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Crafting a Digital Divide Index for Assessing Agricultural Disparities Among Farmers: An Application of AHP Process

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HIGHLIGHTS

- The study incorporates four critical dimensions to assess digital disparitynamely ICT ownership, awareness, accessibility, and usage.
- A standardized digital divide index for farmers was finalized, consisting of 38 items.
- The index is designed to effectively evaluate agricultural disparities within farming communities.

ARTICLE INFO

Keywords: Analytic hierarchy process, Digital agriculture, Information and communication technology, Digital divide, Index development.

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ABSTRACT

a new measurement tool for assessing the digital divide disparity among farmers in e-agriculture was devised during 2023-24. The index comprises four dimensions, namely ICT ownership, awareness, accessibility, and usage, respectively. For dimension selection, the researchers employed the Analytic Hierarchy Process (AHP). The maximum eigen value (ë max) of the pairwise comparison matrix was 4.0049, serving as the overall weight for the decision-making process. In the item selection process, Likert-type scale procedures were used to assess statements for final indicator selection. An interview schedule with 45 indicators was administered to 60 farmers in a non-sampling area, with five ambiguous indicators subsequently removed. The digital divide index customized for farmers demonstrated strong reliability, with a split-half reliability coefficient of 0.846 (Spearman-Brown formula) and a Pearson correlation coefficient of 0.733. Internal consistency was good, as indicated by a Cronbach's Alpha of 0.813, and the test displayed strong validity with a score of 0.919. Overall, these findings confirm the reliability and validity of the test in measuring the intended construct. Ultimately, the 38 items were consolidated into a standardized farmers' digital divide index for assessing agricultural disparities in the farming community.

INTRODUCTION

Farmers widely acknowledge that Information and Communication Technology (ICT) is time-saving and information access benefits tools. I argue that technology is not a neutral object within society. Instead, technology and its different aspects must be understood and explained in a specific context. It is embedded in everyday politics and social interactions and, as such, should be considered as a social and behavioral phenomenon (Barzilai-Naho, 2006). In this connection, ICTs play a significant role in driving agricultural development, particularly in countries like India (Kumar et al., 2023). They connect the rural poor and farming community with essential information, timely availability of resources, and providing better marketing opportunities, effectively bridging the gap (Chandra et al., 2021). The ICT-driven information delivery mechanism has the capability to efficiently engage the intended audience, rapidly distributing precise information with high accuracy, thus ensuring seamless and reliable outreach. This paradigm shift has fundamentally restructured the traditional notions of time and space that have long governed our lives, work, and social

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interactions. The extension services consistently prioritize promoting improved and updated information access to enhance the socio-economic development of farming communities for their better life (Chandra & Singh, 2021). However, as we acknowledge the gravity of this matter, we deliberate on safeguarding human dignity, which has now become a central concern of the global community (Singh, 2004).The fundamental cause of digital inequality stems from the varying economic development levels of countries, leading to a range of social, technological, and other challenges spanning from literacy levels to mental preparedness for transformation (Revenko & Revenko, 2022).The problem of digital inequality is social rather than technical (Popora et al., 2019). Social inequality is the root of the digital divide (Perguna et al., 2021). Digital inclusion is a multifaceted and complex phenomenon (Correa & Pavez, 2016). The digital divide refers to the gap between those with convenient access to digital technology and information and those who lack this (Hennessy et al., 2016). Indian Agriculture suffers the majority of intramural Issues (Khadare & Gawade, 2017). India's agriculture is evolving to improve the quality of life and livelihoods. It is only possible by establishing a comprehensive knowledge management system (Chandra et al., 2023).

METHODOLOGY

The study's methodology involved a process of identifying, validating, and standardizing dimensions and indicators using appropriate statistical techniques. The process began with a comprehensive literature review, involving a thorough examination of research articles, journals, and thesis repositories to identify dimensions and indicators. This entailed gathering a wide array of statements from diverse sources, including literature, discussions with experts, and input from various stakeholders such as scientists, extension professionals, government officials, farmers, teachers, senior citizens, and NGO personnel. Based on this process, the dimensions and indicators were chosen. The AHP process is utilized to establish priorities for dimension selection. Ultimately, four dimensions and 69 items were selected for the study. Subsequently, 120 judges were given the selected indicators for assessment, utilizing both Google Forms and hard copies for their responses. Judges were asked to assess the relevance of each indicator on a three-point scale, with scores of 3, 2, and 1 assigned to indicate "most relevant" (MR), "relevant" (R), and "not relevant" (NR) responses, respectively. The methodology used is comparable to the methods adopted by other scholars, such as Jairu *et al.* (2023); Khalkho & Ghosh (2023). The suitability of each indicator was determined by computing relevancy weightage (RW), mean relevancy score (MRS), and the overall mean relevancy score (OMRS). Following the analysis, 45 statements were chosen based on criteria similar to those employed by Prasad et al., (2016) & Roy et al., (2022). These criteria necessitated a Relevancy Weightage (RW) greater than 0.85 and a Mean Relevancy Score (MRS) exceeding the Overall Mean Relevancy Score (OMRS). However, five of these statements were found to be ambiguous and were subsequently removed. Ultimately, an interview schedule was prepared for data collection in the non-sampled area. The schedule includes four dimensions: ICT ownership, ICT awareness, ICT accessibility, and ICT use. When assessing ICT ownership for the dimension, respondents were asked to provide a binary response, indicating 'yes' or 'no,' with corresponding weight assignments of 2 and 1, respectively, and a three-point psychological continuum was also utilized for each of the ICT dimensions, which include Awareness, Accessibility, and Use. Specifically, in the realm of ICT Awareness, the categories encompassed Fully Aware (FA), Partially Aware (PA), and Not Aware (NA). For ICT Accessibility, the options were Fully Access (FA), Partial Access (PA), and Not Access (NA). Lastly, within the ICT Use dimension, the continuum consisted of Fully Use (FU), Partial Use (PU), and Not Use (NU). In all cases, these dimensions were assigned weight values of 3, 2, and 1, respectively. Following this, the indicators deemed relevant were subjected to reliability and validity testing in a non-sampled area, involving a total of 60 randomly selected respondents. Reliability was evaluated through two approaches: the test-retest method, comparing scores on repeated tests administered two weeks apart (as demonstrated in studies by Bardhan et al., (2023); Jairu et al., (2023); Khalkho & Ghosh (2023) & Chandra et al., (2024) and the split-half method, which involved combining responses from odd and even-numbered items to calculate the correlation coefficient.

RESULTS

Domain Selection and their relevancy

The results of the Table 1 showed the maximum eigenvalue (λ max) of the pairwise comparison matrix is 4.0049. This value represents the overall weight or criteria for the decision-making process. In this case, it suggests that the combined importance of the criteria is relatively high. The Consistency Index (CI) is a measure of how consistent the pairwise comparisons are. A low CI value indicates that the judgments are relatively consistent. In this case, the CI is 0.0013, which is quite low. It suggests that the judgments made by decision-makers are consistent, which is a positive sign. The Consistency Ratio (CR) is the ratio of the CI to the Random Index (RI), and it is used to assess the acceptable level of consistency. A CR value less than 0.1 is often considered acceptable. In your case, the CR is 0.0013, which is below 0.1, indicating that the consistency of the judgments is within an acceptable range. Eigen values can provide insights into the relative importance of criteria. In this case, the larger eigen value indicates that the criteria play a significant role in the decision-making process, and their importance is reflected in the pairwise comparisons. The values in the matrix represent how each criterion is compared to others. For instance, ICT Ownership is given an importance of 1 compared to itself, and the other criteria are ranked relative to ICT Ownership. ICT Awareness is considered slightly more important

Table 1. Weighted Scores for Components of the Digital Divide Index Among Farmers Using the Analytic Hierarchy Process (AHP)

Comparison Matrix	ICT Ownership	ICT Awareness	ICT Accessibility	ICT Use
ICT Ownership	1.0000	0.8330	0.9169	0.9569
ICT Awareness	1.2004	1.0000	1.1333	0.9241
ICT Accessibility	1.0906	0.8824	1.0000	0.9169
ICT Use	1.0450	1.0821	1.0906	1.0000

Lambada Max (Eigan value): 4.0049, CI: 0.0016, CR: 0.0013

(0.833) than ICT Accessibility (0.917) and ICT Use (0.957) in the decision-making process. The low values of CI and CR are encouraging. They suggest that decision-makers have provided consistent judgments, which is crucial for the reliability of the AHP results.

Item selection process

The results of Table 2 assessment of 60 judges who provided evaluations for the set of items, a total of 69 items were deemed relevant and further used to gather responses from 60 farmers in non-sampling areas. The expert responses were then collected and analyzed to calculate the Relevancy Weight (RW), Mean Relevancy Score (MRS), and Mean Relevancy Score (OMRS) for each item using the specified formulas.

$$RW = \frac{\text{Actual score obtained for the item}}{\text{Maximum possible score obtainable for the item}}$$

$$MRS = \frac{\text{Actual Score obtained for item}}{\text{Numbers of judges responded}}$$

$$OMRS = \frac{\text{Sum of relevancy scores}}{\text{Total numbers of scores}}$$

The cumulative scores of all respondents were calculated by adding up the scores of individual items. Respondents were then ranked in descending order based on their total scores. For the purpose of item analysis, the top 25 per cent and the bottom 25 per cent of respondents, as determined by their total scores, were identified as the high group and low group respondents, respectively. Each item was assessed using responses from these two groups through the application of a t-test, which involved a specific formula.

$$t = \frac{\bar{X}H - \bar{X}L}{\sqrt{\frac{\sum(X_H - \bar{X}_H)^2 + \sum(X_L - \bar{X}_L)^2}{n(n-1)}}}$$

Whereas,

$$\sum(X_H - \bar{X}_H)^2 = \sum(X_H)^2 - \frac{(\sum X_H)^2}{n} \text{ and } \sum(X_L - \bar{X}_L)^2 = \sum(X_L)^2 - \frac{(\sum X_L)^2}{n}$$

X_H = Mean score of given statements in the high group, X_L = Mean score of given statements in the low group, $\Sigma(X_H)^2$ Sum of squares of individual scores on a given statement for the high group, $\Sigma(X_L)^2$ = Sum of squares of individual scores on a given statement for the low group, ΣX_H = Summation of scores on a given statement for the high group, and ΣX_L = Summation of scores on a given statement for the low group,

$$R=2r/(1+r)$$

Whereas, R = reliability coefficient of the whole scale, r = Estimated correlation between two (sets) halves

Selection criteria for items should meet the following conditions: the Relevancy Weightage (RW) must be greater than 0.85, and the Mean Relevancy Score (MRS) should exceed the Overall Mean Relevancy Score (OMRS), which is set at 2.54.

The content validity testing was conducted to ensure the adequacy of item selection. It is imperative to thoroughly assess a well-defined domain within the scale of interest (DeVellis, 2003). The comprehensive index addresses all aspects of the digital divide among farmers. It is structured around four key domains: ICT ownership, ICT awareness, ICT accessibility, and ICT use.

DISCUSSION

The overall consistency of our analysis is supported by the calculated Lambda Max (Eigenvalue) of 4.0049, with a Consistency Index (CI) of 0.0016 and a Consistency Ratio (CR) of 0.0013. These values indicate that our comparison matrix is consistent and reliable, with the CR being well below the acceptable threshold of 0.1, confirming the logical coherence and dependability of our weighted scores. In conclusion, the AHP-based weighted scoring of the Digital Divide Index components provides a nuanced understanding of how farmers engage with digital technologies. ICT Use emerged as a critical factor, emphasizing the necessity of practical application. Nonetheless, the roles of ICT Ownership, Awareness, and Accessibility are also vital, offering a comprehensive perspective that supports balanced digital engagement. The consistency measures affirm the reliability of our approach, making the index a robust tool for assessing and addressing the digital divide among farmers. This thorough analysis can inform targeted interventions to bridge the gap and promote digital inclusivity within the agricultural sector.

To ensure the reliability of our measurement instrument, we employed the Cronbach alpha coefficient, a widely recognized measure of internal consistency. The calculated Cronbach alpha coefficient, which was 0.813, suggests a strong level of reliability for the scale. This indicates that the items within the scale are consistently measuring the same construct across different respondents, reinforcing the confidence in the scale's reliability (Cronbach, 1951; Chandra et al., 2024). Furthermore, we conducted additional analyses to support the scale's reliability. The split-half reliability, as measured by the Spearman-Brown coefficient, yielded a value of 0.821 and Guttman Split-Half Coefficient value is 0.809. Additionally, the Pearson correlation coefficient, which measures the consistency of responses across the scale items, resulted in a value of 0.733. These results further validated the strong consistency of the scale's items, reinforcing the reliability of our measurement instrument (Nunnally, 1978; Chandra et al., 2024).

Content validity is essential as it ensures that the items within the scale are relevant and representative of the overall content domain. The analysis of the statistical validity test for the entire assessment resulted in a score of 0.919. This score suggests a high degree of statistical validity for the test, indicating that the test effectively measures what it intends to measure with a high level of accuracy and reliability. In this study, we took several steps to establish content validity. First, we precisely and meticulously reviewed the relevant literature to identify and select items that had been used in previous research and were conceptually related to the construct of interest. This literature review helped us ensure that the selected items were theoretically sound and in line with the research domain. To enhance content validity, we actively engaged experts in extension, leveraging their extensive knowledge and experience in the field. These specialists offered invaluable insights into the suitability and inclusivity of scale items. Their feedback played a pivotal role in refining the scale for precise

Table 2. Relevancy Weightage of statements and t-value for selected items

S.No.	Statements	RW	MRS	t-value
A.	ICT Ownership			
1.	Do you have your own ICT gadgets (mobile phone / Laptop)?	0.97	2.90	1.857
2.	Do you have an internet subscription?	0.92	2.77	1.923
3.	Do you have an account on social networking platforms (Facebook, WhatsApp, Instagram, LinkedIn, etc.) for Agri-product advertisement?	0.93	2.80	1.775
4.	Do you have an account to make digital payments (Phone Pay, Google Pay, etc.) for buying Agri-inputs?	0.91	2.73	1.590*
5.	Do you have traditional ICT gadgets like Radio, T.V., F.M. Radio, etc.?	0.86	2.57	1.857
6.	Do you have an ICT-based platform in your gadgets (Meghdoot App, Mausam App, Hindi weather App, etc.) for real-time weather forecasts?	0.87	2.60	1.657*
7.	Do you have an email account?	0.87	2.60	1.789
B.	ICT Awareness			
8.	Are you aware that social networking platforms (Facebook, Instagram, Twitter, etc.) are used for Agri-product advertisements and selling products?	0.92	2.77	1.938
9.	Do you know basic ICT-based operating functions (Smart Phone, computers, laptops, files, memory, security management, etc.) for agriculture?	0.91	2.73	1.931
10.	Do you know about DD Kisan's Channel was created to disseminate Agri-information for farmers?	0.86	2.57	2.907
11.	Do you know that one time passed (OTP) is not disclosed to others?	0.88	2.63	2.931
12.	Do you know that ICT-based training programs develop digital competency among farmers?	0.87	2.60	2.938
13.	Do you know about SMS-based knowledge-sharing platforms for Agriculture among farmers?	0.89	2.67	1.938
14.	Do you know about video conferences used for communication with experts on advice on crop cultural practices?	0.89	2.67	2.092
15.	Do you know that social networking platforms (Facebook, WhatsApp, Instagram, LinkedIn, etc.) are used for Agri-product advertisements?	0.92	2.77	2.082
16.	Do you know about Krishi Vani Programmers for agricultural activities?	0.84	2.53	1.992
C.	ICT Accessibility			
17.	Do you have access to ICT gadgets (Meghdoot App, Mausam App, Hindi weather App, etc.) for real-time weather forecasts?	0.88	2.63	1.991
18.	Do you have a communication with an expert for advice on crop management practices among farmers?	0.91	2.73	1.938
19.	Do you access internet facilities in your working areas?	0.91	2.73	1.991
20.	Do you access cost-effective & affordable internet facilities?	0.92	2.77	1.992
21.	Do you reach affordable ICT gadgets (Mobile phones, laptops, etc.) for Agriculture?	0.90	2.70	1.991
22.	Do you call Kisan Call Center at the national toll-free number 1800-180-1551?	0.88	2.63	2.064
23.	Do you access e-commerce platforms for Digital Agri-marketing (e-NAM, AGMARKNET, etc.) among farmers?	0.87	2.60	1.992
24.	Do you have access to digital payment Apps (Google Pay, Phone Pay, etc.) for agriculture?	0.90	2.70	2.159
25.	Do you reach Krishi Gyan mobile App that provides a single window platform for farmers?	0.90	2.70	1.992
26.	Do you have reach on ICT- based platforms (Meghdoot App, Mausam App, Hindi weather App, etc.) for real-time weather forecasts?	0.90	2.70	1.992
27.	Do you access a user-friendly mobile-based application (m-Kisan App, e-NAM, Kisan Suvidha App, etc.)?	0.88	2.63	1.993
D.	ICT use			
28.	Do you call to Kisan Call Center for expert advice for agricultural problem-solving?	0.88	2.63	1.993
29.	Do you use Decision Support System for agricultural problem-solving?	0.96	2.87	1.990
30.	Do you use an ICT-based e-service provider platform (m-Kisan portal e-NAM, m-Kisan, & Kisan Suvidha App, etc.)?	0.91	2.73	1.991
31.	Do you use social networking platforms (Facebook, WhatsApp, Instagram, etc.) for Agri-product advertisements and marketing?	0.91	2.73	1.990
32.	Do you use Krishi Gyan mobile App for a single window gateway for farmers?	0.88	2.63	2.083
33.	Do you use e-commerce platforms (e-NAM, AGMARKNET, etc.) for marketing?	0.90	2.70	1.991
34.	Do you use a digital payment app (Google Pay, Phone Pay, etc.)?	0.94	2.83	1.990
35.	Do you use an ICT- based platform (Meghdoot App, Mausam App, Hindi weather App, etc.) for real-time weather forecasts?	0.87	2.60	1.992
36.	Do you watch the DD Kisan YouTube Channel on Agriculture for Farmers?	0.88	2.63	2.324
37.	Do you use ICT-based expert advice on crop management practices in Agriculture?	0.86	2.57	1.992
38.	Do you use mobile phone services for multi-dimensional benefits for agricultural development?	0.87	2.60	2.116
39.	Do you visit Information Kiosks (Common Services Centers) for e-Agri-services?	0.88	2.63	1.991
40.	Do you listen to Krishi Vani Programmers for agricultural activities?	0.90	2.70	1.993

Note: Criteria for statement selection= RW>0.85, MRS>OMRS, *OMRS i.e.,2.54, cutoff point for t-value ≥1.75, * t-value < 1.75 i.e., Rejected measurement of the intended construct. Through a meticulous blend of literature review and expert consultation, we have fortified the content validity of our measurement tool. These collaborative efforts guarantee that the scale items are both conceptually and practically pertinent to the research domain, thus bolstering the instrument's validity (Polit and Beck, 2006, Chandra, et. al.2024). The results of our reliability analyses, as well as the steps taken to establish content validity, provide a strong foundation for the validity of our measurement instrument. These procedures are essential for ensuring that the data collected in our study are not only consistent but also accurately represent the construct under investigation, thus enhancing the overall quality of our research (Chandra et al., 2024).

CONCLUSION

This index provide a solid groundwork for future research into the complex landscape of ICT inequalities affecting farmers. While numerous previous studies have explored the broader concept of the digital divide, this research specifically focuses on the unique challenges and disparities faced by farmers in utilization of digital tools and technique. From the farmers' perspective, ICT inequality in agriculture highlights the significant disparities in access to and usage of digital technologies within the farming community. These inequalities impact their ability to leverage information and communication technologies for improving productivity and competitiveness in the agricultural sector. Moreover, the insights derived from this study serve as a valuable resource for decision-makers in agricultural. Study plays a critical role in addressing the digital gap within the farming community.

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