attitudes. The rural farmers do not believe that humans should dominate over other species, nor be exempted from nature. The findings could indicate the dependence of rural farmers on their environment, especially through land use and climatic forecasts for rain-fed production systems. The reuse of human excreta in agriculture needs to be marketed as sustainable and environmentally friendly behaviour for it to appeal to the environmental dispositions of rural farmers.

The study also unpacked segregated environmental attitudes against the farmers’ demographic and socio-economic characteristics. A meta-analysis of the adoption of agricultural technologies indicates the influence of socio-economic and demographic factors on the adoption of agricultural technologies [66]. The dissemination of agricultural technologies could therefore be enhanced through the identification of the factors that influence the farmers’ decisions to adopt technologies by focusing on early adopters [67]. The identification of early adopters may prevent known barriers to adoption before introducing an innovation [68]. The findings illustrate that the champions of human excreta reuse in agriculture are younger, less formally educated, and non-religious farmers who are not wealthy, but have experience in farming and interact with extension officers. Resource-constrained farmers in rural communities face environmental challenges from waste management, sanitation, pollution, and environmental degradation. The farmers experience first-hand the decline in crop productivity, soil degradation, climate variability, health problems, and environmental pollution. An increase in income could mean that farmers can afford decent sanitation and chemical fertilisers and would therefore lead to farmers not being willing to recycle human excreta. For instance, farmers in the area who cannot afford to empty their full pit latrines may be motivated to want to find ways of dealing with their full pits, such as through recycling, as compared to farmers who can afford to hire pit-emptying services. While empirical evidence suggests a positive relationship between education and human excreta recycling [69–71] an interesting explanation for this would be the interaction of indigenous knowledge stock and the level of formal education. Rural communities often retain indigenous knowledge, which can influence their relationship with the environment. The local formal education system may lack environmentally responsive curricula and national environmental awareness campaigns; to the extent that being formally educated may not necessarily reflect environmental consciousness. The effect of the interaction between variables such as education and income was insignificant and were dropped-out of the analysis during the hierarchical regression process. The impact on the environment on them is higher among experienced farmers in agriculture since human excreta reuse augments soil health and the soil’s resilience to climatic shocks. The results, however, did not find any effect of gender on environmental attitudes. Other studies suggest a positive relationship between women and pro-environmental attitudes, where men perceived risk in urine recycling [72].

The theory of planned behaviour posits that attitude towards behaviour, perceived behavioural control, and subjective norms influence behavioural intentions [73–75]. The fundamental axiom of consistency underlines the attitude-behaviour theory in that, if the direction of the attitudinal dimensions can be established, the human behaviour towards the ‘attitude object’ can be determined. The findings suggest a positive influence of pro-environmental
attitudes on the perceived behavioural control dimension. Empirical evidence supports this attitude-intention hypothesis, where eco-centric and biospheric individuals were reported to exhibit pro-environmental behaviour [76]. Empirical evidence from focus group discussions indicates a correlation between environmental awareness and eco-centric behaviour [72]. Using communication approaches that promote environmental awareness may therefore be sufficient to influence behaviour change and may enhance the demand for sustainable waste-based soil inputs. The ‘awareness-information-decision-action’ approach, for instance, promotes awareness of environmental concerns of interest by promoting factual, evidence-based information and recommendations while assuming behaviour change [76]. Additional costs and efforts could become a barrier to consequential behaviours, especially if the ecologically friendly technologies are not financially supported [72]. The empirical evidence suggests that environmental attitudes are the main drivers for recycling, but financial incentives, rewards, and convenience (through enabling policies) could bridge the value-action gap [77].

4.2 Implications for research and development practice

The findings of this study suggest that there is a considerable number of farmers to champion the use of human excreta in agriculture. The general attitudes are positive, which indicates support for the reuse of human excreta in the rural communities of South Africa. The findings, however, show the strong negative influence of perceived behavioural control, namely self-efficacy and risk perception. A higher degree of perceived behavioural control (associated with negative attitudes towards excreta use) indicates lower self-efficacy but higher risk perception. The technology adoption models, such as the technology acceptance model, posit that the acceptance of an innovation depends on its perceived ease of use and perceived usefulness [78]. Self-efficacy, as proposed by Bandura [79], refers to how well one perceives that they can execute the ‘attitude object’ or technology under investigation; subject to skills, resources, and opportunities, among other factors [80]. The theories have been expanded to incorporate risk and benefit perception. Risk perception refers to subjective judgments of the probability of negative outcomes from adopting a technology, such as diseases, injury, and death [81–83]. The low score on perceived behavioural control indicates that a high perception of health risks and low self-efficacy could negatively influence behavioural intentions and social acceptance. Farmers will only be willing to reuse human excreta in agriculture if the perceived benefits can cognitively compensate for the perceived risks associated with the technology. The positive mean scoring of the other attitudinal dimensions may illustrate this cognitive compensatory behaviour. The results of the scoping review [84] concluded that health risk perception was reported as the main potential barrier to the use of excreta-based fertilisers in 12 out of 22 studies included in the review [71,85–91]. The findings suggest that with proper messaging and targeting, it is possible to identify farmers to champion the dissemination of technological innovations. The findings indicate that championing human excreta reuse in agricultural systems requires young low-income farmers, with fewer years of formal education, as well as experienced, agnostic farmers to represent pro-ecological champions in the South African context. The result is, however, counterintuitive as studies suggest a positive income elasticity of demand for environmental services. Environmental quality is often considered a luxury good, as demonstrated empirically by consumer expenditure surveys, which report an income elasticity of demand greater than 1 [92,93]. However, there is empirical evidence to suggest contextual variation in the factors that explain environmental and sanitation attitudes. More research is also needed to explore the effect of religiosity on environmental attitudes in rural contexts.
The findings indicate the importance of designing context-specific and relational dialectical messaging that appeal to different demographic, sociological, and socio-economic farmer characteristics. Failure to provide targeted messaging may result in technology backlash and criticism. Backlash is likely in the reuse of human excreta, which has been considered taboo in ‘faecophobic’ African contexts [94]. The diffusion of innovation theory states that technology diffusion is explained by the perceptions and social influence of the champions or innovators on potential adopters and the influence of the broader socio-political context [95]. Based on the analysis of innovation theory [68], early adopters or opinion leaders are unconstrained by social norms, and adopt technologies based on their risk-benefit perception. Dissemination and diffusion processes are distinct in that dissemination refers to activities by the development practice to inform farmers and raise awareness of the benefits and sustainability of the innovation. Implementation science, which deals with what happens before, during, and after adopting an innovation, is required to validate the extent to which evidence-based innovation can be effective under practical conditions [96].

The predominance of perceived health risk presents the importance of piloting and pretesting technologies under realistic farmer conditions. Pilot testing not only helps to avoid avertable actual risks and perceived risks, but also ensures that the technologies are tested for financial feasibility, economic impact, and social and environmental sustainability. The influence of environmental attitudes on perceived behavioural control also indicates the importance of appealing to ecological attitudes. Given that pro-ecological farmers are more confident about reusing human excreta in agriculture, raising awareness on environmental benefits of human excreta reuse in agriculture can easily appeal to the already environmentally conscious rural farmers. Community-based pilot-type on-farm demonstration trials could stir a sense of inclusivity and knowledge co-creation, co-investigation, and co-learning, while transferring scientist-farmer knowledge in a relatable dialectical manner. There is evidence that the effectiveness of community-based pilot projects led to community acceptance in other excreta reuse cases [97].

5. Conclusions

The environmental dispositions of rural farmers were explored in this study, by drawing from a sample of 341 rural farmers in the Vulindlela Traditional Authority area, South Africa. The study findings demonstrate that rural farmers in South Africa have embraced the NEP. The findings also indicate that rural farmers are generally positive in almost all dimensions of the attitudes except the perceived behavioural control, which indicated a lack of self-efficacy and the strong influence of risk perception in using human excreta in agriculture. The findings, however, suggest restrictive perceived behavioural control, where farmers exhibited low self-efficacy and strong risk perception in the use of human excreta. The influence of environmental attitudes on perceived behavioural control highlights the importance of environmental awareness in terms of behavioural change. The study results echoed the findings in other studies on the influence of farmer characteristics on behavioural intentions to use human excreta in agri-food systems. However, context-specific differences were noted in the effects of socio-economic and demographic factors on ecological attitudes. Policy and institutional support systems were also discussed to bridge the value-action gap between behavioural intention and practical action.

6. Study limitations and future research directions

There is some caution that needs to be taken in interpreting the results of this study. The influence of environmental attitudes on reported behavioural intentions to reuse human excreta in
agriculture differs from actual observed behaviour. There is a gap between recycling behavioural intention and observed behaviour that requires supporting policies. The implementation of human excreta reuse interventions requires financial resources, effort, skills, and time. Suitable sanitation systems designed for resource recovery and reuse are needed to separate faecal matter from urine to reduce cross-contamination [98]. The construction of such systems may require financial investments beyond the reach of many poor rural farmers. Emptying the contents and applying treatment to remove contaminants to the acceptable levels stipulated by the World Health Organization’s guidelines for reuse of human excreta in agriculture require further investments in time, skill, effort, and finance. Financial incentives and non-pecuniary support structures may enhance the functioning of the recovery value chain while helping to support efforts to promote the social acceptance of human excreta reuse in agriculture. The business models in resource recovery and reuse often lack financial incentives to support the actual treatment and the purchase of end products by the end users. Providing financial support through credit facilities could help young and resource-constrained farmers to start high value chain agricultural activities, including small-scale co-composting ventures. The farmers could be willing to use the co-compost but may lack the ability to finance the required capital investments. The financial constraints can still apply to more organised farmers such as farmer cooperatives, which may also fail to finance investments in human excreta recovery and reuse innovations.

The comparison of this study’s findings with other similar studies suggests some methodological and contextual differences. More contextual studies may be required to validate the findings while providing contextual barriers and opportunities for the adoption of recycled human excreta in agricultural production systems. The influence of education on environmental attitudes was counterintuitively negative; possibly indicating the effect of indigenous knowledge stock. Studies from developed economies indicate the positive influence of education on environmental awareness. Rural communities are commonly endowed with indigenous knowledge stock, which cannot be evaluated using formal education, and hence may positively influence their relationship with the environment. Understanding the nature of this relationship provides an interesting area for future research with implications for the design and dissemination of agricultural technologies in rural contexts.

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