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Research Article

Transforming Apple Farming: A Hybrid Modelling Approach to Understanding High-Density Apple Plantation Adoption in India

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ABSTRACT

India and other emerging nations have dedicated significant research and development resources to enhancing agricultural productivity and output. As the global population grows and commodity prices increase, providing fair food access globally requires enhancing food production efficiency. Apples are highly valued agricultural products. Among the most important fruit crops in Jammu and Kashmir, it has the largest growing area, the highest productivity, and the highest domestic consumption. This study seeks to discover to what extent high-density apple plantation is adopted among the apple growers. A hybrid model of PNTC and TAM was adopted. SEM was used for analysis of the collected data. The study establishes that need characteristics and technology characteristics can be considered as important factors for perceived need technology characteristics of farmers adopting HDAP technologies, along with an extended technology acceptance model, all variables except perceived risk influence farmers intention to adopt HDAP technologies in Kashmir. This paper identifies key factors that enable farmers not only to adapt the technology, but also to sustain agriculture. It is also recommended that factors like cost, subsidy, and bank credit can be added as new factors in future works.

Keywords: TAM, PNTC, Farmers Intention, HDAP

1. INTRODUCTION

Research and development initiatives have focused on improving agricultural productivity and production in developing nations, including India (Bishwajit, 2014; Tadele, 2017). Increasing production and productivity can be achieved by improving existing production practices or adopting higher-yielding technology (Birhanu & Jensen, 2023). As the global population grows and commodity prices increase, providing fair food access globally requires enhancing food production efficiency (Grote et al., 2021; Misselhorn et al., 2012). Over the past few decades, farmers have increased chemical inputs such as insecticides and fertilisers, which have had adverse effects on the environment and the agricultural sector (Li et al., 2020; Lu et al., 2015).

Apples are highly valued agricultural products (Adhikari & Thapa, 2023; Wani et al., 2021). It amounts to the higest production area,the highest productivity, and the highest domestic consumption (Ahmad et al., 2021; Kishore, 2023; Wani et al., 2021). High-density planting is an agricultural or horticultural practice where a greater number of plants are grown in a given unit of space as compared to traditional or standard planting methods (Hassan et al., 2020; Kishore, 2023). Advances in precision agriculture technology have significantly reduced risk and enhanced managerial decision-making in the agricultural industry (Hanson et al., 2022).

High-density planting has certain advantages, such as being highly precocious and reaching full production quickly, leading to a small payback period compared to conventional orchards. The orchard starts producing fruit in the second year, it takes until the fourth year to reach full production (Ladaniya et al., 2020; Wani et al., 2021). The potential benefits of high-density plantations, particularly in terms of maximizing yield, producing high-quality fruits, and gaining a price advantage in the market (Hassan et al., 2020; Kishore, 2023; Wani et al., 2021). However, the area under fruit crops has increased by 6978 Ha i.e. from 334719 Ha in the year 2020-21 to 341697 Ha in 2021-22 thereby recording a growth of 2.08 per cent (J&K GOVT., 2022). The overall fruit production has increased by 3.95 LMTs during 2021-22 i.e. from 20.36 LMTs in the year 2020-21 to 24.31 LMTs recording a growth of 19.39 Percent. An area of 6090.91 Ha has been covered under HDP in the financial year 21-22 registering a growth of 591% over the previous year (J&K GOVT., 2022). In southern districts of Jammu and Kashmir, people are choosing to cut down their apple and almond trees as the demand for highdensity apple planta tions has increased

Fig 1: Shows HDAP Plantation orchad in South Kashmir

The research paper aims to propose a theoretical model and to explore the factors that influence the perception of Indian farmers in the union territory of Jammu & Kashmir toward adopting high-density apple plantation (HDAP) technologies. In the first instance, the key elements that support and hinder the adoption of HDAP in the Indian context will be examined, these factors can, in the long run, also be applied to other emerging agricultural economies.

2. LITERATURE REVIEW

2.1. Perceived need for technological characteristics (PNTC)

Enhanced production and productivity can indeed be achieved through two primary approaches: improving the efficiency of existing production practices and adopting higher-yielding technologies. Task-Technology Fit theories generally focus on how well a technology fits or aligns with a specific task or set of tasks within an organization (Goodhue & Thompson, 1995). The Task-Technology Fit (TTF) model, is a theoretical framework used in information systems research to understand the relationship between task characteristics, technology characteristics, and their combined effect on task performance or outcomes (Lin & Huang, 2008; Zhou et al., 2010). Tasks are broadly defined as the actions carried out in turning inputs into outputs to satisfy information needs (Goodhue & Thompson, 1995).The term "technology" encompasses a broad spectrum of components and systems, and it goes beyond just hardware and software. The perceived need technology characteristics (PNTC) is not solely determined by the technology itself; it's a complex interplay of the technology's perceived capabilities, the task requirements, and the users' competence (Birhanu & Jensen, 2023).

Contrary to many information technologies, such as mobile banking, which are free for the end user, expenses must be taken into account when evaluating agricultural technology adoption (Zhou et al., 2010). Thus, in order to ascertain farmers' perceptions of cost risk, is incorporated into the TAM. To evaluate the match between a farmer's (perceived) requirements and HDAP technologies and ascertain their relevance in forecasting HDAP adoption, perceived need for technology characteristics, or PNTC, was presented as an alternative to the TTF model.

The effective utilization of technology is closely tied to the alignment between the features of the technology and the specific requirements of the task at hand (Goodhue & Thompson, 1995). Aligning technology with user requirements enhances the likelihood of successful adoption, while a mismatch can lead to reluctance and decreased intention to adopt (Lin & Huang, 2008; Zhou et al., 2010). Previous studies have found the influence of task and technology characteristics on PNTC (Li et al., 2020). The two key factors need characteristics and technology characteristics influence PNTC in the context of information systems (Li et al., 2020). PNTC is crucial for promoting user adoption . In contrast, a poor task, in turn, can lead to a decrease in users' adoption intention. Thus, as per the discussion we propse the following hypotheses:

H1: Need Characteristics have a positive impact on perceived need technology characteristics

H2: Technology characteristics have a positive impact on perceived need technology characteristics

H3: perceived need technology characteristics have positive impact on intention to adopt HDAP technology

2.2. Technology Adoption Model

A theoretical framework called the Technology Acceptance Model (TAM) aims to comprehend the variables that affect new technology acceptance and adoption. Since (Davis, 1989) initially proposed it, TAM has been widely used and developed in a number of research studies.According to Davis, the TAM model's notions of PU and PEOU are essential since they not only directly affect intention but also attitude and indirectly affect intention through attitude (Lee et al., 2003; Tarhini et al., 2015).

2.2.1. Perceived Usefulness (PU)

Perceived usefulness is the subjective assessment of a person's view that using a certain technology would enhance their productivity, effectiveness, or job performance in general (Davis, 1989). The relationship between perceived ease of use and purchase intentions is effectively mediated by perceived utility (Noor Ardiansah et al., 2020). The agricultural community is more inclined to accept and value technologies that increase production and efficiency in order to increase economic returns (Suvedi et al., 2017). Farmers are more inclined to have a positive attitude towards a new agricultural technology if they think it will result in significant advantages like higher yields, cost savings, or enhanced efficiency. This upbeat outlook aids in the development of the purpose to use the technology.

H4: Perceived usefulness has a positive impact on intention to adopt HDAP technology

2.2.2. Perceived Ease of Use (PEOU)

PEOU is a term used to describe a user's level of comfort using a certain piece of technology or system (Davis, 1989; Tarhini et al., 2015). The perceived ease of use (PEOU) component is a key concept in the Technology Acceptance Model (TAM), which is widely used in the field of information systems and technology research (Changchit et al., 2020).. The existing studies suggest that ease of use is indeed a critical attribute for the success of e-business applications, including Internet commerce (e-commerce), internet banking (I-banking), and mobile commerce (m-commerce) (Changchit et al., 2020; Mehrad & Mohammadi, 2017). Farmers are more likely to use technology if they believe it to be intuitive and user-friendly since this enhances their opinion of its usability. Hence from the above discussion, we put the hypothesis:

H5: Perceived ease of use have a positive impact on intention to adopt HDAP technology

2.2.3. Perceived Risk (PR)

Perceived risk is, in fact, a key topic in the study of consumer behaviour and innovation uptake. The term "perceived risk" describes a consumer's subjective belief or impression of the uncertainty and possible unfavourable consequences connected to a certain purchase or choice (Featherman & Pavlou, 2003; Noor Ardiansah et al., 2020). Precision agriculture methods may not be widely adopted in agriculture due to farmers' attitudes towards the industry and their perceptions of risk (Tozer, 2009). There are always risks associated with agriculture because of the weather, the state of the market, and other variables. Farmers could be risk-averse and hesitant to embrace new technology that might upset their customs and endanger their means of subsistence (Reichardt & Jürgens, 2009). we propose the following hypothesis:

H6: perceived risk have a positive impact on intention to adopt HDAP technology

2.2.4. Perceived Benefits (PB)

Perceived benefits are the convictions people have about the advantages of engaging in a certain behavior (Kim & Kim, 2020; Tingchi Liu et al., 2013). Benefits that are perceived have a significant impact on people's decisions to accept new technology. These are the arbitrary advantages that people think they will get by using a specific piece of technology. Perceived benefits have been found to be the main element that increases farmers' adoption of new technologies (Pierpaoli et al., 2013).We can propse the following hypothesis as:

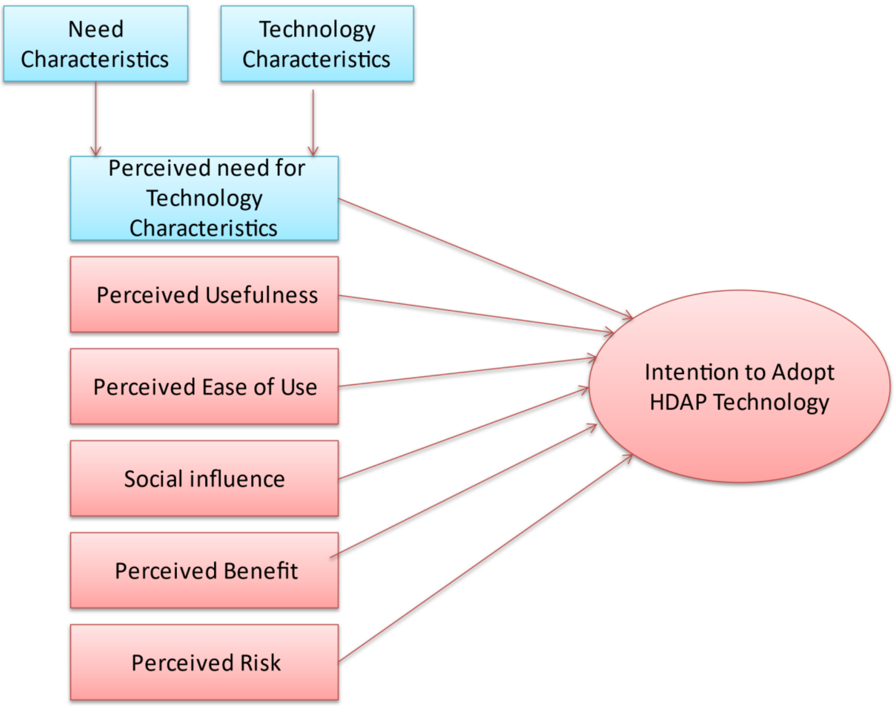
H7: Perceived benefits have a positive impact on intention to adopt HDAP technology

2.2.5. Social Influence (SI)

"The extent to which individuals perceive the opinions or beliefs of important people in their social circles regarding the use of a particular technology" is called as social influence. A farm's operational development is somewhat influenced by the social environment, including friends and family (Foster & Rosenzweig, 1995). Furthermore, it has been found that a farmer's experiences with new technology now have a major impact on how they utilise them in the future (Rieple & Snijders, 2018). The discussion allows us to formulate the following hypothesis:

H8: Social Influence have a positive impact on intention to adopt HDAP technology

Fig 2: Proposed Research Model



3. RESEARCH METHODOLOGY

3.1. Variable measurement and data collection

The survey questions were derived from previous studies on the adoption of new technology (Clark et al., 2018; Davis, 1989; Li et al., 2020; Zhou et al., 2010). In order to collect data , a survey questionnaire was created in english and examined by many proffessors from Jamia Millia Islamia University in New Delhi, India, as well as specialists in the field of agriculture. The views of the experts ensured that the survey questions could be understood from the farmers' point of view on the deployment of high-density plantation technologies.Data were collected with the help of questionnaires and interview methods. The indicators in the survey were measured using a five-point Likert scale, representing from strongly agree = "5" to strongly disagree = "1" except for demographic variables. The survey questionnaire was tested by conducting a pilot study with the help of 45 farmers belonging to five different districts of Jammu and Kashmir.

4. DATA ANALYSIS AND RESULTS

Four steps were taken in the data analysis process for this research . In the first phase, descriptive statistics were done to understand the structure of the sample. A total of 353 out of 400 responses were received from five major apple-producing districts of Union Territory of Jammu & Kashmir (Baramulla, Budam, Ganderbal Shopian, and Anantnag), 47 responses were discarded due to missing data points Therefore, this research study examined 353 valid responses, 78% from male participants and 22% female participants, ensuring the results to be free from gender bias. In addition, most of the participants 38% were from the age group 45-55 years followed by 23% above 55 years 22% between 35-45 years 10% below 25-35 years and 7% below 25 years. Despite the fact that respondents of all ages participated, including the elderly, the majority of respondents belonged to the over-45 age group for the apparent reason that they were more accustomed to using technology. In this survey the income of farmers ranged from (<less than 1 lac=1%, 1lac to 3 lac =9%, 3lac to 5lac=16%,5lac to 10 lac=40%, and above 10 lac=4%) furthermore landholding of farmers lies between 1Hectare =12%, 1-2 hectares=27%, 2-4 hectares=32 and 4-24 hectares 29%). Table 1.1 summarizes demographic variables related to the collected and analyzed sample.

Table 1.1: Demographic profile

Characteristics	Category	Frequency	Percentage
Gender	Male	274	78
	Female	79	22
	Total	353	100
Age	Below 25	23	7
	25-35	37	10
	35-45	77	22
	45-55	133	38
	Above 55	83	23
	TOTAL	353	100
District	Baramulla	115	33
	Budgam	53	15
	Shopian	81	23
	Ganderbal	25	7
	Anantnag	79	22
	Total	353	100
Income	Less than 1,00,000	5	1
	1,00,000 – 3 00,000	31	9
	3,00,000 – 5,00,000	56	16
	5 00,000 - 10, 00,000	140	40
	10, 00,000 or above	121	34
	Total	353	100
Land Holding	Marginal (up to 1 Hectare/8 Kanals)	42	12
	Small (1-2 hectare/ 8- 16 Kanals)	96	27
	Medium (2-4 hectare/ 16-24 Kanals)	109	32

	Large (4 and above/ 24 Kanals and above	103	29
	Total	353	100

4.1. Reliability and validity analysis

The validity and reliability of the constructs were evaluated in the second round of data analysis. The statistical software programmes SPSS 21.0 and AMOS 21.0 were utilised to analyse suggestions for the assessment of reliability and validity components. All retained items were also subjected to tests for construct reliability and validity. Both composite reliability (CR) and average variance extracted (AVE) were considered as suggested by (Joseph F. Hair et al., 2010). As seen in Table 1.2, the CR values for all constructs were noticed to be above 0.70 (Fornell & Larcker, 1981). The largest CR value was recorded for perceived ease of use while the lowest value was for perceived benefit. As for the AVE values, all constructs have an acceptable value of AVE higher than 0.50 as suggested by (Fornell & Larcker, 1981) and (Joseph F. Hair et al., 2010). The highest value of AVE was for perceived ease of use while the lowest value was found in the case of perceived benefits.

Table1.2: Construct Validity and Reliability.

	CR	AVE	MSV	MaxR(H)	PR	PU	PB	TC	SI	PEOU	NC	PNTC	INT
PR	0.914	0.781	0.108	0.966	**0.883**								
PU	0.938	0.791	0.321	0.940	0.290	**0.889**							
PB	0.882	0.653	0.127	0.894	0.053	0.260	**0.808**						
TC	0.939	0.838	0.139	0.944	0.132	0.187	0.101	**0.915**					
SI	0.945	0.852	0.222	0.952	0.160	0.471	0.277	0.113	**0.923**				
PEOU	0.947	0.856	0.301	0.961	0.329	0.445	0.237	0.219	0.375	**0.925**			
NC	0.930	0.817	0.085	0.938	0.070	0.122	0.026	0.152	0.138	0.083	**0.904**		
PNTC	0.917	0.786	0.231	0.917	0.312	0.289	0.173	0.298	0.165	0.320	0.291	**0.887**	
INT	0.917	0.788	0.321	0.919	0.296	0.567	0.357	0.373	0.467	0.549	0.209	0.481	**0.887**

Note: "CR= composite reliability; AVE = average variance extracted; MSV = maximum shared variance; MaxR(H) = maximum reliability; (*) = square root of AVE"

4.2. Measurement Model

In the third step, the measurement model, confirmatory factor analyses, were evaluated to make sure there was a suitable level of model fitness along with construct validity and reliability. Then, the main research hypotheses were tested at the second stage (structural model). As seen in Table 1.3, a number of the fit indices of the measurement model were found to be within their acceptable level (GFI: Goodness-of-Fit Index=.916; AGFI: Adjusted Goodness-of-Fit Index=.893; CFI:Comparative Fit Index=.983; CMIN/DF: Normed Chi-Square= 1.441; NFI: Normed-Fit Index=.947; and RMSEA: Root Mean Square Error of Approximation=.035). Therefore, the model have adequate level of model fitness as all fit indices (Joseph F. Hair et al., 2010; Mir, 2019; Mir et al., 2021; Tabachnick et al., 2013).

Table 1.3: Results of Measurement Model.

Fit indices	Cut off point	Model Fit (Measurement model)	Result
CMIN/DF	≤3.000	1.441	accepted

GFI	≥0.90	.916	accepted
AGFI	≥0.80	.893	accepted
NFI	≥0.90	.947	accepted
CFI	≥0.90	.983	accepted
RMSEA	≤0.08	.035	accepted

4.3. Structural Model

To prevent any issues related to the common method bias, Harman's single-factor test (1976) has to be used before moving ahead with the structural model analysis. Consequently, SPSS 21 was used to retrieve nine latent constructs together with their unremoved items for Harman's single-factor test. This value is less than the recommended one (< 0.50) (Podsakoff et al., 2003). Therefore, it seems that there was no problem regarding the issue of common method bias.

To ensure that multicollinearity problem does not exist between main dependent and independent constructs, variance inflation factors (VIF) were tested and all values extracted in this respect were noticed within their recommended level (< 10) (Baabdullah et al., 2019).

In the last stage, the structural model of SEM was tested to verify the conceptual model and its associated hypotheses. Similar to the measurement model, all fit indices of the structural model were observed to be within their acceptable levels as follows: GFI=0.906; AGFI=0.882; NFI=0.941; CFI=0.977; and RMSEA=0.041 (J. F. Hair et al., 2010; Tabachnick et al., 2013). The conceptual model was also able to predict a large portion of variance on farmers adoption of High density Plantation Tecnologies with R2 value of 0.63. This, in turn, supports the predictive validity of the current study model.

Hypotheses Testing

The main causal paths were tested using path coefficient analyses as seen in Table 1.4. The main factors of PNTC and TAM, namely PEOU (C.R= 5.056 P < 0.000), PU (C.R= 5.022, P < 0.000), SI (C.R= 3.363 P < 0.000), and PB (C.R= 3.084 P < 0.010), were found to have a significant impact on the farmers intention to adopt HDAP technologies . However, PR was not proved to have any statistical association with farmers intention to adopt HDAP technologies (C.R= .593 P > 0.050). As for the PNTC model factor, both TC (C.R= 4.998, p < 0.000) and NC (C.R= 4.642, p < 0.000) were confirmed to be significant predictors of PNTC. In addition, the causal path between PNTC and HDAP was also proved (C.R= 6.435, p< 0.000). Therefore, except for H7, all research hypotheses (H1, H2, H3, H4, H5, H6, and H8) were supported.

Table 1.4: Regression Weights: (Group number 1 - Default model)

			Estimate	S.E.	C.R.	P	Label
PNTC	<---	TC	.227	.045	4.998	***	par_21
PNTC	<---	NC	.222	.048	4.642	***	par_22
INT	<---	PB	.207	.067	3.084	.002	par_23
INT	<---	SI	.170	.050	3.363	***	par_24
INT	<---	PR	.025	.042	.593	.553	par_25
INT	<---	PU	.291	.058	5.022	***	par_26
INT	<---	PEOU	.248	.049	5.056	***	par_27
INT	<---	PNTC	.338	.053	6.435	***	par_28

Note: P < 0.001 ***

5. DISCUSSION

This study endeavours to determine the key factors that influence farmers intention to adopt HDAP technologies in agricultural sectorsThis study revealed a startling conclusion: perceived need for technology characteristics (PNTC) was shown to be significantly positively impacted by farmer's need characteristics (NC) and technology characteristics (TC). These results are consistent with the findings of (Li et al., 2020; Zhou et al., 2010). the advancement of high-density apple technologies, bring them closer to the requirements and goals of farmers.

Perceived ease of use and perceived usefulness , both have a beneficial influence on farmers' inclination to adopt HDAP technology. These results are similar to the previous findings of (Dong et al., 2022; McCormack et al., 2021; Narmilan, 2020). This indicates that if users find these technologies easy to use and see them as helpful, they are more likely to adopt them.

This result might be explained by the fact that farmers' intentions to use HDAP technology are positively impacted by perceived advantages. This outcome is consistent with the earlier discoveries of (Liu & Liu, 2024; Thompson et al., 2019). An important factor is how farmers view the advantages of implementing high-density apple production systems. These advantages may consist of higher yields, better crop quality, more economical use of resources (such as water and fertiliser), less labour demands, and overall higher profitability. Farmers are more likely to declare their willingness to embrace these technologies if they think doing so would lead to positive results.

This study also shows that farmers' intentions to use HDAP technology are not much impacted by perceived risk. This result are consistent with the findings of (Li et al., 2020; Vandana & Mathur, 2022). It suggests that while determining whether to embrace these technologies, farmers do not view anticipated dangers as major obstacles or concerns. In this case, perceived risk may include things like worries about the financial commitment, doubts about technological performance, the possibility of crop loss, or other things that farmers could find dangerous.

Additionally, farmers' intentions to use HDAP technology are positively impacted by social influence.This outcome is in line with other study investigations like (Han et al., 2022; Ramirez, 2013; Ren et al., 2022). A variety of strategies, including social pressure, community involvement, professional assistance, government support, financial incentives, and favourable media attention, can work together to create an environment that is more conducive to farmers adopting HDAP technology. Agriculture cannot successfully absorb new technologies unless the social dynamics inside farming communities are recognised and addressed.

Furthermore, perceived need for technology characteristics positively impacts farmers' intention to adopt HDAP technologies the results are similer to previous research works (Adesina & Zinnah, 1993; Li et al., 2020). Specific technology characteristics can contribute to a positive attitude and intention to adopt HDAP technologies among farmers, fostering the advancement of precision agriculture practices.

6. CONCLUSION, IMPLICATIONS AND FUTURE RESEARCH DIRECTION

The HDAP has immense potential to enhance food security, environmental preservation, and agricultural productivity. Although HDAP technology is widely used in other cropping systems, it is not widely accepted in Jammu & Kashmir. HDAP adoption in Jammu and Kashmir has been studied from a socioeconomic perspective in the past. Other factors affecting technology adoption have been overlooked. This study developed and tested a hybrid model that combines the Extended Technology Adoption Model (TAM) and the Perceived Need for Technology Characteristics (PNTC). HDAP adoption can be predicted more accurately with this model by identifying the factors that will encourage or hinder farmers from adopting it. Farmers' perceptions of their own needs and how well HDAP technology characteristics align with these also had a significant impact on their intention to adopt HDAP. Therefore, throughout the HDAP technology innovation process, providers and regulators must take into account the relationship between technological features and farmers' demands. To accomplish efficient coproduction of HDAP technologies, end users and other interested stakeholders must be contacted early enough in the invention process to ensure that HDAP technologies meet with end-user expectations.It is also recommended that factors like cost, subsidy, bank credit and extension contacts can be added as new factors in extended technology acceptance models to understand and expand the technology adoption in farming community of India.

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