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Understanding wheat farmers' intentions regarding the adoption of integrated pest management

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ABSTRACT

Integrated pest management employs a holistic and sustainable approach to minimize environmental impacts for effective pest control. However, there is limited empirical evidence regarding the implementation and extent of willingness to adopt integrated pest management methods, particularly in developing countries. To address this research gap, this study utilizes an augmented version of the planned behavior model to examine the determinants influencing environmental protection intention among Iranian farmers in adopting integrated pest management practices. This research was descriptive, causal, and correlational, conducted through a cross-sectional survey method on 357 wheat farmers in West Azarbaijan province. The constructs in the original planned behavior model accounted for 51 %, and the extended model accounted for 69 % of the variance in farmers' intention to use integrated pest management practices. According to the findings of structural equation modeling, all constructs, except subjective norm, significantly affect farmers' intention to use integrated pest management. The results suggest that place attachment enhances the relationship between farmers' attitude and intention to use integrated pest management. The model created in this study can serve as a guide for future research and interventions aimed at promoting sustainable agricultural practices worldwide. Policymakers can utilize these insights to develop policies that offer incentives for the adoption of integrated pest management techniques.

1. Introduction

Since the beginning of the 21st century, there has been increasing attention paid to environmental challenges and their profound impacts on human life and the delicate balance of the planet. Human societies are exerting unprecedented pressure on the environment through factors such as rapid population growth, climate change, water wastage, soil erosion, destruction of animal habitats, constant burning of fossil fuels, and excessive deforestation [1–3]. These actions have led to severe and often irreversible damage to the environment, which is a major obstacle to achieving the Sustainable Development Goals, particularly SDG3 and SDG15. A growing body of research, including studies by Goli et al. [4], Haji et al. [5], and Momenpour et al. [6], emphasizes that human activities are the primary cause of environmental degradation. One of the key aspects of optimizing the use of natural resources is related to human agricultural activities. Agricultural practices have a significant impact on the environment [4,7], which can consequently lead to harmful economic and social effects. In conventional agriculture, farmers typically rely on artificial and chemical inputs [8,9]. While conventional agriculture has successfully addressed the issue of food security by increasing crop productivity, it has also had significant adverse effects on the environment, including soil erosion, changes in enzymatic activity, reduction of biodiversity, increased resistance to pests and diseases, and decline in the population of natural enemies [9–11].

One common practice in conventional agriculture is the widespread use of chemical pesticides. Chemical pesticides can significantly reduce the pest population in the short term. The problem arises when the natural enemies of these pests are also killed, resulting in the pest population returning to normal or even increasing beyond the initial amount. This has led to an encouragement for farmers to use more of these substances. Additionally, the use of chemical pesticides often poses harm to the soil, water, plants, and animals [12,13]. Undesirable side effects such as risks to human and animal health, groundwater contamination, pest resistance, and population decline of natural enemies [9] further contribute to the reduction of biodiversity and the population of smaller pollinating insects. A study by Girma & Challa [14] discovered that only 22 % of farmers read the information on the

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containers of chemical pesticides, indicating a lack of sufficient information on their proper use. Given the challenges and environmental damage caused by dependence on chemical pesticides, there is an increasing need for more sustainable and less risky methods for pest management. In this regard, integrated pest management (IPM) has been proposed as an effective and comprehensive approach.

IPM, "… A decision support system for the selection and use of pest control tactics, singly or harmoniously coordinated into a management strategy, based on cost/benefit analyses that take into account the interests of and impacts on producers, society, and the environment" [15]. IPM is an innovative and alternative approach to pest control that combines scientific and rational methods to reduce the use of chemical pesticides or replace them with lower-risk alternatives. This approach offers effective and sustainable solutions for pest suppression [16]. As a holistic strategy for managing plant pests and diseases, IPM emphasizes the coordinated use of cultural (e.g., crop rotation, intercropping, soil management), mechanical (e.g., manual removal of pests, traps), biological (e.g., use of beneficial insects or biopesticides), and chemical methods [17]. The goal is to minimize reliance on chemical pesticides as much as possible to preserve the sustainability of agricultural systems [13,18]. The active use of IPM techniques can reduce water and soil pollution and lower farmers' costs [9]. Key principles of IPM include identifying pests and their hosts, monitoring pest populations, and setting action thresholds for pest management [19]. IPM represents a fundamental shift in agricultural science away from traditional pest control methods that relied heavily on chemical pesticides. The traditional approach often addressed pests after they had already become a problem, with minimal emphasis on prevention and little consideration for the potential harm caused by chemical pesticides to the environment, food, water, humans, animals, and other pest-control methods [9]. Despite recent efforts, farmers still lack sufficient knowledge and awareness to effectively implement IPM [20]. Due to limited understanding of IPM's effectiveness in controlling pests, diseases, and weeds, less environmentally friendly control methods are frequently used. Research indicates that IPM is particularly popular in protected production systems, as demonstrated in previous studies (e.g., [21]). Ultimately, IPM aims to eradicate pests while preserving ecosystem balance.

Despite extensive studies that have used the theory of planned behavior (TPB) model to explain individuals' behaviors and intentions in various contexts, limited research has focused specifically on the application of this model to understand wheat farmers' propensity to adopt IPM practices, especially in developing countries. The indiscriminate use of chemical pesticides and fertilizers in Iran has negative impacts on the soil, such as the accumulation of heavy metals and changes in the physical and chemical properties of the soil [20]. Therefore, as suggested by Shojaei et al. [22], it is important to implement IPM practices to preserve the ecosystem, ensure the reliability and stability of farm output in the Iranian agriculture sector, reduce health and environmental risks for farmers and the general public, promote self-reliance among farmers, and decrease national expenditures on chemical pesticides. The lack of comprehensive empirical evidence currently hinders a full understanding of the factors influencing wheat farmers' decisions to adopt IPM, thereby hindering the development of effective policies and interventions. This research gap is of particular importance in the field of sustainable agriculture, as IPM is recognized as an effective approach to reduce chemical pesticide use and promote ecosystem health. In this regard, the TPB model, as a suitable theoretical framework, can shed light on the factors influencing wheat farmers' decision-making by incorporating other variables. This study aims to use the developed TPB model to identify and explain the factors affecting wheat farmers' willingness to adopt IPM practices, thereby filling the gap in the research literature and providing a basis for designing more effective programs to promote IPM.

2. Theoretical background

Previous studies [23,24] have found that socio-economic factors play a significant role in the adoption of IPM. The impact of extension activities accounted for nearly 50 % of the variation in attitudes toward IPM among vineyard owners [25]. The primary reasons for rejecting IPM among apple growers included uncertainty regarding pest control effectiveness with IPM technology, insufficient information about IPM technologies, and the complexity of these technologies [22,26]. Furthermore, pistachio growers and agricultural experts believed that the most significant barrier to IPM implementation was farmers' economic constraints [20]. Ahmadvand et al. [27] discovered that socio-communicative and psychological factors had the greatest influence on the use of IPM methods. Similarly, Bagheri et al. [28] highlighted the importance of moral and normative beliefs as key variables in explaining IPM adoption. Gaining a more comprehensive understanding of the IPM implementation process can help clarify farmers' psychological constructs regarding environmentally friendly practices that support environmental sustainability.

Furthermore, this understanding can contribute to the development of improved programs and policies aimed at educating farmers and promoting environmentally friendly agricultural practices. In this regard, several studies [9,28–30] indicate that the TPB framework is useful in explaining farmers' behavioral intentions (IN) in both developed and developing countries. Despotović et al. [9] concluded that farm size and the four key TPB factors (values, perceptions, behavioral norms, and control) influenced farmers' IN regarding the implementation of IPM. Given that previous research on farmers' knowledge and awareness of IPM [31] has primarily focused on the behavioral aspects of IPM adoption, the findings of this study provide a fresh perspective and valuable insights. Moreover, in Iran and other developing countries, there is a lack of clear understanding of modern pest control methods, posing challenges for researchers and policymakers in prioritizing appropriate strategies and policies.

The TPB, developed by Fishbein and Ajzen [32], sets itself apart from other theories by including the perceived behavioral control (PBC) variable as a determinant of behavioral IN. It is widely used to analyze human behaviors and understand an individual's intention toward a specific behavior [33]. The TPB framework has been extensively applied in research related to agriculture and the environment. Due to its ability to explore new socio-psychological structures, this model is an effective tool for explaining farmers' behavior in environmental management [34–37]. This socio-psychological theory is based on three factors: AT, subjective norm (SN), and PBC [38]. AT represents a person's positive or negative evaluation of a specific action. SNs reflect an individual's perception of social pressure regarding whether to engage in an action, while PBC indicates a person's belief in their ability to successfully perform the behavior [39]. Generally, behavioral intention is stronger when there is a more favorable AT and SN, along with greater control over the behavior [40]. According to the TPB, individuals are more likely to engage in a behavior if they view it positively. This tendency is influenced by people's inclination to imitate influential and significant individuals [41].

The TPB falls short in fully predicting or explaining pro-environmental behaviors. Rise et al. [42] found that the three components of TPB only account for an average of 20–40 % of the variation in behavioral IN. Consequently, researchers have sought to incorporate additional factors to enhance the model's predictive efficacy [43]. Despite the theory's widespread publication and application, it has been criticized for overlooking the inclusion of ethical variables, such as moral norms (MNs) [44]. MNs encompass individuals' emotions, moral commitment, and sense of responsibility towards their behavior, all of which influence their actions [38]. These MNs draw on theories like altruistic norm activation, as proposed by psychologists such as Schwartz [45]. An individual's perception of right and wrong affects their judgment, which subsequently impacts their behavior. Prior studies, like those conducted by Lu et al. [46], have demonstrated the significant role of personal morality in environmental behavior. This is because the presence of a MN engenders a sense of reward and guilt that guides behavior.

The MN, as a mediating variable, can mediate the effects of AT, SN, and PBC on intention. In other words, these three main constructs not only directly affect intention but also influence intention by affecting the moral norm. If farmers believe that IPM is beneficial for the environment or farm economy (positive AT), this belief can strengthen their sense of MN (high MN). Thus, the belief in reducing the use of chemical pesticides may increase the sense of moral responsibility to protect nature, which in turn strengthens the intention to use IPM. Additionally, farmers who feel that society expects them to implement IPM may experience social pressure that leads to the reinforcement of moral norms [47]. For example, social approval may lead farmers to believe that using IPM is a moral duty to maintain the health of the community, and this moral norm then increases their intention to adopt IPM. Farmers who believe they have the knowledge, skills, or access to the tools necessary to implement IPM (high locus of control) may experience increased confidence, strengthening their sense of MN [48,49]. For example, when a farmer knows they are capable of successfully implementing IPM, they may feel MN to do so because not using it, despite having the ability, would seem irresponsible.

Moreover, the incorporation of the variable place attachment (PA) into the TPB model aims to enhance its predictive capacity regarding the adoption of IPM methods. PA refers to the emotional bond that individuals form with specific locations, which is influenced by both physical and social factors. It signifies the emotional connection between individuals and their surroundings [50]. Research suggests that PA develops over time through frequent and extended interactions [51]. Functionally, PA can be described as an attachment to a place where individuals can achieve their goals by accessing resources and perceiving the environment's support in goal achievement [52]. Numerous studies have demonstrated that individuals with a stronger attachment to a location are more likely to engage in environmental actions [51,53]. Thus, individuals who possess a profound connection to their place of residence are more inclined to protect the environment. Prayitno et al. [26] found that farmers with higher levels of PA are more likely to preserve their land. Therefore, it can be argued that the constructs that make up the original TPB model can play a role in influencing IN. Essentially, participants who exhibit a strong attachment to their land are more determined to conserve it.

In this study, two significant implications for planners and policymakers in Iran are explored, which have not been previously investigated by other researchers. Firstly, this study is noteworthy as it examines the implementation of IPM using the original TPB. Secondly, to the best of our knowledge, this investigation is distinctive as it tests the extended TPB structures that influence wheat farmers' inclination to adopt IPM in northwestern Iran. Based on the theoretical framework (Fig 1), the following assumptions can be inferred:

H1. AT has a significant effect on the IN to use IPM.

H2. SN has a significant effect on farmers' IN to use IPM.

H3. PBC has a significant effect on farmers' IN to use IPM.

H4. MN has a substantial effect on farmers' IN to use IPM.

H5a. PA positively and significantly moderates the effect of AT on the IN of farmers to use IPM.

H5b. PA positively and significantly moderates the effect of SN on the IN of farmers to use IPM.

H5c. PA positively and significantly moderates the effect of PBC on the IN of farmers to use IPM.

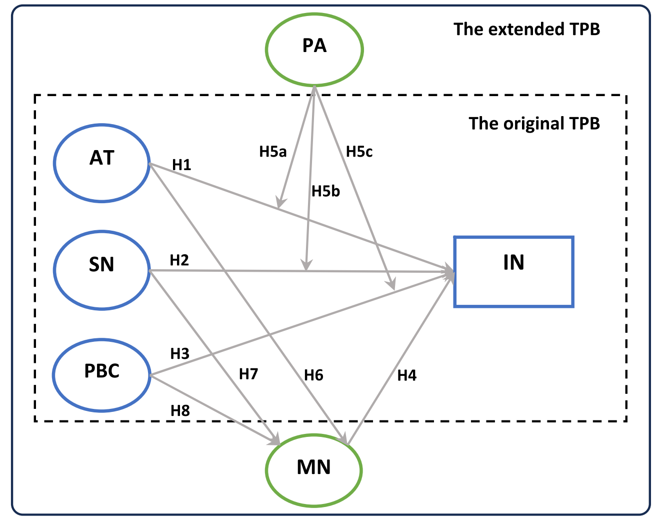

Fig. 1. The theoretical framework of the research.

H6. AT has a significant effect on the MN.

H7. SN has a significant effect on the MN.

H8. PBC has a significant effect on the MN.

3. Materials and methods

3.1. Research design

This study falls under the category of applied research due to the potential usefulness of its findings for various stakeholders, including extension agents, farmers, agricultural managers, planners, and policymakers. It aligns with the framework of quantitative studies within the research paradigm and is considered non-experimental as it does not involve direct manipulation of variables. Since the key variables in this study - such as AT, SNs, PBC, PA, MNs, and IN - are all psychological and unobservable constructs, a self-report survey method was chosen as the most appropriate tool for data collection. Previous studies in the field of sustainable agricultural technology adoption and farmers' environmental behavior have successfully used survey methods within the TPB framework, validating it as a reliable approach for assessing behavioral intentions and their influencing factors [20,54]. This research is cross-sectional in terms of its time scope, as data were collected at a single point in time. Additionally, in terms of data analysis methodology, it is both descriptive and relational. A descriptive-correlational approach based on causal-relational analysis was employed to analyze the data. Considering that agriculture in Iran is significantly influenced by social, cultural, and attitudinal factors, the survey method provided researchers with detailed insights into farmers' beliefs, perceptions, and motivations, allowing them to evaluate the impact of key variables on their decision-making. Fig 2. offers a summary of the research implementation stages.

3.2. Study area

Bukan City is located in the northwestern part of Iran (Fig. 3). This region is known for its favorable climatic conditions, making it one of the best places for agriculture in the country. West Azarbaijan's climate is generally cold and dry, but it boasts a diverse topography with different climates and an average annual rainfall of 400-450 mm [25]. Agriculture in this region is carried out in two ways: rainfed and

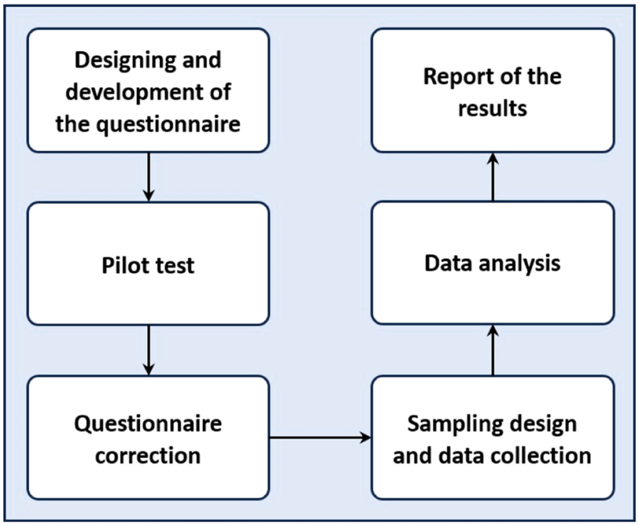

Fig. 2. The process of the research method.

irrigated, which also influence the type of crops grown. Wheat is the predominant crop in this area, accounting for 4.38 % of Iran's total wheat production. However, over the past decade, the excessive use of agricultural chemical pesticides, misuse of herbal medicine, lack of oversight by relevant institutions, and farmers' overuse of pesticides have led to significant environmental issues. These problems include pest resistance to chemical pesticides, loss of natural enemies, water pollution, increased pesticide residues in agricultural products, and health problems for humans and other organisms [55]. Furthermore, there has been a lack of necessary control and training in the field of IPM among Bukan farmers.

3.3. Data collection and analysis

First, the questionnaire was prepared based on the literature review, incorporating the components of TPB, MN [28], and PA [56]. Following a pre-test study conducted with a sample similar to the target population, the questionnaire was modified based on the results. Subsequently, data gathering was carried out, with 400 questionnaires initially distributed among individuals. After data filtering, 357 questionnaires (the desired number according to the Krejcie & Morgan [57] table) were finalized for analysis. The collected data was then analyzed, and the results were reported and discussed.

The stratified random sampling method with proportional assignment was utilized, with strata consisting of geographic regions with varying wheat yields per unit area. Sampling within each stratum began in residential units located in the northwest of the study area, with households listed from north to south within each village, and questionnaires completed. Once it was confirmed that the individuals were wheat farmers, the questionnaire was administered. Participation in the research was entirely voluntary. If individuals were ineligible, sampling continued by moving to the adjacent area on the right side of the current location until the required number of samples was achieved. Data for this research was collected using a structured questionnaire, completed face-to-face. It's worth noting that during questionnaire distribution, the researcher and trained team were present on-site to clarify any uncertainties for respondents. A total of 400 questionnaires were provided to the trained team, with data collection halted once the desired number of completed questionnaires (357) was reached. Data collection for this research took place in the spring of 2021 (Table 1).

3.4. Questionnaire design and development

As mentioned by Hair et al. [58], multivariate testing is suitable for examining established theory and additional independent variables. Since structures cannot be directly measured, indices are utilized to assess factors, with each index representing the weight of the structure. All indices are rated on a Likert scale from 1 to 5 (1= strongly disagree, 2= disagree, 3= neither agree nor disagree, 4= agree, and 5= strongly

Table 1
Sample size based on stratified random sampling method.

Township	Rural district	Number of selected villages	Total number of villages	Statistical population	Sample size
Bukan	Akhtachi	3	175	1450	95
	Mahali Akhtachi	3		680	44
	Ale Timur	2		523	34
	Ale Gavork	3		1100	72
	Dehbikri	2		810	53
	Fezalahbaigi	2		600	39
	Eastern Akhtachi	1		310	20
Total	7	16	175	5473	357

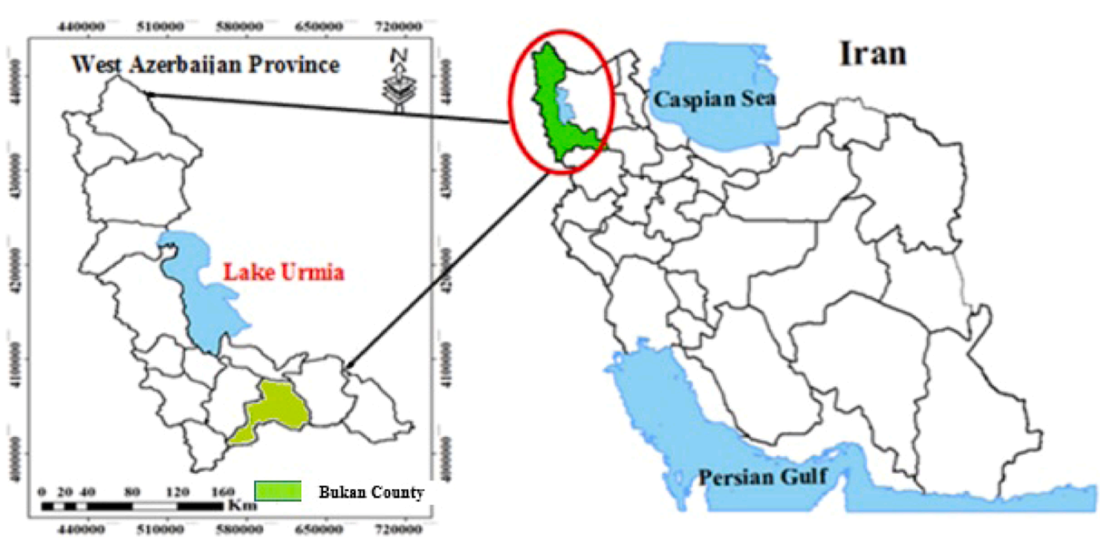

Fig. 3. Location of the studied area.

agree).

Table 3 displays the list of extended TPB components and indicators. A thorough literature review was conducted to select indicators that best represent the model's structure. The questionnaire design was split into two sections. The first section included the TPB components: AT, SN, and PBC [9,28], with each structure consisting of 4 items, including MN, attachment to place, and behavioral IN (see Table 3). The second section covered respondents' demographic information such as gender, age, education level, income, and agriculture experience. The research utilized a structured questionnaire with questions pertaining to measuring both the dependent and independent variables. A list of measured latent variables and their corresponding references is provided separately in Table 3. Respondents were instructed to rate their agreement with each item on a five-point scale from 1 to 5 (1= strongly disagree to 5= strongly agree).

3.5. Data analysis strategy

Data was analyzed using structural equation modeling (SEM). SEM is typically one of the best analytical methods used in social disciplines, ranging from psychology and extension surveys to marketing [59]. Therefore, in this study, a SEM relational map was created and data analysis was conducted to determine whether the proposed model required further revisions. In this study, the "Maximum Likelihood" method was utilized to estimate the causal relationship of the research model. The first phase involved "confirmatory factor analysis" (CFA) to determine the structural model of the research. The second phase further examined the causal relationship between variables and investigated research assumptions.

Once the validity and reliability of the measurement model were established, the structural model could be analyzed. The first criterion was the size and significance of the path coefficient, which indicates the strength of the relationship between the two components. Path coefficients demonstrate the correlation strength [23]. SEM is essentially a combination of CFA and regression. The relationship between the latent variables measured by observed variables is known as the measurement model. On the other hand, a structural model defines the relationships between the latent dependent and independent variables. As the next step, composite reliability (CR) was calculated and confirmed; CR> 0.7 [60]. Based on the results, all calculated values exceeded the proposed threshold values (above 0.70) and indicated the reliability of the research tool (Table 3) [60]. Furthermore, convergent validity was analyzed using the average variance extracted (AVE). The extracted AVE was higher than 0.5 (Table 3), according to the results. Therefore, it can be concluded that the analysis model has high validity and reliability.

4. Results

Based on the results, 284 of the respondents were males (79.6 %) and 73 were females (20.4 %). While 37.8 % of them were 17–30 years old, 26.9 % were 30–40, 18.2 % were 40–50, and 17.1 % were 51 years and older. Furthermore, the majority (71.8 %) was living in rural areas, 9.6 % in the city, and 18.6 % in the city and rural regions. In residential areas, 50 % of them were privately owned (77.6 %) and (20.2 %) were rented. The average age was 35.44 (SD = 11.03) and the number of people per household was 5.06 (SD = 1.60). The range of annual income was 150 to 1350 US Dollars. The mean of their experience in agriculture was 14.36 years. About 87 % of the respondents depended on agricultural business as their main job (Table 2).

Table 3 shows the TPB items and the results. The higher factor loadings show the greater contribution of these factors to the embedded components. The results showed that the farmers generally have a significant and positive AT towards decreasing the consumption of chemical pesticides. However, they believe it will reduce farm profits. Because wheat farmers do not find biological pest control very efficient, and such measures are difficult for other farmers to accept, the desire to decrease the consumption of chemical pesticides is low.

Table 2
Socio-demographic characteristics of wheat farmers.

Variable	Category	Frequency	Percentage
Gender	Male	284	79.6
	Female	73	20.4
	Total	357	100
Age	≤ 30	135	37.8
	31 - 40	96	26.9
	41 - 50	65	18.2
	≥ 51	61	17.1
	Total	357	100
Level of education	Lower	132	36.9
	Middle	151	42.3
	Upper	74	20.8
	Total	357	100
Income in USD	$≤ 4240	79	22.1
	$ 4241 - 6080	205	57.4
	$ 6081 - 7200	29	8.1
	$7201 - 8200	30	8.4
	$≥ 8201	14	3.9
	Total	357	100
Experience in agricultural activities	≤ 5	58	16.2
	6 – 10	69	19.3
	11 - 15	114	31.9
	16 - 20	30	8.4
	≥ 21	86	24.1
	Total	357	100

The results of the Pearson correlation analysis conducted among the latent constructs of the extended model demonstrate that a positive and statistically significant relationship exists between all constructs (Fig 4). Also, to establish divergent validity, the correlation coefficient between structures was lower than the AVE variables in the diagonal, demonstrating good reliability of the structures [54]. In addition, the Heterotrait-Monotrait (HTMT) criterion [61] was also used for validity-oriented assessment, and its results (<0.90) were favorable (Appendix 2).

The AVE, CR, and Cronbach's α values are displayed in Table 3. The reported Cronbach's alpha coefficient for all structures was above 0.8, indicating significant validity and normal internal consistency of the variables, suggesting considerable reliability and good internal stability. In this study, CR was utilized to test structural validity, with results showing that the CR values of all items exceeded the standard value of 0.8, indicating normal structural reliability. Additionally, the AVE for each variable was above 0.5, with a variance participation rate of over 50 %, confirming the structure of each factor considered in the logical model [54].

4.1. Model fit

Following the establishment of accuracy and precision in the measurement model, the next phase in SEM involves evaluating the relationships among latent variables. This study utilizes partial least squares structural equation modeling (PLS-SEM) to examine the hypothesized interrelationships among the research constructs. The structural model acts as a foundational framework for assessing causal linkages between latent variables. Through the application of PLS-SEM, these relationships are systematically analyzed to determine if there is enough statistical evidence to support the proposed research hypotheses.

To evaluate the structural model, an assessment was conducted to analyze the relationships among latent variables and test the research hypotheses. The results of this analysis are presented in Figs 5 and 6. To assess the goodness-of-fit of the model, multiple fit indices were used within the PLS-SEM framework. Specifically, the Standardized Root Mean Square Residual (SRMR), d_ULS, d_G, Chi-square (χ^2), Normed Fit Index (NFI), and Root Mean Square Theta (RMS_theta) were utilized. The evaluation of these indices indicated that the model demonstrated

Table 3
Factor and descriptive items.

Items	Mean	SD	Loading	Refrences
AT (α= 0.892, CR (roh_a) = 0.895, CR (roh_c) = 0.925, AVE= 0.756)				
AT1: Implementing IPM in wheat fields safeguards the environment and protects farmers' health.	3.76	0.84	0.886	Ajzen, [38]; Despotović et al., [9]; Bagheri et al., [28]
AT2: Implementing IPM on agricultural farms has the potential to improve both the yield and quality of wheat production.	3.66	0.87	0.866	
AT3: IPM is a more efficient and sustainable approach compared to traditional pest control methods.	4.21	0.81	0.863	
AT4: Implementing IPM strategies in wheat cultivation diminishes dependence on chemical pesticides while simultaneously reducing operational costs.	4.39	0.85	0.862	
SN (α= 0.898, CR (roh_a) = 0.902, CR (roh_c) = 0.929, AVE= 0.765)				
SN1: My family and those around me expect me to use sustainable practices, such as Integrated Pest Management (IPM), on my wheat farm.	3.24	0.94	0.830	Ajzen, [38]; Despotović et al., [9]; Bagheri et al., [28]
SN2: If I implement IPM in my wheat field, other farmers will perceive me as knowledgeable and innovative.	3.18	0.99	0.883	
SN3: The leading and successful farmers in our region employ IPM practices.	3.22	0.99	0.895	
SN4: Agricultural experts and extensionists recommend using IPM in wheat fields.	3.23	1.01	0.889	
PBC (α= 0.838, CR (roh_a) = 0.843, CR (roh_c) = 0.892, AVE= 0.675)				
PBC1: I have access to sufficient training and resources to effectively implement IPM in wheat fields.	3.13	0.96	0.761	Ajzen, [38]; Despotović et al., [9]; Bagheri et al., [28]
PBC2: The implementation of IPM is advantageous and cost-effective in comparison to conventional pest control methods.	3.29	1.00	0.805	
PBC3: Implementation of IPM would be easier for me if the government and agricultural organizations provided the necessary support.	3.29	1.05	0.863	
PBC4: I believe I have sufficient control over the implementation of IPM strategies in my wheat farming.	3.27	1.00	0.853	
PA (α= 0.839, CR (roh_a) = 0.841, CR (roh_c) = 0.892, AVE= 0.674)				
PA1: I am more satisfied with living in this area than anywhere else.	3.78	0.94	0.813	Xu et al. [56]
PA2: Doing my activities in this area is more important to me than doing them anywhere else.	3.78	0.90	0.834	
PA3: When I spend time in the natural environment in this area, I have a deep sense of oneness with the natural environment.	3.75	0.87	0.805	
PA4: Living in this area has a positive effect on my work.	3.76	0.92	0.831	
MN (α= 0.862, CR (roh_a) = 0.870, CR (roh_c) = 0.906, AVE= 0.707)				
MN1: I feel good regarding IPM.	3.31	1.02	0.862	Bagheri et al. [28]
MN2: I feel an ethical responsibility to use integrated management.	3.33	1.04	0.880	
MN3: I think biological control is moral.	3.55	0.93	0.829	
MN4: Decreasing pesticides consumption is honorable.	3.67	0.83	0.789	
IN (α= 0.847, CR (roh_a) = 0.847, CR (roh_c) = 0.897, AVE= 0.685)				
IN1: I intend to implement IPM strategies, which include prevention, monitoring, and control throughout the wheat growth cycle, as an alternative to the widespread use of chemical pesticides.	3.72	0.99	0.844	Ajzen, [38]
IN2: In the forthcoming growing season, I aim to advance my knowledge of IPM strategies through specialized training, and subsequently, I will implement these methodologies on my farm.	3.88	0.85	0.831	
IN3: In the upcoming growing season, I intend to implement IPM strategies, such as biological control and crop rotation, to reduce reliance on chemical pesticides in my wheat field.	3.84	0.77	0.817	
IN4: I am determined to assess the level of pest infestation through trapping and field monitoring before resorting to chemical pesticides in the upcoming year.	3.78	0.91	0.820	

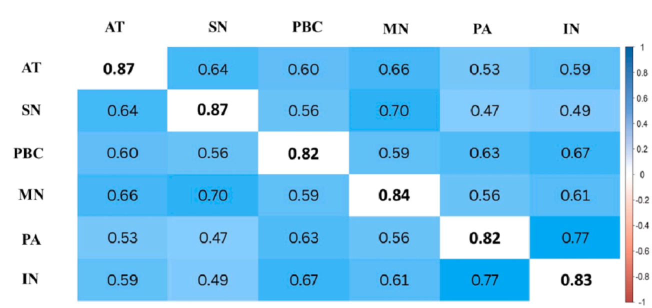

Fig. 4. Correlation between latent constructs and square root value of AVE.

an acceptable fit, affirming its suitability for hypothesis testing. Although the NFI alone does not suggest an optimal fit, the overall assessment based on multiple fit indices confirms the model's adequacy. Appendix 1 presents the test outcomes using the SEM for the tendency of wheat farmers to use IPM methods. These results indicate that the experimental data are consistent with the original model and the extended model presented in this study.

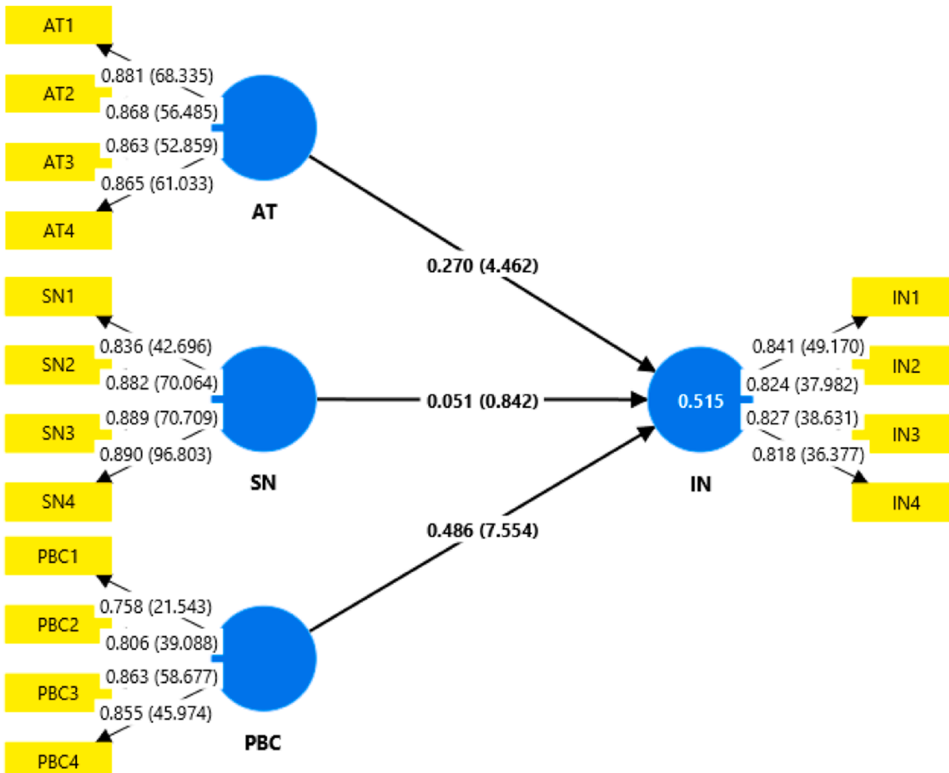

Fig. 5. Findings from the fit of the original TPB model.

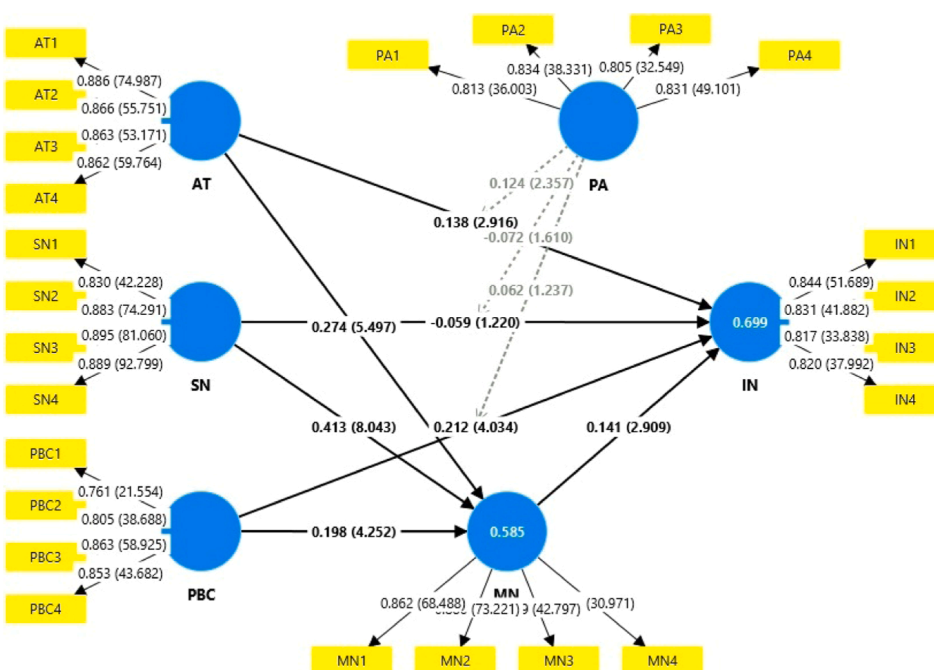

Fig. 6. Findings of the Extended TPB Model Fit.

4.2. Results of the original TPB model fit

A structural model was conducted to test the original TPB model. To assess the model's compatibility with the data, the overall model fit was evaluated using various fit indices. The results indicated that most of the reported fit indices fell within acceptable ranges for overall model fit (Appendix 1). Therefore, it can be concluded that the model is compatible with the employed data set. Based on the findings from the original TPB model fit, the model's constructs were able to explain 51 % of the variance in wheat farmers' intention to adopt IPM. The results also indicate that among the three core constructs of the model, AT toward the behavior and PBC had a positive and significant effect on farmers' intention to adopt IPM. In contrast, the effect of SN was not statistically significant (Fig. 5).

4.3. Results of the extended model fit

The findings regarding the fit of the extended TPB model are presented in Fig. 6 and Appendix 1. Similar to the original model, all fit indices in this model were within an acceptable range. The results indicate that the constructs of the extended model explain 69 % of the variance in farmers' intention to adopt IPM, demonstrating an improvement in the model's predictive power (Table 4). Furthermore, the findings confirm that the MN variable not only has a direct and significant effect on intention but also plays a notable mediating role. Additionally, the results show that the influence of the PA construct on the original TPB constructs is significant and positive, specifically, it positively and significantly affects the relationship between AT and IN (Table 4).

The results presented in Table 4 indicate that all hypotheses were supported except for hypotheses H5a, H5c, and H7. The VIF was used to assess multicollinearity among the independent variables. When testing each hypothesis, the VIF value indicates whether the independent variables are highly correlated with one another. Low VIF values for the hypotheses in the model suggest that the independent variables exert distinct effects on the dependent variable, enhancing the reliability of the model's fit. Furthermore, the f^2 index results, which evaluate the effect size of an exogenous (independent) variable on an endogenous (dependent) variable, demonstrated that the independent variables have a strong and statistically significant impact on the dependent variable.

4.4. Results of the moderating variable effects

Table 4 and Fig. 7 illustrate the moderating role of PA in the relationship between AT and IN. Since PA is considered a moderating variable, this implies that the effect of AT on IN varies depending on individuals' level of attachment to place. The results indicate that wheat farmers with low PA exhibit a very low intention to adopt IPM practices (around 1.5). These individuals potentially lack the strong motivation to take action. Interestingly, even with a low attitude score, farmers with high PA demonstrate a higher intention to adopt IPM methods (around 3.5), highlighting the positive influence of PA on behavioral intention, even when attitudes are negative. Furthermore, among farmers with a low level of PA, intention increases with a more positive attitude but remains relatively low (around 2.5). In contrast, farmers with high PA and a positive attitude show a significantly greater intention (around 4.5) to adopt IPM practices. These findings suggest that a positive attitude strongly influences intention to act and that place attachment amplifies this effect.

5. Discussion

This study aimed to reduce the use of chemical pesticides and promote environmentally friendly methods for pest and disease control among wheat farmers. The research was conducted within the broader context of global efforts to achieve the United Nations Sustainable

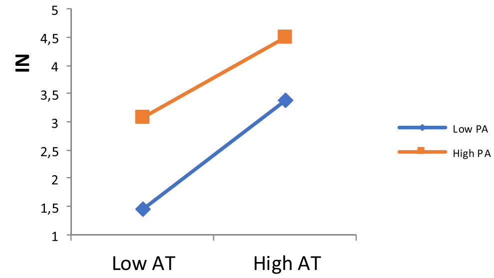

Fig. 7. Moderating the role of PA on the relationship between AT and IN.

Development Goals, particularly in environmental protection and biodiversity conservation. Given the ongoing environmental crises and the pressing need for active participation in conservation initiatives, this research sought to identify ways to strengthen sustainable practices among wheat growers. While the study focused on Bukan County in Iran, its findings and methodology can serve as a model for analyzing similar data in other developing countries. Through the development of a theoretical model, the study examined the factors influencing farmers' intentions and, by utilizing a representative field survey, reflected the perspectives of Iran's agricultural community.

The primary objective of this research was to identify the most influential factors in predicting farmers' willingness to adopt IPM practices. Given the challenges of recording all relevant behaviors, reliable and valid instruments were employed to assess their intentions. The findings from the model evaluation demonstrated that the model effectively explains the intention to adopt IPM practices and the factors influencing it. Furthermore, the moderating effect of PA on the relationship between attitude and intention was investigated. The study also assessed whether a set of independent variables—including the core constructs of the TPB and MN, which reflect individuals' perspectives on adopting IPM practices—could accurately predict the willingness to implement such methods.

5.1. Interpretation of the structural relationships in the core TPB model

Considering that ATs have been identified as advantageous in reducing chemical pesticides, Despotović et al. [9] and Rezaei et al. [20] found a significant effect of ATs on IN. This finding is consistent with many studies that focused on ATs as the primary predictor of individuals' IN. Rezaei and Ghofranfarid [62] stated that individuals are more mentally prepared when they have a favorable AT towards innovations and can respond more effectively. This mental preparedness may make farmers more receptive to the process of adopting innovations. Since IPM technology is in the early stages of introduction in West Azarbaijan province and Bukan County, ATs towards IPM can be important determinants in predicting environmental protection behavior and the use of this technology. Therefore, the views and ATs of farmers are crucial because the implementation and success of all

Table 4
Results of the hypotheses testing and effect size.

Hypothesis	Paths	Path Coefficients	T-values	P-Values	VIF	R^2	f^2	CI 2.5 %	CI 97.5 %	Hypothesis test results
H1	AT -> IN	0.138	2.916	0.004	2.251		0.029	0.091	0.266	Confirmed
H2	SN -> IN	−0.059	1.220	0.222	2.294		0.005	−0.089	0.088	Rejected
H3	PBC -> IN	0.212	4.034	0.001	2.457		0.062	0.139	0.349	Confirmed
H4	MN -> IN	0.141	2.909	0.004	2.356		0.027	0.050	0.237	Confirmed
H5a	PA x AT -> IN	0.124	2.357	0.018	3.738		0.029	0.235	0.025	Confirmed
H5b	PA x SN -> IN	−0.072	1.610	0.107	3.995		0.009	−0.160	0.013	Rejected
H5c	PA x PBC -> IN	0.062	1.237	0.216	4.961		0.009	−0.037	0.155	Rejected
H6	AT -> MN	0.274	5.497	0.001	2.001		0.091	0.176	0.370	Confirmed
H7	SN -> MN	0.413	8.043	0.001	1.872		0.221	0.310	0.514	Rejected
H8	PBC -> MN	0.198	4.252	0.001	1.714		0.056	0.101	0.282	Supported
IN						0.699				
MN						0.585				

programs related to the development and adoption of IPM technology are influenced by them. When farmers have a positive attitude towards IPM, they may view it as a beneficial approach that enhances crop health, reduces reliance on chemical pesticides, and improves long-term soil and crop sustainability. This favorable perception motivates them to adopt IPM more willingly. Additionally, this finding suggests that programs aimed at promoting IPM should prioritize building positive attitudes by educating farmers on the benefits of IPM. For instance, extension services could offer demonstrations, share success stories, and emphasize the economic and environmental advantages of IPM. Ignoring the role of AT can render all measures ineffective [54].

The current research has confirmed that PBC has a significant and positive impact on the IN to use IPM methods. The hypothesis that "PBC has a significant impact on farmers' intent to use IPM" is supported by the extended TPB model. Additionally, wheat farmers have demonstrated a high level of confidence in their IN to use IPM methods. These findings align with previous studies by Rezaei et al. [20] and Feisthauer et al. [11]. PBC refers to a person's belief in their capacity to successfully execute a specific action. This finding suggests that farmers' confidence in their ability to adopt and implement IPM methods directly influences their willingness to do so. Farmers who feel they have the necessary knowledge, resources, skills, and support to adopt IPM are more likely to be willing to try it. When they believe they can overcome obstacles associated with implementing IPM methods, such as costs, training, or time, they are more open to adoption. The significance of PBC indicates that farmers require access to resources such as training programs, technical support, and financial resources. If they perceive that these resources are available and accessible, it enhances their belief in their ability to successfully adopt IPM. Additionally, farmers may perceive behavioral control based on external factors, such as the availability of IPM tools, support from agricultural extension services, or access to markets for sustainably produced crops. The more they feel supported by these external structures, the more control they perceive over adopting IPM. Given that the implementation of IPM practices requires knowledge, skills, and additional equipment (such as light traps), it may result in increased production expenses for farmers, potentially limiting the adoption of IPM methods among wheat farmers. Programs could focus on reducing adoption barriers by offering subsidies, access to IPM resources, training workshops, and practical demonstrations. Providing such support increases farmers' perceived control and, thus, their willingness to adopt IPM.

The research findings indicated that the influence of SNs on wheat farmers' willingness to adopt IPM practices is not statistically significant. This suggests that although SNs-namely, the perceived social pressure from others-often play an important role in behaviors related to sustainable agriculture, they may not be a decisive factor in this particular context. One possible explanation for this result could be the lack of awareness or consensus among farmers' reference groups (such as peers, family members, or agricultural experts) regarding the benefits of IPM. Moreover, other factors such as knowledge, personal experience, or economic incentives might exert a stronger influence on farmers' decision-making. This finding highlights the importance of focusing on other motivational variables-such as individual ATs and PBC-in policy-making aimed at promoting the adoption of IPM.

5.2. Interpretation of the relationships of structures added to the main TPB model

Previous studies [63–65] in other fields have added the MN to the TPB model. Savari et al. [66] have provided significant findings that align with the results of the present study, showing that the MN plays a crucial role in behavioral IN. The findings indicate that MNs are the third most influential factor in determining the IN to utilize IPM practices among farmers. This finding is consistent with the results of Razali et al. [39], suggesting that the stronger one perceives IPM usage as a MN, the more likely they are to intend to use IPM at a high level. Decision-makers should leverage this tendency to establish IPM methods as a MN among farmers and emphasize the importance of these practices as some of the cleanest and most environmentally friendly options [28]. This finding suggests that personal moral values and a sense of responsibility play a significant role in farmers' decisions to adopt sustainable practices. Moral norms often reflect a farmer's personal beliefs about what is 'right' or 'wrong' [63]. In this context, farmers with strong moral norms may feel a personal obligation to adopt IPM as part of their responsibility to protect the environment, public health, and future agricultural productivity. This sense of moral commitment encourages them to choose sustainable pest management practices over conventional chemical-based approaches. Farmers with strong moral norms may also be more environmentally conscious and perceive IPM as an ethical choice aligned with their values of reducing pollution, preserving biodiversity, and minimizing the negative impacts of agriculture on ecosystems. This moral commitment can drive them to adopt IPM, even if it requires additional effort or costs. Unlike incentives or regulations, moral norms represent an intrinsic motivation. This means that these farmers adopt IPM not only for personal gain but because they believe it is morally right. This intrinsic motivation is often a stronger and more enduring driver of behavior than external pressures because it aligns with their personal beliefs. Farmers guided by moral norms are more likely to adhere to IPM over time because their motivation is based on ethical principles rather than short-term benefits. This can lead to more flexible and sustainable adoption of sustainable practices in farming communities. Furthermore, providing evidence to farmers about how IPM contributes to broader societal goals, such as reducing water pollution, protecting beneficial insects, and improving soil health, can further strengthen these moral norms and provide an ethical justification for IPM adoption. Therefore, it is recommended that organizations involved with farming communities prioritize the creation and promotion of MNs among farmers. This can be achieved through educational and awareness-raising programs that significantly influence farmers to perceive IPM as a moral and ethical imperative.

The results of the research indicate that wheat farmers' attitudes have a significant impact on their ethical norms regarding the adoption of IPM practices. This finding suggests that farmers with a more positive attitude towards these practices also tend to feel stronger ethical responsibility towards implementing them. In other words, belief in the environmental and economic benefits of IPM not only influences behavioral intention but can also strengthen farmers' sense of ethical responsibility. This connection highlights the key role of individual beliefs in shaping the ethical norms associated with environmentally friendly behaviors, a topic that has been less explored in the environmental psychology literature. Schwartz [45] also states that if an individual believes that a behavior (such as IPM) is morally right, they are more likely to strengthen their MN in that regard. Moreover, the TPB [38] suggests that positive attitudes toward a behavior can lead to personal and ethical commitments, which here manifest as MN for implementing IPM. De Groot and Steg [67] have shown that a positive attitude towards sustainable methods can increase the ethical and social responsibility to implement them. This new finding could contribute to a deeper understanding of the cognitive and value processes that facilitate the adoption of sustainable agricultural practices, and open new avenues for designing effective interventions to enhance farmers' ethical commitment to environmental protection. This emphasizes the importance of promoting awareness and education, as attitude change through supportive policies and educational programs can lead to improved ethical commitment among farmers to sustainable practices.

The results of this study revealed that SNs significantly impact farmers' MNs regarding the adoption of IPM practices. This suggests that perceived social pressure from significant others, such as family members, peers, or relevant institutions, can strengthen farmers' sense of moral responsibility towards adopting sustainable practices. From an environmental psychology perspective, this indicates that collective beliefs and social norms not only influence pro-environmental behaviors but also facilitate the internalization of moral values associated with environmental protection. Previous research in social psychology has shown that social interactions and the expectations of others can influence an individual's moral beliefs. For example, if farmers perceive that the use of sustainable methods like IPM is supported and endorsed by those around them (family, colleagues, agricultural experts), they may internalize this attitude and transform it into a moral commitment. These findings align with environmental psychology theories, such as the VBN theory [47]. According to this theory, when individuals perceive that society expects sustainable behaviors, these expectations can evolve into moral obligations, thereby increasing the likelihood of engaging in environmentally friendly actions. This new insight in the environmental psychology literature underscores the critical interplay between social and moral factors in shaping farmers' sustainable decision-making. It can serve as a foundation for developing promotional and educational policies aimed at enhancing the adoption of sustainable pest management practices.

The study's findings revealed that PBC significantly influences MNs related to the adoption of IPM practices among wheat farmers. This result is consistent with previous studies [45,49]. Similarly, Bamberg and Möser [48] showed that enhancing individuals' sense of efficacy and personal control strengthens their moral commitment to sustainable behaviors. This suggests that the more farmers feel capable and adequately resourced to implement IPM strategies, the stronger their moral commitment to these practices becomes. The findings indicate that an individual's perception of control over their actions not only influences their intentions and actual behavior but also shapes the moral norms underlying environmental decision-making. Farmers who believe they have the necessary resources, knowledge, and support to apply IPM methods are more likely to view such practices as beneficial and as a moral and social responsibility. In contrast, when farmers perceive these practices as beyond their control due to factors such as high costs, lack of knowledge, or insufficient infrastructure, their moral commitment to implementing them is likely to diminish. This relationship has received limited attention in the environmental psychology literature. Therefore, this study contributes a new perspective by providing empirical evidence on the role of PBC in shaping MNs in sustainable agricultural behavior. These findings can help inform the development of supportive policies aimed at strengthening farmers' sense of control, thereby enhancing their moral commitment to environmental practices.

5.3. Interpreting the moderating effect of PA on the relationship between AT and IN

Based on these findings, PA moderates the effect of attitude on intention. This means that farmers who have a stronger attachment to their land are more likely to turn their positive attitudes towards IPM into a concrete intention to adopt it. The results suggest that farmers with a higher sense of place attachment are more influenced by their positive attitude towards IPM when it comes to their intention to implement these practices. This could be because these farmers value preserving their local environment and see IPM as an effective way to reduce negative environmental impacts. This finding is consistent with theories of pro-environmental behavior, such as the Norm Activation Theory and theories of place attachment. These theories suggest that individuals with a strong sense of place attachment feel a moral obligation to engage in environmentally responsible behavior, which in this case translates to a greater willingness to adopt IPM. Additionally, in line with the TPB, behavioral intention is affected by attitudes. However, this study indicates that PA can enhance this effect. This suggests that programs promoting IPM should not only focus on improving farmers' knowledge and attitudes but also work on strengthening their emotional connection to the land and agricultural environment. Agricultural policymakers can use this insight to create educational and motivational programs that encourage farmers to take more responsibility for their local environment.

6. Conclusion

The findings of this study suggest that the extended TPB model offers better predictive accuracy compared to the original model in explaining farmers' intentions to adopt IPM. The results of the PLS-SEM analysis confirmed that AT and PBC have a significant and positive impact on farmers' behavioral intentions, while SN did not show a meaningful effect. Additionally, MN not only directly influenced behavioral intention but also played a significant mediating role. One key finding was the identification of the moderating role of PA in the relationship between Attitude and Intention. Specifically, for farmers with a stronger sense of place attachment, the positive effect of Attitude on behavioral intention was more pronounced and strengthened. These findings provide new insights into environmental psychology and sustainable agricultural behavior, emphasizing the importance of psychological and social factors in farmers' decision-making processes. Therefore, it is recommended that policymakers and extension agencies, in addition to enhancing farmers' technical knowledge, develop programs that focus on strengthening place attachment and moral commitment to environmental protection. The results of this study not only contribute to the development of existing theoretical frameworks but also lay the groundwork for designing practical strategies to promote the adoption of sustainable pest management practices in agricultural systems.

Availability of data and material

Data and material will be available on request by first author.

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Ethical approval

Informed consent was obtained from all subjects involved in the study. All materials and methods were performed in accordance with the instructions and regulations. Also, the Research Ethics Committee of the School of Agriculture, Tarbiat Modares University, Iran approved this study.

CRediT authorship contribution statement

Yadgar Momenpour: Writing – original draft, Visualization, Validation, Software, Resources, Investigation, Formal analysis, Data curation, Conceptualization. **Shahla Choobchian:** Writing – review & editing, Visualization, Supervision, Project administration, Investigation, Data curation. **Hassan Sadighi:** Writing – review & editing, Visualization, Validation, Project administration, Funding acquisition.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix 1. Evaluation of model fit

	Criteria	Chi-Square/df	d_G	d_ULS	GOF	SRMR	NFI	Rms Theta
	Minimum Cut-Off	<5.0	$p > 0.05$	$p > 0.05$	>0.36	<0.08	>0.90	<0.12
The original model	**Parameter Estimates**	1.062	0.181	0.374	0.608	0.052	0.90	0.101
The extended model	**Parameter Estimates**	2.084	0.361	0.850	0.689	0.053	0.90	

Note: Geodesic distance (d_G), Squared Euclidean distance (d_ULS), Goodness of fit (GOF), Standardized root mean square residual (SRMR), Normal fit index (NFI), Root Mean Square (RMS-theta).

Appendix 2. HTMT

	AT	IN	MN	PA	PBC	SN	PA x AT	PA x SN	PA x PBC
AT									
IN	0683								
MN	0744	0711							
PA	0610	0915	0658						
PBC	0693	0799	0700	0748					
SN	0719	0569	0790	0548	0652				
PA x AT	0344	0632	0388	0618	0502	0321			
PA x SN	0314	0623	0386	0652	0491	0331	0805		
PA x PBC	0370	0636	0440	0665	0637	0370	0827	0831	

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