Plant Archives Vol. 26, No. 2, 2026 pp. 1101-1108 e-ISSN:2581-6063 (online), ISSN:0972-5210

Plant Archives

Journal homepage: http://www.plantarchives.org

DOI Url : https://doi.org/10.51470/PLANTARCHIVES.2026.v26.no.2.149

DEVELOPMENT AND VALIDATION OF A DIGITAL TRANSFORMATION INDEX FOR ASSESSING DIGITAL READINESS OF KRISHI VIGYAN KENDRAS

Praneeth Machapathri*, Bhaskaran A., Manisha M., Shaik Humera Tabbassum, Harini D., Vinutha M., Rohini B. and Shaik N. Meera

ICAR-Agricultural Technology Application Research Institute (ATARI), Hyderabad, Telangana, India

*Corresponding author E-mail: mpraneeth95@gmail.com

(Date of Receiving-07-06-2026; Date of Revision-30-08-2026; Date of Acceptance-07-09-2026)

ABSTRACT

The Krishi Vigyan Kendra (KVK) system, comprising 731 district-level agricultural extension institutions across India, plays a pivotal role in disseminating agricultural technologies and delivering frontline extension services. The rapid advancement of digital technologies has created an urgent need for a systematic and evidence-based assessment of the digital readiness of these institutions. This paper presents the conceptual and methodological framework for the development and statistical validation of a Digital Transformation Index (DTI) designed to assess the digital readiness of KVKs. A census-based digital survey was administered to all 731 KVKs functioning under the eleven ICAR–Agricultural Technology Application Research Institutes (ATARIs), yielding 682 valid responses. The DTI was constructed from six thematic components, namely Digital Infrastructure, Digital Content and Resources, Digital Literacy among KVK Staff, Digital Extension Services, Awareness of Emerging Technologies, and Integration of Emerging Technologies, comprising 41 indicators. Indicator scores were standardized using Min-Max normalization, aggregated using equal weighting within components, and weighted across components using Principal Component Analysis. Statistical validation demonstrated satisfactory reliability and construct validity of the framework. A four-category classification system, ranging from Foundational Readiness to Strategic Transformation, was developed to facilitate institutional benchmarking. The proposed framework represents the first nationally representative composite index for assessing the digital readiness of the Indian KVK system and provides a transparent, replicable, and empirically grounded approach for evaluating digital readiness across agricultural extension institution.

***Key ords*:** Digital Transformation Index, Krishi Vigyan Kendra, ATARI, Composite Index, ICT in Agriculture

Introduction

Agricultural extension systems play a pivotal role in transferring scientific knowledge from research institutions to farmers and supporting technology adoption in agriculture. In India, this function is institutionalized through the Krishi Vigyan Kendra (KVK) network, a nationwide network of district-level agricultural extension institutions operating under the Indian Council of Agricultural Research (ICAR) through eleven Agricultural Technology Application Research Institutes (ATARIs) (Singh *et al*., 2012; ICAR KVK Portal, 2025). Over time, KVKs have evolved from training-oriented centres to multifunctional institutions responsible for technology assessment, frontline demonstrations, farmer capacity building, and extension advisory services (Sahoo *et al*., 2021).

Agriculture is undergoing rapid digital transformation through the increasing use of mobile applications, precision farming technologies, remote sensing, cloud platforms, and data-driven advisory systems (Chourad *et al*., 2024; Miller *et al*., 2025). These technologies have expanded the potential for improving extension outreach and decision support (Sen *et al*., 2025). However, the effectiveness of digital agriculture depends not only on

technology availability but also on the institutional readiness of extension organizations, including infrastructure, connectivity, organizational support, and human competencies (Eastwood *et al*., 2019; Klerkx *et al*., 2019). Despite these advances, disparities in digital infrastructure and institutional capacity continue to influence the quality and reach of ICT-enabled extension services across India (TRAI, 2026). Consequently, digital advisory services remain unevenly distributed, limiting their accessibility to many agricultural households (Thirumal *et al*., 2026).

Digital literacy among extension personnel is a key determinant of effective digital service delivery. Access to training, technical competence, and institutional support shape the extent to which digital tools are integrated into professional practice (Adithyan *et al*., 2025; Aranguri *et al*., 2025; Singh *et al*., 2026). Similar constraints reported across extension systems in developing countries indicate persistent structural and capacity-related barriers to digital uptake (Choruma *et al*., 2024; Dujali *et al*., 2025). At the same time, social media platforms such as WhatsApp, Facebook, YouTube, and Telegram are increasingly being used for agricultural information dissemination, farmer engagement, and peer-to-peer learning (Ramavhale *et al*., 2024).

Awareness and operational integration of emerging technologies, including artificial intelligence, drones, Internet of Things, remote sensing, cloud computing, and data analytics, are increasingly recognized as indicators of digital maturity in agricultural organizations (Trendov *et al*., 2019; Dhanaraju *et al*., 2022; Lajoie-O'Malley *et al*., 2020). Contemporary digital-maturity frameworks therefore emphasize that institutional digital transformation is multidimensional and should be assessed across technological, organizational, and human-capacity domains (Hohagen & Wilkens, 2025). Composite indices provide a systematic framework for integrating diverse indicators through normalization, weighting, and aggregation procedures (Nardo *et al*., 2008).

Evidence from the literature indicates that institutional digital readiness in agricultural extension is shaped by interconnected dimensions, including digital infrastructure, communication systems, staff competencies, technology-enabled advisory services, awareness of emerging technologies, and their operational integration (Chounta *et al*., 2024; Skargren *et al*., 2025; Eastwood *et al*., 2019; Klerkx *et al*., 2019; Hohagen & Wilkens, 2025). These dimensions constitute the conceptual foundation of the Digital Transformation Index developed in the present study.

Despite growing research on digital agriculture and ICT adoption, systematic and nationally representative evidence on the digital readiness of frontline agricultural extension institutions remains limited. Existing studies are often geographically restricted, farmer-centric, or focused on isolated indicators rather than comprehensive institutional assessment. Furthermore, most available studies emphasize technology adoption by farmers rather than the institutional readiness of extension organizations responsible for technology dissemination. Within the Indian extension system, no nationally representative composite framework has been developed and statistically validated for assessing the digital readiness of the entire KVK network. To address this gap, the present study develops and statistically validates a Digital Transformation Index (DTI) that provides a transparent, reliable, and replicable framework for assessing institutional digital readiness across the Krishi Vigyan Kendra network in India.

Materials and Methods

Research Design

The study employed a cross-sectional, census-based institutional survey design to assess the digital readiness of Krishi Vigyan Kendras (KVKs) across India during 2025–26. Quantitative data were collected for the construction of the Digital Transformation Index (DTI) and for comparative assessment across institutions. A questionnaire also included a small number of open-ended questions to capture contextual information on digital extension initiatives and institutional support requirements. These responses were used only for qualitative interpretation and were not included in the computation of the DTI.

Study Universe and Data Collection

The study universe comprised all 731 KVKs functioning under the administrative jurisdiction of the eleven ICAR–Agricultural Technology Application Research Institutes (ATARIs). A census approach was adopted to ensure complete institutional coverage. The structured baseline questionnaire was administered digitally through Google Forms to all KVKs, with responses obtained from the Head of the KVK in consultation with relevant Subject Matter Specialists. Data received from 682 KVKs were complete and were retained for index development and statistical validation.

Instrument Development and Structure

The survey instrument was developed through a multi-stage process involving review of literature on digital transformation, digital maturity, ICT adoption in agriculture, and institutional digital-readiness assessment. The preliminary instrument was examined by agricultural

Table 1: Components and Indicator Domains of the Digital Transformation Index.

S. No	Component	Indicator Domains Included
1.	Digital Infrastructure	Digital Devices and Equipment, Audio-Visual Equipment, Internet Connectivity, IT Personnel and Maintenance, Power Backup, KVK Website, Social Media Presence
2.	Digital Content and Resources	Digital Tools Used and Farmer Reach, Digital Content Creation
3.	Digital Literacy among KVK Staff	Basic Digital Literacy, Advanced Digital Skills, Understanding of Artificial Intelligence
4.	Digital Extension Services	SMS Services, WhatsApp Groups, Digital Farmer Groups and Online Communities
5.	Awareness of Emerging Technologies	Awareness of AI, Machine Learning, Blockchain, IoT, Drones, Precision Agriculture, Remote Sensing, Decision Support Systems, Cloud Computing, Big Data and Analytics, Robotics, VR/AR, Digital Platforms, and Mobile Applications
6.	Integration of Emerging Technologies	AI and Machine Learning, IoT, Blockchain, Drone Technologies, Cloud Computing and Big Data, Precision Agriculture, Remote Sensing, Augmented Reality (AR) and Virtual Reality (VR), Robotic Technologies, Big Data and Analytics, Digital Marketing Tools, Mobile Applications

extension scientists, ICT specialists, and senior KVK experts to assess the relevance, clarity, and contextual suitability of the indicators, and revisions were made accordingly.

The final questionnaire comprised ten sections, including general institutional information (Section 1), quantitative data across the six DTI components (Sections 2 to 7), perceived impact of fourteen emerging technologies on KVK activities (Section 8), state-specific digital-extension strategies (Section 9), and recommendations on the support needed to strengthen digital readiness (Section 10). The instrument incorporated binary, ordinal, range-based, cumulative multi-select, and open-ended response formats aligned with the constructs measured, thereby enhancing survey accuracy and reliability.

Digital Transformation Index Framework

The Digital Transformation Index (DTI) was developed as a composite measure for the systematic, comparative assessment of KVK digital competencies, grounded in a clear conceptual framework defining the dimensions to be measured before indicators were selected (Nardo *et al*., 2008). This framework emerged from a review of literature on digital transformation, digital maturity, ICT adoption in agriculture, and institutional readiness, with particular attention to studies emphasizing infrastructure, digital resources, human competencies, service delivery, and technology adoption within public-sector institutions, and was further refined through discussion with agricultural extension scientists and KVK experts to ensure its relevance to the Indian context. This process resulted in the identification of six thematic components representing the core dimensions of KVK digital competencies. Table 1 presents these components and their constituent indicator domains.

Digital Infrastructure (DI)

Digital Infrastructure represents the availability, adequacy, and functional efficiency of physical, technological and institutional digital facilities that support ICT-enabled extension activities in a Krishi Vigyan Kendra. This construct was operationalised through seven indicators, namely digital devices and equipment, audio-visual facilities, internet connectivity, IT support and maintenance, power backup, KVK website infrastructure, and institutional social media presence.

Digital devices and equipment encompassed six categories of essential digital hardware. The availability of each device category was assessed using a six-point ordinal scale ranging from no availability to more than ten units, resulting in a maximum score of 30. Audio-visual facilities comprised 11 components related to training, communication, and digital content delivery. Each available component was assigned a score of one, resulting in a maximum score of 11.

Internet connectivity was assessed using four indicators, namely availability, type of connection, internet speed and connection stability. Availability was assessed using binary scoring. Connection type was assessed on a six-point scale ranging from telephone modem to fibre optic broadband. Internet speed was assessed using a four-point ordinal scale based on bandwidth, while stability was rated from 0 for unstable to 3 for stable connectivity. The combined maximum score for internet connectivity was 14.

Institutional IT Personnel and maintenance were assessed through availability of dedicated IT personnel, servicing and maintenance practices, frequency of equipment upgradation, and cybersecurity measures. IT personnel were scored dichotomously, whereas maintenance and equipment upgrades were scored on four-point ordinal scales and cybersecurity measures were scored on a three-level protection scale. The maximum score was 9. Power backup facilities were assessed using binary scoring, based on the availability of uninterrupted power support (UPS systems, Generator or solar based support).

Website infrastructure was evaluated based on website availability, functionality across 32 predefined features, and frequency of content updates using binary and ordinal scoring, resulting in a maximum score of 36. Institutional social media presence was assessed across 13 digital communication platforms using an ordinal scale reflecting platform adoption and audience reach, with a maximum attainable score of 91.

The overall Digital Infrastructure Score was derived by summing all seven indicators, resulting in a maximum attainable score of 193.

Digital Content and Resources (DCR)

Digital Content and Resources referred to the extent to which a KVK creates, curates, and disseminates agricultural information through digital platforms. Two indicators were included. The first indicator, Digital Tools Used and Farmer Reach, assessed the use of 17 digital tools and platforms supporting agricultural information dissemination and advisory services. Each tool was scored using an eight-point ordinal scale based on the extent of farmer reach, resulting in a maximum score of 119. The second indicator assessed digital content creation across multiple digital formats. This indicator was measured using binary scoring, resulting in a maximum score of one. The cumulative Digital Content and Resources score ranged from 0 to 120.

Digital Literacy among KVK Staff (DL)

Digital Literacy among KVK Staff refers to the level of digital competence demonstrated by KVK personnel in the effective use of digital technologies for professional activities. This component was operationalized using three indicators assessed on a four-point ordinal scale. Basic Digital Literacy measured the proportion of staff proficient in the use of computers, smartphones, email, and basic software. This indicator was assessed using a four-point ordinal scale representing increasing levels of staff competency, with a maximum score of 3. Advanced Digital Skills assessed staff proficiency in data analysis software, digital content creation, and digital platform management using the same four-point ordinal scale, with a maximum score of 3. Understanding of Artificial Intelligence assessed staff awareness and understanding of artificial intelligence, machine learning, deep learning, and their agricultural applications using the same four-point ordinal scale, with a maximum score of 3. The cumulative Digital Literacy score ranged from 0 to 9.

Digital Extension Services (DES)

Digital Extension Services refers to the operational use of digital communication platforms and online interaction channels for delivering advisory services, technical information, and extension support to farmers. Three indicators were assessed, namely SMS services, WhatsApp groups, and other digital farmer groups or online communities. Each indicator included a service-quality or engagement dimension and an annual farmer-reach dimension. SMS services were scored as 0 for not provided, 1 for need-based services, and 2 for regular and comprehensive services. WhatsApp groups were scored as 0 for not organized, 1 for low engagement, and 2 for active and well-managed groups. Other digital farmer groups and online communities were scored as 0 for no participation, 1 for active participation, and 2 for active participation with knowledge sharing. Annual farmer reach for all three indicators was assessed using an eight-point ordinal scale ranging from no farmers reached to more than 5,000 farmers. The cumulative Digital Extension Service Score ranged from 0 to 27.

Awareness of Emerging Technologies (AET)

Awareness of Emerging Technologies refers to the extent to which KVK scientists are informed about contemporary digital and smart-agriculture technologies relevant to research, extension, and farm advisory services. This component assessed the proportion of KVK scientists aware of 14 emerging technologies. Awareness was measured using a six-point ordinal scale representing increasing levels of staff awareness, with scores ranging from no awareness to more than 70 percent of scientists being aware of the technology. The cumulative Awareness of Emerging Technologies score ranged from 0 to 70.

Integration of Emerging Technologies (IET)

Integration of Emerging Technologies refers to the extent to which advanced digital technologies are actually used, promoted, demonstrated, developed, experimented with, or incorporated into the operational activities of a KVK. This component assessed technology integration across 12 emerging technology domains. Each technology domain was first assessed through a binary adoption item followed by a second item capturing the specific

Table 2: Category-wise Classification of KVKs Based on DTI Scores.

Category	Stage	Description
A	Foundational Readiness Stage	Basic or fragmented digital infrastructure, limited device availability, low staff digital literacy, minimal digital extension services, limited wareness of emerging atechnologies, and little to no technology integration
B	Capacity Strengthening Stage	Essential digital infrastructure established, selective use of digital tools, improving staff digital literacy, basic digital extension services such as SMS and WhatsApp, and growing but limited technology integration
C	Operational Integration Stage	Functional digital infrastructure, active digital extension services with substantial farmer reach, moderate awareness of emerging technologies, and partial integration of technologies such as drones, IoT, precision agriculture, and cloud platforms
D	Strategic Transformation Stage	Robust digital infrastructure, institutionalized and data-driven digital extension services, high awareness of emerging technologies, and strategic integration of advanced tools including AI/ML, IoT, big data, precision agriculture, and VR/AR into research, extension, and advisory workflows

applications, devices, or use cases associated with it, with each selected item contributing one additional score. The maximum possible scores for the individual technology domains were 9 for artificial intelligence and machine learning, 7 for the Internet of Things, 6 for blockchain technology, 10 for drone technologies, 7 for cloud computing and big data technologies, 7 for precision agriculture, 8 for remote sensing technologies, 6 for virtual reality and augmented reality, 10 for robotic technologies, 11 for big data and analytics, 8 for digital marketing tools, and 8 for mobile applications. The cumulative Technology Integration Score carried a maximum possible value of 97.

Scoring and Normalization Procedure

The six DTI components were measured on different scales. Therefore, Min–Max normalization was used to convert all indicator scores to a common scale ranging from 0 to 1 before aggregation. Min–Max normalization was preferred because it preserves the relative distribution of the original data while transforming all indicators to a common unit-free scale suitable for composite index construction (Mazziotta & Pareto, 2022). The normalized score for each indicator was calculated as:

$$N_i = \frac{R - R_{min}}{R_{max} - R_{min}}$$

Where,

N_i is the normalized score for the i^{th} indicator, R is its raw score, and R_{min} and R_{max} are the minimum and maximum observed scores for that indicator. The normalized indicator scores within each component were aggregated using equal weighting to derive the component score:

$$C_j = \frac{\sum_{i=1}^{n} N_i}{n}$$

Where,

C_j is the score of the j^{th} component, N_i is the normalized score of the i^{th} indicator, and n is the number of indicators under that component. Equal weighting was adopted at the indicator level because no theoretical or empirical evidence was available to justify differential weights among indicators (Nardo *et al.*, 2008), who advocate equal weighting when objective evidence for alternative weighting schemes is unavailable.

Computation of the Digital Transformation Index (DTI)

The overall DTI score for each KVK was obtained by weighted aggregation of the six normalized component scores:

$$DTI = \sum_{j=1}^{m} (W_j \times C_j)$$

Where,

DTI is the Digital Transformation Index score, W_j is the PCA-derived weight of the j^{th} component, and C_j is its normalized score.

Categorization of KVKs

To facilitate interpretation, KVKs were classified into four categories based on their component wise scores and overall DTI score, using the quartile classification method, with category boundaries set at the first quartile (Q1), the median (Q2), and the third quartile (Q3) of the observed score distribution. This approach was adopted because it classifies institutions according to the observed distribution of scores rather than predefined or arbitrary thresholds (Sharma, 2005). The four categories are presented in Table 2. The same classification procedure was applied independently to each DTI component, enabling component-wise identification of institutional

strengths and digital competency gaps across KVKs.

Results and Discussion

This section presents the statistical evaluation of the Digital Transformation Index framework, including derivation of component weights, assessment of reliability and validity, and evaluation of its methodological robustness.

Derivation of Component Weights Through Principal Component Analysis

Principal Component Analysis was employed because factor loadings reflect the relative contribution of each component to the overall variance, thereby providing an objective and data-driven alternative to expert-assigned weights (Field, 2018).

The Kaiser-Meyer-Olkin measure of 0.812 indicated good sampling adequacy, and Bartlett's Test of Sphericity was highly significant ($\chi^2 = 736.480$, df = 15, $p < .001$), confirming that the correlation matrix departed meaningfully from an identity matrix. Together, these results indicate that the dataset was appropriate for PCA and supported extraction of an underlying latent dimension (Field, 2018).

PCA yielded a single dominant component with an eigenvalue of 2.641, explaining 44.02 percent of the total variance. All remaining components had eigenvalues below one and were not retained under Kaiser's criterion. The retained component reflects the common latent dimension underlying institutional digital transformation among KVKs.

Principal Component Loadings and Derived Component Weights

All six DTI components showed positive and substantial loadings on the retained component, indicating that each component contributed meaningfully to the underlying construct of institutional digital transformation (Table 3).

Based on these normalized weights, the operational equation used for DTI computation was:

DTI = (0.155 × DI) + (0.177 × DCR) + (0.168 × DL) + (0.173 × DES) + (0.162 × AET) + (0.165 × IET)

The principal component loadings were converted into weights for each DTI component using the following expression:

$$W_j = \frac{L_j}{\sum_{j=1}^{m} L_j}$$

Where,

W_j is the weight assigned to the j^{th} component, L_j is the principal component loading of the j^{th} component and m is the total number of components. The sum of component loadings was 3.978, and the resulting normalized weights summed to 1.000, confirming appropriate proportional scaling across all six DTI components.

Table 3: Principal Component Loadings and Derived Component Weights.

Sr.	Component	LD	WT
1.	Digital Infrastructure	0.615	0.155
2.	Digital Content and Resources	0.705	0.177
3.	Digital Literacy among KVK Staff	0.670	0.168
4.	Digital Extension Services	0.689	0.173
5.	Awareness of Emerging Technologies	0.643	0.162
6.	Integration of Emerging Technologies	0.656	0.165
LD: Loading; WT: Weight			

DTI values ranged from 0 to 1, with higher values indicating greater institutional digital readiness and digital transformation. PCA-derived weights were adopted to reflect the empirical contribution of each component to the overall construct rather than relying on subjective expert judgment, thereby strengthening the statistical validity and reproducibility of the index (Mazziotta & Pareto, 2024). Descriptive statistics, including means, standard deviations, and quartiles, were computed for all component scores and the overall DTI using IBM SPSS Statistics, whereas Google Sheets was used for index computation and data management.

Reliability Analysis

Internal consistency reliability of the DTI framework was assessed using Cronbach's alpha in IBM SPSS Statistics based on the normalized scores of the six DTI components. The Cronbach's alpha coefficient was 0.732 and the standardized alpha coefficient was 0.745. Both values exceeded the commonly accepted threshold of 0.70, indicating satisfactory internal consistency among the six components and supporting the reliability of the DTI framework for composite-index construction and comparative assessment across KVKs.

Validity of the Instrument

Validity of the DTI framework was examined through content and construct validity procedures. Content validity was established during instrument development through an extensive review of literature and expert evaluation by agricultural extension scientists, ICT specialists, and senior KVK experts, confirming the relevance, clarity, comprehensiveness, and contextual suitability of the selected indicators. Construct validity was supported by the Principal Component Analysis results presented in Section 4.1. The satisfactory KMO statistic, significant Bartlett's Test of Sphericity, extraction of a single dominant

component, and positive component loadings collectively confirmed that the six DTI components represented a common latent construct of institutional digital transformation.

Collectively, the PCA, reliability, and validity analyses demonstrate that the Digital Transformation Index is a statistically robust and methodologically sound framework for assessing institutional digital readiness across Krishi Vigyan Kendras. The framework therefore provides a reliable basis for subsequent application of the DTI to evaluate institutional digital transformation and compare digital readiness across KVKs.

Conclusion

This study developed and statistically validated a Digital Transformation Index (DTI) as a comprehensive framework for assessing the digital readiness of Krishi Vigyan Kendras (KVKs) across India. The framework integrates six components, namely Digital Infrastructure, Digital Content and Resources, Digital Literacy among KVK Staff, Digital Extension Services, Awareness of Emerging Technologies, and Integration of Emerging Technologies, providing a multidimensional approach to evaluating institutional digital transformation within the agricultural extension system. The DTI was developed using a systematic methodology involving indicator standardization through Min–Max normalization, equal weighting of indicators within components, and Principal Component Analysis for deriving objective component weights. The framework demonstrated satisfactory statistical performance, with acceptable sampling adequacy, internal consistency, and construct validity, supporting its reliability as a composite measure of institutional digital readiness. The quartile-based classification further provides a practical approach for benchmarking KVKs according to their stages of digital transformation.

The proposed framework offers a scientifically robust and operationally relevant tool for evidence-based planning and decision-making. It enables policymakers, ATARI administrators, and KVK management to identify component-specific strengths and gaps, prioritize investments in digital infrastructure and capacity building, and monitor institutional progress over time. Beyond the KVK system, the methodological framework may also be adapted for assessing digital readiness in other agricultural extension organizations and public-sector institutions engaged in technology dissemination.

Acknowledgment

The authors gratefully acknowledge the support of the Indian Council of Agricultural Research (ICAR) and the eleven ICAR-Agricultural Technology Application Research Institutes (ATARIs) for facilitating the nationwide baseline survey on digital competencies of Krishi Vigyan Kendras (KVKs) conducted across the eleven ATARI zones in India. The authors sincerely thank all participating KVKs and the scientists, officials, and technical staff for their cooperation and support during the study.

Conflict of interest: All authors declare that they have no conflict of interest.

References

Adithyan, R., Devika V., Smitha S. and Sreedaya G.S. (2025). Bridging the digital divide: Constraints to digital literacy among joint liability groups women farmers in Kerala. *Indian Journal of Extension Education*, **61(4)**, 220-224. https://doi.org/10.48165/IJEE.2025.614RN07

Aranguri, M., Mera H., Noblecilla W. and Lucini C. (2025). Digital literacy and technology adoption in agriculture: A systematic review of factors and strategies. *Agri. Engineering*, **7(9)**, 296. https://doi.org/10.3390/agriengineering7090296

Choruma, D.J., Dirwai T.L., Mutenje M.J., Mustafa M., Chimonyo V.G.P., Jacobs-Mata I. and Mabhaudhi T. (2024). Digitalisation in agriculture: A scoping review of technologies in practice, challenges, and opportunities for smallholder farmers in sub-Saharan Africa. *Journal of Agriculture and Food Research*, **18, Article** 101286. https://doi.org/10.1016/j.jafr.2024.101286

Chounta, I.A., Ortega-Arranz A., Daskalaki S., Avouris N. and Rodriguez-Triana M.J. (2024). Toward a data-informed framework for the assessment of digital readiness of higher education institutions. *International Journal of Educational Technology in Higher Education*, **21**, **Article 59**. https://doi.org/10.1186/s41239-024-00491-0

Chourad, R., Beeraladinni D., Naik K.V., Jamdar R., Joshi A. and Deshmanya J.B. (2024). Economic impacts of digital transformation in agricultural extension services. *International Journal of Agriculture Extension and Social Development*, **7(12)**, 197-201. https://doi.org/10.33545/26180723.2024.v7.i12c.1403

Dhanaraju, M., Chenniappan P., Ramalingam K., Pazhanivelan S. and Kaliaperumal R. (2022). Smart farming: Internet of Things (IoT)-based sustainable agriculture. *Agriculture*, **12(10)**, 1745. https://doi.org/10.3390/agriculture12101745

Dujali, I., Inutan S., Bacus M., Quijano-Pagutayao A. and Sarita V. (2025). Transforming agricultural extension in the digital age: A review of ICT-based approaches and innovations. *International Journal of Research and Scientific Innovation*, **12(3)**, 840-851. https://doi.org/10.51244/IJRSI.2025.12030064

Eastwood, C., Klerkx L., Ayre M. and Dela Rue B. (2019). Managing socio-ethical challenges in the development of smart farming: From a fragmented to a comprehensive approach for responsible research and innovation. *J. of Agricultural & Environmental Ethics*, **32(5-6)**, 741-768.

Field, A. (2018). Discovering statistics using IBM SPSS statistics (5th ed.). SAGE Publications.

Hohagen, S. and Wilkens U. (2025). How to measure digital maturity in agriculture? Conceptual outline, instrument development and measurement results from German farms. *International Food and Agribusiness Management Review*, **28(5)**, 927-947. https://doi.org/10.22434/IFAMR.1027

ICAR KVK Portal (2025). About Krishi Vigyan Kendras. Indian Council of Agricultural Research. https://kvk.icar.gov.in/aboutkvk.aspx

Klerkx, L., Jakku E. and Labarthe P. (2019). A review of social science on digital agriculture, smart farming and agriculture 4.0: New contributions and a future research agenda. *NJAS-Wageningen Journal of Life Sciences*, **90-91**, 100315.

Lajoie-O'Malley, A., Bronson K., van der Burg S. and Klerkx L. (2020). The future(s) of digital agriculture and sustainable food systems: An analysis of high-level policy documents. *Ecosystem Services*, **45**, 101183.

Mazziotta, M. and Pareto A. (2022). Normalization methods for spatio-temporal analysis of environmental performance: Revisiting the Min-Max method. *Environmetrics*, **33(4)**, Article e2730. https://doi.org/10.1002/env.2730

Mazziotta, M. and Pareto A. (2024). Principal component analysis for constructing socio-economic composite indicators: Theoretical and empirical considerations. *SN Social Sciences*, **4, Article 114**. https://doi.org/10.1007/s43545-024-00920-x

Miller, T., Mikiciuk G., Durlik I., Mikiciuk M., Lobodzinska A. and Snieg M. (2025). The IoT and AI in agriculture: The time is now, a systematic review of smart sensing technologies. *Sensors*, **25(12)**, 3583. https://doi.org/10.3390/s25123583

Nardo, M., Saisana M., Saltelli A., Tarantola S., Hoffmann A. and Giovannini E. (2008). Handbook on constructing composite indicators: Methodology and user guide. OECD Publishing. https://doi.org/10.1787/9789264043466-en

Ramavhale, P., Zwane E. and Belete A. (2024). The benefits of social media platforms used in agriculture for information dissemination. *South African Journal of Agricultural Extension*, **52(2)**, 77-90. https://doi.org/10.17159/2413-3221/2024/v52n2a15342

Sahoo, A.K., Sahu S., Meher S.K., Begum R., Panda T.C. and Barik N.C. (2021). The role of Krishi Vigyan Kendras (KVK) in strengthening national agricultural research extension system in India. *In Insights into economics and management*, **8**, 112-122. B P International. https://doi.org/10.9734/bpi/ieam/v8/2453E

Sen, L.T.H., Phuong L.T.H., Chou P., Dacuyan F.B., Nyberg Y. and Wetterlind J. (2025). The opportunities and barriers in developing interactive digital extension services for smallholder farmers as a pathway to sustainable agriculture: A systematic review. *Sustainability*, **17(7)**, 3007. https://doi.org/10.3390/su17073007

Sharma, R. (2005). Statistics in social sciences. Kanishka Publishers.

Singh, K.M., Singh P., Shahi B. and Shekhar D. (2012). Role of Krishi Vigyan Kendras in agricultural extension: An overview (MPRA Paper No. 104339). Munich Personal RePEc Archive. https://mpra.ub.uni-muenchen.de/104339

Singh, S., Doharey R.K., Meena N.R., Singh R. and Singh A. (2026). Analysis and prioritization of constraints affecting ICT tools adoption among KVK personnel. *Indian Journal of Extension Education*, **62(3)**, 305-308. https://doi.org/10.48165/IJEE.623RN02

Skargren, F., Lagsten J., Hatakka M. and Garcia Ambrosiani K. (2025). Learning by assessing digital government: A case study of the digital index framework. *Transforming Government: People, Process and Policy*, **20(3)**, 595-615. https://doi.org/10.1108/TG-06-2025-0182

Telecom Regulatory Authority of India. (2026). The Indian telecom services performance indicators (January-March 2026). https://www.trai.gov.in

Thirumal, A., Babu G.S., Deepika R.B. and Harish B.P. (2026). Digital extension in agriculture: A review of WhatsApp groups for information dissemination in India. *Asian Journal of Agricultural Extension, Economics & Sociology*, **44(4)**, 125-135. https://doi.org/10.9734/ajaees/2026/v44i42916

Trendov, N.M., Varas S. and Zeng M. (2019). Digital technologies in agriculture and rural areas. *Food and Agriculture Organization of the United Nations*. https://openknowledge.fao.org/items/ba78b670-0947-4e73-ad10-091009c0dfc3