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Construction of a Scale to Measure Correlates of Adoption of Sustainable Domains in On-Farm Testing Interventions

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HIGHLIGHTS

- 84 dimensions under nine correlates of adoption viz. economic, social, psychological, technological, physical, temporal, spatial, human resource, and institutional correlates of adoption, were retained after relevancy testing.
- The final scale consisted of thirty-two dimensions under seven correlates of adoption.
- All 7 correlates of adoption are positively and significantly related to farmers' adoption behaviour.

ARTICLE INFO

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ABSTRACT

The study was conducted in 2023 with an aim to identify SRDs and develop a reliable scale for adoption correlates within these domains. The development of the scale follows a systematic Likert scale development methodology involving identification of SRDs of OFT interventions, delineation of different dimensions of each correlate of adoption, dimension analysis and selection, and its standardisation by reliability and validity assessment. The final scale comprises 32 dimensions under seven adoption correlates, selected via exploratory factor analysis (EFA) and item discrimination index calculation. The scale demonstrated strong content, construct, and convergent validity, with an average variance extracted (AVE) value of 0.69 and composite reliability (CR) score of 0.97. It also exhibited high internal consistency, with a Cronbach's alpha of 0.97 and a split-half reliability coefficient of 0.963. The standardized scale is effective for measuring factors related to the adoption of improved technologies and practices, providing a valuable tool for researchers in various fields. The administration of the developed scale and the subsequent correlation analysis revealed significant relationships, with human resource correlates showing the highest correlation (r = 0.895), followed closely by technological (r = 0.872) and economic correlates (r = 0.87), underscoring the critical factors influencing farmers' adoption behaviour.

INTRODUCTION

The growth and development of frontline extension systems are crucial for ensuring farmers receive and adopt the latest agricultural information and technologies (Sahoo et al., 2021). Krishi Vigyan Kendras (KVKs), as a major frontline extension system at the district level, play a vital role in disseminating improved agricultural technologies and practices nationwide. The Indian Council of Agricultural Research (ICAR) established KVKs to enhance district-level agricultural economies through activities such as assessment, refinement, and demonstrations of location-specific technologies in agriculture and related sectors (ICAR, 2023).

A key activity of KVKs is on-farm testing (OFT), which assesses and refines technologies through multi-locational trials on farmers' fields, fostering an interactive approach. OFTs bring together farmers, experts, scientists, the extension system, and the

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government to develop farmer-centric innovations tailored to specific needs (Venkatasubramanian et al., 2009; Sajeev & Venkatasubramanian, 2012). The potential impact of OFT interventions on agricultural production and productivity is maximized when targeting locations with Sustainable Recommendation Domains (SRDs). SRDs, defined by biophysical and socio-economic characteristics, are critical for scaling improved technologies and practices in agriculture and allied sectors for particular locations (Muthoni et al., 2017).

Socioeconomic characteristics significantly influence farmers' perceptions of adopting sustainable practices and household food security (Chikkalaki et al., 2023; Jatav & Mubeena, 2023; Singh et al., 2023). Properly targeting locations for scaling up improved technologies and practices through OFTs is a key determinant of the adoption rate, significantly increasing the probability of adoption. KVKs conduct OFTs in selected farmer fields to identify and validate suitable agricultural technologies and practices. The SRD of OFT interventions affects farmers' adoption behaviour due to variations in the biophysical and socioeconomic characteristics of each SRD (Ram et al., 2010).

The actual adoption of technologies and practices among OFT participants is determined by these factors, known as correlates of adoption, and their subcomponents, called dimensions, based on the SRDs of OFT interventions. Therefore, it is crucial to identify and delineate different correlates of adoption as a measure of the sustainable recommendation domains of OFT interventions and to develop a scale to assess the factors affecting the adoption of technologies and practices disseminated through OFTs.

METHODOLOGY

The development of this scale follows the Likert summated rating method, intended to serve as a specific research tool that can introduce new dimensions and correlates in studying farmers' adoption behaviour. The study hypothesizes that a standardized scale measuring the correlates of adoption in sustainable domains of OFT interventions can accurately determine a range of factors influencing farmers' adoption behaviour of the latest technologies. This insight enables the research system to develop technologies and practices aligned with farmers' needs and directs extension systems to best serve farmers' requirements.

The scale development on correlates of adoption as a measure of sustainable recommendation domains (SRDs) of OFT interventions followed a systematic step-by-step process of the Likert method of scale construction. This process involved identification of SRDs of OFT interventions, delineation of dimensions under different correlates of adoption, selection and operationalization of dimensions, or item analysis, and its standardisation with the intention of measuring the correlates of adoption based on the performance of sustainable recommendation domains of OFT interventions of KVKs.

The scale development process commenced with the identification of five sustainable recommendation domains (SRDs) of OFT interventions, followed by the delineation of twelve correlates of adoption and a total of ninety dimensions under the identified twelve correlates of adoption through a comprehensive review of available literature and discussions with experts and scientists in the field. Editing and selection of dimensions were performed by following the criteria of Edwards (1969), leading to the elimination of dimensions and correlates that are irrelevant in measuring the construct. Relevancy score in percentage was calculated to assess the relevancy of the dimensions under each correlate as depicted below:

$$\text{Relevancy score (\%)} = \frac{\text{Total scores obtained on each items}}{\text{Maximum possible score}} \times 100$$

Dimensions and correlates with more than 80 percent relevancy score were retained for further study involving 40 participating farmers of OFTs by KVKs in Kerala, based on which further reduction of dimensions under each correlate was carried out using exploratory factor analysis (EFA). Based on factor loadings, communality and uniqueness values, 40 dimensions under nine correlates of adoption were retained for further analysis.

The discrimination power of dimensions under each correlate of adoption was calculated to distinguish respondents in the high adoption and low adoption groups based on the SRDs of OFT interventions for further endorsement of scale validity (Kocdar et al., 2016). The formula used to find discrimination power in terms of the discrimination index is as follows:

$$\text{Discrimination Index, DI} = \frac{\text{RU - RL}}{\text{NU or NL}}$$

Where, RU- Number of respondents in the upper group who responded correctly

RL- Number of respondents in the lower group who responded correctly

NU- Number of respondents in the upper group

NL- Number of respondents in the lower group

The scale was standardized using reliability and validity tests, with Cronbach's alpha and the split-half method used to determine internal consistency. Cronbach's alpha measured overall consistency by indicating how well high responses align with other high responses and low responses align with other low responses across all items (Singh, 2019). The formula used to calculate Cronbach's alpha is given below.

$$\text{Cronbach's Alpha, } \alpha = \frac{K}{K-1}\left[1 - \frac{\sum Si^2}{Sy^2}\right]$$

Where, K-Number of items

ΣSi^2 – Sum of variance of individual items

Sy^2 – Total variance

Split-half reliability was estimated using the Pearson product-moment method, and the reliability coefficient for the entire scale was then calculated using the Spearman-Brown prophecy formula.

$$\text{Split half reliability, } r^{1/2} = \frac{N\sum XY - \sum X \sum Y}{\sqrt{[N\sum X^2 - (\sum X)^2][N\sum Y^2 - (\sum Y)^2]}}$$

Where, X= Score of odd items

Y= Score of even items

$$\text{Reliability co-efficient of the scale, } R = \frac{2r^{\frac{1}{2}}}{1+r}$$

The scale's validity was assessed through both content and construct validity. Content validity was evaluated by examining the

scale's ability to cover relevant subject domains related to factors influencing adoption behaviour within sustainable recommendation domains of OFT interventions. This evaluation involved a thorough literature review, expert opinions, and assessments by subject matter specialists. Convergent validity, a component of construct validity, was assessed using the criteria established by Fornell and Larcker (1981). Average variance extracted (AVE) and composite reliability (CR) were used to measure the convergent validity of the scale (Campbell and Fiske, 1959; Alarcón and Sánchez, 2015).

$$AVE = \frac{\sum_{i=1}^{n} \lambda i^2}{n}$$

$$CR = \frac{\sum_{i=1}^{n} \lambda i^2}{\sum_{i=1}^{n} \lambda i^2 + \sum_{i=1}^{n} \mathrm{Var}\,(\mathrm{ei})}$$

Where, $\sum_{i=1}^{n} \lambda i^2 -$ Sum of squared loadings

$\sum_{i=1}^{n} \mathrm{Var}\,(\mathrm{ei}) -$ Total of variance of the error term for i[th] indicators.

n- Number of items or indicators

The error variance of i[th] indicator or item was found using the formula,

$$\sum_{i=1}^{n} \mathrm{Var}\,(\mathrm{ei}) = \sum_{i=1}^{n} 1 - \lambda i^2$$

The final administration of the scale among the participating farmers of OFTs on a five-point scale and subsequent analysis clarify different correlates that affect the adoption behaviour of respondents and the extent to which each dimension and correlate contributed to the adoption of OFT interventions based on its sustainable recommendation domains. The correlation analysis between the adoption of sustainable technologies and practices disseminated through OFTs and various adoption correlates was conducted to determine the extent to which each factor influences farmers' adoption behaviour.

RESULTS

Identification of sustainable recommendation domains of OFT interventions

Sustainable Recommendation Domains (SRDs) of OFT interventions are designated areas where technological and other interventions through on-farm trials are implemented only with a focus on sustainability (Muthoni et al., 2017; USGGFI, 2023). Identification of sustainable recommendation domains of OFT interventions was done through a process involving extensive review of literature, interaction with experts, different stakeholders involved in OFTs, focus group discussions with participating and non-participating farmers of OFTs, and close inspection of areas where OFTs were conducted. On Farm Trials focus on sustainable intensification mainly in five key domains such as productivity, economic, environmental, human, and social domains through their peculiar activities in each agro-ecological zone.

Delineation of different correlates of adoption of improved technologies and practices among farmers

Correlates of adoption were delineated through a step-by-step process of identification and collection of different factors affecting the adoption behaviour of farmers and other stakeholders involved in OFTs in the identified SRDs, identification of different dimensions of each correlate of adoption, collection of items that reflect each dimension, editing, analysis, and selection of dimensions and suitable statements to measure each dimension, standardisation, and final administration of the scale among the respondents.

Based on a review of relevant literature and discussions with experts in the field, various factors influencing the adoption of improved technologies and practices among farmers were identified as indicators of sustainable recommendation domains within OFT interventions. Each category of adoption correlates was further subdivided into different dimensions. Editing of items and dimensions under each correlate of adoption was carried out with the help of reviewing relevant literature and from the insight received through expert interactions. Relevance of the dimensions under each correlate of adoption was tested through judges ratings involving forty five judges, where the expert's responses were solicited on a five-point continuum, viz., Most Relevant, Relevant, Somewhat Relevant, Less Relevant, and Not Relevant. The scores assigned were 5, 4, 3, 2, and 1, respectively, and the relevance score of each dimension was calculated as a percentage. Dimensions with more than 80 percent relevancy score were retained for conducting further study among respondents in the non-sampling area. Thus, a total of 84 dimensions under nine correlates of adoption, such as economic, social, psychological, technological, physical, temporal, spatial, human resource, and institutional correlates of adoption, were retained.

Exploratory factor analysis (EFA) was conducted to analyze and reduce dimensions under each adoption correlate. A total of eighty-four dimensions that passed the relevancy test were selected for analysis, focusing on factor loading, communality, and uniqueness values. Data were collected from forty OFT farmers in non-sample areas, where participants rated their agreement with each dimension on a five-point Likert scale ('strongly agree' to 'strongly disagree', scored as 5 to 1, respectively). In R-Studio, exploratory factor analysis (EFA) was conducted using the psych package. The initial step involved assessing data suitability with the Kaiser-Meyer-Olkin (KMO) test, recommended by Kaiser (1970); Kaiser & Rice (1974). The KMO test evaluates sampling adequacy for each variable, where a higher KMO value (>0.6) indicates greater variance among variables, confirming data appropriateness for factor analysis. Specifically, the KMO scores for economic, social, psychological, technological, physical, temporal, spatial, human resource, and institutional correlates of adoption were 0.8, 0.85, 0.91, 0.88, 0.72, 0.79, 0.79, 0.77, and 0.79, respectively. These scores underscored the suitability of the dataset for exploratory factor analysis. The dimensions with large loading values (more than 0.5) indicate a strong association with the factor. Communality was extracted during the factor analysis. Exploratory factor analysis of each correlate of adoption was carried out independently and interpretations on dimensions under each correlate of adoption were drawn based on factor loading, communality value, and uniqueness value.The exploratory factor analysis resulted in the retention of 4 dimensions out of 14 for economic correlates, 5 dimensions out of 10 for social correlates, 8 dimensions out of 13 for psychological correlates, 5 dimensions out of 8 for technological correlates, 3 dimensions out of 6 for

physical correlates, 1 dimension out of 7 for temporal correlates, 3 dimensions out of 6for spatial correlates, 7 dimensions out of 13 for human resource correlates and 4 dimensions out of 7 for institutional correlates of adoption. These dimensions showed high factor loading (> 0.5), high communality, and low uniqueness values, indicating their significant contribution to the respective domains. The factor loading, communality and uniqueness values of selected dimensions in the final scale is depicted in Table 1.The analysis and selection of dimensions through exploratory factor analysis resulted in the omission of 44 dimensions under different correlates of adoption, and the remaining 40 dimensions under 9 correlates of adoption were selected for further validation and reliability checks, leading to the development of a final scale on correlates of adoption as a measure of SRDs of OFT interventions.

The discrimination power of dimensions under each correlate of adoption was calculated through a step-wise process involving the identification of high adoption groups (upper 27%) and low adoption groups (lower 27%) of respondents and determining the number of respondents who gave correct responses in each category, followed by the calculation of the discrimination index to determine the discrimination power of each dimension in measuring the construct of interest. Dimensions with a discrimination index value above 0.30 were selected for the scale to measure correlates of adoption, as they are ordinarily regarded as satisfactory for meeting the purpose of the study. Therefore, 32 dimensions under 7 adoption correlates, each showing significant discriminatory power, were retained. These dimensions are crucial for assessing how effectively the scale items capture meaningful interpretations. The discrimination index (DI) value of dimensions in the final scale on correlates of adoption is displayed in Table 1.

The internal consistency of the scale was assessed using Cronbach's alpha and split-half reliability. The Cronbach's alpha

Table 1. Selected dimensions on correlates of adoption as a measure of SRDs of OFT interventions

S.No.	Correlates of adoption	Communality after extraction	Uniqueness	Factor loading	DI
I	Economic correlates of adoption				
1	Price stability	0.644	0.356	0.643	0.64
2	Annual income	0.639	0.360	0.719	0.55
3	Farm income	0.755	0.245	0.805	0.45
4	Expenditure	0.650	0.350	0.805	0.45
II	Social correlates of adoption				
5	Linkages	0.730	0.270	0.783	0.64
6	Extension service orientation	0.690	0.310	0.734	0.45
7	Information source utilization	0.854	0.146	0.897	0.64
8	Resource utilization	0.698	0.302	0.827	0.64
III	Psychological correlates of adoption				
9	Awareness	0.745	0.254	0.863	0.64
10	Attitude	0.690	0.309	0.831	0.55
11	Innovativeness	0.713	0.286	0.845	0.36
12	Problem solving ability	0.710	0.289	0.843	0.45
13	Information seeking behaviour	0.734	0.265	0.857	0.64
14	Decision making ability	0.687	0.312	0.829	0.55
IV	Technological correlates of adoption				
15	Compatibility	0.801	0.199	0.895	0.36
16	Sustainability	0.781	0.218	0.884	0.45
17	Quality	0.778	0.222	0.882	0.36
18	Reliability	0.808	0.191	0.899	0.45
V	Physical correlates of adoption				
19	Topography	0.760	0.239	0.872	0.45
20	Farming situation	0.649	0.350	0.806	0.55
21	Infrastructure support	0.690	0.309	0.831	0.55
VI	Human resource correlates of adoption				
22	Proficiency	0.716	0.284	0.846	0.45
23	Work Competence	0.785	0.215	0.886	0.64
24	Work commitment	0.787	0.213	0.887	0.36
25	Efficiency	0.700	0.299	0.837	0.64
26	Acceptability	0.723	0.276	0.851	0.36
27	Availability	0.674	0.325	0.821	0.45
28	Knowledge in farming	0.770	0.229	0.878	0.73
VII	Institutional correlates of adoption				
29	Accessibility	0.605	0.394	0.723	0.45
30	Accountability	0.732	0.268	0.765	0.64
31	Authenticity	0.698	0.302	0.774	0.73
32	Responsibility	0.787	0.211	0.835	0.55

value obtained was 0.97, indicating excellent internal consistency, as it exceeds the recommended threshold of 0.90.

$$\alpha = \frac{32}{32-1}\left[1 - \frac{33.78}{635.63}\right] = 0.97$$

The reliability coefficient calculated using split-half reliability and the Spearman-Brown prophecy formula was 0.963. This confirms that Cronbach's alpha is nearly equivalent to the average of all possible split-half reliabilities of the test. Therefore, the developed scale was found to be highly reliable for measuring the correlates of adoption among OFT farmers.

$$r^{1/2} = \frac{40*2091387 - 6346*6627}{\sqrt{[40*2120738 - (6346)^2][40*2220591 - (6627)^2]}} = 0.93$$

$$R = \frac{2 * 0.93}{1 + 0.93} = 0.963$$

Content validity of a scale can be assessed through logical analysis of its content or by judgment from experts in the field (Said et al., 2011; Gupta et al., 2022). The content validity of all selected items, dimensions, and adoption correlates was rigorously evaluated. This evaluation included testing internal consistency, consulting with experts, and conducting a comprehensive literature review. These steps confirmed that the scale adequately covered all aspects related to various factors influencing farmers' adoption behaviour within the sustainable recommendation domains of OFT interventions.

Convergent validity assesses the correlation among multiple dimensions of the same construct and is crucial for determining the construct validity of a measure (Carlson & Herdman, 2010; Singh, 2019; Shrestha, 2021). According to Fornell and Larcker (1981), convergent validity of a measuring instrument is evaluated using average variance extracted (AVE) and composite reliability (CR). AVE measures the amount of variance captured by a construct relative to measurement error variance, while CR provides a more reliable estimate than Cronbach's alpha. Both the AVE value and the composite reliability value were determined to be 0.69, which is considered acceptable. This finding confirms the convergent validity of the measuring instrument for assessing the adoption correlates among OFT farmers.

$$AVE = \frac{21.98}{32} = 0.69$$

$$CR = \frac{21.98}{21.98 + 10.02} = 0.69$$

The scale for measuring different correlates of adoption of improved practices and technologies was finalised for administration among farmers after satisfying the reliability and validity requirements of a standard measuring instrument. The final scale consisted of thirty-two dimensions under seven correlates of adoption, where each dimension is represented by a number of items representing the measurement criteria of each dimension. For scoring, respondents will indicate their level of agreement on a five-point scale ranging from "strongly agree" to "strongly disagree," scored as 5, 4, 3, 2, and 1, respectively. The correlation results indicate that all correlates of adoption are positively and significantly related to farmers' adoption behaviour at the 0.01 level of significance. The correlation coefficients (r) are as follows: economic (0.87), social (0.87), psychological (0.867), technological (0.872), physical (0.759), human resource (0.895), and institutional (0.862). These values, shown in Table 2, highlight the strong influence of each factor on adoption behaviour.

Table 2. Correlation between adoption and correlates of adoption in On-Farm Testing (OFT) (N=235)

S. No.	Correlates of adoption	Correlation co-efficient (r)
1	Economic correlates of adoption	.870**
2	Social correlates of adoption	.870**
3	Psychological correlates of adoption	.867**
4	Technological correlates of adoption	.872**
5	Physical correlates of adoption	.759**
6	Human resource correlates of adoption	.895**
7	Institutional correlates of adoption	.862**

**. Correlation is significant at the 0.01 level (2-tailed).

DISCUSSION

The correlation analysis reveals the intricate interplay between various factors influencing the adoption of sustainable technologies and practices disseminated through On-Farm Testing (OFT). Human resource correlates, with the highest correlation coefficient (r = .895), emerge as the most significant driver, underscoring the importance of behavioural dimensions such as skills, knowledge, and motivation in the adoption process. This highlights that while technological correlates (r = .872) are crucial, the success of technology adoption heavily depends on the capacity and readiness of individuals, emphasizing the need for integrated strategies that address both human and technological factors. Economic (r = .870) and social correlates (r = .870) also play pivotal roles, indicating that financial viability and social influences are key determinants in the decision-making process. Although physical correlates (r = .759) have a slightly lower impact, they remain essential in providing the necessary infrastructure for adoption. Additionally, institutional support (r = .862) is vital, reinforcing the idea that effective policies and organizational structures are crucial for enabling adoption. The close correlation values across these factors suggest a highly interdependent relationship, where the effectiveness of one factor often relies on the strength of others, pointing to the need for a holistic approach in designing agricultural extension programs that can effectively drive adoption.

The results of the correlation analysis highlight the relevance and importance of each adoption correlate in influencing the adoption of sustainable technologies and practices disseminated through OFT interventions. These correlates act as key determinants, aiding extension personnel and scientists in analysing the various dimensions of technologies and practices that bring them to farmers' attention. They help identify factors that favour and affect the farming process, make farmers ready to accept disseminated technologies and practices, and improve their overall situation. This understanding is crucial in guiding the adoption of sustainable technologies and practices introduced and refined through OFTs. Furthermore, it offers insights into the key areas or domains that need more focus when formulating new OFTs and in

the development and selection of technologies and practices to be tested. Identifying the effect of correlates on overall adoption helps researchers and other stakeholders in diagnosing the technology needs of farmers, planning and conducting OFTs with the selected technology or practice, assessing its sustainability, and ensuring its proper diffusion among farmers.

CONCLUSION

The goal of this study was the delineation of different correlates of adoption and the subsequent development of a scale based on sustainable recommendation domains of OFT interventions. To achieve this goal, the Likert method of scale construction was followed, starting from the literature review and expert interaction to identify sustainable recommendation domains of on-farm tr interventions, identification and delineation of dimensions under different correlates of adoption, analysis and selection of dimensions using exploratory factor analysis, validation and reliability assessment of the instrument through various statistical methods, and finally the administration of the standardised scale for measuring different correlates of adoption among farmers based on the performance of sustainable recommendation domains of OFT interventions by KVKs. The final scale comprised thirty-two dimensions across seven correlates of adoption, with each dimension consisting of multiple items to ensure accurate measurement of the intended construct.

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