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How to enhance agricultural plastic waste management in China? Insights from public participation



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Abstract

Agricultural plastics play a pivotal role in agricultural production. However, due to expensive costs, agricultural plastic waste management (APWM) encounters a vast funding gap. As one of the crucial stakeholders, the public deserves to make appropriate efforts for APWM. Accordingly, identifying whether the public is willing to pay for APWM and clarifying the decisions' driving pathways to explore initiatives for promoting their payment intentions are essential to address the dilemma confronting APWM. To this end, by applying the extended theory of planned behavior (TPB), the study conducted an empirical analysis based on 1,288 residents from four provinces (autonomous regions) of northern China. Results illustrate that: 1) respondents hold generally positive and relatively strong payment willingness towards APWM; 2) respondents' attitude (AT), subjective norm (SN), and perceived behavioral control (PBC) are positively correlated with their payment intentions (INT); 3) environmental cognition (EC) and environmental emotion (EE) positively moderate the relationships between AT and INT, and between SN and INT, posing significant indirect impacts on INT. The study's implications extend to informing government policies, suggesting that multi-entity cooperation, specifically public payment for APWM, can enhance agricultural non-point waste management.

Keywords: agricultural plastic waste, extended theory of planned behavior, public payment, environmental cognition, environmental emotion

1. Introduction

Agricultural plastic waste management (APWM) is conducive to attaining the intended targets of the UN-Sustainable Development Goals (SDGs) (UN 2015), remarkably SDG 12: Sustainable consumption and production, and SDG 13: Climate change. As critical agricultural inputs, agricultural plastics play a vital role in guaranteeing food security and raising farmers' income

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(Gao *et al.* 2019; Feng *et al.* 2022). Globally, 12.5 million tons of agricultural plastics are utilized annually (FAO 2021), while only a tiny fraction of agricultural plastic waste (APW) is properly disposed of (Yan *et al.* 2010). A large amount of APW is either left untreated or improperly disposed of (open burning and on-site landfill), turning the “white revolution” deteriorate into severe “white pollution” (Liu *et al.* 2014). APW inevitably leads to a succession of issues, including visual pollution, water contamination, farmland degradation, and agricultural products quantity decrease (Rillig *et al.* 2021). Simultaneously, generated microplastics can enter the food chain and pose potential crises to human health and well-being (Rillig *et al.* 2021; Leslie *et al.* 2022; He *et al.* 2023).

While APWM is indeed a global issue, China confronts unique challenges. To begin with, China is the world’s largest agricultural plastics consumer, accounting for approximately half of the total (FAO 2021). Particularly, mulch film, which is more challenging to recycle than other kinds of APW for its poor mechanical strength, makes up half of the agricultural plastics utilized in China (NBSC 2022a) and 3/4 of the world (FAO 2021). It is broadly and diversely utilized in the vast northern Chinese farmland, further complicating recycling.

In recent years, the Chinese government has progressively recognized the significance, urgency, and arduousness of APWM and primarily promoted it by subsidizing recycling utilization enterprises. During 2012–2015, the central government cumulatively funded APWM with more than 900 million CNY (128.6 million USD, 1.0 USD=7.0 CNY) in 10 pilot provinces. Local governments also allocated special funding following financial capacity and actual APWM demands. Nevertheless, APWM faces the profound challenge of a vast funding gap. To achieve the target of an 80% recycling rate, 7.1 billion CNY (1.0 billion USD) would be required for nationwide mulch film recycling (Appendix A). Notably, the gap may expand considerably, assuming other kinds of APW are taken into the estimation. APWM is so costly that it narrows the profit margin of recycling utilization. Without follow-up financial subsidies after piloting, it is challenging for recycling enterprises to maintain stable profitability and even sustain operations. In this regard, the government has explored innovative schemes. Represented by the extended producer responsibility (EPR) and deposit return, multi-entity, including the government, farmers, agricultural plastic producers, and recycling enterprises, are incorporated in the management system.

The agricultural environment is closely relevant to everyone, and the environmental pollution, food security, and human health threats offset by APWM will benefit all people. Yet the existing APWM scheme does not

account for the public’s potential cooperation. The public, the crucial APWM stakeholder with triple identities of the service recipient of agricultural plastics, the victim of the APW, and the beneficiary of APWM, should not be left as an outsider. Meanwhile, the public’s environmental awareness is steadily growing along with the progress of society and the improvement in citizen literacy. As the Environmental Kuznets Curve (EKC) indicates, people would be more attentive to environmental pollution and ecological degradation as income increases and thus seek more environmental investments than before (Grossman and Krueger 1995; Panayotou 1997). People donate to special funds and charities to satisfy their demands for more effective environmental management (Wu *et al.* 2020). Accordingly, as a public issue, APWM requires the public’s assistance to enable a more sustainable and resilient APWM scheme. If the public is willing to participate and pay for APWM, they will conduce to mitigating the APWM funding gap to some extent while satisfying their advanced demands (Fig. 1).

The public’s payment willingness towards environmental management has been investigated in three fields: Air pollution, water pollution and solid waste. According to relevant research, 53–83% of the respondents were willing to pay for air pollution management (Sun *et al.* 2016; Zahedi *et al.* 2019; Khuc *et al.* 2022). The majority of the respondents, accounting for 77–87%, expressed positive payment intentions towards water pollution remediation (Jiang *et al.* 2011) or water quality improvement (Ureta *et al.* 2022). There are no exceptions for solid waste management. The amounts respondents intended to pay were even higher than waste removal and disposal costs (Véliz *et al.* 2022). Comparable results on waste electrical and electronic equipment (Islam *et al.* 2016) and municipal solid waste (Liang *et al.* 2021) have also been found. Moreover, research on the public’s payment willingness towards plastic waste has gradually emerged along with the rising knowledge of plastics. Relevant research indicated that respondents in Indonesia showed high concern for marine plastic pollution and positive payment willingness for plastic pollution mitigation (Tyllianakis and Ferrini 2021). Most respondents (85%) in Norway supported initiatives to reduce marine plastics (Abate *et al.* 2020). Similar studies were also conducted in Australia (Borriello and Rose 2022), South Korea (Choi and Lee 2018), Ecuador (Zambrano-Monserrate and Ruano 2020), Greece (Latinopoulos *et al.* 2018), and Bulgaria and the Netherlands (Brouwer *et al.* 2017). To sum up, the public is normally willing to pay for the management of waste that is closely related to them. Studies concerning plastic waste management concentrate mainly on marine plastics, congruent with the reality that the perception of plastic pollution originates from

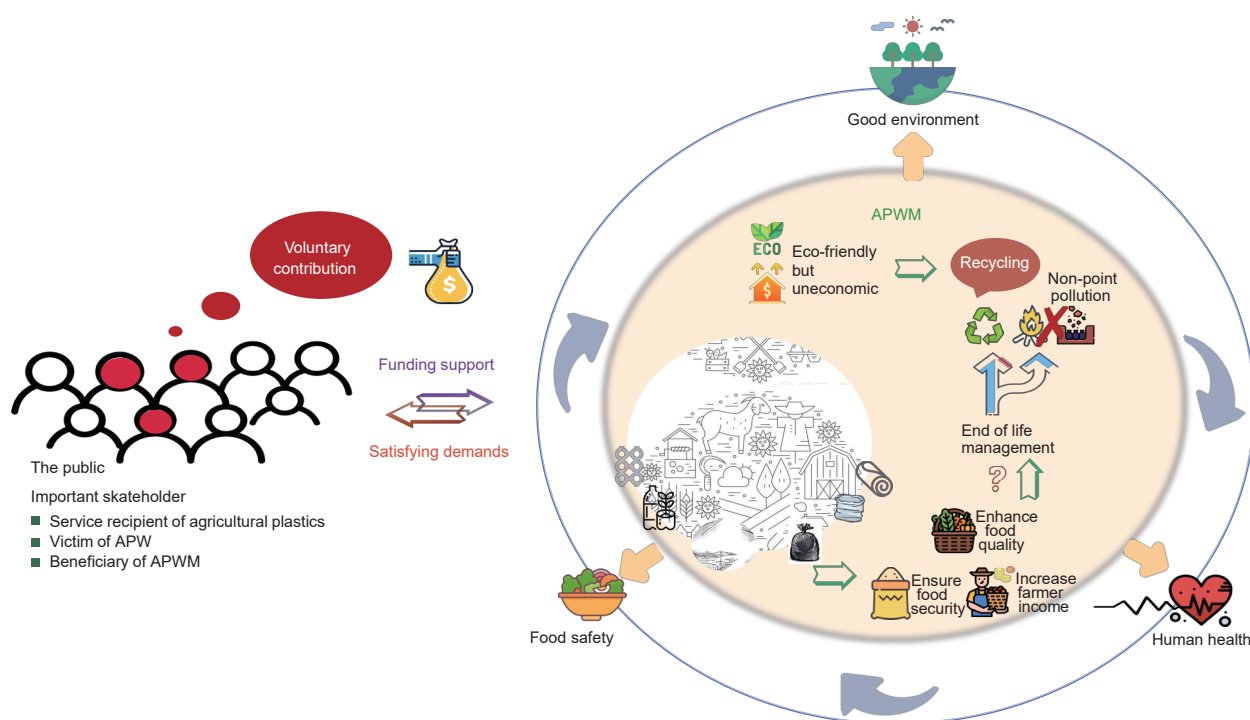


Fig. 1 A win-win solution accomplished by public payment for agricultural plastic waste management (APWM).

marine sources (Santos *et al.* 2021). A limited number of studies regarding APW were conducted merely from the perspective of farmer payment (Wang *et al.* 2019). As the major agricultural plastics consumer, China should place greater emphasis on APW. Moreover, explicit evidence indicates that plastic waste from soil sources is even worse (Bläsing and Amelung 2018; Santos *et al.* 2021), implying APWM deserves to attract due attention.

Parallel to identifying the payment willingness, clarifying the pathways that drive the public's payment intention facilitates understanding the mechanisms that motivate the public's payment decision. The socio-psychological paradigm allows to provide detailed information on behavioral decision-making mechanisms and unlocks the black box of decision-making in which the public is willing to pay for APWM. As a typical socio-psychological analytical framework, theory of planned behavior (TPB) is an established, empirically validated theoretical framework for understanding, explaining, and predicting a specific or a category of behavior (Ajzen 1991; Ajzen 2020). It has been favored and widely applied because of its simple structure, thoughtful analysis of the interplay between individual, social, and environmental components, and universal validity in various domains (Morren and Grinstein 2021). To obtain a robust conclusion on the public payment for APWM, the study adopts TPB as the theoretical framework. According to TPB, behavior is predicted

by intention (INT), which in turn is jointly determined by attitude (AT), subjective norm (SN) and perceived behavioral control (PBC) (Chan and Bishop 2013; Morren and Grinstein 2021). Notwithstanding the applicability and predictability of TPB in environmental behaviors, the average explanation of the variance in behavioral intentions by the three antecedent constructs of TPB is 44.3% (Yuriev *et al.* 2020). There is a certain proportion of variance that the TPB framework cannot explain. Extending the TPB framework with extra constructs is a common practice to improve understanding and interpretation (Ajzen 2005; Bird *et al.* 2018). The study appends environmental cognition (EC) and environmental emotion (EE) to TPB and applies extended TPB to provide more information on the formation mechanism of the public's decision to pay for APWM.

Therefore, the study aims to explore whether public payment can be a promising solution to mitigate the APWM funding gap. Specifically, the study offers some new insights into the following two aspects. Foremost, the payment willingness towards APWM is innovatively investigated to determine the possibility of raising APWM funding through public payment. Subsequently, employing the extended TPB, the driving pathways of the public's payment decision are clarified to guide initiatives for promoting public payment. The findings offer two-fold contributions. Theoretically, the study innovatively applies TPB to public payment for APWM and extends the

framework by environmental cognition and environmental emotion. The extended TPB is proven to have great explanatory and predictive power for target behavioral intentions, contributing to the application and development of TPB. Practically, the study also provides the scientific basis for developing a sustainable and resilient agricultural non-point waste management scheme to promote the public's participation in APWM.

The paper is structured into 6 sections. Section 2 outlines the theoretical framework and research hypotheses. Section 3 describes the data and methods. Section 4 presents the research results. Section 5 discusses the results. Section 6 provides the conclusion.

2. Theoretical framework and research hypotheses

According to the logic of collective action, public payment for APWM can be conceptualized as a collective payment by contributors to set up a public pool to provide public goods without explicit tangible rewards (Olson 1965). It has a broad public interest to create better living conditions for the whole society and is a typical case of the private provision of public goods (Bergstrom *et al.* 1986; Fraser 1992). Accordingly, public payment for APWM is in line with the logic of the economic theory. Then, is the public willing to pay for APWM? What are the factors that influence their payment intentions? What are the pathways that drive the public's payment decision? These are fascinating and vital topics to be investigated.

2.1. Theory of planned behavior

Public payment is an envisioned scheme to mitigate the funding gap for APWM. There is no actual payment behavior in reality, so the study only examines the public's payment intention. As stated above, INT is guided by AT, SN, and PBC.

AT indicates individuals' positive or negative evaluations of specific behaviors (Ajzen 1991). Individuals with a positive attitude towards a behavior are more likely to perform it (Hori *et al.* 2013; Akhtar *et al.* 2018). APWM can alleviate agricultural non-point waste, mitigate the potential environmental, food safety, and human health threats, and benefit multiple entities, including individuals, society, and the whole ecosystem. Individuals may thus have a favorable evaluation for APWM, manifested as a tendency to pay for it. Six indicators characterize individuals' AT towards APWM, including that they consider APWM to be "enjoyable and satisfying for themselves," "good for the society," "sensible

as a government policy," "good for the ecosystem," "important and urgent," and "responsible for the future".

SN refers to the perceived social pressure to perform or not a behavior, reflecting the social influence on individuals' behavioral decisions (Chen and Tung 2014). When individuals perceive social pressure for not acting, they are more inclined to perform it to avert pressure (Ajzen 1991). SN explicitly refers to the norms of relatives, friends, social media, communities, and governments in the study. When these people or groups suggest paying for APWM, individuals perceive social pressure if not implemented, and their payment intentions are thus motivated.

PBC describes the degree of difficulty that individuals perceive in performing a behavior (Lazzarini *et al.* 2018). Individuals are less likely to engage in it if they perceive limited behavioral control. For instance, there are seen to be numerous uncertainties involved, or it lacks the necessary external conditions to perform (Yuriev *et al.* 2020). If individuals perceive control over their payment for APWM, including knowing how to pay for APWM, believing that there is no financial burden for them to pay, and trusting the payment would bring about the expected outcomes, they would have more confidence and enthusiasm and show stronger payment intentions.

Based on the above analysis, the following hypotheses are proposed:

Hypothesis 1a: AT positively affects payment INT.

Hypothesis 1b: SN positively affects payment INT.

Hypothesis 1c: PBC positively affects payment INT.

2.2. Extension of the TPB

EC, the understanding of the severity of environmental pollution and the urgency of environmental waste management, is the prerequisite for the public's payment decision (Kollmuss and Agyeman 2002; Gifford and Nilsson 2014). Environmental education and publicity initiatives have increased the public's EC to some extent and significantly promoted pro-environmental behaviors like recycling (Chen *et al.* 2021), energy conservation (Zhang *et al.* 2022), and green consumption (Trivedi *et al.* 2018). As previously stated, the environmental and health threats posed by APW, as well as the vast funding gap of APWM, are objective. If the public's EC can arouse their awareness of voluntary payment to APWM, it can undoubtedly assist in tackling the dilemma. Accordingly, it is essential to investigate the influence of EC on individuals' decisions to pay for APWM.

Besides, TPB assumes that people's decision-making is guided by rationality and deliberation and is always the outcome of self-interest driven by cost–benefit trade-

offs (Reiling 1986). It indicates that TPB disregards the emotional factor, which is an essential part of practically all human decisions (Ajzen 1991; Mellers *et al.* 1999; Koenig-Lewis *et al.* 2014). It is one of the major arguments why TPB is contested (Conner and Armitage 1998). Some studies introducing emotional factors to individuals' behavioral decisions inaccurately confound them with perception, knowledge, and awareness (Wang 2015). Appending individuals' psychological reaction of satisfaction or not to the environmental status and environmental behaviors (Koenig-Lewis *et al.* 2014; Yan *et al.* 2018), namely EE, into the TPB framework as an independent dimension can compensate for the lack of irrational decisions (Ajzen 1991; Mellers *et al.* 1999) and enhance the understanding of individuals' payment decisions.

Accordingly, the study appends EC and EE to construct an extended TPB framework to offer comprehensive insights for driving pathways of individuals' payment decisions.

Environmental cognition Individuals with a high level of EC possess a profound knowledge of environmental knowledge and environmental quality (Barney *et al.* 2005). They can thoroughly capture the broad impacts of environmental pollution (Kotchen and Reiling 2000). Individuals involved in environmental conservation activities more actively have a higher level of EC than others; the same goes for environmental public welfare donations (Lu *et al.* 2023). *Vice versa*, those with a higher level of EC are more likely to exhibit responsible environmental behaviors (Kotchen and Reiling 2000; Halkos and Matsiori 2014; Yu and Yu 2019). Studies have verified that individuals' payment intentions towards environmental services can be reinforced by EC (Halkos and Matsiori 2014; Yu and Yu 2019). EC not only directly evokes a sense of urgency to carry out APWM but also helps to transform psychological motivations into responsible behavioral intentions (Yang *et al.* 2021), expressed in a stronger payment intention towards APWM. Six indicators, including environmental pollution status cognition, environmental pollution threat cognition, and waste management importance cognition, are applied to characterize EC to examine its influence on the public's payment decision. Accordingly, the following hypotheses are proposed.

Hypothesis 2: EC has a positive impact on INT.

Hypothesis 3: EC positively moderates the relationship between AT and INT, SN and INT, and PBC and INT, respectively.

Environmental emotion Individuals with strong EE have more emotional energy than those indifferent to the environment (Kalantari *et al.* 2015). Their emotional reactions to the changes in environmental situations and different environmental behaviors are more likely to be

aroused (Kals *et al.* 1999; Meneses 2010). EE can evoke individuals' sense of environmental connections and environmental loyalty affecting environmental behaviors (Loewenstein *et al.* 2001; Kollmuss and Agyeman 2002). Individuals with stronger EE are more likely to put forth efforts and make sacrifices for environmental preservation once conscious of the environmental threats (Song and Qu 2017). Positive emotions, like aspiration and appreciation for environmental improvement and pro-environmental behaviors, generate immediate positive feedback, reinforcing previous pro-environmental behaviors. Negative emotions, like anxiety and disgust for environmental deterioration and eco-unfriendly behaviors, induce cognitive dissonance and psychological distress, which the individuals eliminate by modifying behavioral motivations and adjusting behavioral patterns (Forgas 1995; Bamberg and Möser 2007). Further, EE is compatible with multiple processes that affect behavioral decisions both directly, and indirectly through emotional information that affects the relationship between rational cognition and behavioral intentions (Forgas 1995). Six indicators are used to define EE and verify the role of EE in the public's payment decision, which involve the aspiration for a better living environment, anxiety about environmental degradation, approval of pro-environmental behaviors, and disapproval of eco-unfriendly behaviors. As a result, the following hypotheses are proposed:

Hypothesis 4: EE has a positive impact on INT.

Hypothesis 5: EE positively moderates the relationship between AT and INT, SN and INT, and PBC and INT, respectively.

The analysis framework and research hypotheses are shown in Fig. 2.

3. Data and methods

3.1. Study region

Four provinces (autonomous regions) in northern China — Xinjiang, Gansu, Ningxia, and Inner Mongolia, make up the study region. The region is the largest cotton-planting area and a vital corn and potatoes-planting area in China; coupled with the arid and cold climate and poor agricultural endowment, mulch film has become an essential agricultural input. In this region, 30% of cultivated land is mulched, far exceeding the national average of 12%. Approximately 411,000 tons of mulch film were used in 2020, roughly one-third of nationwide utilization. The average intensity of mulch film utilization is 21.4 kg ha⁻¹, more than twice the average in China. In summary, the region has the most widespread application and the highest utilization intensity of mulch film, as

well as the most prevalent APW and the most pressing demand for APWM in China (Yan *et al.* 2014).

3.2. Questionnaire design and survey procedure

The questionnaire survey was conducted online. Public payment for APWM is similar to donation-based crowdfunding (DCF) (Stanko and Henard 2017), commonly relying on dedicated websites and social applications (Colombo *et al.* 2015; Ghobadi 2022). The online survey also has the advantages of a broad target population, low cost, and fast response (Fricker and Schonlau 2002; Wright 2005). Questionnaire Star (<https://www.wjx.cn/>), the largest online survey platform in China with over 300 million active users, was commissioned to survey in June–July 2022.

The questionnaire comprises three main parts. The first part includes the demographic characteristics of the respondents. The second part is the respondents' payment willingness towards APWM. It begins with a Likert scale investigating respondents' payment intentions towards APWM, ranging from 1 (not at all) to 5 (very much), and then the maximum amount they are willing to pay (i.e., WTP) per household per year. The third part, aiming to assess the constructs of the extended TPB framework, contains six latent variables, totaling 32 observable variables (Appendix B). In this

part, respondents rate their degree of agreement or disagreement with each statement, using a Likert scale ranging from 1 (completely disagree) to 5 (completely agree). The questionnaire was placed in the user pool of Questionnaire Star to collect data. After eliminating ones outside the study region, with terse completion times or with apparent errors, 1,288 valid questionnaires are obtained, and the effective rate of the questionnaire is 91.7%. It is verified the sample size satisfies the sample reasonableness test (Li *et al.* 2021).

3.3. Data analysis

AMOS 24.0 was employed to perform the structural equation model (SEM) to simulate and estimate the relationships of different constructs in extended TPB (Wu 2010; Qiu and Lin 2019). Moreover, hierarchical regression was used to test the moderation effects of EC and EE by applying SPSS 25.0.

4. Results

4.1. Descriptive statistics

The demographic characteristics of the respondents (Table 1) show that approximately half of the respondents

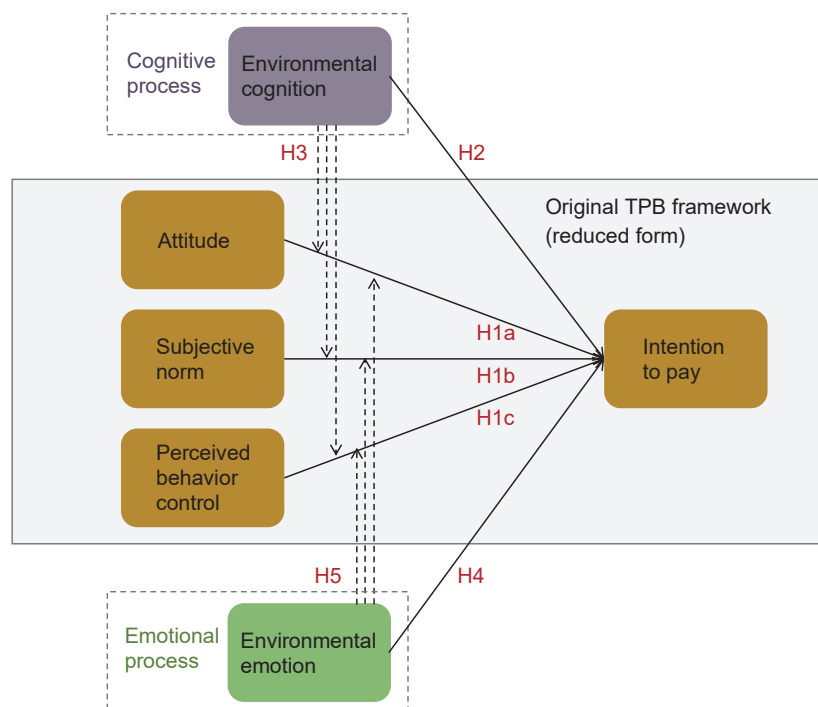


Fig. 2 Analysis framework of the extended theory of planned behavior (TPB) and research hypotheses in the study. H1–H5, different hypotheses.

Table 1 Demographic characteristics of respondents

Characteristics	Frequency	Percent (%)
Gender		
Male	611	47.4
Female	677	52.6
Age (year)		
<18	95	7.4
18–29	629	48.8
30–39	367	28.5
40–49	136	10.6
>49	61	4.7
Place of residence		
Urban	560	43.5
Rural	728	56.5
Education level		
Primary school	42	3.3
Junior high	141	10.9
Senior high	201	15.6
College	822	63.8
Postgraduate	82	6.4
Marital status		
Unmarried	589	45.7
Married	699	54.3
Number of household		
<3	45	3.5
3–5	1,032	80.1
6–8	207	16.1
>8	28	2.2
Number of teenager		
<3	1,232	95.7
3–4	56	4.3
Number of the elderly		
<3	1,244	96.6
3–4	44	3.4
Household annual income (CNY)		
<10,000	105	8.2
10,000–29,999	127	9.9
30,000–69,999	268	20.8
70,000–129,999	328	25.5
130,000–209,999	318	24.7
210,000–310,000	100	7.8
>310,000	42	3.3

are male and married. The distribution of residence places in urban and rural areas is roughly equal, at 43.5 and 56.5%, respectively. The majority are 18–39 years old and 80% of respondents have a high school or college education, indicating the younger and the educated population are over-represented to a certain degree for the online survey. Most respondents have a household size of 3–8 persons, with less than three teenagers and less than three elderly. Half of the respondents' annual household income is 7,000–210,000 CNY (1,000–30,000 USD). Respondents' characteristics of household

population and income are consistent with the statistics in the study region (NBSC 2022b).

4.2. Estimation of payment willingness and TPB constructs

A significant portion of the respondents, specifically 40.9%, express positive payment intentions towards APWM. The average WTP of all the respondents is 482.6 CNY (68.9 USD). The 95% confidence interval of WTP is 375.2–538.9 CNY (53.6–77.0 USD), statistically significant at the 5% level (Queralt 2012). The statistics of constructs (Appendix B) demonstrate that respondents generally have moderate AT and SN, relatively low EE, and relatively high EC and PBC. Eventually, they have a moderate payment INT.

4.3. Reliability testing

The internal consistency coefficient, Cronbach's α , is applied to conduct the reliability testing. The Cronbach's α for the six latent variables are 0.905 (AT), 0.919 (SN), 0.871 (PBC), 0.871 (PBC), 0.925 (EC), and 0.853 (INT). Each statistic exceeds the general discriminant of 0.800 (Garrett 1926), confirming the reliability of the study.

4.4. Validity testing

Construct validity, convergent validity, and discriminant validity are conducted for validity testing (Wu 2010). The construct validity testing (Appendix C) indicates the extended TPB framework provides a good fit for the data (Wu 2010; Qiu and Lin 2019). The convergence validity testing shows that all constructs are convergent (Appendix B) for the standardized factor loading greater than 0.6, composition reliability (CR) greater than 0.7, and average variance extracted (AVE) greater than 0.36 (Wu 2010). Cross-loadings, Fornell-Larcker criterion, and Heterotrait-Monotrait Ratio (HTMT) are applied to test the discriminant validity, and the results indicate that the discriminant validity test is passed (Appendices D–F) (Fornell and Larcker 1981; Wu 2010; Henseler *et al.* 2015).

4.5. Common method variance and multi-collinearity testing

Harman one-way test is performed to exclude common method variance (CMV) (Podsakoff *et al.* 2003). The result shows that one component explains at most 30.23% of the model variance, bellowing the 40% threshold to exclude CMV. None of the standardized regression

coefficients is greater than 1 (Marsh *et al.* 2004), and the variance inflation factor (VIF) for each measure is less than 10, ruling out covariance problems (Qiu and Lin 2019).

4.6. Hypotheses testing

AT, SN, and PBC exert significant positive effects on INT (Fig. 3), verifying H1a, H1b, and H1c. Besides, EC and EE significantly affect INT, thus validating H2 and H4. EC and EE improve the overall understanding of INT, increasing the proportion of explained variance from 55.9 to 61.5%. Multiple regression analyses are performed to test the moderating effects of EC and EE on AT→INT, SN→INT, and PBC→INT, respectively (Appendix G). The regression coefficients of AT×EC and SN×EC are positive and significant. In contrast, the regression coefficient of PBC×EC is not statistically significant. Results reveal that EC enhances the relationship between AT and INT, between SN and INT, but not between PBC and INT. Likewise, EE improves the relationship between AT and INT and between SN and INT. Hypothesis H3 and H5 are partially confirmed.

To sum up, AT, SN, and PBC all have significant positive effects on INT, with AT exerting the most prominent effect. In addition, EC and EE influence INT significantly and positively, yet their direct effects are relatively small compared to the three antecedent constructs of TPB. They positively moderate the relationship between AT and INT and between SN and INT, posing indirect effects on INT (Appendix H).

5. Discussion

It is challenging to sustain APWM with existing funding in China, leaving the threats posed by APW to persist and trigger social concern. The result reveals the possibility of public payment in addressing the funding gap. Further, the driving pathways of payment decisions are investigated by applying the extended TPB framework. The findings enhance the understanding of the public's voluntary contribution to APWM and shed light on critical initiatives to strengthen individuals' payment intentions.

5.1. Individuals' payment willingness towards APWM

More than 2/5 of the respondents are willing to pay for APWM, and the average WTP is 482.6 CNY (68.9 USD) per household per year, approximately 0.5% of their annual household income. The amount exceeds most yearly WTP for marine plastic waste management, which

was 2.6 USD for South Korean residents (Choi and Lee 2018), 0.7–8.1 USD per visitor in Greece, Bulgaria and the Netherlands (Brouwer *et al.* 2017), 4.9–14.5 USD for Ecuadorian families (Zambrano-Monserrate and Ruano 2020), and 11.9–34.6 USD per household for Australians (Borriello and Rose 2022). However, it is lower than 5,485 NOK (642 USD) per household per year of Norwegian households for eliminating marine plastic pollution (Abate *et al.* 2020), which surpasses the WTP found in other comparable studies. The result demonstrates the public's payment willingness towards APWM is relatively strong in general. Referring to respondents' reported WTP, the public of four provinces (autonomous regions) in the study region will raise a total of 12.2 billion CNY (1.7 billion USD) APWM funding. It implies the initiative of public payment can be a promising supplement to the existing APWM scheme, which is beneficial to mitigate the funding gap. Of course, according to the ladder of citizen participation (Arnstein 2019), public payment which is currently being verified may remain at the ladder's bottom rung. How to gradually climb the higher rungs of public participation in environmental issues through institutional construction may be a core topic in the future.

5.2. Driving pathways of individuals' payment decisions

Attitude AT exerts the most significant positive influence on INT among all the five constructs studied. Studies on green purchase (Ajzen 2005; Martinho *et al.* 2015) and renewable energy support (Cass *et al.* 2010) backed up the proposition. Indicators' PCs suggest that evaluation from a self-needs perspective (AT1) occupies an absolute advantage, followed by the evaluations from the surrounding environment (AT4), with comparatively small impacts from others (AT2) and society (AT3). It aligns with the degree of impact on individuals, enlightening that positive evaluations towards APWM may derive from self-interest realization motivations rather than altruism (Sugden 1984). That is to say, individuals' payment decisions stem more from the desire to satisfy ego needs, which accords with earlier observations in charitable donations (Chang 2014). Additionally, evaluations based on future demands matter more than present-based ones. The preference for "investing for the future" may be attributed to the fact that although the APW threats are perceived, it is silent and invisible. Out of rational and prudent consideration, individuals deem that APWM is of the essence to lessen possible future threats.

The result corroborates the crucial role of environmental education and advocacy in enhancing the public's comprehensive evaluation and good attitude towards

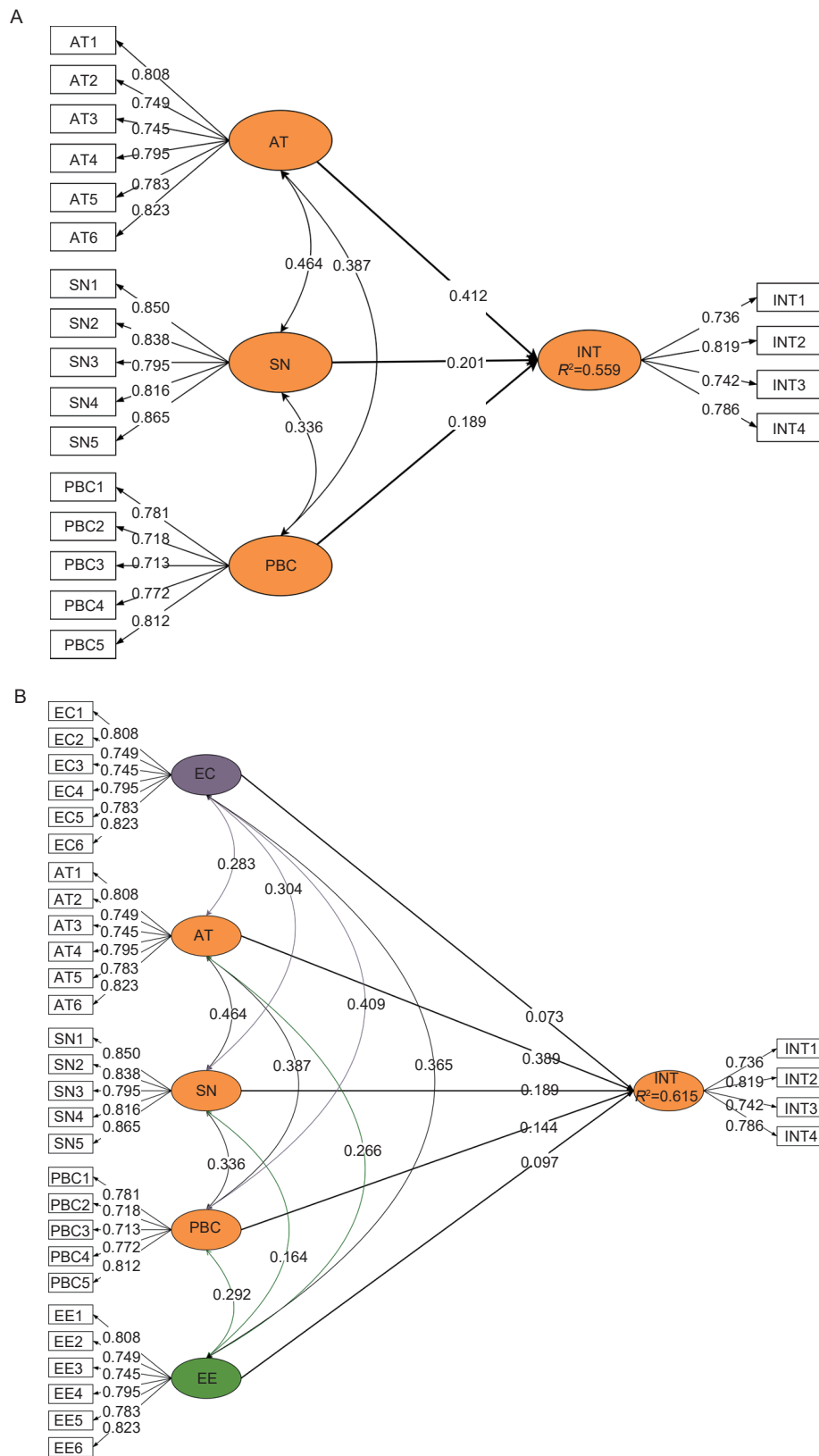


Fig. 3 Original (A) and extended (B) theory of planned behavior (TPB) framework with standardized path coefficients (PCs). AT, attitude; SN, subjective norm; PBC, perceived behavioral control; INT, intention; EC, environmental cognition; EE, environmental emotion.

APWM, which can further motivate their payment decisions. The forms of education and advocacy should be innovatively diversified in practice. On one hand, traditional mass media such as books, newspapers, radio, film and television should be utilized (Xu 2020). Outstanding public service announcements should be produced and broadcasted, and slogans and posters can be displayed outdoors and on public transportation to publicity vividly. On the other hand, social media, video websites, mobile applications and other online promotional platforms should be employed actively (De Fano *et al.* 2022). Environmental education-themed online literature, animation, audiobooks, games, and short videos allow the public to grasp a more comprehensive understanding of agricultural non-point pollution enjoyably and subtly. As for designing public education and advocacy, it is necessary to give full consideration to the critical impacts of APWM on themselves and future sustainable development.

Subjective norm Individuals with higher SN are more prone to pay for APWM, in harmony with previous study (Wang *et al.* 2016). Indicators' PCs reveal that social pressures, from relatives (SN1) and friends (SN2) to social media (SN4) and authorities (SN3), are diminishing. It indicates that pressure from closely connected others is the most significant source of SN, with others being less influential. A possible explanation might be that public payment is typical behavior with public welfare attributes and altruistic tendencies, and the resulting norms are mainly reflected in informal public opinion and moral restraint. The external pressure individuals perceive diminishes from relatives and friends to social media and authorities, consistent with social distances and connection tightness to the pressure sources. The finding that donation willingness enhances along with social proximity corroborates earlier findings (Fong and Luttmner 2011).

Specifically, expectations from relatives and friends are pivotal components of SN. In an acquaintance society, individuals gain social inclusion by following what others consider good (Taylor and Todd 1995). Individuals' decisions are generally influenced by relatives and friends of the tradition of collectivism (Fei 2009). Besides, the finding enables us to conclude that exposure to APWM-themed information on social media can enhance payment INT, in line with the announcement that exposure to media information regarding pro-environmental behaviors effectively engages people in them (Zhang *et al.* 2021). Furthermore, the norms from the authorities cannot be ignored. While public payment holds weak mandatory binding (Bergstrom *et al.* 1986), the appeal and encouragement from authorities with high credibility

are practical (Osbaldiston and Sheldon 2003). The result is in line with studies on curbside recycling programs (Gamba and Oskamp 1994) and food waste management (Soorani and Ahmadvand 2019).

The critical role of SN should be fully aware of in public payment schemes. Consensus concerning the hazards of APW and the importance of APWM should be thoroughly reached and spread out within personal circles. Individuals, groups, and organizations that made special contributions to APWM should be highly praised and widely publicized. The demonstration and guidance role of models should be sufficiently exhibited to inspire everyone to cooperate and make efforts for APWM. Engaging celebrities, public figures, and other influencers in public payment schemes can also be beneficial in amplifying social norms. In addition, social media can also be developed as a tool to disseminate public payment schemes. Web-based publicity with the theme of public cooperation in environmental management should be carried out to advocate positive energy in social interaction. Furthermore, authorities' publicity also makes sense and serves to assist the public in identifying their entity identity in environmental governance, which can foster the public's civic responsibility and social awareness to promote a "mission community" for environmental public welfare (Zhong and Luo 2021).

Perceived behavior control Individuals who have more confidence in the controllability and self-efficacy of paying for APWM are more willing to pay, which has been discerned earlier (Khan *et al.* 2019; Shang and Xiong 2021). Indicators' PCs suggest that a sense of self-control (PBC4) and expected effectiveness (PBC5) are major elements of PBC, followed by available opportunity (PBC2), while financial burden (PBC3) exerts relatively little.

As the homo economicus, one of the individuals' behavioral motivations is to lessen damage or benefit. Paying for APWM is a sacrifice for individuals, and the promotion of altruistic behaviors primarily originates from the belief that they will reap the rewards (Liu and Hao 2017). Respondents expect their payment can alleviate the APW and bring about an improved living environment rather than being futile. Consequently, institutions that guide public payment schemes should have high social credibility. With a convincing institution to endorse, the public will be inclined to eliminate indecision and be convinced that their efforts will be rewarded. In addition, making sure the feedback concerning APWM is available to contributors may be effective in promoting payment intentions as well.

Being an envisaged scheme, the absence of payment channels may be the major challenge. The finding emphasizes the necessity of opening up the payment

access of APWM to create favorable conditions. Based on intelligent terminals and mobile payments, the Internet shows great potential to aggregate numerous contributors. The online payment platform seems to be a promising choice for not only simplifying the payment process but also enlarging information dissemination through social applications (Zhang and Li 2022). Enlarging the information disclosure of public payment schemes, including constantly announcing the progress and effectiveness of APWM's efforts and timely response to issues that are highly concerned, enables the potential contributors to know more about the details of the scheme and their associated benefits (Zhao and Shneur 2020). This will allow greater transparency and accountability of the scheme and increase public trust (Ferreira *et al.* 2022). It's worth noting that the amount individuals are willing to pay is a basic attribute to evaluate. The voluntariness principle can lower the threshold and ease the perceived difficulty.

Environmental cognition EC strengthens the relationships between AT and INT and between SN and INT. Individuals with a higher level of EC have a more profound comprehension of APW (Sauer and Fischer 2010; Juvan and Dolnicar 2014) and are more inclined to make reasonable decisions on APWM (Weber 2017). EC strengthens INT by facilitating the conversion of rational motivations into responsible behavior decisions. However, EC does not affect the relationship between PBC and INT. PBC closely correlates with individuals' perceived control over targeted behaviors based on their experiences and expected obstacles (Ajzen 1991). The discrepancy could be attributed to the fact that PBC is closely tied to objective reality, which EC cannot alter.

Indicators' PCs reflect that the perceived threat to food safety (EC4 and EC6) is the major source of EC. The reason may be that scientific researches on the risks of plastics are on the upsurge, notably the threats to the food system and human health (Leslie *et al.* 2022; Zhu *et al.* 2023), and related reports are becoming ubiquitous in social media like Weibo, Tiktok, and WeChat. In this context, the consensus has emerged among the public that plastics are "invisible killers," causing vast public concern. Next, environment pollution cognition (EC1) makes up a reasonable proportion of EC. The study region is located in the Loess Plateau area of China, which is poor in natural endowments with scarce precipitation, arid climate and rare vegetation, making the locals acutely aware of environmental crises. However, ecosystem importance cognition (EC2) and environmental threat cognition (EC3 and EC5) are comparable and relatively minimal. This may signal that respondents' cognition of environmental pollution lies at a relatively unilateral level.

Efforts should be made continuously to popularize environmental knowledge and deliver the facts about the seriousness of environmental pollution and the urgency of taking action to mitigate environmental degradation. Environmental education should be further deepened so that the public can acquire more systematic learning on the intrinsic logic of "environmental pollution-food safety-human health". The psychological anchor that individuals attach great concern to food safety and human health can be grasped in popularization and education to strengthen environmental cognition and stimulate the motivation to perform responsible behaviors. Furthermore, the key moment of environmental education such as World Environment Day, focusing on "Solutions to Plastic Pollution" in 2023 (UNEP 2023), can be leveraged to foster public environmental literacy on a larger scale. This can be done by utilizing digital media with extensive reach (Yuan *et al.* 2023), as well as by creating local events such as workshops, lectures, and other activities to broaden the impact of the education campaigns.

Environmental emotion Similarly to EC, EE enhances the relationships between AT and INT and between SN and INT. Limited association between rational motivations and behavioral decisions is a typically embarrassing dilemma, presenting a violation of "knowledge as action". It may be that such perception and awareness fail to match with equivalent emotional empathy (Thomas *et al.* 2009). By reinforcing the bond that individuals identify with the environment, EE facilitates rational motivations to transform into responsible environmental behaviors (Adhami and Akbarzadeh 2010). Decisions reinforced by emotional factors are more respectful and generous to the environment, even beyond self-interest (Olivos *et al.* 2011). If perceptions of environmental issues rise from rational levels to emotional ones, individuals' comprehension of payment for APWM will be elevated to a profound and stable spiritual touch.

Indicators' PCs suggest that positive emotions are the core elements of EE compared to negative ones. The finding supports the evidence that pro-environmental behaviors were more correlated with positive emotions (Meneses 2010; Kostka and Mol 2013; Zelenski and Desrochers 2021). Specifically for positive EE, individuals who appreciate the beautiful environment (EE1) are more likely to make efforts and sacrifices for it (Hartmann and Apaolaza-Ibáez 2008). In addition, if individuals appreciate (EE4) and approve of (EE6) pro-environmental behaviors, they are likely to be appealed to and assimilated to perform the same behaviors (Kals *et al.* 1999). In light of this, initiatives like experience and participation in environmental practices can be employed to encourage individuals to discover the beauty of nature, understand the value of

ecology, and thereby strengthen their EE to enhance payment intentions. Furthermore, environmental protection ambassadors can be set to subtly stimulate individuals' positive emotional energy and promote their identification with the cooperation to environmental management. Negative emotions are minor but meaningful to EE. Environmental anxiety (EE2) is a sense of worry developed by cognition, reflecting emotional shock at environmental deterioration (Böhm 2003). Additionally, individuals may feel disgusted (EE3) and guilty (EE5) about eco-unfriendly behaviors (Kollmuss and Agyeman 2002; Harth *et al.* 2013). These feelings can cause cognitive dissonance, leading to psychological suffering (Böhm 2003). Individuals thus modify former behavioral motivations and patterns (Carrus *et al.* 2008). In this regard, information that the environment is continuously getting worse and the ecosystem crisis is progressively increasing should be appropriately disseminated to create a sense of anxiety and crisis. Additionally, typical ecological damage behaviors should also be disclosed timely. Negative incentives like criticism and education can stimulate feelings of disgust and guilt for eco-unfriendly behaviors.

In summary, the direct effects of EC and EE on INT are minor compared to AT, SN, and PBC, implying that the public's payment decision is driven more by motivations associated with APWM than by pro-existing EC or stable EE. Given their inspiration in understanding the public's payment decision, it is equally compelling to enhance EC and EE through the aforementioned initiatives. Furthermore, it is worth pointing out that the study extends TPB by EC and EE. Indeed, many other factors may affect the public's payment intention. Upcoming research would consider other determinants as extended constructs to obtain in-depth knowledge.

5.3. Government's guidance to promote APWM

The public is an essential component of a systematic environmental governance system (Kostka and Mol 2013), and multi-entity cooperation is a comprehensive solution to environmental pollution (Mauerhofer 2016; Carvalho *et al.* 2019). Pursuing sustainable and resilient APWM necessitates seeking open-ended and innovative schemes through increasing awareness and cooperation among all stakeholders, which is aligned with the common interests and shared values of humanity. Accordingly, the government can undertake the following efforts.

Foremost, the government should actively foster the social atmosphere of public payment for APWM. Aiming at consolidating the consensus of multi-entity cooperation in environmental management, the government can strengthen education and publicity to improve the public's

comprehensive evaluation of APWM and upgrade their environmental cognition, reinforce the subjective norm of public payment for APWM, and nurture the public's environmental emotion. Especially, the government should assist in constructing authoritative and accessible public payment channels. As stated, public payment for APWM is essentially the DCF, which consists of the creator, platform, and funder (Shneor and Maehle 2020). Creators in China are primarily foundations, charities, government departments, and social organizations. Enterprises, individuals, and social organizations can fund a specific DCF on 32 online fundraising information platforms designated by the Ministry of Civil Affairs of China. The government can guide authoritative creators, such as the China Environmental Protection Foundation and the Inner Mongolia Autonomous Region Charity Federation, to take the lead in initiating public payment for APWM. The government's guidance and endorsement will efficiently facilitate the construction of public payment channels, increase the public's trust in online donations (Liu *et al.* 2022), and mobilize the public to pay.

Additionally, the government should upgrade financial support for APWM. The public interest is the origin and destination of the government's environmental management. Thus, financial expenditures on environmental protection should be directed towards fields of great social concern and pressing public demands. The public's high payment willingness towards APWM implies that the government should restructure the financial allocation of environmental protection funding and place more emphasis on agricultural non-point waste such as APW. The government can consider setting up a particular category for APW inside the "211 Energy Conservation and Environmental Protection" (Appendix I) and provide precise and differentiated financial support to various stakeholders and management links. For plastics production enterprises, government purchases of APW-based regenerated products can be increased to enhance their market competitiveness. For APW recycling enterprises, APW categories that are eligible for the VAT instant refund policy could be expanded, interest discounts for purchasing and upgrading environmental equipment could be offered, APW processing equipment could be included in the agri-machinery subsidy category, and the investment in recycling station construction should be enlarged. Additionally, farmers who purchase APW-based regenerated mulch film ought to be subsidized.

6. Conclusion

The study conducts an empirical analysis based on 1,288 residents in four provinces (autonomous regions)

of northern China. Under the premise of verifying the applicability of public payment for APWM, the extended TPB is applied to investigate the driving pathways of the public's payment decision. Results illustrate that: 1) Public payment scheme holds potential promise in alleviating the fund gap confronting APWM; 2) AT, SN, PBC, EC, and EE have significant positive influences on payment INT towards APWM, with AT exerting the greatest impact, followed by SN and PBC, and EC and EE showing minimal direct effects; 3) the extended TPB framework has better interpretability to INT, and EC and EE strengthen the relationship between AT and INT and between SN and INT.

The study provides a new perspective on public payment in tackling the APWM dilemma, which is quite revealing. The initiatives highlighted by the driving pathways of the payment decision, which include strengthening the public's comprehensive evaluation of APWM and environmental cognition, reinforcing subjective norms of paying for APWM, establishing the payment platform to open up channels for the public to pay, and nurturing the public's environmental emotions, can be served as the entry point for formulating an open and diverse APWM scheme. In this regard, the government should play its guidance, organization and support role in APWM. Practical collaborations among multiple entities should be actively promoted along with the planning of public payment schemes. The combined efforts of multiple entities will highlight the synergy between the non-market value and the market value of APWM and ultimately achieve sustainable and resilient agricultural non-point waste management. Furthermore, agricultural non-point waste may also occur in pursuing economic development in other developing countries. Public participation can be an innovative approach to enhance agricultural waste management.

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Declaration of competing interest

The authors declare that they have no conflict of interest.

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