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Technology-Enabled Livelihood Transformation in Korwa Tribal Regions of Chhattisgarh: Geospatial and Data-Driven Perspectives Study

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Abstract
Tribal regions in India suffer from chronic vulnerabilities of livelihood, which is explained by geographical isolation, ecological sensitivity and limited access of services to both infrastructure and institutional structures. Among these, Korwa tribal areas of the State of Chhattisgarh are one of the most under studied and developmentally marginalised places, amidst sustained policy focus. In recent years, technological improvements in geographical information systems (GIS), remote sensing and data driven analytics have certainly shown great potential in creating and improving livelihood assessment, planning & governance in rural and tribal landscapes. This paper presents a comprehensive review of the available literature on Technology enabled livelihood transformation with a specific contextualization to Korwa tribal areas of Chhattisgarh. The review integrates studies related to sustainable livelihood frameworks, geospatial applications, satellite based environmental monitoring and new machine learning approaches of tribal and rural development research. Key research gaps, method limitations and future opportunities are critically identified. Grounded in the synthesized evidences, a conceptual review framework is proposed taking both livelihood assets, spatial indicators, and data driven decision support for sustainable tribal development. The present review, therefore, is dedicated to sustainable development discourse in terms of offering a systematic and technology-centric approach geared towards inclusive livelihood transformation in the ecologically sensitive and socially vulnerable tribal areas.

Keywords: Korwa Tribe, Tribal Livelihoods, Sustainable Development, GIS, Remote Sensing, Data-Driven Planning, Review Study

1. Introduction

Tribal communities form a significant proportion of the rural Indian demography and act as the central reservoirs of the ecological resources and the traditional knowledge systems [1]. Nevertheless, despite their critical functions, tribal regions continue to be disproportionately affected by poverty and livelihood insecurity over Byron, and they do face societies of social exclusion. Structural impediments, such as geographical remoteness, lack of sound infrastructure, limited market access and over-dependence on natural resources have limited the effectiveness of traditional development approaches. The Kore tribe

ethnic groups of society in Chhattisgarh exemplify such hindrances as subsistence based livelihood activity in this rate of the environmental and socio-economic instability [2].

The paradigm of sustainable development brings inclusive expansion, environmental protection, and equitable social outcomes to the fore. Realization of these aspirations within tribal precincts requires resilient and evidence-based planning instruments that could map heterogeneity space-wise and temporal dynamics. Recent advances in geospatial science, satellite remote-sensing and analytical data science have provided new methods to assess the allocation of resources, identify infrastructure gaps and survey the frailties of livelihood in spatially complex areas. Nevertheless, current work on tribal livelihoods is not synthetically developed and subsists between socioeconomic analysis and technological appraisals in isolation. This review brings together, in a systematic way, the literature collected on technology enabled livelihood transformations with special reference to the Korwa communities of Chhattisgarh. Its aim is to critically analyze the use of geospatial and data-driven approaches in tribal development research, assess the relevancy of those strategies in the Korwa context, and plan ways to move the research and policy forward.

Table 1. AI/ML applications in Tribal Livelihood Studies

AI/ML Category	Techniques	Application in Livelihood Planning	Key Benefits	Limitations
Supervised Learning	Random Forest, SVM, Decision Trees	Land-use and crop classification	High accuracy	Requires labeled data
Unsupervised Learning	K-means, Hierarchical Clustering	Vulnerability zone identification	Reveals hidden patterns	Sensitive to input variables
Predictive Analytics	Regression, Ensemble Models	Yield and income forecasting	Proactive planning	Data-intensive
AI–GIS Integration	Spatial ML models	Livelihood risk mapping	Spatial precision	Technical complexity
AI–RS Integration	Image classification, feature extraction	Environmental change monitoring	Automation & scalability	Data quality dependence

2. Literature reviews

This research examined dependency of indigenous households with forest-based livelihoods in the Bundu block of Ranchi, Jharkhand, in terms of its relation with the socioeconomic characteristics. Elaborate a multi stage random sampling design and participatory data collection techniques, study employed the correlation and multiple regression analysis techniques to study the inter-relationships. The results showed that minor forest products (fuelwood, fodder, small timber, sal leaf, lac and tooth brush sticks) comprised main sources of income with forests as the second most important livelihood contributor. The majority of socioeconomic variables showed significant positive association with forest dependency, apart from age and landholding size. Collectively, socioeconomic factors explained about 70% of the variance in forest dependency and the model indicated that family composition was the only significant influence on forest dependency. These findings have substantial implications for how targeted interventions designed for rural development interventions for indigenous communities are designed [4]. The discourse highlighted the historical fact that the forests all over India have maintained tribal community's sustainability of economic,

livelihood and sociocultural imperatives through a mosaic of forest types comprising of a plethora of both timber as well as non-timber forest products. Concurrently, unsustainable extraction, overgrazing, lack of scientific knowledge on the harvesting and increasing biotic pressures - in the form of pests, invasive species and biotic pressures like that of rare plant taxa - are mounting threats to these forest resources. These dynamics taken together point to the need for the devising and implementation of contextually appropriate management strategies to ensure long-term sustainability of resources, protection of livelihood security and promotion of the economic upliftment of forest-dependent populations [5]. This paper illustrates a stepwise approach to operationalize livelihood resilience for climate affected rural communities, based on aiming to incorporate the Sustainable Livelihood Framework with Cross-Scale Resilience Analysis. It shows that the combined framework identifies assets, processes, institutions and shocks in a systemic way that reveals the fact that changes in government policy actually have a more powerful and negative influence on rural livelihoods than climate change alone, especially when concurrent. The authors argue that this integrated approach provides a practical and standardized method for resilience analysis to be done in natural resource-dependent communities and emphasize the need to better understand the dynamic nature of complex social-ecological systems [6].

The present research evaluated provisioning ecosystem services of forest using tropical dry deciduous forest of eastern India by examining local patterns of livelihood dependency and forest resource exploitation practices at village level using survey based indices to quantify utilisation patterns. Findings showed that the most heavily relied upon resources in terms of fuelwood, timber, fodder and leaves were found with pronounced seasonal and spatial variations. The work further recorded that collection, lopping and cutting which are often carried out in unsustainable ways have been widely used extraction methods, thus highlighting the need to harmonise the forest ecosystem services with livelihood considerations. This integration, the research argues, is the key to the formulation of evidence-based policies that simultaneously protect environmental resources and help build human well-being [7]. The investigation focused on the case of small-scale afforestation and reforestation efforts on the Clean Development Mechanism within two Joint Forest Management areas of Uttar Pradesh using Sustainable Livelihood Framework to evaluate outcomes pre- and post-project implementation. Household surveys and composite capital indices were used to calculate the Sustainable Livelihood Index, which showed that, whilst evidenced marginal improvement at one site there was slight decline at the other, suggesting even after several years these carbon forestry initiatives have not achieved a substantive delivery of livelihood benefit. Consequently, the study calls for an SLI-based framework to be used to assess non-carbon outcomes in future forest carbon programmes [8]. This investigation had made an assessment of livelihood vulnerability of the tribal households to climate change in the Chhindwara and Dhar districts Central India. By combining data from short-term household surveys and long-lasting climatic data, and implementing mixed analysis techniques, such as trend, using the Standardized Precipitation Index (SPI-1), the LVI-IPCC framework and the use of multiple linear regression, researchers found that there are distinct changes in rainfall and temperature patterns. The results showed that there was moderate overall vulnerability and that vulnerability was increased for the locality of Dhar, while the contribution of income sources, extreme weather events, water access, and livelihood strategies to vulnerability was laid bare. Consequently, the study urges the need for targeted and evidence-based interventions focusing on improving the adaptive capacity and resilience of the climate vulnerable tribal communities [9]. The study estimated the vulnerability to poverty among the tribal households in Eastern India by using the household survey data in combination with some very sophisticated econometrics techniques. It found that the projected future

poverty risk was greater than the current levels of poverty; chronic illness, climate shocks and asset sales increased vulnerability; the participation in livelihood programmes slightly mitigated the risk of vulnerability; and large disparities existed among geographically disadvantaged communities. These findings highlight the need to enhance and further target social protection interventions [10].

In the present study the vulnerability of livelihood due to climate change among the Santal, Munda, Bhumij and Lodha tribal population of the West Bengal were quantified using the construction of a composite vulnerability index based on the comprehensive household survey data and subsequent beta - regression analysis. The findings show that Lodha community experiences the highest level of vulnerability that is strongly determined by factors like family size, poverty status, agricultural income, and market accessibility. These results highlight the need for policy interventions targeting socioeconomic development and improved health and educational infrastructures and food security for the support of tribal populations who depend on forests [11]. This article discusses the nature and extent of rural livelihood diversification in North-Eastern India and explains how tribal communities are engaging in diversification as a strategy of risk coping in context of low agricultural productivity and population pressure. While agriculture remains the major source of income most diversification potential is under-utilised due to rugged topography and geographical isolation. The review concludes with stressing the importance of dedicated research and policy interventions to harness the region's underutilised livelihood opportunities [12]. This study carefully arylcased long term land use and land cover change across India through the generation of decadal national scale land use and land cover maps from medium to high resolution satellite imagery assisted with on screen visual interpretation. The analysis reported region - specific trends of forest depletion in central and northeastern states, cropland expansion in western parts, peri - urban expansion, plantation growth and powerful linkage between cropping patterns and monsoon - induced precipitation. Moreover, the work showed an increased landscape detail and accuracy of the global datasets thus demonstrating the relevance of the database in the context of sustainable resource management and climate change science [13].

The study made an intensive assessment of the rural infrastructure issues using the deployment of a Public Participation Geographic Information System, detailed assessment of the system requirements, architectural design of a geolocation-based reporting interface and comprehensive usability trials in a sub sample of villages. Findings indicated most often reported deficiency was regarding the water supply and sewage management. Moreover, the data found the overwhelming use of point-centric mapping methodologies by participants. While villagers responded with a receptive attitude towards embracing the system, there were some pragmatic barriers that hindered its optimal exploitation, including the need for user training in its entirety, the requirement to streamline the interface, and the need to raise the level of communal awareness about participatory geospatial technologies [14]. The study used high-tech geospatial technologies, including Remote Sensing, Geographical Information System (GIS) and Global Positioning System (GPS), to build a comprehensive village level spatial database for planning decentralization for Salt Nomane Karimui District, Papua New Guinea. By integrating and carefully analysing infrastructure data in areas such as roads, bridges, health facilities, and schools, the research was intended to translate into evidence based decision-"making, improve service delivery, bring transparency and build local administrative capacity able to foster inclusive and efficient rural development [15]. This effect of climate change on agricultural livelihoods was the subject of this study in which an analysis was performed regarding the spatial diversity of the agricultural livelihood vulnerability to climate change in coastal Bangladesh using an integrated vulnerability index developed in the framework of the IPCC that

combines a set of indicators of multiple indicator of exposure, sensitivity and adaptive capacity. Through the use of vulnerability mapping and the construction of indices to support them, the studies showed that the central coastal districts show the highest level of risk, which can be explained by the simultaneous effects of climatic variations and socio-economic pressures. This finding highlights important geographic disparities affecting livelihoods of millions of people dependent upon agriculture [16].

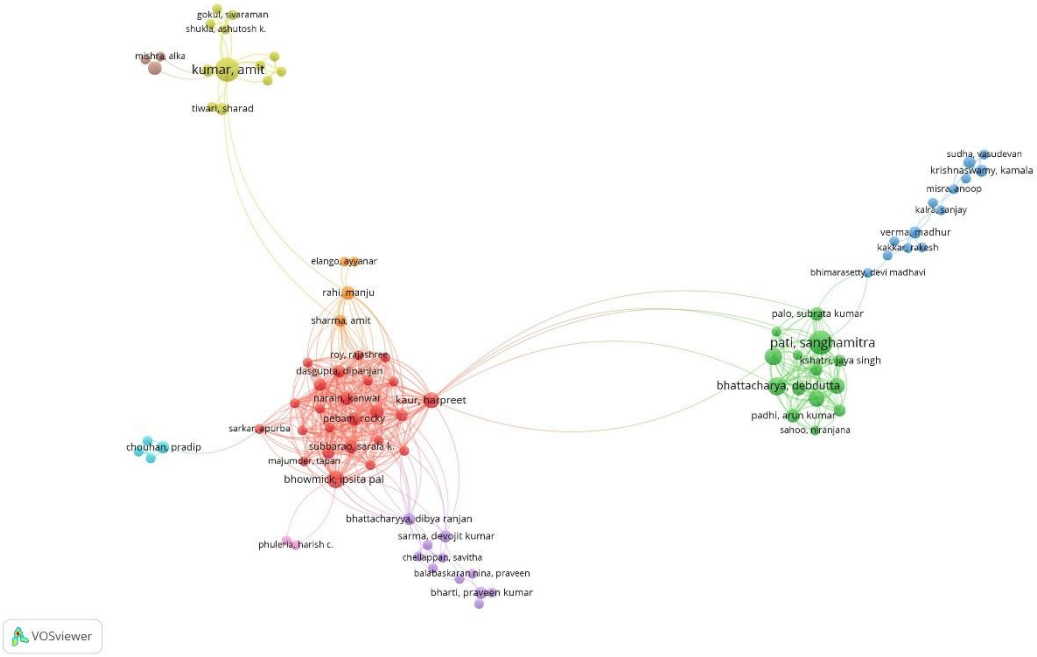

Figure 1. Authors' Interconnection Bibliographic

This research measured livelihood vulnerability among riparian communities in the western Indo conspicuous of Gangetic Plain by utilizing the Livelihood Vulnerability Index together with spatial statistical means within zones based on the space to the river. The results suggest that households located nearer to the river face greater vulnerability due to greater exposure to erosion and flooding, increased sensitivity due to lack of access to basic amenities, and lower capacity to adapt due to lower socioeconomic conditions. Spatial hotspot analyses also show clearly defined patterns of high and different levels of vulnerability; however, interventions to counter livelihood risks are needed to be geographically targeted and also stratified socially to be effective in the riverbank districts [17]. This study focused on the land-use and land-cover changes in Achanakmaar Amarkantak Biosphere Reserve using the multi-temporal satellite data to reveal the displacement of the forest ecosystem. The results showed a large amount of vegetation attrition and changes between forest types, which can be attributed to biotic stressors, overgrazing, agricultural encroachment and the invasion of exotic species. In particular, marked decline was recorded across sal-mixture forests, dense mixed forests, teak plantations and bamboo thickets highlighting the need for specific conservation intervention. The study calls for natural regeneration strategies and tight control of invasive taxa as the climax measures in therapeutic restoration of forest biodiversity and the maintenance of livelihoods, which are dependent on the tribal communities [18].

This study attempts to quantify the loss of forest cover in Indian state of Odisha due to mining activities using an analytical framework based on the Hansen Global Forest Change time-series dataset for the period between 2001 & 2019 accessed through the Google Earth Engine GE platforms. The results identify

strong district-level attrition of forests, especially in Rayagada and Koraput where the rate of annual losses is at its maximum. Furthermore, the data outline a detectable pattern, by which the expansive growth of mining operations contributes to an increasing deforestation inexorably. The geospatial methodology followed here also turns out to be an economically efficient tool to take up forest conservation programmes and to protect the livelihood of forest dependent tribal populations [19]. The present study demonstrated a scalable and low - cost methodology for estimation of expenditure on consumption and the value of assets in data scarce developing regions. By combining high resolution satellite imagery with survey data and training a convolutional neural network, the authors demonstrated that visual characteristics extracted from imaging data explain a significant proportion of variation in the local economic outcomes in several African countries. These results highlight the potential of machine-learn algorithms for poverty monitoring, targeting, and policy design based on data leveraging publicly available data, in areas where traditional data are scarce [20]. This investigation examined the ability of high spatial resolution satellite imagery as an independent variable to measure accurately poverty and economic well-being in Sri Lanka. By extracting object based, textural, and spectral indicators and creating linear regression models reliant on small area estimates of census data, the researchers showed that built environment, infrastructure, and land use characteristics are together responsible for a large portion of the variability in consumption levels and poverty rates. Furthermore, the predictive performance was robust across the welfare distribution and when spatially extrapolating, though the accuracy declined when welfare estimates were based on less family samples [21].

The manuscript carried out a detailed analysis of Earth Observation approaches and their role in the realization of the United Nation Sustainable Development Goals, with a particular focus on the rapidly growing impact of machine learning in parsing complex, multi-scale geospatial datasets. The results show Earth-Observation systems provide cost-effective and comprehensive monitoring capabilities, whereas the performance of machine learning depends very much on feature extraction and data synthesis techniques. Moreover, combining rapidly evolving methods of analysis has become increasingly critical to understanding sustainability drivers and providing evidence-based support to achieving progress towards the Sustainable Development Goals [22]. This investigation developed a fast, cost-effective framework for large scale evaluation of agricultural land quality using multiple integration of freely available Multi modal datasets in the Google Earth Engine and two machine and enhanced learning approaches. The results show that multimodal inputs provide better prediction performance than random forest models achieve significantly better performance than deep neural networks in both paddy and dry land systems. Paddy fields, due to their higher homogeneity, were estimated at higher precision and, in general, the approach allows reliable provincial-scale assessments for more efficient management of the land and food security planning [23]. This research tried to model the risk of rural depopulation in the Valencian Community combining land - use and socioeconomic variables using conventional statistical and machine learning methodology. The findings highlighted how many non-demographic factors for population are a significant determinant (particularly the intensity of cropland area), as this influence was particularly high with regard to the determination of the path of depopulation, obtaining a significant hit in terms of classification accuracy. These results support the relevance of the expansion of sustainable land use in agriculture could significantly hedge against the risk of depopulation, thus providing evidence in favor of policy interventions targeted towards land-use reforms for the revitalization of rural territory [24].

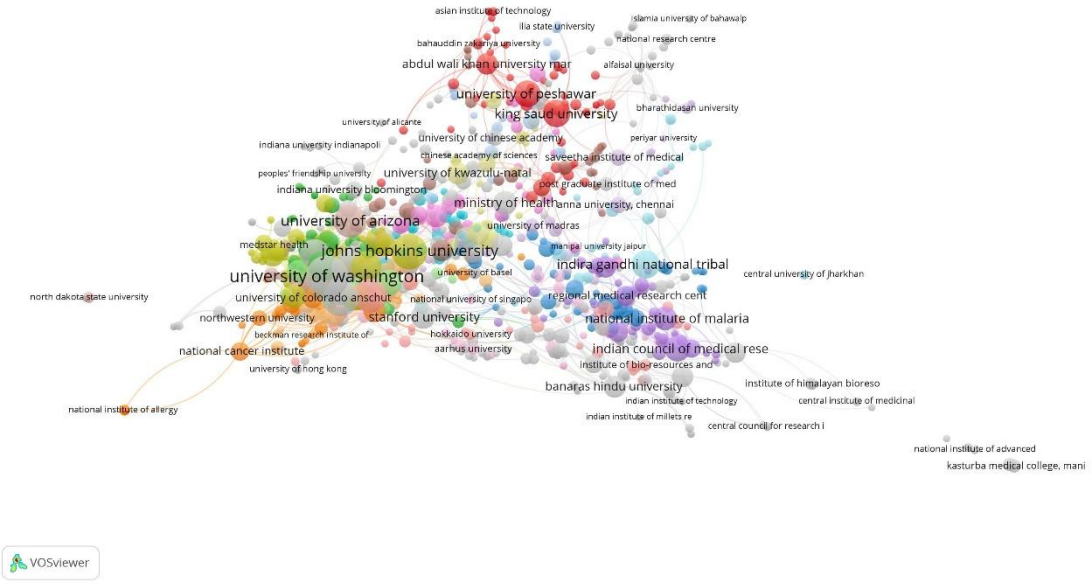

Figure 2. Organization Interconnection Review

The current investigation made a systematic review of the global scholarship related to the use of machine learning techniques in the field of sustainable agriculture. Utilising a PRISMA guided bibliometric framework, it sheds light on a rapidly growing body of literature, an ever-growing confluence of heterogeneous data streams, the Internet of Things, remote sensing modalities and smart-farming apparatuses. At the same time, the analysis points to often remaining hurdles of data fusion, infrastructural preparedness and local contextualisation, while emphasising the need to live with the more sophisticated algorithms -- especially deep learning approaches -- in order to strengthen resilience of agricultural systems and the care of the environment [25]. The paper provided a critical review of smart governance practices bringing them into context with some of the enduring debates on the implementation gap of planning support systems. It showed that too much emphasis on technology-driven approaches often ignored user needs and realities and in contrast to that, insights shared through planning support systems is highlighting the need of contextual alignment of smart governance to user's capacity, task specific-requirements and local context. Consequently, it called for a shift to a socio-technical, demand-driven and application-based governance approach, instead of continuing to use a purely technocratic approach [26].

3. Overview of Korwa Tribal Regions

Korwa tribal territories in Chhattisgarh form some of the ecologically-most fragile and the socio-economically most peripheral landscapes of central India [27]. Korwa community is officially considered one of the Particularly Vulnerable Tribal Groups (PVTGs), which gives an indication of historically low development indicators, a heavy reliance on natural resources for livelihood, and a lack of integration into the wider,programme of mainstream economic conditions. These regions are widely distributed in forest-dominated, hilly environment with high levels of physical remoteness and environmental constraints which have significant impacts on the pattern of settlement, the character of the livelihood practices and access to basic public services. Geographically, the habitation patterns of the Korwa communities are

spread out in low density settlements set amongst contiguous forest patterns. The topography is undulating and all-weather road infrastructure is sparse, thereby limiting mobility as well as market integration. This spatial seclusion has immediate consequences for livelihood resilience by curtailing the prospects of agricultural intensification, diversification into non-farm sectors and engagement with wider economic linkages. Although ecological bounty of the region holds great promise for forest based economic activities, it simultaneously presents conservation constraints that further complicate livelihood decision making [28].

Korwa territory is exposed to a monsoon-governed precipitation pattern, which causes strong variations in the agronomic production. Predominantly rain breastsed agriculture, coupled with insufficient infrastructure for irrigation makes the livelihoods highly sensitive to climatic variability and extreme climatic events. Soil profiles contamination is rather restrictedly shallow and moderately fertile and limits crop diversity and yield potential. Consequently, farming and agriculture is not focused on commercial gain but instead on subsistence to sustain livelihoods and continues to trap populations into cycles of economic fragility. Socio-economics in the Korwa enclaves are low educational attainment, limited access to healthcare services, and poor physical infrastructures, such as electricity, potable water and sanitation systems. Financial inclusion stands at a minimum and penetration of formal banking and credit entities remain at a minimum. These are shortcuts to these multifaceted bottlenecks and reductions in the community's ability to adopt advanced livelihood strategies or improvements in technology. Although the level of social cohesion among Korwa communities still enjoys a relatively strong degree, institutional connections with development agencies and governing frameworks remain low, and this negatively affects effective participation in welfare and livelihood enhancement initiatives.

Korwa tribe maintain an intimate relationship with traditional knowledge systems, customary practices and forest-based management of resources. These socio-cultural dimensions constitute an important fulcrum in the livelihood decisions and adaptation strategies. Nevertheless, development interventions often find fault in appropriately integrating indigenous knowledge and hence creating incongruencies in policy design and realities on the ground. This disjunction of sorts highlights the need for context-substantive planning modalities which respect cultural identities and at the same time foster sustainable livelihood transformations. From the developmental planning perspective, Korwa tribal territories represent an interesting case for technology enabled assessment and intervention. The interactions between ecological sensitivity, spatial isolation, and socio - economic vulnerability require analytical tools that are capable of capturing spatial heterogeneity and also temporal flux. Geospatial technologies and satellite based observations have some very great potential in this context to enable objective mapping of the settlement, lack of infrastructure, land usage patterns and environment. Such spatially explicit insights are necessary for the design of targeted, equitable and sustainable livelihood strategies.

4. Sustainable Livelihood Framework in Tribal Studies

The Sustainable Livelihood Framework (SLF) provides a comprehensive and multidimensional approach to understanding livelihood systems in tribal and marginalized regions by emphasizing the interaction of assets, vulnerability contexts, and institutional structures rather than income alone. In tribal contexts, the five livelihood capitals—natural, human, physical, financial, and social—are unevenly developed, with natural capital often abundant but constrained by access, governance, and market limitations, while human, physical, and financial capitals remain critically deficient. Literature consistently highlights that weak infrastructure, low human capital, limited financial inclusion, and restricted institutional linkages

significantly hinder livelihood diversification and resilience. The SLF also underscores the heightened vulnerability of tribal regions to environmental and socio-economic shocks and the decisive role of governance in shaping livelihood outcomes. Although widely applied, traditional SLF implementations lack spatial and technological integration, prompting recent studies to advocate its enhancement through GIS and data-driven tools. When contextually adapted and combined with geospatial and analytical approaches, the SLF offers a robust foundation for evidence-based and scalable livelihood planning in tribal regions such as the Korwa areas.

5. Review of Geospatial Applications in Tribal Livelihood Assessment

Geospatial technologies have become a vital analytical foundation for assessing livelihood systems in tribal and remote regions where conventional surveys are constrained by accessibility, cost, and time. GIS and remote sensing enable the integration of socio-economic, environmental, and infrastructural data to capture spatial disparities in settlement patterns, accessibility, land use, and resource distribution that strongly influence tribal livelihoods. Reviewed studies highlight the effectiveness of GIS-based accessibility analysis and satellite-derived land-use monitoring in identifying infrastructure deficits, livelihood vulnerabilities, and environmental changes affecting food security and income stability. The integration of socio-economic indicators with spatial datasets has further enabled the development of livelihood vulnerability indices and targeted intervention planning. Although participatory GIS has enhanced the inclusion of indigenous knowledge, limitations related to data resolution, socio-cultural integration, and technical capacity persist. Recent literature indicates a gradual shift toward combining geospatial analysis with machine learning for advanced pattern detection and predictive planning, though such applications in tribal contexts remain limited and require careful methodological and ethical consideration [29].

6. Data-Driven and Machine Learning Approaches in Livelihood Planning

With the escalating prospects of socio-economic, environmental and geospatial data sets, data-driven and machine learning methodologies have begun to gain acceptance in the scholarly community for livelihood planning especially in a complex tribal and rural setting. Unlike traditional methods of description, these approaches allow for the analysis of large, multidimensional datasets in a thorough manner, revealing hidden patterns, spatial interdependencies and time dynamics that help improve precision of targets and transparency of decision-making. Machine-learning techniques, such as the supervised classification, unsupervised clustering, and predictive modelling, have been widely used in poverty mapping, land-use analysis, agricultural productivity estimation, and assessing the vulnerability to livelihood. These methods offer robust analytical frameworks that are able to interpret heterogeneous data sources and generate actionable insights. By combining the socio- economic variables and the geospatial data, the machine learning (ML) models provide spatially explicit and context sensitive planning tools, the role of the ML models is to allow the policy makers to anticipate the risks of livelihood and plan interventions to mitigate those risks. The synergy between the quantitative measures and geographic prerciosity underlies nuanced and site specific policy formulation. Nevertheless, despite the potential for evidence-based governance that comes through data-driven decision-making support systems, their use in tribal territory is still limited by a range of constraints including data quality issues, low technical capacity, model interpretability, and ethical issues that involve citing privacy and community involvement.

7. Role of AI and Machine Learning in Sustainable Livelihood Research

The fields of Artificial Intelligence and Machine Learning have risen to the front line of the sustainable development research, equipping researchers with more tools than ever to be able to probe complex, multi-dimensional datasets constituting socio-economic and environmental systems. Within the context of tribal livelihood planning, these computational paradigms allow for the ability to assimilate diverse and heterogeneous data sources from range of information types such as demographic indicators and geospatial datasets to satellite imagery and environmental variables in a way that allows for evidence - based decision making. Unlike the conventional statistical techniques, Machine Learning algorithms are extremely good at finding non-linear relationships, latent patterns and spatial relationships that are specially recognizable in the heterogeneous and ecologically sensitive context of tribal regions.

Reviewed literature shows that the use in rural and development studies of AI - ML techniques is growing in importance for purposes such as poverty mapping, resource allocation, agricultural productivity estimation, and vulnerability assessment. The value of such approaches is particularly clear in tribal settings, where livelihood is dependent on many different factors interacting with one another - forgot facts of topography, forest cover, accessibility and institutional constraints. By combining Artificial Intelligence and Machine Learning and leading-edge geospatial software, researchers can bypass the descriptive reports and move toward predictive modelling and scenario-based planning of livelihoods.

8. Machine Learning Techniques Relevant to Tribal Livelihood Planning

Machine learning applications in livelihood studies may roughly be divided into supervised learning, unsupervised learning, and predictive analytics. Supervised learning methods such as decision trees, random forests, support vector machines have been extensively applied for land-use classification, identification of crops and socio-economic categorization. These approaches have proven to be excellent for generating high accuracy spatial outputs when there are good sources of labeled datasets. Unsupervised learning techniques such as clustering algorithms are important and useful in tribal livelihood studies for which labeled data, sometimes, may be scarce. Clustering allows to identify the vulnerability zones for livelihoods by grouping areas or households with similar socio-economic and environmental characteristics. This method has implications for targeted planning of interventions that can identify priority areas in need of further immediate attention.

Predictive modeling techniques make it possible to forecast the future (livelihood-related) outcomes such as the variability of agricultural yields, the instability of income, and the demand for resources under various environmental or policy scenarios. When used in combination with geospatial inputs, predictive ML models can be used to underpin a strategy of proactive planning and climate-resilient livelihood strategies in tribal regions.

9. AI–GIS–Remote Sensing Integration for Livelihood Assessment

The combination of artificial intelligence and machine learning technologies with geographic information systems and remote sensing is a key development in the evaluation of tribal livelihoods. Satellite imagery is providing the rich, temporal data sets for land-use change, vegetation lushness and ecological degradation, and geographic information systems (GIS) is enabling both spatial and spatial-temporal analyses and representation. Machine-learning algorithms add value to these platforms through the phonetic extraction of features, classification and pattern recognition that can be automated. In the reviewed studies, hybrid GIS-ML frameworks have been used to create spatial vulnerability maps, map

the optimal placement of infrastructures and assess the development scenarios. Such integrated systems are especially suited to the Korwa tribal regions, where the combination of scattered settlements and sensitivity to the environment imply the need for spatial planning instruments that are very precise and adaptive.

10. Challenges and Ethical Considerations in AI-ML Applications

Despite their proficiency in potential, the use of artificial intelligence and machine learning techniques in the exclusive province of tribal livelihood planning are beleaguered with a constellation of formidable challenges. Chief among them is the continuing under availability and poor quality of data; many tribal jurisdictions are void of high resolution socio-economic information that would otherwise serve as the foundation for rigorous analysis. Equally pressing is the problem of model interpretability, especially in governance applications where the need for transparency and accountability is paramount; the appeal to the power of sophisticated algorithms can be obfuscating of decision making processes and lose public trust. Ethical considerations are as big in these environments: issues of data privacy, the acquisition of informed consent, the alleviation of algorithmic bias, the inclusion, or exclusion of indigenous epistemologies require a careful analysis. A thorough review of the literature emphasizes that AI - ML tools should be adjunct software instead of replacement of participatory methods and community engagement to protect socially acceptable and culturally relevant outcomes.

11. Relevance of AI and ML to Korwa Tribal Regions

The tribal areas of Korwa in Chattisgarh presents an interesting rationale for application of AI-ML assisted livelihood planning due to their strong heterogeneity in both spatial dimension and environmental vulnerability and infrastructural deficiencies. Nevertheless, the existing scholarship is not taking full advantage of AI- ML techniques that are as local scale as possible. This gap paved in the foundation to establish an important scope for future studies, where development of context-specific, ethically viable and participatory AI-ML frameworks that integrate geospatial intelligence and indigenous knowledge systems is an important way forward.

Table 2. Traditional Analysis vs AI-ML–Enabled Approaches

Aspect	Traditional Approaches	AI/ML-Enabled Approaches
Data Handling	Limited variables	High-dimensional datasets
Spatial Analysis	Manual interpretation	Automated spatial learning
Prediction	Minimal	Scenario-based forecasting
Adaptability	Static	Dynamic and adaptive
Decision Support	Descriptive	Predictive and prescriptive

Table 3. Data-Driven and Machine Learning Applications in Livelihood Planning

Approach Category	Techniques Used	Livelihood Planning Application	Key Advantages	Key Limitations
Classification	Decision Trees, SVM, Random Forest	Land-use and crop type mapping	High accuracy, scalable	Requires labeled data

Clustering	K-means, Hierarchical Clustering	Vulnerability zone identification	Reveals hidden patterns	Sensitive to input variables
Predictive Modeling	Regression, Ensemble Models	Yield and income forecasting	Supports proactive planning	Data-intensive
Spatial ML Integration	GIS–ML hybrid models	Spatial livelihood risk mapping	High spatial precision	Technical complexity
Decision Support Systems	Dashboards, ML-based tools	Policy evaluation and monitoring	Improves governance	Institutional capacity needed

12. Technology–AI–GIS Integrated Perspective

By utilizing the holistic power of Artificial Intelligence (AI), Machine Learning (ML), neural network models, and Geographic Information Systems (GIS) this review is designed to create a systematic and forward-looking framework, useful for understanding and evaluating the transformation of livelihood in tribal environments, in this case in the tribe lands of Korwa, Chhattisgarh. The integration of geospatial intelligence with data driven analytical architectures is facilitated spatially explicit discernment of socio-economic, environmental and infrastructural changes unseen under conventional assessment methodologies. Neural,-network,-based models and machine learning algorithms have tremendous potential to cut through complex high dimensional datasets generated from satellite imagery, census measures, ecological parameters, etc. as a means for detecting subtle patterns, transitions through time and non - linear interactions that are integral to tribal livelihood mechanisms.

When implemented as part of GIS platforms, these artificial intelligence (AI) based methods lie at the heart of vulnerability mapping, change detection analysis, and predictive scenarios scenes of changes in land usage, accessibility, resources, and living resources over time presented in a systematic way. Such an integrated structure strengthens the ability to monitor developmental patterns, assess the consequences of policies, and to highlight new risks and opportunities in ecologically sensitive tribal areas. Moreover, the adoption of AI - ML - GIS based approaches allows for scalable, reproducible and evidence based planning mechanisms which can bridge the chasm between policy formulation and on the ground realities. By integrating information on the application of sustainable livelihood theory, geospatial analysis, and the use of modern data analytics, the study shows that modern technologies can take a catalytic role to identify transitions in livelihood, promote governance for inclusion, and achieve sustainable development outcomes in marginalized tribal communities. This integrated paradigm of technology not only strengthens the ground of analytical rigour but also provides a rock solid foundation for adaptive decision-making, long term monitoring and designing specific interventions aimed towards increasing the resiliency of livelihoods in tribal areas.

13. Identified Research Gaps and Critical Insights

The synthesis of literature shows some important areas of gaps. First, Korwa specific studies on integrating geospatial with data-driven approaches are limited. Second, most livelihood assessments still remain descriptive without any predictive or scenario-based analysis. Third, the substandard attempts to convert technology into policy practices in terms of measures and other regulatory frameworks remain limited.

Addressing these gaps demands interdisciplinary cooperation and connecting together spatial analytics with the problem of governance mechanisms.

14. Proposed Conceptual Review Framework

Based on the reviewed literature, this study has proposed a conceptual framework that will integrate sustainable livelihood assets, the geospatial indicators and data-driven decision support mechanisms. The framework puts interaction of livelihood capital and spatial accessibility, environmental condition and policy interventions in the foreground. Such an integrative approach is meant to form the basis for planning and adaptive governance on an evidence base tribal regions seem to lack.

15. Conclusions

1. The study systematically reviewed recent literature on tribal livelihood systems with specific contextual relevance to the Korwa tribal regions of Chhattisgarh.
2. It consolidated fragmented research on sustainable livelihoods, geospatial technologies, and data-driven methods into a unified analytical perspective.
3. The review confirmed that tribal livelihood sustainability is constrained by persistent deficiencies in human, physical, and financial capital despite relatively abundant natural resources.
4. Structural issues such as spatial isolation, limited infrastructure, and weak institutional access continue to undermine livelihood resilience.
5. GIS and satellite remote sensing were identified as critical tools for spatially explicit assessment of settlement patterns, infrastructure accessibility, land-use dynamics, and environmental change.
6. These technologies enable objective, scalable, and repeatable evaluation of livelihood conditions in geographically inaccessible tribal regions.
7. The review highlighted the growing potential of AI and ML, including neural network–based models, for identifying complex patterns, detecting livelihood transitions, and forecasting development scenarios.
8. When integrated with GIS and remote sensing, AI–ML approaches support systematic, predictive, and evidence-based livelihood planning.
9. Technology-enabled analytical frameworks improve transparency, targeting efficiency, and monitoring capabilities in tribal development programs.
10. AI–GIS–ML integration bridges the gap between policy formulation and ground-level realities.

Identified Research Gaps

1. Limited Korwa-specific and localized studies using integrated geospatial and AI–ML frameworks were observed.
2. Insufficient incorporation of socio-cultural dimensions, indigenous knowledge systems, and ethical considerations remains a major limitation.

Future Research

1. Future studies should focus on localized, participatory, and ethically grounded AI–GIS frameworks.
2. Strengthening institutional capacity and data infrastructure is essential for effective implementation in tribal regions.

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