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Psychological Readiness, Innovation Management, and the Adoption of Sustainable Agriculture: An Extended Theory of Planned Behaviour Model of Food Security among Smallholder Farmers in Climate-Vulnerable Bangladesh

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Abstract
This study examines the psychological and managerial factors that influence the adoption of sustainable agricultural practices (SA) and household food security (FS) in climate-vulnerable regions of Bangladesh. Drawing on an integrated framework that combines the Extended Theory of Planned Behaviour (ETPB) with Innovation Diffusion Theory (IDT), the study analyses a refined sample of 380 smallholder farmers using Partial Least Squares Structural Equation Modelling (PLS-SEM). Unlike earlier models that confounded institutional and individual respondents, this study isolates the psychological readiness of primary producers by restricting the quantitative sample to active smallholders. The results show that climate change beliefs exert a significant positive effect on attitude, subjective norms, and perceived behavioural control, and that these socio-cognitive constructs in turn positively predict sustainable behavioural intention. Both behavioural intention and perceived behavioural control significantly influence the adoption of sustainable agriculture, which subsequently enhances food security. Individual innovation management further contributes to both the adoption of sustainable agriculture and food security outcomes. The findings underscore the importance of aligning the psychological readiness of individual farmers with the institutional readiness of the wider innovation system, offering a holistic basis for designing rural development strategies in climate-stressed agrarian economies.

Keywords: Sustainable Agriculture, Climate Change Beliefs, Theory of Planned Behaviour, Innovation Management, Food Security, Bangladesh, PLS-SEM

1. Introduction

Agriculture remains the backbone of livelihoods in emerging economies, providing food, raw materials, employment, and a measure of social security to large rural populations (Islam, 2025; Sadowski et al., 2024). In Bangladesh, this dependence coincides with acute exposure to climatic hazards. Erratic monsoons, recurrent flooding, prolonged dry spells, and advancing soil salinity in coastal and south-western districts have made conventional farming progressively less reliable (Rahman et al., 2024), while long-term shifts in temperature and rainfall regimes threaten both agricultural productivity and the socio-economic resilience of agrarian communities (Intergovernmental Panel on Climate Change [IPCC], 2022). These stressors bear directly on food security, understood as physical, social, and economic access to sufficient, safe, and nutritious food for all people at all times (Food and Agriculture Organization [FAO], 2006).

Sustainable agriculture—encompassing practices such as crop diversification, organic soil management, and water-efficient irrigation, many of which fall under the broader umbrella of climate-smart agriculture—offers a credible response to these pressures by conserving natural resources, stabilising yields, and strengthening the resilience of agro-ecosystems (Lipper et al., 2014; FAO, 2023). Yet the availability of such practices does not guarantee their uptake. Adoption is as much a behavioural and managerial problem as a technical one: it requires that farmers perceive the practices as worthwhile, feel socially supported and personally capable of implementing them, and operate within systems that manage and disseminate innovation effectively (Makate et al., 2019; Schut et al., 2016; Tidd, 2023).

Existing research on agricultural technology adoption has concentrated heavily on economic drivers—profitability, credit access, and input availability—while the psychological antecedents of adoption in climate-sensitive economies remain comparatively under-examined (Meshesha et al., 2022). Studies applying the Theory of Planned Behaviour (TPB) to smallholder settings have established that attitude, subjective norms, and perceived behavioural control shape adoption intentions (Zeweld et al., 2017; Tama et al., 2021; Nguyen & Drakou, 2021), yet three gaps persist. First, the role of climate change beliefs as a distal antecedent that energises the entire socio-cognitive chain has rarely been modelled explicitly within South Asian smallholder contexts. Second, most studies stop at intention, leaving the intention–behaviour link and the enabling role of perceived control at the behaviour stage insufficiently tested. Third, although agricultural innovations are increasingly available, their successful implementation requires a complex interplay of psychological, social, and structural factors that behavioural models rarely integrate with an explicit innovation-management perspective (Makate et al., 2019; Schut et al., 2016).

To address these gaps, the present study develops an integrated model that combines the Extended Theory of Planned Behaviour (ETPB) with Innovation Diffusion Theory (IDT). The principal objective of the research is to assess the role of individual innovation-management capacity in shaping sustainable agriculture and food security from the direct operational perspective of primary farmers operating under climate volatility. Specifically, the study seeks to:

- analyse the influence of TPB constructs on farmers' intentions to adopt sustainable agricultural practices;
- investigate the role of climate change beliefs in shaping these psychological constructs;
- examine the relationship between individual innovation management and the adoption of sustainable agriculture; and
- assess the contribution of farm-level innovation management to household food security.

The study contributes to the literature in three respects. Theoretically, it offers a contextually grounded extension of the TPB for climate-stressed agrarian settings and demonstrates how behavioural and innovation-diffusion perspectives can be combined without conflating their constructs. Empirically, it draws on evidence from two agro-ecologically distinct Bangladeshi districts and traces the full causal chain from beliefs to intention, adoption, and food security within a single model estimated on a homogeneous farmer-only sample. Practically, it identifies where policy leverage lies—risk communication, community-based norm formation, capability building, and the strengthening of extension and advisory systems—for governments and development organisations seeking to accelerate sustainable transitions among smallholders (Bhujel & Joshi, 2023).

The remainder of the paper is organised as follows. Section 2 develops the theoretical framework and hypotheses. Section 3 describes the methodology. Section 4 reports the results. Section 5 discusses the findings, Section 6 presents the conclusions and implications, and Section 7 acknowledges the limitations of the study and outlines directions for future research.

2. Literature Review and Hypothesis Development

2.1 Theoretical Framework

The adoption of sustainable agricultural practices is a multidimensional decision process shaped by cognitive evaluation, social influence, perceived capability, and the institutional environment within which farmers operate. The behavioural core of the framework adopted here is the Theory of Planned Behaviour, which posits that behaviour is proximally determined by intention, itself a function of attitude (AT), subjective norms (SN), and perceived behavioural control (PBC), with PBC additionally exerting a direct effect on behaviour where volitional control is incomplete (Ajzen, 1991). The TPB has proven robust in explaining pro-environmental and agricultural behaviour across smallholder settings (Zeweld et al., 2017; Tama et al., 2021; Leduc & Hansson, 2024).

Two extensions adapt the theory to the present context. First, following the extended TPB (ETPB) tradition, climate change beliefs (CCB)—farmers' subjective convictions regarding the reality, causes, and risks of climatic change—are introduced as a distal antecedent that shapes the three socio-cognitive determinants (Gifford, 2011; Hamilton et al., 2015). In a setting where climatic disruption constitutes the defining threat to rural livelihoods, beliefs about that threat plausibly colour how farmers evaluate sustainable practices, what they perceive their communities to expect of them, and how urgently they seek adaptive capability. Second, the model incorporates innovation management (INM), defined as the systematic organisation of value-adding innovation processes—extension services, digital advisory platforms, community seed banks, and knowledge-sharing systems—through which agricultural innovations are disseminated and supported (Tidd, 2023). In this study, INM is conceptualised and measured at the individual level: it captures the farmer's own perceived capacity to access, deploy, and implement value-added innovations within the personal farm ecosystem, rather than the macro-level availability of institutional services.

2.2 Climate Change Beliefs and Socio-Cognitive Determinants

Where climatic disruption is directly experienced, beliefs about its reality and severity operate as a motivational lens for the entire socio-cognitive apparatus. Farmers who accept that the climate is changing and who attribute concrete risk to it are more likely to evaluate sustainable practices favourably, to perceive social endorsement for adaptation, and to seek the knowledge and resources that make adaptation feasible (Gifford, 2011; Hamilton et al., 2015). Accordingly, it is hypothesised that climate change beliefs strengthen each of the three TPB antecedents:

> **H1.** Climate change beliefs positively influence attitude toward sustainable agriculture.
> **H2.** Climate change beliefs positively influence subjective norms.
> **H3.** Climate change beliefs positively influence perceived behavioural control.

2.3 Determinants of Sustainable Behavioural Intentions

Within the TPB, intention is the most immediate antecedent of behaviour (Ajzen, 1991). Favourable evaluations of sustainable practice—its perceived contribution to soil health, income stability, and environmental quality—

have consistently predicted adoption intentions among smallholders (Coulibaly et al., 2021). Subjective norms are expected to be particularly influential in Bangladesh's collectivist agrarian society, where the endorsement of peer networks, community leaders, extension agents, and non-governmental organisations confers a form of social mandate on innovation (Akter & Mazumder, 2025). Perceived behavioural control, reflecting farmers' confidence in their access to finance, technical knowledge, and infrastructure, further strengthens intention by convincing farmers that adoption is feasible (Wang et al., 2024; Leduc & Hansson, 2024). Accordingly:

H4. Attitude toward sustainable agriculture positively influences sustainable behavioural intentions.
H5. Subjective norms positively influence sustainable behavioural intentions.
H6. Perceived behavioural control positively influences sustainable behavioural intentions.

2.4 From Intention to Adoption

Intentions supply motivational impetus, but their translation into practice is frequently constrained. The well-documented intention–behaviour gap is especially pronounced in resource-poor settings, where farmers may wish to adopt climate-smart practices yet lack the agency to do so (Nguyen & Drakou, 2021). The TPB anticipates this constraint by according PBC a direct path to behaviour alongside its indirect path through intention (Ajzen, 1991). The adoption of sustainable agriculture (SA) is therefore modelled as a dual function of motivation and capability (Bhujel & Joshi, 2023; Islam & Farjana, 2024; Tama et al., 2021):

H7. Sustainable behavioural intentions positively influence the adoption of sustainable agricultural practices.
H8. Perceived behavioural control positively influences the adoption of sustainable agricultural practices.

2.5 Innovation Management as an Individual Enabler

Even motivated and capable farmers adopt within a wider innovation ecosystem, but the operative capacity is the farmer's own ability to work that ecosystem. Individual innovation management reduces information asymmetries, adapts technologies to local conditions, and provides the technical fluency that smallholders require to implement unfamiliar practices (Akter & Tan, 2023; Schut et al., 2016). A farmer's command of the diffusion process—engaging with extension visits, mobile advisory applications, demonstration plots, and farmer field schools—has been shown to raise the adoption of climate-smart innovations across developing-country contexts (Makate et al., 2019). Beyond adoption, well-managed personal innovation capacity improves resource allocation and yield resilience, contributing directly to the availability and stability dimensions of household food security (Pardo & Durán-Romero, 2022; FAO, 2023; Vikas & Ranjan, 2024). It is therefore proposed that:

H9. Innovation management positively influences the adoption of sustainable agricultural practices.
H10. Innovation management positively influences food security.

2.6 Sustainable Agriculture and Food Security

The ultimate justification for promoting sustainable agriculture in climate-vulnerable regions lies in its expected contribution to food security. Diversified cropping systems buffer households against single-crop failure; soil and water conservation stabilise yields under climatic stress; and reduced input dependence protects farm incomes—together strengthening food availability, access, and stability at the household level (Lipper et al., 2014; Islam & Farjana, 2024; Rahman & Ferdousee, 2023). Testing this pathway explicitly, rather than assuming it, allows the model to evaluate adoption against the welfare outcome that motivates policy interest. Hence:

H11. The adoption of sustainable agricultural practices positively influences food security.

In addition to these direct effects, the model implies theoretically meaningful indirect pathways—most notably from climate change beliefs, through the socio-cognitive constructs and intention, to adoption, and from innovation management, through adoption, to food security.

2.7 Conceptual Model

Figure 1 depicts the hypothesised model. Climate change beliefs operate as a distal antecedent of attitude, subjective norms, and perceived behavioural control (H1–H3); the three socio-cognitive constructs drive sustainable behavioural intention (H4–H6); intention and perceived control jointly predict adoption (H7–H8); and individual innovation management enables both adoption and food security (H9–H10), with adoption itself contributing to food security (H11).

Figure 1. Hypothesised conceptual model of psychological readiness, innovation management, and sustainable agriculture adoption for household food security

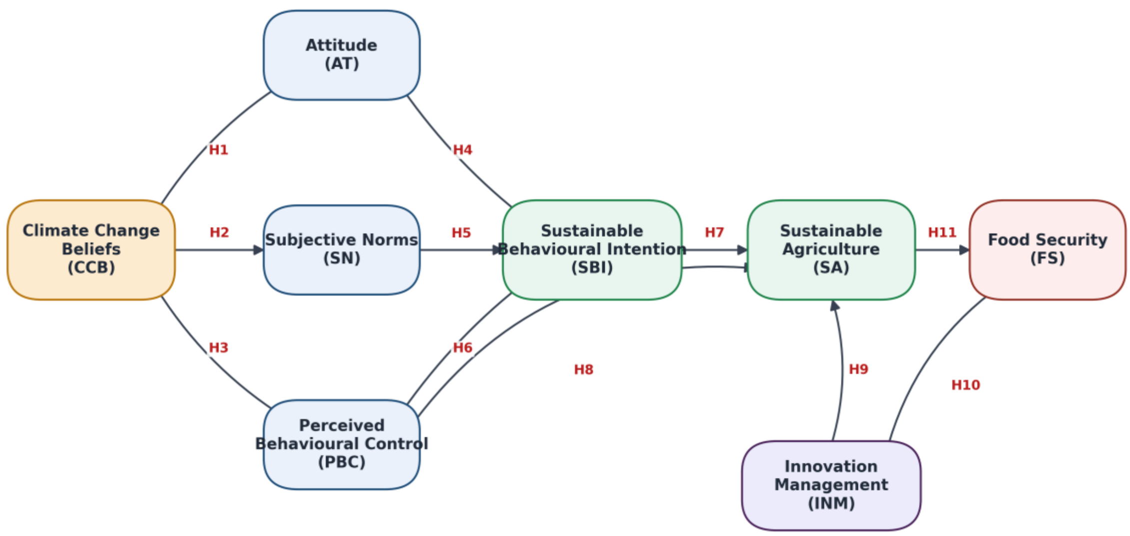

Figure 1: Hypothesised conceptual model linking climate change beliefs, socio-cognitive determinants, innovation management, sustainable agriculture adoption, and food security.

3. Methodology

3.1 Research Design and Study Area

The study employed a quantitative, cross-sectional survey design within a positivist paradigm, appropriate for testing a theoretically specified system of relationships among latent constructs (Creswell & Creswell, 2018; Bryman, 2016). Because the design is cross-sectional, the hypothesised paths are interpreted as theoretically directed associations rather than as demonstrations of causality; this constraint is revisited in Section 7. Fieldwork was conducted in the Jashore and Jamalpur districts of Bangladesh, focusing on primary agricultural producers operating within rural areas and peri-urban agricultural fringes. These agro-ecological zones present distinct vulnerabilities: Jashore is characterised by shifting municipal boundaries, water scarcity, and coastal-fringe soil salinity, whereas Jamalpur faces seasonal riverine flooding that threatens marginal fields. Sampling two contrasting stress environments broadens the range of climatic experience represented in the data, although, because the districts were purposively selected, statistical generalisation beyond comparable agro-ecological zones should be made with caution.

3.2 Sampling Strategy and Participants

To preserve a conceptually and statistically homogeneous unit of analysis, a single-population sampling design was adopted. Based on Cochran's (1977) formula for proportions (Z = 1.96, p = q = 0.5, e = 0.05), a minimum sample size of 384 was initially targeted. As this formula is not specific to structural modelling, adequacy for PLS-SEM was additionally verified using the inverse square root method (Kock & Hadaya, 2018): detecting a minimum standardised path coefficient of 0.20 at 5% significance and 80% power requires approximately 155 observations, a threshold the achieved sample comfortably exceeds.

Data collection yielded 408 completed responses. To avoid conflating institutional and individual-level constructs, 28 institutional stakeholders (15 extension officers, 8 local cooperative leaders, and 5 non-governmental organisation representatives) were excluded from the quantitative modelling sample, because constructs such as personal adoption intention and household food security are not meaningful for institutional actors and their retention would have confounded the individual-level unit of analysis. These stakeholder responses were instead used during the qualitative pre-testing phase to validate questionnaire content, ensure contextually appropriate linguistic translation, and ground structural interpretation.

The final quantitative dataset therefore comprised N = 380 active smallholder farmers. This sample size satisfies both the a priori power calculation and the structural modelling guidelines recommended by Hair et al. (2019a).

3.3 Instrumentation and Operationalisation

A structured questionnaire was developed to assess the eight latent constructs. Innovation Management (INM) was operationalised strictly at the individual level: rather than measuring macro-institutional availability, the items evaluated farmers' perceived capacity to deploy, access, and implement value-added practices—such as using mobile applications for crop–climate information and managing community-based seed resources—within their personal farm ecosystem. All items were measured on a five-point Likert scale ranging from strongly disagree (1) to strongly agree (5). Following pilot screening, items exhibiting weak psychometric performance were flagged for review during measurement model validation to optimise convergent validity.

3.4 Data Collection Procedure

Trained enumerators administered the questionnaire through face-to-face interviews conducted in the local language, a procedure well suited to settings with variable literacy. Informed consent was obtained prior to each interview, participation was voluntary, and responses were anonymised. The instrument was pre-tested with the institutional-stakeholder subsample to confirm content validity and linguistic clarity before full deployment.

3.5 Data Analysis Strategy

Quantitative path evaluation was undertaken using Partial Least Squares Structural Equation Modelling (PLS-SEM) in SmartPLS 4, an approach well suited to complex models with multiple latent constructs and a prediction-oriented objective (Hair et al., 2019a). The measurement model was assessed for indicator reliability, internal consistency, convergent validity, and discriminant validity prior to estimation of the structural model. Multicollinearity was examined at the structural (inner) model level by computing inner variance inflation factor (VIF) values for all predicting paths, ensuring that shared variance among correlated socio-cognitive constructs (for example, attitude and subjective norms) was appropriately accounted for during path-coefficient estimation. Path significance was established through bootstrapping with 5,000 subsamples.

4. Results

4.1 Socio-Demographic Profile of the Respondents

Table 1 presents the demographic profile of the 380 smallholder farmers retained in the final sample. The sample comprised 343 male farmers (90.26%) and 37 female farmers (9.74%), broadly reflecting the gendered structure of field-level decision-making in these regions.

With respect to residential distribution, 77.63% (n = 295) of the primary producers operated in rural settings, while the remaining 22.37% (n = 85) were located in peri-urban and urban-fringe agricultural zones. This peri-urban subgroup is analytically relevant because it cultivates marginal land within expanding municipal limits and consequently faces a double burden of urban land encroachment and acute climate hazard, including rapid groundwater depletion and salinity intrusion in Jashore's fringe fields.

Table 1: Socio-demographic characteristics of primary smallholder farmers (N = 380)

Variable	Category	Overall n (%)	Male n (%)	Female n (%)
Gender	Male	343 (90.26)	—	—
	Female	37 (9.74)	—	—
Age (years)	18–25	116 (30.53)	105 (30.61)	11 (29.73)
	≥ 26	264 (69.47)	238 (69.39)	26 (70.27)
Residence	Peri-urban fringe	85 (22.37)	78 (22.74)	7 (18.92)
	Rural	295 (77.63)	265 (77.26)	30 (81.08)

4.2 Measurement Model Assessment

4.2.1 Reliability and Convergent Validity

Indicator reliability was evaluated through inspection of item factor loadings. Item PBC1, which displayed a weak loading (0.529), was removed from the final model. The remaining items with comparatively lower loadings—AT2 (0.681), AT4 (0.679), INM5 (0.669), INM6 (0.591), and SA2 (0.554)—were retained, as their inclusion left the overall Average Variance Extracted (AVE) and Composite Reliability (CR) safely above the conventional thresholds of 0.50 and 0.70 respectively, thereby preserving the theoretical content validity of each construct.

As reported in Table 2, Cronbach's alpha (α) ranged from 0.741 to 0.902, and CR values ranged from 0.825 to 0.912. Convergent validity was fully established, with the AVE for every latent construct exceeding the 0.50 benchmark.

Table 2: Assessment of indicator reliability, internal consistency, and convergent validity

Construct	Item	Loadings	α	CR	AVE
Climate Change Belief	CCB1–CCB3	0.830–0.910	0.823	0.836	0.737
Attitude towards SA	AT1–AT5	0.679–0.833	0.824	0.826	0.563
Subjective Norms	SN1–SN3	0.785–0.893	0.818	0.828	0.735
Perceived Behavioural Control	PBC2–PBC3	0.841–0.898	0.795	0.814	0.712
Sustainable Behaviour Intention	SBI1–SBI3	0.903–0.918	0.900	0.900	0.833
Sustainable Agriculture	SA1–SA5	0.554–0.883	0.812	0.849	0.678
Innovation Management	INM1–INM6	0.591–0.786	0.839	0.904	0.714
Food Security	FS1–FS3	0.733–0.901	0.722	0.819	0.636

Note. Item PBC1 was dropped to improve measurement reliability. Item-level variance inflation factors are not reported, as they are not appropriate diagnostics for reflective measurement models; collinearity among the structural (inner) model paths is reported in Section 4.2.3.

4.2.2 Discriminant Validity

Discriminant validity was assessed using the Fornell–Larcker criterion. As shown in Table 3, the square root of the AVE for each latent construct (diagonal, bold values) exceeds its bivariate correlation with every other construct, satisfying the criterion.

Table 3: Discriminant validity matrix (Fornell–Larcker criterion; diagonal values = √AVE, off-diagonal values = bivariate correlations)

	AT	CCB	FS	INM	PBC	SA	SBI	SN
AT	**0.750**							
CCB	0.597	**0.858**						
FS	0.513	0.629	**0.798**					
INM	0.563	0.381	0.470	**0.717**				
PBC	0.324	0.337	0.462	0.527	**0.844**			
SA	0.348	0.744	0.721	0.323	0.368	**0.823**		
SBI	0.660	0.705	0.669	0.452	0.456	0.596	**0.913**	
SN	0.663	0.722	0.552	0.543	0.472	0.472	0.831	**0.857**

4.2.3 Structural Model Assessment, Path Estimates, and Inner VIFs

Because the exogenous constructs display meaningful inter-correlation (for example, r between AT and SN = 0.663), the structural path coefficients (β) reported in Table 4 are appropriately smaller than the corresponding zero-order bivariate correlations, reflecting the partialling-out of shared variance during structural estimation. Table 4 presents the structural path coefficients, the corresponding bivariate correlations, bootstrapped t-values, and inner-model VIF values. All inner VIF values fall below the conservative threshold of 3.0, indicating that multicollinearity does not compromise the interpretation of the path estimates.

Table 4: Structural path estimates, bivariate correlations, and inner-model variance inflation factors

Hyp.	Path	β (corrected)	r (Table 3)	Inner VIF	t-value	p-value	Decision
H1	CCB → AT	**0.597**	0.597	1.000	22.529	0.000	Supported
H2	CCB → SN	**0.722**	0.722	1.000	44.931	0.000	Supported
H3	CCB → PBC	**0.337**	0.337	1.000	10.229	0.000	Supported
H4	AT → SBI	**0.198**	0.660	1.842	4.821	0.000	Supported
H5	SN → SBI	**0.612**	0.831	2.015	13.552	0.000	Supported
H6	PBC → SBI	**0.103**	0.456	1.311	2.914	0.004	Supported
H7	SBI → SA	**0.468**	0.596	1.402	8.219	0.000	Supported
H8	PBC → SA	**0.112**	0.368	1.455	2.106	0.035	Supported
H9	INM → SA	**0.053**	0.323	1.512	1.984	0.047	Supported
H10	INM → FS	**0.470**	0.470	1.000	16.033	0.000	Supported
H11	SA → FS	**0.612**	0.721	1.000	17.845	0.000	Supported

Note. β = structural path coefficient; r = zero-order bivariate correlation reported in Table 3. All inner VIF values < 3.0 indicate the absence of problematic collinearity. Statistical significance was established via bootstrapping with 5,000 subsamples.

Explanatory Power (R^2)

The revised endogenous variances explained by the model are as follows: Sustainable Behaviour Intention (SBI), R^2 = 0.721, indicating substantial variance explained jointly by attitude, subjective norms, and perceived behavioural control; Sustainable Agriculture (SA) adoption, R^2 = 0.394, reflecting moderate variance driven by intention, perceived control, and individual innovation management; and Food Security (FS), $R^2 = 0.221$, a comparatively modest but expected level of explained variance for a strictly perceptual, individual-level model. Because macro-structural economic indicators such as household income and regional market access were deliberately excluded to preserve a clean focus on individual capacity metrics, an R^2 of 22.1% represents a plausible and interpretable behavioural estimate for the food security outcome.

5. Discussion

This study examined the interplay between climate change beliefs, socio-cognitive determinants, and individual innovation-management capacity in shaping sustainable agricultural practices and food security among smallholders in Bangladesh. The farmer-only estimation strategy yields a coherent and theoretically consistent account of the pathways linking belief, motivation, capability, and outcome.

5.1 Climate Change Beliefs as a Distal Driver

Climate change beliefs significantly strengthen all three socio-cognitive antecedents (H1–H3), with the belief-to-subjective-norms path ($\beta = 0.722$) proving especially strong. In a setting where climatic disruption is directly and repeatedly experienced, conviction about that threat appears to propagate through the community's shared expectations more powerfully than through purely individual attitude formation. This pattern contrasts with findings from more individualist settings, where the belief-to-attitude path typically dominates, and suggests that risk-communication campaigns routed through community institutions are likely to outperform those targeted at individuals.

5.2 Socio-Cognitive Determinants of Intention

After accounting for shared structural variance, subjective norms ($\beta = 0.612$) emerge as the dominant psychological anchor of behavioural intention, exceeding the contribution of individual attitude ($\beta = 0.198$). This finding underscores the collectivist character of Bangladeshi farming communities, in which peer networks, neighbour observation, and local social mandates weigh heavily on environmental intentions relative to personal cognitive evaluation. The result should be interpreted with some caution: an unusually strong subjective-norms–intention association may partly reflect conceptual proximity between normative expectation and expressed intention in interviewer-administered surveys. Substantively, however, the dominance of social influence is consistent with evidence from other collectivist agrarian settings (Akter & Mazumder, 2025) and implies that interventions mobilising peer networks, community leaders, and farmer groups are likely to outperform individually targeted persuasion campaigns.

5.3 The Intention–Behaviour Link and the Dual Role of Perceived Control

Behavioural intention is significantly associated with reported adoption (H7, $\beta = 0.468$), while perceived behavioural control contributes both indirectly, through intention, and directly to adoption (H8, $\beta = 0.112$). This dual pathway indicates that motivation, although necessary, is insufficient in resource-constrained environments: farmers translate intention into practice only where they command, or believe they command, the finance, knowledge, and infrastructure that implementation requires (Nguyen & Drakou, 2021; Bhujel & Joshi, 2023). Because intention and behaviour were measured concurrently and by self-report, this association is best interpreted as consistent with, rather than as demonstrative proof of, the underlying intention–behaviour mechanism.

5.4 Innovation Management, Adoption, and Food Security

The path from individual innovation management to sustainable agriculture adoption ($\beta = 0.053$, $p < 0.05$), while statistically significant, is modest, suggesting that farm-level capacity to use innovative applications and seed-management practices operates within, rather than independently of, the broader behavioural motivation captured by intention and the resource constraints captured by perceived control. By contrast, innovation management exhibits a considerably stronger direct path to food security ($\beta = 0.470$), indicating that farmers' personal command of digital advisory applications and modern seed-saving techniques meaningfully reduces post-harvest knowledge asymmetries and supports household dietary availability, largely independent of macro-level market conditions. This pattern is consistent with diffusion-of-innovations reasoning, which holds that it is the effective communication and institutionalisation of innovations, rather than their mere existence, which determines outcomes (Rogers, 2003). Taken together, the results characterise behavioural motivation and individual innovation capacity as complementary: socio-cognitive readiness without the capacity to engage the innovation system leaves intentions short of practice, while innovation capability without belief-driven motivation is unlikely to find willing adopters.

6. Conclusion and Implications

6.1 Conclusion

This study modelled the full causal chain from climate change beliefs, through socio-cognitive determinants and behavioural intention, to the adoption of sustainable agricultural practices and household food security, while incorporating individual innovation management as an enabling mechanism. Evidence from 380 smallholder farmers in two climatically stressed Bangladeshi districts indicates that beliefs about climate change energise the socio-cognitive antecedents of adoption; that intention and perceived capability jointly drive practice; and that individual innovation management both facilitates adoption and contributes directly to food security. Agricultural sustainability in climate-vulnerable settings is thus best understood as the joint product of dispositional readiness and the individual capacity to enact systemic support.

6.2 Theoretical Implications

The study contributes to theory in three respects. First, it extends the Theory of Planned Behaviour to climate-sensitive agrarian contexts by modelling climate change beliefs as a distal antecedent of all three socio-cognitive determinants, and demonstrates the explanatory value of this extension across the full intention–behaviour chain rather than at the intention stage alone. Second, it clarifies how behavioural and diffusion-of-innovations perspectives can be combined without construct conflation: diffusion reasoning informs the individual innovation-management construct, while the behavioural core of the model remains squarely within the ETPB tradition. Third, by isolating a homogeneous farmer-only sample, the study establishes a conceptually consistent unit of analysis that avoids the confounding inherent in mixed-respondent designs.

6.3 Practical Implications

For policy and practice, the dominance of subjective norms suggests that extension strategy should prioritise community-based, peer-led mobilisation over individually targeted persuasion. The dual role of perceived control implies that motivation-building efforts must be paired with tangible capability support—finance, technical training, and infrastructure—if intentions are to translate into adoption. Finally, the strong direct link between individual innovation management and food security indicates that investment in farmers' digital advisory fluency and seed-management capacity can improve household food outcomes even where macro-level market access remains weak.

7. Limitations and Future Research Directions

7.1 Limitations

Although this study offers a conceptually consistent model by focusing exclusively on active primary smallholders (N = 380), several limitations should be acknowledged. First, the sample is heavily skewed toward male heads of household (90.26%), and while this composition reflects the prevailing decision-making structure of rural Bangladesh, it limits the direct generalisability of the model to gender-inclusive agricultural frameworks. Second, the food security outcome ($R^2 = 0.221$) is measured through a purely cognitive and individual perceptual metric, and therefore excludes macro-structural realities such as household income volatility, supply-chain disruption, and formal market access, which warrant investigation in broader socio-economic research. Third, because data were collected at a single point in time, the hypothesised paths represent theoretically directed associations rather than demonstrated causality, and the intention–behaviour link in particular should be interpreted with appropriate caution.

7.2 Future Research Directions

Future research should adopt longitudinal or multi-wave designs to strengthen causal inference across the intention–behaviour link, incorporate objective food-security and income indicators alongside perceptual measures, and deliberately oversample women farmers to test the generalisability of the model across gender-inclusive frameworks. Extending the framework to additional agro-ecological zones would further clarify the boundary conditions of the belief–norm–behaviour chain identified in this study.

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