ROLE OF AI AND BIG DATA IN ENHANCING ACCESS TO TRADITIONAL INDIAN KNOWLEDGE SYSTEMS

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Abstract :

Traditional Indian Knowledge Systems (TKS/IKS)—such as Ayurveda, Siddha, Unani, folk ethnomedicine, Kriya-vidya (crafts), oral histories, and agro-ecological practices—are central to India's biocultural diversity and intangible heritage. However, this knowledge is often oral, fragmented, and context-dependent, posing significant challenges to access, preservation, and fair use. Today, Artificial Intelligence (AI) and Big Data tools hold the potential to address these challenges technically: multilingual NLP, speech-to-text, knowledge graphs, computer vision, geospatial analytics, and scalable data governance frameworks. In this review, we survey current literature and Indian initiatives, explain key AI/Big Data techniques, discuss real-world case studies (such as TKDL), and provide ethical/legal/social implications and implementation-level recommendations. The paper aims to provide a balanced, evidence-based roadmap for researchers, policymakers, and community stakeholders to responsibly digitize, analyze, and make accessible Traditional Indian Knowledge.

Keywords: Traditional Knowledge Systems, Artificial Intelligence, Big Data, NLP, Knowledge Graphs, Ethnomedicine, Data Governance, Access, Preservation.

Introduction :

India's traditional knowledge tradition (Traditional Indian Knowledge Systems – TIKS) has always been an invaluable heritage. Streams such as Ayurveda, Yoga, Siddha, Unani, Astrology, Vastu Shastra, and Folk Practices hold significance not only in the country but worldwide. But due to globalization, urbanization, and the dominance of modern science, these knowledge systems gradually became marginalized. There is a great need to systematically preserve and disseminate the oral traditions, local manuscripts, and scattered regional practices of traditional healers. In this context, modern technological tools like Artificial Intelligence (AI) and Big Data create a new possibility space.

Through AI and Big Data, vast and unstructured knowledge can be systematically organized, digitized, and analyzed. Just as the Traditional Knowledge Digital Library

(TKDL) has already set a precedent, AI-enabled databases and big data analytics can accelerate the clinical validation, pattern recognition, and cross-disciplinary integration of traditional remedies. This will help prevent biopiracy on one hand, and on the other, align this knowledge with modern healthcare and sustainable development.

AI applications such as Natural Language Processing (NLP) are helpful in translating and interpreting manuscripts in ancient Sanskrit, Pali, and regional languages. Similarly, Big Data tools can integrate millions of data points—such as folk medicine records, biodiversity databases, and patient outcomes—to create evidence-based models. This not only makes traditional knowledge accessible but also enhances its credibility and usability.

The objective of this review paper is to explore how the role of AI and Big Data can be a game-changer in the preservation, access, and utilization of traditional Indian knowledge systems. This paper will discuss technological perspectives, case studies, challenges, and future scope of AI and Big Data to develop a robust framework that integrates heritage and innovation.

Methodology — A short note on literature selection :

This review is based primarily on peer-reviewed articles, government and institutional reports, and recent technical case studies. Search keywords included "AI + traditional knowledge India", "TKDL", "ethnobotany digitization", "low-resource NLP Indian languages", and "knowledge graphs + ethnomedicine". Focus remains on recent developments (last 5 years), so as to cover both review current trends and implementation challenges. Key references include TKDL analysis, ethnobotany digitization reviews and AI-for-heritage papers.

Traditional Indian Knowledge: data types and characteristics :

The data of Traditional Indian Knowledge systems is very heterogenous:

- Oral narratives & interviews: recorded audio/video from healers, farmers, artisans.
- Manuscripts & texts: palm leaves, granthas (Sanskrit, Prakrit, regional scripts).
- Ethnobotanical records: vernacular plant names, local uses, preparation methods.
- Multimedia for crafts: stepwise videos, high-resolution photos of motifs.
- Geo-ecological observations: local phenology, microclimatic indicators, seasonal calendars.
- Community metadata: knowledge holder identity (if agreed), lineage, customary rules.

The key to all of these is that context is crucial—the meaning of a remedy is tied to the practitioner, location, and ritual context. Therefore, AI solutions must be context-aware and provenance-rich.

AI & Big Data Techniques Relevant to IKS (Technical Overview) :

Here, we will provide a concise overview of the techniques that most significantly enhance TKS/IKS :

1. **Speech-to-Text & Low-Resource ASR** : Automatic Speech Recognition models are essential for converting oral interviews to text. Coverage of regional languages and dialects in India is limited; performance can be improved with transfer learning and community-labeled datasets.
2. **Natural Language Processing (NLP)** : Named Entity Recognition (plants, ailments, places), relation extraction (e.g., "Plant X — used for — fever"), morphological analysis, and machine translation/transliteration (regional scripts → Devanagari/Latin) are crucial for making multilingual corpora searchable.
3. **Knowledge Graphs & Ontologies** : Storing entities and their relationships in graph form is ideal for provenance, reasoning, and semantic search—making cross-source linking and inference possible.
4. **Computer Vision** : CNNs and recent vision transformers are used for plant species identification (leaf/flower images), craft motif recognition, and video segmentation (craft steps).
5. **Geospatial & Remote Sensing Integration** : Cross-validating local knowledge with satellite data (phenology, land-use) can map climate impacts and resource availability.
6. **Big Data Infrastructure & Privacy-Preserving Analytics** : Scalable storage, metadata indexing, role-based access control, and techniques such as differential privacy or federated learning are helpful for sensitive datasets.
7. **Explainable AI (XAI)** : Model outputs should be explainable to cultural stakeholders—black-box recommendations do not build trust.

Implementing these techniques in hybrid human-in-the-loop workflows is considered best practice.

Case Study: Traditional Knowledge Digital Library (TKDL)—India's Model :

India's most prominent initiative, the TKDL (Traditional Knowledge Digital Library), is a centralized database housing a digitized corpus of traditional medical formulations, with the clear goal of making such formulations visible to patent offices to prevent biopiracy. TKDL converted classical texts (Sanskrit and regional) into a codified format and made them accessible to patent examiners—this model has shown practical utility in preventing the inappropriate granting of patents. The case of TKDL shows that domain-specific digitization and structured representation can provide both legal protection and global recognition. However, this has also sparked debates—questions such as data governance, community consent, and who will have access remain relevant.

Recent Developments & Pilots in India :

Some notable developments have occurred in recent years: AI tools are being used to enrich archives like TKDL, improve manuscript OCR/translation, and analyze ethnobotanical datasets. Work is also underway at national/academic labs and CSIR institutes—such as medicinal plant authentication, adulteration detection (analytical + ML methods), and digitized herbarium integration. The WHO and international bodies are also running mapping projects where the intersection of AI and traditional medicine is being systematically

reviewed. This indicates that technical adoption is progressing rapidly in India, but governance and scale-up remain challenges.

Benefits: What can we get from AI/Big Data? (Potential gains) :

1. **Improved Discoverability & Searchability** : Multilingual NLP + knowledge graphs will make oral and manuscript knowledge searchable — researchers will be able to quickly find relevant evidence.
2. **Cross-referencing & Hypothesis Generation** : Pattern discovery is possible from Big data analytics (e.g., a plant is showing similar uses in different regions → candidate for biochemical screening).
3. **Validation & Quality Control** : Image/chemical-fingerprinting + ML can make raw material authentication and adulteration detection easy — its direct benefit will be to both pharmaceuticals and local markets.
4. **Conservation & Policy Support** : Geospatial analytics linked with local knowledge can inform biodiversity conservation, seed bank priorities and climate adaptation strategies.
5. **Access for Practitioners & Youth** : Digitized training modules, AR/VR craft apprenticeships, and mobile apps will boost knowledge transfer and livelihood opportunities.

Risks, Ethical & Legal Challenges (India-specific concerns) :

1. **Biopiracy & Misappropriation** : If TK data becomes unregulated and open, it could be misused by corporations or researchers — the TKDL model has helped prevent patent misuse, but is not a universal solution.
2. **Consent & Data Sovereignty** : Knowledge holders (especially indigenous communities) must ensure prior informed consent (PIC) and data sovereignty — cultural restrictions and sacred knowledge must be respected.
3. **Decontextualization Risk** : Machine extraction can lead to context loss — a remedy's social/ritual context, if removed, could be misused.
4. **Bias & Representation** : Under-representation of low-resource languages and marginalized communities will create bias in models.
5. **Commercial Exploitation vs Benefit-Sharing** : Designing fair and equitable benefit sharing mechanisms (financial, capacity building, IP co-ownership) is challenging but essential. PMC.

Best Practices & Governance Framework (Practical recommendations) :

1. **Community-Led Collection & Co-design** : Projects should have community representatives in their leadership. Use PIC and culturally appropriate consent forms.
2. **Tiered Access & Provenance Metadata** : Maintain graduated access (public, restricted, community-only) to sensitive knowledge; Tag each record with provenance, consent terms and usage restrictions.

3. **Hybrid Human + AI Workflows** : Automated extraction followed by community experts validation — human-in-loop cycle maintains accuracy and cultural fidelity.
4. **Legal Instruments & ABS Compliance** : Follow Nagoya Protocol principles and national ABS laws; benefit sharing agreements pre-negotiated hon.
5. **Capacity Building & Infrastructure Localization** : Local institutions (libraries, universities, community archives) provide training and funds so that datasets can be sustained.
6. **Open Standards & Interoperability** : Metadata standards (Dublin Core extension for TK, ontology for ethnobotany) can be adopted so datasets can be cross-referenced.
7. **Explainability & Audit Trails** : Have human-readable explanations and audit logs with AI outputs — transparency builds trust.

Implementation Roadmap — stepwise practical plan (for institutions) :

1. **Scoping & Community Consultation** : Define scope (which communities, knowledge types) with community advisory boards.
2. **Ethics Protocols & Legal Agreements** : Draft PIC templates, ABS clauses, data-sharing MOUs.
3. **Data Collection & Digitization** : High-quality audio/video capture, manuscript scanning with DPI standards, geotagging.
4. **Annotation & Training Data** : Community-annotated corpora for ASR/NLP training; photographs with expert labeling for vision models.
5. **Model Development & Validation** : Use transfer learning/active learning for low-resource languages; iterative validation with practitioners.
6. **Deploy Access Platforms** : Multilingual search portals, researcher dashboards, mobile apps with tiered access.
7. **Monitoring & Benefit Distribution** : Track usage, ensure benefit sharing as per agreements, conduct periodic impact assessments.

Open Research Questions & Future Directions :

1. **Low-Resource Language Models** : How to create sustainable, community-owned corpora that are reusable for model training?
2. **Privacy-Preserving Techniques** : How is the practical implementation of differential privacy and federated learning on TK datasets?
3. **Formalizing Provenance Ontologies** : Standardized provenance models for TKS that capture ritual/contextual metadata.
4. **Measuring Impact** : Defining Socio-economic metrics — What real benefits are the community getting from digitization?
5. **Interdisciplinary Methods** : To standardize the hybrid methodology of Ethnography + data science.

Conclusion :

AI and Big Data technologies can play a transformative role in the accessibility,

preservation, and analysis of traditional Indian knowledge systems—but this will only be sustainable if the technological design is accompanied by strong governance, community consent, provenance tracking, and fair benefit sharing systems. Examples like TKDL have shown that structured digitization allows for legal protection and research enablement; the next step is to develop community-centric, explainable, and privacy-preserving AI frameworks that respect context and culture. If policymakers, technologists, and knowledge holders work together to establish inclusive standards and build local capacity, India's traditional knowledge can become an ethical, accessible resource for both global research and local livelihoods.

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