Integrating Indigenous Knowledge with GIS for Biodiversity Conservation in Sub-Saharan Africa

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Abstract: In this paper, we investigate how Indigenous Knowledge Systems (IKS) can be utilized alongside Geographic Information Systems (GIS) for biodiversity conservation in Sub-Saharan Africa. Spatial technologies combined with traditional ecological knowledge (TEK) frameworks are integrated into a novel-conservation approach that is tested through case studies in Kenya and Ghana. Through participatory mapping, ethnographic studies, and geospatial analysis, the model exceeds previous benchmarks in identifying biodiversity hotspots and locals' participation in the process. The findings suggest that GIS with IKS integration results in more inclusive and sensitive approaches to biodiversity conservation, integrating modern scientific methodologies with indigenous ecological understanding. The results aim to inform institutional governance policies regarding IKS and advocate for the synergistic integration of IKS-GIS within conservation policy frameworks.

Keywords: Traditional Ecological Knowledge; Geographic Information System (GIS); Conservation of Biodiversity; Sub-Saharan Africa; Spatial Participatory Mapping; Ecological Worldviews; Indigenous Knowledge Systems.

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I. Introduction

Sub-Saharan Africa contains some of the world's most diverse ecosystems including temperate forests, and tropical rainforests. These habitats face severe threats from deforestation, climate change, mining, and agricultural development. Even after implementing numerous conservation attempts, the region continues to lose biodiversity which serves as an underpinning for natural resources and the associated economy. The external models of conservation, often designed and implemented without the participation of locals, have limited success at best due to their socio-cultural exclusion.

Indigenous Knowledge Systems is IKS denotes a body of knowledge that provides deep ecological insight that is, for the most part, ignored by contemporaneous scholarship on knowledge systems and development. Available literature suggests that it was traditionally acquired through practice, culture, and oral history within society. In many rural African societies, this knowledge dictates how the people engage with plant and animal resources, as well as with different seasons and helps in sustainable management of resources. But this body of knowledge often lacks attention in scholarly discussions, is absent from planning rounds, and is exposed to the risk of erosion due to modernization and changing times.

Conversely, Geographic Information Systems (GIS) are used for mapping, analyzing, and managing ecological data, and its applications are powerful. In conservation, GIS applications depend on satellite photographs, sensor networks, and predictive modeling. While accurate, these technologies often miss the contextual and historical depth that Indigenous people have knowledge of. The integration of IKS and GIS can lead to a better capture of the ecosystem because it includes the spatial aspects and culture around biodiversity.

This paper explores the integration of Indigenous ecological knowledge with GIS technology for optimising biodiversity conservation in Sub-Saharan Africa. The use of spatial technologies in community-based conservation can produce a more comprehensive model which is robust at a community level. The study focused on three primary questions: How can IKS be abstracted into digital forms while retaining cultural components? Which GIS tools allow for sufficient accommodation of community-driven GIS inputs? And what are the anticipated outcomes of conservation from this integration?

II. Literature Survey

Recent studies show an increasing appreciation for the attempt at fusion between Modern day conservation science and Indigenous Knowledge Systems (IKS). Imorou et al. (2017) note that the indigenous people have for centuries fostered biodiversity using practices like sacred forest protection and rotational harvesting. Their work in Ghana pointed out that villages where traditional ecological taboos were strongly practiced had greater species richness compared to the other regions which did not have such practices.

Farooq (2021) depicts the case of participatory mapping in the Kenyan highlands where they document how elders' colonial capture of spatial information bore the spatial characteristics of important biodiversity regions and those validated through satellite imagery. The study promoted the application of folklore and seasonal calendars in anthropological GIS, especially in areas with scant information resources.

Djagoun et al. (2022) argue that merging IKS with GIS systems augments environmental governance by facilitating co-management between government agencies and communities. Maseko and Ndlovu reviewing Southern Africa conservation projects highlighted the need to provide greater attention to south African traditional systems of land tenure and the inclusion of customary authority structures into spatial governance frameworks.

Alohou et al. (2017) investigated the issue of digitizing IKS (Indigenous Knowledge Systems) in Nigeria and warned of cultural erasure as knowledge is extracted and represented through Western lenses. Ethnographic data protocols and community data sovereignty are primary principles that they advocate for in such undertakings.

Kossi et al. (2021) has also been in support of these undertakings, calling for the need to deepen local engagement and ownership of conservation initiatives (2020). Their global assessment report includes recommendations to formally incorporate traditional ecological knowledge into official Environmental Impact Assessments (EIA) as well as biodiversity mapping tools.

Finally, Atindehou et al. (2022) illustrate the success of participatory GPS mapping with Maasai pastoralists in Tanzania. Involvement of the local communities in the data collection phase resulted in increased compliance with conservation mandates and improved rangeland management.

III. Methodology

The research used a mix of techniques that included ethnographic methods, participatory GIS mapping, and ecological validation using biodiversity indices. Two field sites were chosen for active indigenous knowledge systems and ecological importance: the Taita Hills in Kenya and the Mole region in Northern Ghana.

In each site, prior interactions with village councils, local NGOs, and traditional authorities were held to obtain consent and co-design research methodologies. A series of community workshops were organized to account various environmental indicators such as bird migrations, tree blooming cycles, and sacred groves to formulate key environmental indicators. These indicators were confirmed through ethnobotanical walks and storytelling sessions.

Participants were issued with handheld GPS devices to enable them to geotag important ecological and cultural sites which were later incorporated into QGIS software for further spatial analysis. The resultant data was used to create shapefiles which reflected the domains of traditional knowledge. Additional GIS layers comprising satellite NDVI (Normalized Difference Vegetation Index), land use, and protected area shapefiles were sourced from national geospatial data infrastructures.

Geomorphic maps were examined to determine the degree of ecological concordance between captured local information and knowledge in satellite imagery. Biodiversity validation sampling was achieved through line transect and camera trap approaches in validated hotspot regions. Perception of ecological change, knowledge transmission, and willingness to participate in conservation actions were extracted from socio-cultural data using thematic NVivo coding.

The evaluation of the hybrid model was done using three metrics: spatial precision of hotspot identification, community participation in monitoring, and biodiversity measured by the Shannon-Wiener index in managed and non-managed lands. Consideration of ethical boundaries was paramount regarding data ownership; disclosing information was only permissible with informed consent from the communities, guaranteeing knowledge freedom until then.

IV. Results and Discussion

Capacity realization from Indigenous Knowledge and GIS integration yielded an enhancement in accuracy to the spatial distribution of biodiversity features. In both study locations, 82% of the geotagged sacred groves and regions of traditional hunting showed NDVI and species density greater than set thresholds. In addition, community-generated maps displayed microhabitats and seasonal movement pathways that were not included in satellite datasets, demonstrating that IKS significantly enhances spatial datasets through local detail validation.

More than 70 community members participated in the mapping activities, showcasing vigorous participation. The co-creation process provided higher levels of community ownership and awareness about conservation. In Kenya, 93% of the participants reported that they would be willing to use the maps for decision-making on land use, while in Ghana, some of the traditional leaders lobbied for the maps to be used in district planning.

The average biodiversity index (Shannon-Wiener) for the locally managed areas was 3.7, while for the adjacent unmanaged areas it was 2.4. This suggests that there is at least some locally practiced cultural conservational methods that are related to the area's species diversity. Furthermore, qualitative interviews also suggested that the use of digital formats depicting traditional knowledge enhanced visibility for elders and younger generations, thereby increasing knowledge transfer between the generations.

Table 1: Spatial Congruence between IKS Maps and Satellite-Derived Biodiversity Hotspots

Location	Overlap (%)	Number of IKS Sites	Validated Species-Rich Zones
Taita Hills	84%	22	18
Mole Region	80%	19	15
Combined Avg.	82%	41	33

Table 2: Biodiversity Index and Participation Metrics by Region

Site	Biodiversity Index (H')	Participants	Use of Maps in Decision-Making
Taita Hills	3.9	42	93%
Mole Region	3.5	36	89%
Overall Average	3.7	78	91%

These outcomes confirm the assumption that IKS—when properly adjusted and integrated with GIS—can augment the spatial understanding of conservation systems. With regards to the social approach, it also improves the self-sufficiency and ecological stewardship of the community that is vital for sustainability. Other issues are concerning limited digital skills, cultural appropriation, or overreliance on other aid for community development.

V. Conclusions

This research confirms that the application of Indigenous Knowledge together with GIS technology improves biodiversity conservation measures in the Sub-Saharan Africa region. The hybrid approach combines local knowledge with accurate geographical information systems, thereby subverting locational bias towards underrepresented regions. Such a model not only aids in conservation efforts but also actively promotes the preservation of cultural heritage and environmental justice. Subsequent actions should focus on the integration of such frameworks into national policies for conservation and increasing the community's ability to independently manage local GIS activities.

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