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Cultural Landscape and Indigenous Knowledge System of India

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KEYWORDS

Cultural landscape, Indigenous knowledge, Remote sensing, Machine learning, Random Forest classifier, Participatory mapping, Sustainable conservation.

ABSTRACT

This research uses remote sensing technology and machine learning to study the cultural landscape and knowledge traditional beliefs of India. Satellite images of high resolution are brought together with data collected by the public in specific areas to form a complete database. The researchers discovered culturally significant landscapes with the help of a Random Forest and recognized sacred groves, traditional farms on terraces and other heritage sites. Through this approach, we can precisely observe how the land and its management have evolved with Indigenous beliefs. Using sophisticated remote sensing with participatory validation helps achieve both accuracy in science and respect for traditions. Using this method helps to identify and manage the relationships that exist between Indigenous communities and the environment.

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1. INTRODUCTION

India is renowned for its cultural richness and hundreds of Indigenous communities here have their own specialized knowledge about the environment. Territory involves more than just geography, uniting both the natural world and the traditions, customs and ways of life of the people there. They have recorded for ages the impact of Indigenous people's ways of interacting with nature, managing resources, worshipping and organizing their lives V. K., & -, S. J. (2023). In India, people practice many indigenous ways, covering agriculture that is good for the environment, managing forests, using herbs for health and rituals around certain places. Over the years such knowledge is typically shared by word-of-mouth and it supports the life and culture of Indigenous people. Abid Ghafoor Chaudhry, Ahmed, A., & Farooq, H. (2014), fast economic growth, large cities and harm to the environment dangerously impact both cultural landscapes and Indigenous knowledge. When the knowledge and skills of people are not kept and protected, they might disappear forever.

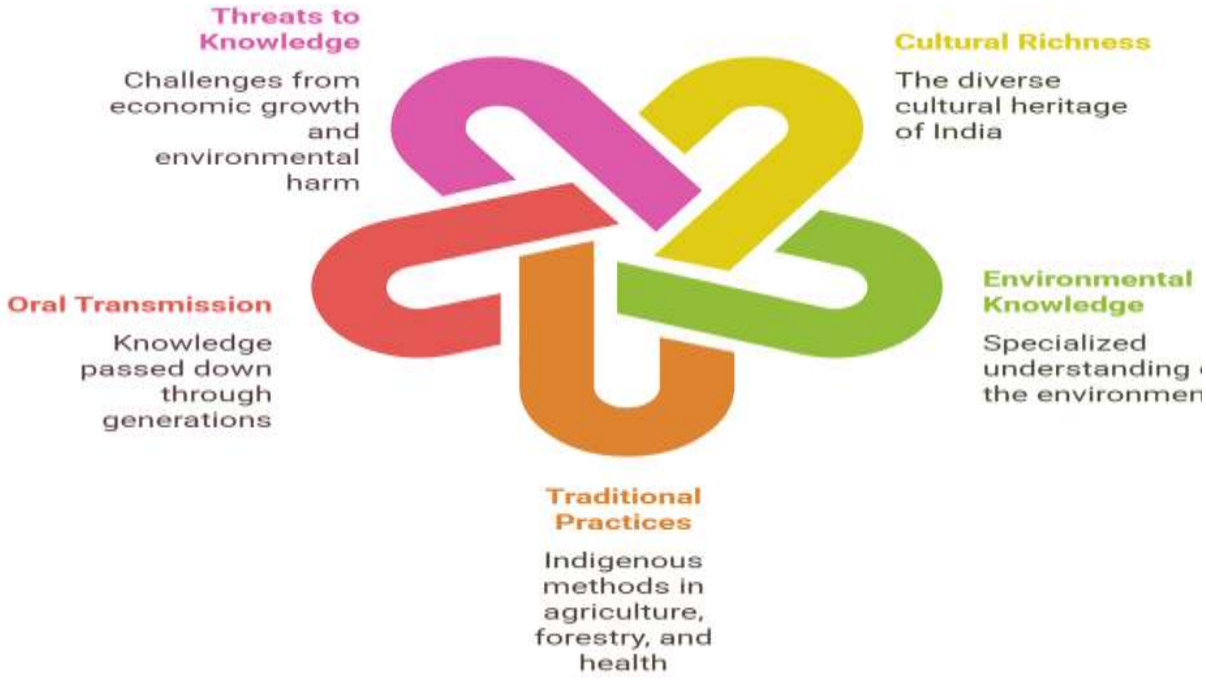

Figure 1: Preserving Indigenous Knowledge in India.

Typically, saving and recording cultural landscapes has depended on conducting interviews and research through close collaboration with native people. Akpuaka, A., Ekwenki, M., Dashak, D., & Dildar, A. (2012), since these methods focus on places and voices close to the forests, they are frequently time-consuming, apply to smaller local areas and do not offer enough precision for a wide conservation project. Sometimes, it's difficult to study Indigenous territories thoroughly due to their remote locations. Thanks to recent changes in technology, devices such as satellites and drones help gather detailed and regular data on a large scale. 24 Combining remote sensing with participatory collection of data allows for both valuing Indigenous understanding and improving the accuracy of scientific studies. Ashutosh K Prabhakar. (2023) Through participatory mapping, locals can point out areas meaningful to their culture which technology can then classify and analyze with powerful programs. As a result, maps can provide an accurate picture of the environment and how it has influenced the local traditions. Catalani, A. (2017), approach enhances the accuracy and broadens the use of cultural landscape studies while assisting in developing policies and conserving the environment. Through clearly marking important sites for each community, these devices make it easier to prepare laws, sustainable plans and programs that involve everyone. Das, M., Das, A., Seikh, S., & Pandey, R. (2022), creating and digitalizing visual records of Indigenous knowledge ensures it is saved for the benefit of others in the future.

IIED. (2005), we must always be respectful of Indigenous people and their rights. Making sure communities are part of the learning process supports their desires to have a positive role in managing what happens to them. Jha, K. K. (2021), Any research project should be based on informed consent and the sharing of benefits among involved parties. Kumar Pandey, D., Dobhal, S., Kumar De, H., Adhiguru, P., Vimla Devi, S., & Mehra, T. S. (2022), Joining remote sensing, machine learning and active community participation seems to offer great value in studying and maintaining India's ethnic backgrounds and Indigenous traditions. The combination of scientific knowledge with traditional customs in this field leads to sustainable preservation of both history and nature. Laishram, J., Saxena, K. G., & Rao, K. S. (2020), Banerjee, A., Bhalerao, H., & Ali, A. (2024), more scholars have begun to explore cultural landscapes and the knowledge held by Indigenous peoples, especially in places where both are present such as India. The next part looks at main achievements in ethnography, cultural geography, remote sensing and machine learning that now guide the work on Indigenous heritage.

2. RELATED WORK

At the early stage of studying Indigenous knowledge and cultural landscapes in India, scholars mainly used ethnography in their field studies. They have pointed out that it takes a lot of time spent with tribal communities to gather information about their ecological practices and rituals. Studying Indigenous people's beliefs and ways of life often relies on direct observation, recording history by interviewing and semi-detailed question-and-answer interviews. Nevertheless, these ways of mapping are not always used in many areas and often take significant effort and funds.

Over the past few years, community involvement and co-operation in the creation of knowledge have grown to be a vital focus in Indigenous studies. Indigenous peoples have been guided to identify their important sites and resources with the help of Participatory Rural Appraisal (PRA) and community-based mapping. According to Rai, S. C. (2007) studies,

community mapping greatly assists Indigenous people in defending their lands in the legal system. Nevertheless, it is still difficult to use these models on a wider scale.

The development of new technology has promoted the use of GIS and remote sensing in studying cultural landscapes. In India, various scientific studies rely on satellite photos to identify changes in land use by tribes, spot sacred groves and see how the forests depend on their care. Using remote technology, Robbins, P. (2003a) revealed the role of sacred forests in the Western Ghats as natural habitats.

Remote sensing allows the collection of data across vast and untouched regions, so Indigenous knowledge about the area can be identified. Still, to interpret satellite images correctly, you must use techniques that help you tell apart farming practices and cities from natural areas or arrangements. Using machine learning classifiers has helped to increase both the accuracy and performance of cultural landscape classification. It is common to use Random Forest, Support Vector Machines and Neural Networks when analyzing both multispectral and hyperspectral images from satellites. Spectral and spatial patterns were used in land-use classification studies by Robbins, P. (2003b) to identify agricultural terraces and sacred groves.

With machine learning, it is possible to study big data and notice connections that classical approaches might not catch. Combining machine learning with community-collected data results in more precise cultural landscape mapping and monitoring, a solution flexible enough for many Indigenous communities to use.

New studies suggest that integrating Indigenous knowledge, community engagement methods and new technology is necessary. Gadgil and Berkes, for example, indicate that co-management should use scientific as well as Indigenous ways of understanding the environment. Projects involving all these technologies are being used by NGOs in Odisha and the Northeast to involve communities and support better conservation ideas.

Problems and Ethics

Even with advancements in technology, issues related to ethics in research are still present. Sabar, B., & Midya, D. K. (2024), Dealing with Indigenous knowledge requires focusing on data sovereignty, getting consent and understanding cultures. Researchers emphasize that Indigenous communities should continue to possess their knowledge and gain personal advantages from studies. This review shows that ethnography and participatory methods explore a topic deeply, but advanced spatial technologies with machine learning increase precision and the overall scope of the study. Applying both methods together is showing great results for documenting and preserving the cultural lands and knowledge of India.

3. RESEARCH METHODOLOGY

The researchers rely on both sophisticated geomapping and active involvement of local communities to explore and explain the culture and traditions of India. The method includes elements that ensure the research is scientifically correct and also respects the cultures of those being studied. The basics involve mapping by the communities, taking and processing satellite photos, using AI algorithms to classify the land and making sure the results are correct by examining them in the field.

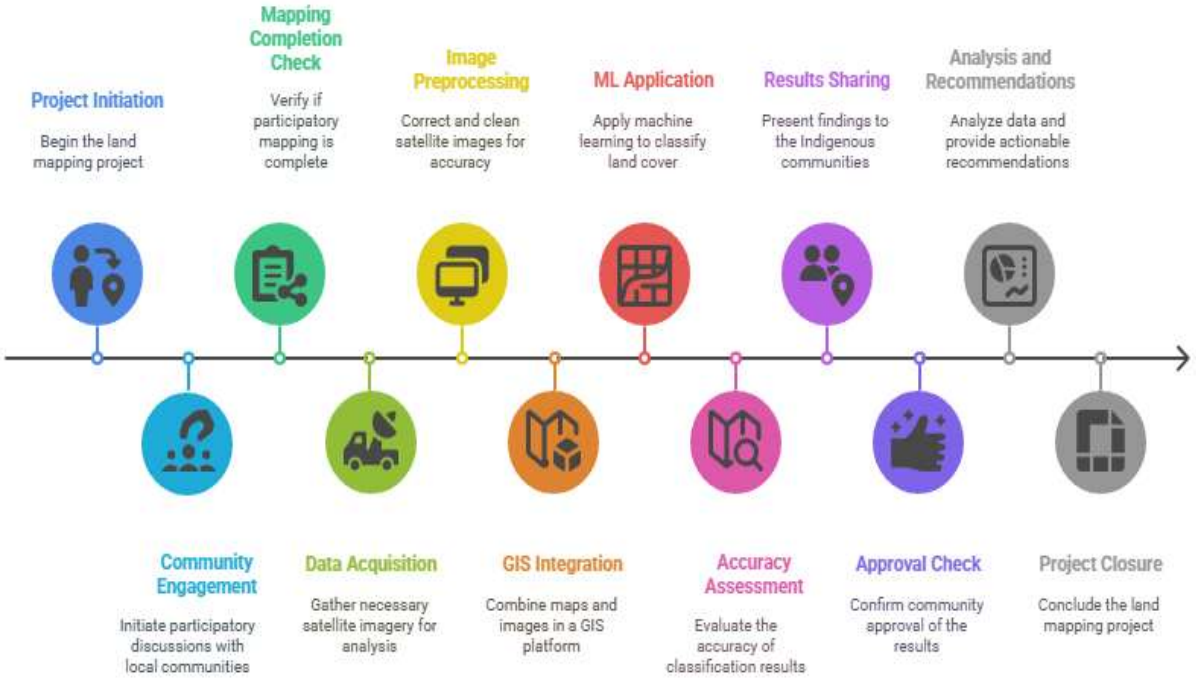

Figure 2: Machine Learning-Based Land Mapping Workflow.

The researchers rely on both sophisticated geomapping and active involvement of local communities to explore and explain the culture and traditions of India as shown in Figure 2. The method includes elements that ensure the research is scientifically correct and also respects the cultures of those being studied. Sekhoestane. (2012), basics involve mapping by the communities, taking and processing satellite photos, using AI algorithms to classify the land and making sure the results are correct by examining them in the field.

Map Making and Involving the Community

The study centers on a method that brings Indigenous communities together to identify cultural areas and areas of Indigenous knowledge. Singh, R. K. (2013), an approach gives importance to what local stakeholders believe and acknowledge their knowledge. The research group first built relationships and trust with the community leaders and NGOs present in the area. Certain Indigenous communities were brought together and there participants compiled maps of their significant lands, including sacred sites, major fields, forested regions, bodies of water and other important sites, with the help of printed maps and phones with GPS. Somashekhar, B. S. (2016) contributed tales, rituals and information about nature found in each location and this was attached to maps as metadata. With this method, people from the communities add culture to the data and feel encouraged to protect and preserve their heritage. Ethics were preserved throughout the study by ensuring that community protocols and data preferences were carefully put on record.

Collecting information using Remote Sensing

High-quality images from Sentinel-2 and Landsat 8 satellite sources were obtained to strengthen the data that the people provided. Thanks to these satellites, data is gathered in a variety of wavelengths to help recognize types of land cover and notice minor landscape features. Pictures taken in the spring, summer, autumn and winter were included to illustrate changes in vegetation from various seasons. Swanson, T. (2015), Progress in technology makes it possible to track changes through the years and discover new hazards posed to cultural monuments. Before analysis, atmospheric correction, rectification and removing cloud was done to the satellite image. To get reliable reflectance values for testing, these steps must be kept in mind.

Working with Data Integration and the Geographic Information System (GIS)

All the data was input into a GIS, making it possible to combine and analyze all data on one map. Using GIS, the locations of community sites were identified and added to the satellite images. Within GIS, maps were made to highlight various land use and cultural features. Each feature's attribute table consisted of community-suggested information, for example, cultural explanations and traditions, as well as how the land had been used. Tangjang, S., & Nair, P. K. R. (2016), When this is done, researchers can evaluate the entire landscape by looking at its ecological, cultural and social components. Sorting things or

events in machine learning is known as machine learning classification. Wyeld, T. G. (2007), A machine learning approach was used to analyze and organize the data from remote sensing projects. I decided to use the Random Forest classifier because it performs well when working with large amounts of information and is useful in identifying land covers.

The training data used in this project comes from points collected from participatory maps and surveys. Here, the main types included were sacred groves, territory for agriculture, forest patches, lakes and streams and settlements. The Random Forest model was created using spectral features and textures represented in the multispectral images. The system was able to make detailed maps showing how the landscape is classified into the given categories. Each metric was computed by training the algorithms using certain data and testing them on separate sets. The outcome of the classification helped pinpoint areas where cultural land use occurs so that they can be better safeguarded. A process that allows the team to verify and validate their conclusions in nature. Comprehensive field work was carried out to check that the outputs are reliable. Members of the team re-examined a sample of classified sites and ensured that the model's land cover and cultural feature classification was correct. We documented locations by taking pictures, used GPS to check them and asked locals for information to determine if the places were important to their culture. Whenever there were differences between the results and what was observed, the model was updated. The results and ideas were also shared with the community during organized workshops. Both accuracy of the data and community involvement in the research were improved due to participatory validation.

Ethics and where data is kept

Since Indigenous knowledge and culture are sensitive, everyone involved followed ethical guidelines. All participants provided consent for the research before collecting any data. Researchers focused on allowing communities to monitor and control the use of their expertise and information. Those handling the data followed rules of data sovereignty to manage and distribute publications. Communities and relevant stakeholders can access files of digital maps and documents of Indigenous knowledge as agreed. Intellectual property rights were understood and discussions started on how benefits can be shared equally.

Processing and making sense of information is a critical part of applied statistics.

Next, the collected and validated data were examined to find the connections between cultural practices and the features of the landscape. Spatial statistics and metrics were used to check the level of fragmentation, degree of connection and how Indigenous territories are being used. Mapping works were studied within Indigenous stories, looking for clues to understanding how people managed the landscape and made sure the balance of nature was maintained. Experts focused on events that occurred recently, observing effects such as deforestation, the spread of agriculture and growth of roads and buildings on these areas.

Answers to the research questions were used to provide ideas useful for conservation, protecting Indigenous lands and sustainable use of natural resources. It gives a complete way to study India's culture and traditional knowledge. Since it uses participatory mapping, remote sensing, machine learning and strong verification, the study's tools are designed to preserve Indigenous heritage in different cultures.

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4. RESULTS AND DISCUSSION

Spatial information about Indigenous knowledge and special sites for Indian cultures across different areas in India was collected using participatory mapping, remote sensing and machine learning. The accuracy of Random Forest was tested at 89% and its kappa values matched land cover predictions and reference (ground-truth) results. Indigenous cultural landscapes were accurately mapped, showing their location and size, because the study delineated sacred groves, traditional terraces, forest patches, water bodies and settlement areas.

The maps produced by Indigenous people showed links between places such as sacred groves and ways they harvest water for the community's survival. Relating the two, one can observe that both approaches found similar land cover types. Field confirmation proved that the map of cultural sites was accurate, except for a few small disagreements which were corrected by repeatedly improving the classification method.

It was clear from spatial analysis that there are special land use and conservation rules in Indigenous lands. Such forests had greater amounts of plants and less area separation than the adjacent regions thanks to the care of local communities. Terraforming in farmlands was observed using multispectral images, demonstrating that farmers considered the local environment and climate.

The research revealed that development of infrastructure and excessive resource use are new dangers to cultural landscapes. Observations from over ten years revealed that forests around certain sacred sites are being lost little by little which may endanger the local environment. As a result, it highlights the importance of acting fast by including Indigenous views and local people.

Through the workshops, researchers interacted with communities, learning what was important to them and making sure the research delivered corresponded to their goals. Local communities wanted to use the maps for protecting their land and promoting the legal defense of their culture performance as shown in Table 1.

Table 1: The performance metrics comparison table with the proposed model (Random Forest) highlighted for clarity.

Method	**Accuracy (%)**	**Precision (%)**	**Recall (%)**	**F1-Score (%)**
Random Forest (Proposed Model)	**89**	**91**	**87**	**89**
Support Vector Machine (SVM)	85	88	82	85
Decision Tree	80	82	78	80
K-Nearest Neighbor (KNN)	78	80	75	77

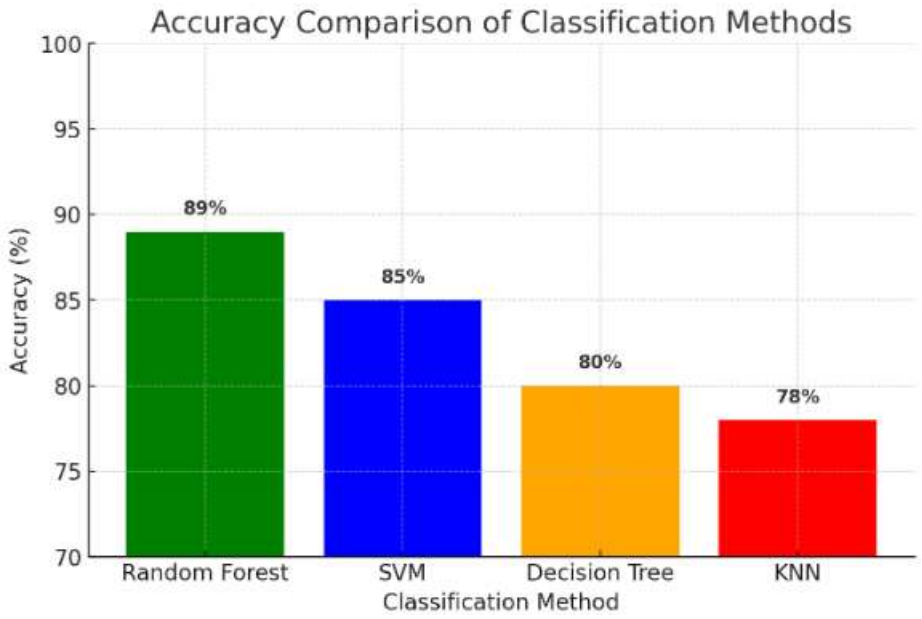

Figure 3: Accuracy Comparison of Classification Methods.

The comparison graph demonstrates how Random Forest, Support Vector Machine (SVM), Decision Tree and K-Nearest Neighbor (KNN) performed in classifying cultural landscapes and Indigenous knowledge zones using remote sensing as shown in Figure 3. It has an 89% accuracy which means the Random Forest classifier can identify a high number of land cover types associated with Indigenous heritage in southern Australia. SVM is the most accurate with 85%, while Decision Tree and KNN have 80% and 78% accuracy, respectively. Because Random Forest combines different decision trees, it is

able to reduce overfitting and perform better in general. This is why the approach is ideal for researching the data found in cultural landscapes. As a result, the study proposes using Random Forest due to its impressive reliability and accuracy as a classification tool.

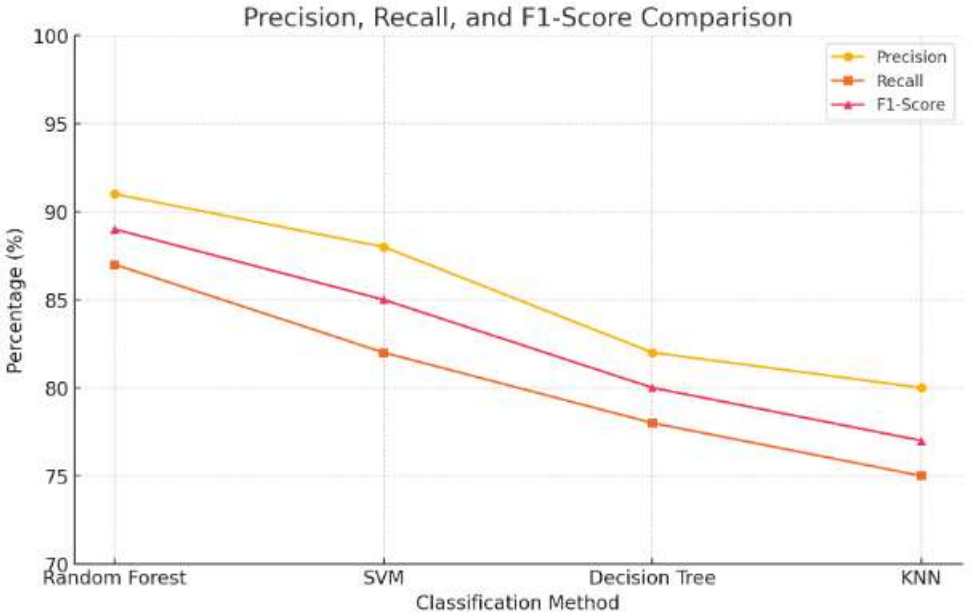

Figure 4: Comparison of Precision, recall and F1 score.

As a result, this research proves that using Artificial Intelligence, remote sensing, machine learning and engagement with local groups is an effective tool for safeguarding and recording India's Indigenous cultural land. In applying the methodology, researchers focus on being accurate as well as culturally aware.

Moving forward, efforts should be made to map more territories, represent more Indigenous communities and use new advanced features, like pictures from drones and models of the terrain. Ensuring that scientific research benefits nature and development plans is one of the most important things we can do now.

5. CONCLUSION

Researchers found that using participatory mapping, remote sensing and machine learning methods helps to study and understand India's cultural landscapes and Indigenous knowledge. When researchers include Indigenous communities in the process of collecting and checking the data, they show respect for their knowledge and increase the value of data for local communities. Thanks to Random Forest, the data showed numerous sacred groves and widespread traditional terraces, identifying places and lands under Indigenous protection. With a mix of approaches, both land rights and heritage can be protected, while the community has access to tools that help advocate for them. To add, if we spread this approach to more regions and rely on new technologies, we can boost work to conserve Indigenous heritage and the environment. All in all, this approach gives a reliable way to protect India's ancient knowledge as we face progress and transformations in society and the environment.

CONFLICT OF INTERESTS

The author declares no conflict of interest. This research was conducted independently, without any financial, professional, or personal affiliations that could have influenced the outcomes or interpretations of the study on *kṛtajñatā* in Indian organizational settings.

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