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Determinants of Farmers' Willingness to Participate Agricultural Waste Recycling in Iran

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Abstract

Technical advances have enabled the conversion of agricultural waste into high-value-added products. However, the lack of proper recycling in developing countries leads to environmental pollution, public health risks, and lost economic opportunities. This survey examined farmers' willingness to recycle agricultural waste in Kamyaran County, western Iran ($n = 375$, analyzed using structural equation modeling). The theory of planned behavior (TPB) was extended by incorporating "moral norms" and "knowledge" as additional explanatory constructs. The results indicated that while farmers' knowledge regarding waste recycling strategies and value-added products was limited, they exhibited a high willingness to recycle waste properly rather than discarding or burning it. The extended TPB model explained a substantial proportion of the variance in willingness to recycle ($R^2 = 0.70$). Attitude, subjective norms, and moral norms were identified as significant predictors of willingness. Furthermore, moral norms mediated the effect of subjective norms, whereas attitude mediated the relationship between knowledge and willingness. Based on these findings, we recommend leveraging educational programs and mass media to enhance farmers' knowledge of the practical and economic benefits of recycling. Additionally, agricultural extension services should be utilized to cultivate positive attitudes and strengthen ethical and social norms toward sustainable waste management.

Keywords: Agricultural waste, Farmers, Knowledge, Willingness, Moral norm, Theory of planned behavior.

1. Introduction

Inadequate management of agricultural waste is a major environmental and economic challenge in many developing countries. Agricultural residues are often burned in open fields or discarded improperly, contributing to air pollution, greenhouse-gas emissions, soil and water contamination, and risks to human health (Peng et al., 2023; Koul et al., 2022; Maji et al., 2020; Khan et al., 2024; Adejumo and Adebiyi, 2020). In addition to its environmental consequences, poor agricultural-waste management results in the loss of valuable biomass that could otherwise be converted into useful products and generate economic benefits (Baruah et al., 2024). Open burning of agricultural waste, which remains common in some developing regions, not only reduces the potential economic value of these materials but also exposes farmers and nearby residents to hazardous concentrations of airborne particles that may contribute to cardiorespiratory diseases (He et al., 2019). It may also reduce soil fertility and increase the risk of forest and grassland fires (Dey et al., 2020).

Traditionally, agricultural production systems generated relatively limited waste because crop residues were commonly reused as organic fertilizer, livestock feed, household fuel, or construction material. However, rapid population growth and the rising demand for food and agricultural products have accelerated the shift toward more intensive and industrialized agricultural systems (Ogbu and Okechukwu, 2023). Although this transition has improved food production, it has also increased the volume of agricultural waste considerably (Koul et al., 2022). According to international reports, approximately 151 billion tons of agricultural residues are

produced annually, with an estimated annual growth rate of 5% to 10% (Taimur et al., 2022). If managed effectively, this large volume of biomass could provide substantial environmental and economic benefits (Ghanbari et al., 2018).

Advances in research and technology have created a wide range of opportunities for recycling agricultural waste into value-added products. Examples include the use of *Rhodococcus* bacteria to produce oil from plant residues such as wheat straw, the production of biogas and biofuels from plant and animal waste, and the use of earthworms for decomposition and vermicompost production (He et al., 2019). Proper recycling of agricultural waste can improve both environmental sustainability and rural livelihoods. For example, recycled organic inputs can enhance soil structure and fertility while reducing dependence on chemical fertilizers and lowering water and soil pollution. Similarly, energy recovered from agricultural waste, such as biogas and biofuels, can reduce reliance on fossil fuels and help mitigate greenhouse-gas emissions (He et al., 2019; Hsu, 2021). In economic terms, agricultural-waste recycling may also create additional income opportunities for small-scale farmers and rural households, particularly in resource-constrained settings (Khosravani et al., 2014).

In Iran, the agricultural sector generates approximately 170 million tons of waste annually (Safaralmouti and Shams, 2016). At the same time, inadequate storage and weak marketing infrastructure reportedly lead to the loss of a substantial share of agricultural products before consumption (Khosravani et al., 2014). This large volume of biomass highlights the need for more effective waste-management and recycling strategies. The issue is particularly important given that a variety of products that can be derived from agricultural waste—including biofuels, chemical solvents, pulp and paper, essential oils, and specialized feed additives—are already produced in developed countries, whereas Iran continues to rely on imports for some of these commodities (Bani Imam and Nasiri, 2017; Daryabeigi Zand and Razaghi, 2014). Therefore, improving agricultural-waste recycling could contribute not only to environmental protection but also to rural development and resource efficiency.

Because farmers make the day-to-day decisions about how agricultural residues are stored, reused, treated, or discarded, they play a central role in the adoption of agricultural-waste recycling practices (Yang et al., 2021). However, previous studies in developing countries suggest that the adoption of such practices remains limited and slow (Kabir et al., 2023; Kamoga and Ssekyewa, 2021; Ghanbari Movahed et al., 2019). One possible explanation is that farmers may lack adequate knowledge about recycling methods, derived products, and the environmental and economic benefits of proper waste management. In addition, in some behavioral theories (e.g. theory of planned behavior by Ajzen (1985) and technology acceptance model by Davis (1989)) and studies (e.g. Fischer, 2017; Shirokova et al., 2016 and Sutton, 2006), willingness is emphasized as a predictor for behavior. Therefore, when researcher seeks to investigate probability of a behavior arising in future, it is necessary to determine whether individuals generally have willingness to do that behavior or not (Faham and Asghari, 2019). Accordingly, this study seeks to investigate farmers' knowledge regarding recycling of agricultural waste and also as multiple studies have consistently demonstrated the Theory of Planned Behavior efficacy in predicting behavioral willingness (Huang and Chen, 2015; Rivis et al., 2009), this study extends the TPB framework by incorporating knowledge and moral norm as additional explanatory variables to examine farmers' willingness to recycle agricultural waste in Kamyaran County, western Iran.

2. Theoretical basis and research model

2.1. The theory of planned behavior (TPB)

This study is grounded in the Theory of Planned Behavior (TPB), which represents an extension and refinement of earlier rational decision-making frameworks, such as the Theory of Reasoned Action (TRA) (Mahdavi, 2021). A central premise of the TPB is that behavioral willingness or intention is the primary driver of actual behavior. In this regard, Armitage and Conner (2001) argue that while the TPB has successfully predicted various behaviors, it is often more effective at predicting behavioral willingness than the behavior itself. Similarly, Ajzen (2005) posits that the willingness to perform a behavior serves as its immediate antecedent. Within the TPB framework, willingness is determined by three core constructs: attitude, subjective norm (SN), and perceived behavioral control (PBC). Attitude is defined as an individual's favorable or unfavorable evaluation of a given behavior; SN refers to the perceived social pressure to perform or not perform the behavior; and PBC reflects an individual's assessment of their capability to perform that behavior (Ajzen, 2002). These three constructs—attitude, SN, and PBC—are conceptually rooted in behavioral, normative, and control beliefs, respectively (Senger et al., 2017).

2.2. Application of the TPB in studying pro-environmental behaviors

Over the three decades since its inception, the TPB has remained a widely adopted framework for analyzing diverse pro-environmental behaviors. These include waste reduction (Hidalgo-Crespo and Amaya-Rivas, 2024; Wang et al., 2024), the adoption of alternative transportation (Lee et al., 2023), pollution control and management (Wang et al., 2019a), combating marine litter (Ngoc et al., 2024), biodiversity conservation (Samus et al., 2023), pesticide use (Sarma, 2022; Damalas, 2021), corporate environmental initiatives (Greaves et al., 2013; Blok et al., 2015) and waste recycling (Zhao et al., 2023; Zhu et al., 2021; Savari et al., 2023; Sonnenfeld, 2018; Mak et al., 2020; Islam, 2021; Wang et al., 2020a). The framework has also been extensively applied to assess the determinants of recycling willingness (See; Ding et al., 2023; Xu et al., 2023; Arli et al., 2019; Mahmud and Osman, 2010).

Despite its popularity, concerns have been raised regarding the sufficiency of the original TPB in predicting pro-environmental intentions and behaviors (Franco, 2024). Addressing this, Ajzen noted that the TPB is, "in principle, open to the inclusion of additional predictors if they can be shown to capture a significant proportion of the variance in intention or behavior" (Yazdanpanah and Forouzani, 2015). In this regards, Stern (2000) believes that the individuals' pro-environmental behavior is heavily influenced by knowledge—a variable not explicitly integrated into the original TPB. Empirical evidence suggests that knowledge-based behaviors are more sustainable than those driven by mere perception without cognitive foundations (Putra et al., 2022). Consequently, numerous studies have demonstrated the substantial influence of knowledge on environmental willingness and behaviors (See Tamar et al., 2020; Mansoor and Wijaksana, 2022, Onel and Mukherjee, 2016; Nahavandian et al., 2022; Sousa et al., 2020).

Moreover, The TPB has been criticized for overemphasizing rational utility while neglecting moral considerations in behavioral decision-making (Manstead, 2000; Kaiser et al., 2006; Ding et al., 2023). This issue is particularly outstanding in situations when moral considerations are important such as environmental problems (Kaiser et al., 2006). Schwartz's (1977) in norm-activation theory statements that "moral norm (MN) is activated in individuals who believe that environmental conditions pose threats to other people, other species, or the

biosphere, and that the actions they do could prevent those threats" (Yazdanpanah and Forouzani, 2015). In this regard, various studies have indicated that incorporating moral norms into the TBP can enhance its predictive power and clarify the role of moral dimensions in decision-making, particularly in predicting pro-environmental behaviors (See Poškus, 2015; Tsai and Tan, 2022; Brehmer, 2023; Batool et al., 2023; Ateş, 2020; Zhang et al., 2026). Another point is that a significant portion of studies based on the TPB assess willingness to act environmentally rather than behavior, mainly for the reason that they believe there are no validated measures for many pro-environmental behaviors (Yuriev et al., 2020; Senger et al., 2017; Xu et al., 2022; Ding et al., 2023**).** In present study, we used an extended model of the TPB as a framework to investigate farmers' willingness to recycle agricultural residue. Knowledge and moral norm were added to this framework for increase predictable power of the model.

2.3. Research model and hypotheses

This study used an expanded model of the TBP to study farmers' willingness to recycle agricultural waste. Fig. 1 indicates research model. As mentioned above, knowledge and moral norm added to the TPB and their effects on willingness to recycle agricultural waste was investigated.

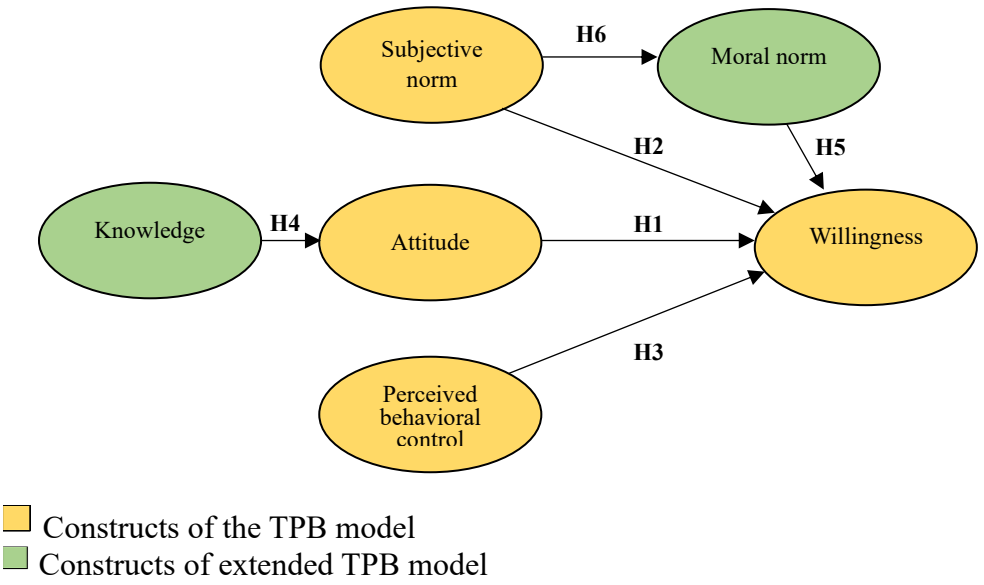


Fig. 1. Research model

The study hypotheses proposed based on the research model are:

H1. Attitude has a significant positive impact on the willingness to recycle agricultural waste.

H2. Subjective norm has a significant positive impact on the willingness to recycle agricultural waste.

H3. Perceived behavioral control has a significant positive impact on the willingness to recycle agricultural waste.

As mentioned above, knowledge is also an important precondition for adopting the correct behavior in any given situation (De Kok et al., 2020). As stated by Zenker et al. (2014), Fabrigar et al. (2006) and Kaiser and Fuhrer (2003), while knowledge provides information necessary for conscious behavior change, attitude provides willingness to change behavior based on that knowledge. In fact, knowledge affects attitude, and attitude in turn impacts willingness to act and then behavior. In this regard, Kaiser and Fuhrer (2003) believe that knowledge "can be viewed as a distal antecedent of behavior conveyed by attitude". In this regard, some previous studies also confirm the importance of knowledge to shape environmental attitude and then willingness and behavior. For example, Maichum et al. (2016) indicated that while environmental knowledge is positively linked with consumers' attitude towards green products which further impacts their purchase willingness. Also, Liu et al. (2020) showed how environmental knowledge forms environmental attitudes and attitudes effect on environmental behavioral willingness. Finally, bbased on these arguments, another hypothesis of the study is:

H4. Attitude plays a mediating role between knowledge and willingness to recycle agricultural waste.

Moral norm refers to ethical values and principles that are internalized within individuals and likely manifest in their behavior (Liu et al., 2020). Subjective norms can serve as an external source for the internalization of moral norms (Zhang et al., 2026). In fact, there are some specific standards in society that are imposed via social pressures and deeply embedded in individuals as personal norm (Sia and Jose, 2019). There are evidences about causal link between SNs and MNs in previous studies. For instance, Onwezen et al. (2013) argued in a study that emotions have been to some extent mediating the influence of SNs on willingness. Based on these claims, moral obligations inspire people to behave in consistent with the norms of reference groups such as family and friends. The hypotheses of this section which will be perused are:

H5. Moral norm has a significant positive impact on the willingness to recycle agricultural waste.
H6. Moral norm plays a mediating role between subjective norm and willingness to recycle agricultural waste.

3. Methodology

3.1. Research method and participants

Participant of this cross-sectional survey study were farmers of Kamyaran County in Kurdistan province- western Iran. The statistical sample size was estimated based on the Cochran formula (1963:75) of 375 farmers. Stratified random sampling technique was used to select this number of farmers to conduct the study. Villages were treated as strata. Then by considering the population of each village; the numbers of farmers in strata were randomly selected.

3.2. The study area

The study area was Kamyaran County with an area of about 2035 km2, the southernmost city of Kurdistan province in western Iran. This county is surrounded by Shaho and Behistun mountains. Average annual rainfall and temperature of this area are 520 mm and 5.13 degrees Celsius respectively (Mahmoudzadeh et al., 2021). Cultivated area of this county is 36,509 hectares, of which 32,230 hectares are crop cultivated (12,187 hectares of irrigated and 20,043

hectares of rainfed) and 4,279 hectares of gardens, which covers about 34% of the total area of the county (Kurdistan Province Management and Planning Organization, Deputy of Statistics and Information, 2018). National lands and natural resources constitute 66% of the area of the county, of which about 11% (28,000 hectares) is forest (Mahmoudzadeh et al., 202). Overll, the main uses of this area include oak forest, orchards of strawberry and fruit trees (walnut, grape), irrigated agriculture (wheat, corn, and alfalfa), rainfed (wheat, barley and chickpea) and pasture (Kurdistan Province Management and Planning Organization, Deputy of Statistics and Information, 2018). Figure 2 shows the geographical location of Kamyaran county.

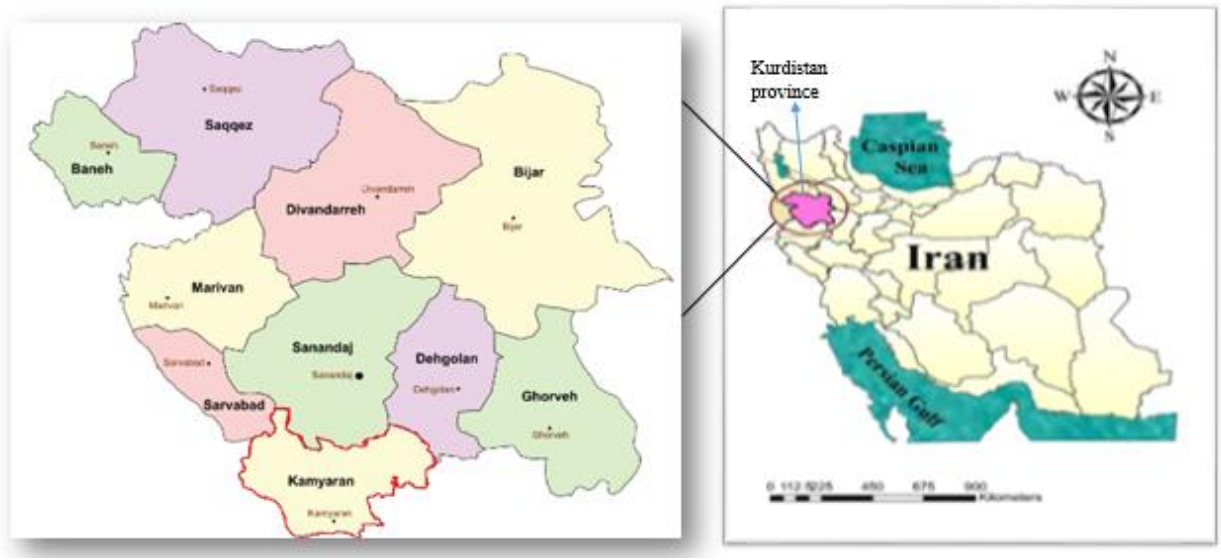


Fig. 2. Study area: Kamyaran in south of Kurdistan Province in Iran (Retrieved from Jamshidi et al., 2021)

3.3. Data collection technique, measures and analysis

A questionnaire was designed to collect data. The questionnaire was organized in two parts; in the first part, the socio-economic qualities of the participants were questioned and in the second part, items for measuring research variables were designed on a 5-point Likert scale. Questionnaire validity was approved by a panel of professionals from agriculture and environment. Cronbach alpha coefficients for most variables indicated a good reliability; between 0.7 to 0.95 (Table 1). As shown in Table 1, alpha coefficient for MN was 0.6 which according to some resources such as Peterson and Kim (2013); Taber (2018) and Daud et al. (2018), this amount of Cronbach's alpha is moderate and acceptable. After distributing the questionnaires among 375 study subjects, only 330 of them returned, which shows that the questionnaire return rate was 88%. According to the study of Cook et al. (2000) a return rate higher than 55.6% for the questionnaire is acceptable. Table 1 indicates the studied variables and items to measure them. Finally, data were analyzed using SPSS and AMOS software.

Table 1. Variables, measurement and Cronbach alpha coefficients

Variable	Definition	Items	α coefficient	Standardized loading	AVE	CR
Willingness	Farmers' willingness to recycle agricultural waste	I am willing to recycle agricultural waste and recycle them in the future.	0.88	0.766	0.668	0.852
		If an organization or group be created to recycle agricultural waste, I am willing to cooperate with it.		0.810		
		I am willing to transport my agricultural waste to a short distance for recycling.		0.811		
Attitude	Farmers' positive or negative opinion about collecting and recycling agricultural waste.	I think collecting and recycling agricultural waste reduces environmental pollution	0.69	0.725	0.891	0.817
		I think recycling agricultural waste can creates economic benefits.		0.802		
		I think burning or improper handling of agricultural waste will affect human health.		0.734		
		I think it is necessary to have an organization for recycling agricultural waste.		0.739		
Subjective norm	Farmers' perceptions of how much others approve their probability behavior regarding waste recycling.	If my neighbors collect and recycle agricultural waste from their farms, I will do the same.	0.75	0.698	0.819	0.814
		Agricultural organization will support recycling agricultural waste from the farm.		0.786		
		My family support recycling agricultural waste from the farm.		0.623		
Perceived behavioral control (PBC)	Farmer's belief in his/her own ability to collect and recycle agricultural residues.	I have access to the equipment needed to collect and recycle agricultural waste.	0.73	0.712	0.887	0.808
		I have enough money for collecting and recycling agricultural waste.		0.692		
		I have enough time to collect and recycle agricultural waste and residues.		0.665		
Moral norm	Farmer's internal commitment to collect and recycle agricultural waste	I consider protecting environment as my duty and a moral responsibility.	0.60	0.844	0.900	0.925
		I feel guilty about burning plant residues		0.832		
		Collecting and recycling agricultural waste is a valuable action for the future generation and health of the community.		0.811		
Knowledge	Farmers' knowledge about products and advantages of recycling agricultural residues and also strategies for doing that.	Enriching soil through the correct return of agricultural waste such as straw and stubble to the soil.	0.83	0.746	0.911	0.914
		Reducing the attack of pests and diseases following the collection of agricultural waste from the farm.		0.897		
		Decreasing health problems following animal waste collection around settlements.		0.720		
		Providing compost from agricultural waste.		0.701		
		Producing chemicals such as alcohol and acetone from agricultural waste.		0.884		
		Producing energy and biological gases from agricultural waste.		0.832		
		Manufacturing paper from agricultural waste.		0.800		
		Producing raw cosmetic ingredients from agricultural waste such as rice bran.		0.841		

3.4. Statistical tool

Statistical analyses were conducted using SPSS (v. 24) and AMOS (v. 23) software packages. SPSS was utilized for data management, descriptive statistics, and correlation analysis. The measurement model was subsequently validated via confirmatory factor analysis (CFA). Finally, structural equation modeling (SEM) was implemented through AMOS to test the proposed hypotheses and identify the key determinants influencing farmers' willingness to recycle agricultural waste.

4. Results and discussion

4.1. Socio-economic qualities of farmers

267 people (80.9%) were male and 63 people (19.1%) were female. The studied farmers were aged from 20 to 75 with an average age of 41 ± 10.67 years. The first occupation of 85.5% of the participants was farming with an average experience of 15.19 ± 11.28 years. Their average level of education was 9.86 ± 3.81 years. Moreover, the average cultivated land of farmers was 3.50 ± 5.02 hectare and the mean annual income of the respondents from agriculture was 217± 338.73 million Rials (Iranian currency) per year.

4.2. Descriptive status of research variables

Based on the results reported in Table 2, the mean scores of willingness (3.56 ± 0.47) and attitude (3.33 ± 0.36) towards recycling agricultural waste were higher than average. These findings indicate that farmers have a positive opinion regarding the collection and recycling of agricultural waste, and the majority are willing to carry out this practice in the future, provided suitable conditions are met. Also, the findings (Table 2) indicated subjective norm (2.61 ± 0.44) and moral norm (2.60 ± 0.41) had a mean value relatively higher than average (on a range of 1 to 5). While, PBC (1.13 ± 0.41) and knowledge (2.05 ± 0.57) had a mean value of lower than average. The low level of PBC can be due to cost and time consuming of collecting agricultural waste and the lack of necessary infrastructure and technologies in the study area for recycling them. Also, this finding is in accordance with the results of the study by Zhu et al. (2021) who found PBC for agricultural waste recycling is lower than average and farmers believe that straw recycling would require a lot of time and effort, and they don't have the capacity to do it. Also, in relation to the low level of farmers' knowledge, findings showed that although most of farmers had relatively good knowledge of the benefits of recycling agricultural waste, including enriching soil and reducing the attack of pests and diseases, as well as use of agricultural waste in compost production, but they did not have enough knowledge about the possibility of producing paper, raw cosmetic materials, alcohol and biofuels from agricultural residues. This finding confirms the findings of Ghanbari Movahed et al. (2019) and Saberi Riseh et al. (2024) who claim Iranian farmers have low awareness about the methods of recycling agricultural waste and its economic potential. Also, this is in line with the findings of study by Kabir et al. (2023) in Bangladesh who found farmers have a medium to high knowledge about agricultural waste management concept, but they had low perception of recycling agricultural waste. Lee et al. (2023) also acknowledged in their study that people in developing countries have less environmental knowledge than people in developing countries. In general, lack of knowledge about recycling agricultural waste among farmers may as mentioned by Kabir et al. (2023) be due to the lack of providing them with the necessary training on the application of agricultural waste and the lack of sufficient information exchange in the community about the recycling of these wastes which this issue needs a deeper study.

4.3. Correlation between variables

According to Table 2, there were significant positive and relatively strong correlations between attitude ($r=0.52$; $P\leq0.01$) and willingness towards recycling agricultural waste among

farmers. This finding is consistent with the results of studies by Wan et al. (2017), Sulaiman et al. (2019), Lim et al. (2018), Majid et al. (2021) and Zhang et al. (2026) who found that there is significant positive relationship between attitudes of various groups of people, including farmers, toward waste recycling with their willingness to recycle. Based on the results, subjective norm ($r=0.48$; $P\leq0.01$) also had significant positive correlation with willingness to recycle agricultural waste. While correlation between the subjective norm and recycling willingness has been empirically proved in various studies (e.g. Comber and Thieme, 2013; Ramayah et al. 2012; Wan et al. 2017), this finding indicates that farmers' willingness to recycle agricultural waste in future is directly related to the feedback they receive from various trusted individuals and social groups regarding such recycling; consequently, if society encourages and incentivizes farmers to recycle waste, their willingness to do so increases. The study results also indicated a positive and significant correlation between moral norms among farmers and their willingness to recycle agricultural waste moral norm ($r=0.43$; $P\leq0.01$). This finding, which aligns with the results of studies by Chan and Bishop (2013), Liu et al. (2020) and Majid et al. (2021) indicates that there is a direct relationship between individuals' sense of internal commitment to environmental conservation and the recycling of agricultural waste, and their willingness to recycle such waste in the future. The findings indicated that moral norm has also significant positive correlation with subjective norm ($r=0.51$; $P\leq0.01$). This finding is consistent with the results of studies by Wan et al. (2017) and liu et al. (2020). In addition, the results of the correlation analysis revealed a significant positive relationship between knowledge and willingness to recycle agricultural waste ($r=0.38$; $P\leq0.05$), as well as between knowledge and attitudes toward recycling ($r=0.54$; $P\leq0.01$). These findings align with the results of studies by Noh (2024) and Ali et al. (2022) and indicate a direct relationship between an increase in farmers' knowledge regarding strategies for recycling agricultural waste and its derived products, and their attitudes and willingness to recycle agricultural waste. According to the findings, no significant correlation was detected between PBC and willingness.

Table 2. Descriptive statistics and correlations between research variables

Variable	Mean ± SD	Knowledge	MN	PBC	SN	Attitude
Willingness	3.56 ± 0.47	0.38*	0.43**	0.11	0.48**	0.52**
Attitude	3.33 ± 0.36	0.54**	0.38**	0.29*	0.22*	1
SN	2.61 ± 0.44	0.12	0.51**	0.31**	1	
PBC	1.13 ± 0.41	0.09	0.18	1		
MN	2.60 ± 0.41	0.14	1			
Knowledge	2.05 ± 0.57	1				

Note: $1\leq$ Mean ≤ 5; ** significance at ≤0.01; * significance at ≤0.05

4.3. Determinants of willingness towards recycling agricultural waste on farm

4.3.1. Model goodness-of- fit evaluation criteria

The first step to use structural equation modeling to determine factors affecting willingness to recycle agricultural waste was to check measurement and theoretical models' fitness. To evaluate the measurement model, its reliability and validity were measured. To assess reliability, Cronbach's alpha coefficients and composite reliability (CR) criteria were measured, and convergent validity was examined using mean extracted variance index (AVE). CR higher than

0.7, and AVE higher than 0.5 are acceptable for all studied constructs (Abassi Esfanjani, 2017). Consistent with the recommended benchmarks, the measurement model's reliability and convergent validity were substantiated by the findings in Table 1, where Cronbach's alpha and CR values were greater than 0.7, and AVE exceeded 0.5 for every construct.

To evaluate the theoretical model fitness, the indices shown in Table 3 were used. As shown in this table, the modified Chi-square ($\chi 2/df$) value was 0.3.428. Although, the estimated $\chi 2/df$ value was higher than the recommended value, but as Cole (1987) states, in large samples, small differences between recommended and observed value can accrue. Other indices examined in present study included Root-mean square error of approximation (RMSEA), Comparative Fit Index (CFI), Bentler-Bonett Normed Fit Index (NFI), Goodness of Fit Index (GFI) and Incremental Fit Index (IFI). According to Hu and Bentler (1999), RMSEA ≤ 0.060 indicate good model fit. Also, according to Gupta and Singh (2015), CFI$\geq$0.90, IFI$\geq$0.90, NFI$\geq$0.90 and GFI$\geq$0.90 are recognized as indicative of a good model fit. However, even with these cut-offs, Gupta and Singh (2015) based on the studies of some other researchers believe that values such as 0.87 and above for the mentioned indices are also marginally acceptable. In this study, IFI of 0.948 and CFI of 0.940 shows fit perfectly. Also, NFI of 0.866 and GFI of 0.892 indicate fit well. In present study, the value of RMSEA was 0.0.76 which indicates an acceptable fit between the model and data.

Table 3. Model fit summary statistics

Indices	χ^2/df	IFI	CFI	NFI	GFI	RMSEA
Estimated value	3.428	0.948	0.940	0.866	0.892	0.076
Recommended value	≤3	0.9≤	0.9≤	0.9≤	0.9≤	≤0.05

4.3.2. The structural model for willingness towards recycling agricultural waste on farm

Fig. 3 illustrates the SEM analysis results. According to this figure, attitude with a path coefficient of 0.67 that is significant at 0.01 level (β=0.67; Sig≤0.01) (Table 4), has strong effect on willingness to recycling agricultural waste (Confirms Hypothesis 1). This finding is in congruent with the outcomes of studies by Abadi (2023), Zhu et al (2021), Wang et al. (2019b) which concluded attitude is the main factor influencing willingness towards waste recycling because attitude is positive or negative opinion towards an issue. So, if farmers have positive attitude towards recycling, it is natural that their willingness to recycling agricultural waste increases and as a result, efforts to improve farmers' attitudes towards the environmental, economic, and health importance of recycling agricultural waste will be the most important step in increasing the likelihood of recycling this waste in the future.

The results of significant effect of SN on willingness (β=0.49; Sig≤0.01) supported Hypothesis 2 and is align with the findings of studies by Wan et al. (2017), Chan and Bishop (2013) and Mahmud and Osman (2010). These findings display the more role that trusted individuals and groups play in encouraging farmers to recycle agricultural waste, willingness to recycle agricultural waste in future will increase. Contrary to studies by Murod et al. (2023), Kotyza et al. (2024), Lin et al. (2021), Hidalgo-Crespo and Amaya-Rivas (2024), Wang et al. (2020b), and Mahmud and Osman (2010) who found that PBC is a predictive factor of willingness to do a behavior such as waste recycling, the PBC effect on willingness in present study was not statistically significant. Based on this finding, hypothesis 3 of the research was rejected. As shown in Table 2, the mean score of PBC was low among the studied farmers. This issue is due to the obstacles that people perceive to recycle agricultural waste, such as poverty of essential

infrastructure and technologies in the study area. Although the presence of such obstacles did not directly affect farmers' willingness to recycle, they can probably cause a gap between willingness and behavior in recycling waste.

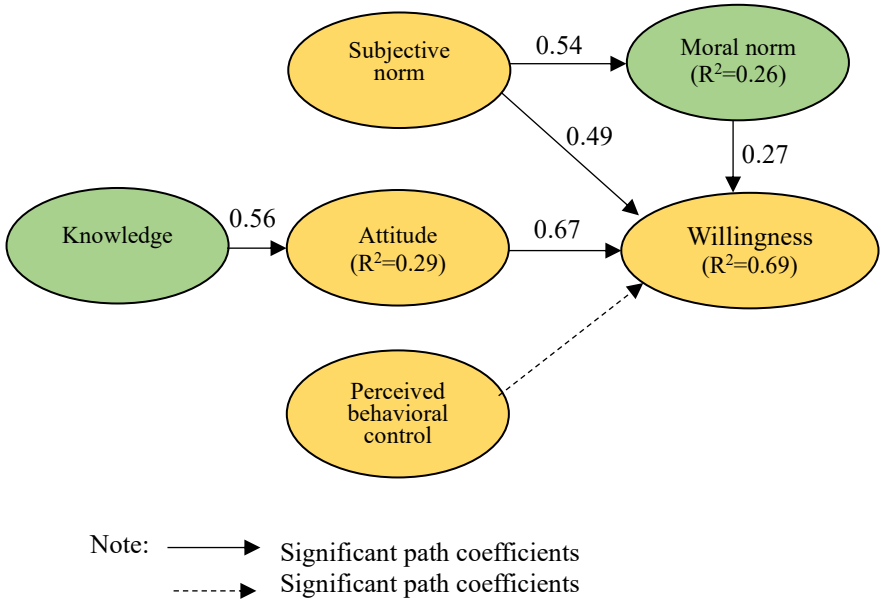


Fig. 3. Structural model for willingness towards recycling agricultural waste on farm

The result of knowledge effect on farmers' attitude toward recycling agricultural waste (β=0.56; Sig≤0.01) supported Hypothesis 4 and corroborated the findings of Noh (2024) and Ali et al. (2022). This finding indicates that knowing about products and advantages of recycling agricultural residues and also strategies for doing that can determine farmers' attitude towards recycling waste.

According to Fig. 3 and Table 4, moral norm is also a determinant factor of willingness to recycle agricultural waste that directly and significantly affects it (β=0.27; p≤0.05). As predicted, farmers with higher internal obligation to conserve environment and human well-being have also stronger willingness to recycle agricultural waste. This finding accepts the Hypothesis 5 and is in agreement with the outcomes of researches by Turner et al. (2024), Ceschi et al. (2021), Wang et al. (2020b), Botetzagias et al. (2015), Poškus (2015) and Chan and Bishop (2013) who found moral norm is a prediction factor for behavioral willingness towards agricultural waste recycling and concluded people who are more morally committed have more behavioral obligations towards the environment.

Based on the findings, moral norms also mediate the impact of subjective norms on farmers' willingness to recycle agricultural waste (β=0.54; p≤0.01). This finding verifies the hypothesis 6 and is in agreement with the findings of Onwezen et al. (2013) who believed moral obligations motivate individuals' behavioral willingness in accordance with the perceived norms from reference groups and people. In total, the research variables were able to explain about 0.70% of the changes in the variance of willingness to recycle agricultural waste.

Table 4. SEM results—standardized parameter estimates for the structural model

Endogenous variables	Exogenous variables			Endogenous variables		Structural equation fit (R^2)
	X_1	X_2	X_3	Y_1	Y_2	
Y_1	-	-	0.56^{**}	-	-	0.29
Y_2	0.54^{**}	-	-	-	-	0.26
Y_3	0.49^{**}	0.13^{ns}	-	0.67^{**}	0.27^{*}	0.70

Y_1: Attitude
Y_2: Moral norm (MN)
Y_3: Willingness
X_1: Subjective norm (SN)
X_2: Perceived behavioral control (PBC)
X_3: Knowledge

Note: ns=Not significant; ** significance at ≤0.01; * significance at ≤0.05

5. Conclusion and policy implications

This study investigated farmers' willingness to recycle agricultural waste in Iran using an extended model of the theory of planned behavior. Moral norm and knowledge were two added constructs to the model. The results showed that the model used was able to explain about 70% of farmers' willingness to recycle agricultural waste, which indicates the good power of this model in predicting willingness. We found that farmers' average knowledge of the benefits, products, and strategies for recycling agricultural waste is lower than average, while they have a relatively high willingness to recycle this waste in the future.

We found that attitude is the strongest predictor of willingness to recycle agricultural waste. Subjective norm and moral norm were other variables that had positive and significant effect on willingness to recycle agricultural residue. In addition, Moral norms mediated the influence of subjective norms on farmers' willingness to recycle agricultural waste. Also, attitde mediated the influence of knowledge on willingness. Based on the results, perceived behavioral control effect on willingness was not statistically significant. In general, this study develops the literature on agricultural waste management by incorporating knowledge and moral norms into the theory of planned behavior and measuring their effect on willingness towards recycle agricultural waste.

Given the direct impact of knowledge on attitudes towards recycling agricultural waste and its indirect effect on willingness on the one hand and low level of farmers' knowledge about the methods of recycling agricultural waste, the potential capacity of these wastes to become other products such as bioenergy, cellulose, alcohol and compost, and the economic and environmental benefits resulting from that on the other hand, it is necessary to have regular and continuous training programs to increase knowledge and awareness of farmers regarding this issue. For this, it is possible to use both educators and specialists and the capacity of mass media. Also, regarding the significant impact of attitude on willingness to recycle agricultural waste and the effective role that agricultural extension can play to change individuals' attitude towards new ideas and technologies, it is possible to use capacity of agricultural extension to improve farmers' attitude towards recycling agricultural residue In this regard, extension messages can be provided for farmers that explain the negative impacts of inappropriate management of agricultural waste, including burning or improper burial, as well as the benefits of recycling these wastes causally and with sufficient evidence. The influence of subjective norm on willingness suggests the importance of recycling agricultural residue should be considered as a social process and try to fit in as a norm in the society. Also, it appears that recycling willingness is in a large part morally driven. These

findings suggest that highlighting moral norms particularly in the time of scheming an intervention to increase farmers' knowledge about recycling agricultural waste, particularly the negative subsequences of not properly recycling waste on the environment and any living beings such as human and animals is an effective strategy for improve waste recycling willingness among farmers.

6. Limitations and suggestions for forthcoming research

Likewise other studies, present research has also a series of limitations that mention to them can be a guide for future researches. Regardless of our considerable attempts, our literature review may not have recorded some relevant papers. Nevertheless, this systematic review contributes to improve existing knowledge on the waste recycling. This research used an extended model of the TPB as the research model. The impact of moral norm and knowledge beside independent constructs of the TPB on willingness was measured. Future researchers can use other theories and models introduced in the social, health and environmental sciences to study the effect of other variables on waste recycling willingness. The study showed that farmers' knowledge about agricultural waste recycling methods and the economic benefits of this work is little. But the issue of what is the reason for the low level of people's knowledge needs a deeper study. Finally, the present study is quantitative in nature. This is while, using in-depth qualitative research methods in combination with quantitative studies can provide more knowledge and perception of agricultural waste management.

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Clinical Trial Registration: Clinical trial number: not applicable.

Declarations

Ethical Approval: To ensure adherence to ethical standards, the research protocol was reviewed by the University of Kurdistan, Ethics Review Board, in accordance with the principles of the Declaration of Helsinki and the university's ethical guidelines. Although the board does not issue a formal ethical code, all study procedures, including participant recruitment, informed consent, and data collection, were conducted in alignment with established ethical standards to safeguard participant rights and well-being

Consent to Participate: Informed consent was given by all participants after being informed of the study's purpose, procedures, and their rights. Confidentiality and anonymity were assured, and participation was entirely voluntary.

Consent for Publish: Not applicable.

Competing Interests: The author declares that there are no competing financial or non-financial interests directly or indirectly related to this work.

Data Availability: Data for this study were collected via questionnaires through a survey conducted in Kamyaran County, Kurdistan Province, western Iran. The respondents were farmers from the region. The data will be made available upon request.

Author contributions

All authors contributed to th

e study conception and design. Project administration, Supervision and validation were performed by (Hamideh Maleksaeidi), data collection and initial analysis were performed by (Shabnam Fathi). The first draft of the manuscript was written by [Hamideh Maleksaeidi] and all authors commented on previous versions of the manuscript. Farzad Eskandari and Mehdi Karami Dehkordi reviewed and edited the final manuscript."

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