Vision Paper

GROUND TRUTH AND LOCAL ROOTS: A FRAMEWORK FOR GROUNDED GISCIENCE AND PARTICIPATORY LAND MANAGEMENT

Leah M. Mungai[1*], Raechel A. Portelli[2*] and Zhijie Zhou[2*]

[1] Department of Geography and the Environment, University of Alabama, Tuscaloosa, USA
[2] Department of Geography and Geographic Information Science, University of Illinois Urbana-Champaign, Urbana, USA
* lmmungai@ua.edu, raechel@illinois.edu, zhijiez2@illinois.edu

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Introduction

GIScience can contribute to more equitable, accurate, and socially meaningful environmental decision-making by developing human-centered geospatial systems that integrate local knowledge as a core source of geospatial intelligence rather than merely a source of validation.

The digital representation of Earth has reached unprecedented levels of spatial and temporal detail. Advances in remote sensing, foundation models, and GeoAI have transformed how geographers monitor environmental change and classify land-cover dynamics. These developments have encouraged a vision of increasingly automated geographic analysis. However, automation alone does not guarantee understanding. A persistent challenge in GIScience is the distinction between observing land cover and understanding land use, management, and meaning, creating a semantic gap between remotely sensed observations and the socio-ecological realities they are intended to represent (Comber et al., 2008; Riva & Nielsen, 2021).

The Vision Towards Grounded GIScience: Reframing Ground Truth

Traditional notions of ground truth assume that the role of people is to verify or validate geospatial observations generated by remote sensing systems. Within this paradigm, local actors function primarily as data collectors or sources of validation, rather than sources of knowledge. Grounded GIScience expands the concept of ground truth beyond field validation to include locally situated knowledge of landscape practices, seasonal dynamics, and environmental stewardship. Geographic understanding emerges not only from remotely sensed observations but also from experiences and interpretations that cannot be inferred from spectral data alone. Within this framework, Human-in-the-Loop (HITL) systems become mechanisms for knowledge co-production rather than simply tools for improving classification accuracy.

Where Pixels Fail: Lessons from *Dambos* and *Dimbas*

To illustrate the limitations of automated land-cover classification, we consider the seasonal wetland systems (*Dambos*) and embedded dry-season cultivation gardens (*Dimbas*) of Southern Africa (Kotze & Wood, 2021). *Dambos* are shallow, seasonally saturated wetlands that provide critical hydrological, pastoral, and agricultural functions. Within these systems, smallholders cultivate *Dimbas*, intensive dry-season vegetable gardens that play a central role in household food security and livelihood resilience.

In land-cover mapping, these landscapes present multiple challenges. First, *Dambos* exhibit substantial spectral ambiguity. During seasonal transitions, their spectral signatures often resemble degraded shrublands, grasslands, or fallow agricultural fields, making them difficult to distinguish using remotely sensed imagery alone (Kpienbaareh et al., 2021; Mungai et al., 2022). Second, *Dimbas* consist of small, irregular, and highly heterogeneous plots that frequently fall below the spatial resolution of commonly used Earth observation products. Third, and most importantly, many of the processes that define these landscapes are not directly observable from above. Practices such as groundwater exploitation through hand-dug wells, seasonal grazing rotations, selective vegetation management, and locally adapted cultivation strategies are central to landscape function but remain largely invisible to existing classification systems.

The revealed challenge extends beyond classification accuracy. Local farmers understand these landscapes not simply as wetlands or vegetation communities, but as socio-ecological systems shaped by generations of environmental knowledge and adaptive management. When such contextual knowledge is absent, classification systems may produce technically plausible yet socially misleading representations of the landscape.

The consequences are not merely analytical. Land-cover classifications increasingly inform conservation planning, agricultural development, and environmental governance. When *Dambos* and *Dimbas* are classified as “unused,” “degraded,” or “low-productivity” lands, these representations can legitimize interventions that undermine hydrological functions, threaten local food systems, and marginalize the communities most dependent on them. This example demonstrates that errors in working-land classifications are not solely statistical problems. They are also ontological failures, reflecting a mismatch between machine-defined categories and the lived realities through which landscapes are understood and managed. In this sense, the challenge is to reconsider what kinds of geographic knowledge are recognized, represented, and encoded within geospatial systems.

A Research Agenda for Grounded GIScience and Local-Rooted GeoAI

First, advancing Grounded GIScience requires methods capable of incorporating experiential knowledge derived from interviews, oral histories, field observations, and participatory mapping. Emerging approaches based on large language models and knowledge graphs offer opportunities to translate these unstructured narratives into machine-readable representations. Such representations could guide classification models through locally derived contextual knowledge. Equally important, future systems must respect principles of community ownership and data sovereignty, ensuring that local knowledge remains governed by the communities from which it originates.

A second priority concerns pedagogy. As GeoAI becomes increasingly central to GIScience, the education of future geospatial scientists must extend beyond technical proficiency in programming, remote sensing, and machine learning. Students should also be trained to critically evaluate how geographic representations are produced and whose knowledge they reflect. Ground-truthing should therefore be understood not only as a technical exercise in validation but also as an ethical practice that considers the social consequences of misclassification. In working landscapes such as *Dambos*, classification errors affect livelihoods, food security, and environmental governance, making contextual interpretation as important as statistical accuracy.

Finally, Grounded GIScience requires stronger connections among GIScience, cartography, social science, and policy communities. Progress will depend on the development of frameworks that combine satellite observations with socioeconomic data, local governance structures, and community knowledge systems. The goal stems from improvement of classification accuracy in particular landscapes to develop scalable approaches for the co-production of geographic knowledge towards a more inclusive and socially responsive model of geospatial analysis.

Implications for Cartography and GIScience

As GeoAI becomes increasingly integrated into environmental governance and land management, ensuring that machine-generated representations remain accountable to local realities will become a central challenge for the discipline.

If the most sophisticated geospatial systems remain insensitive to the socio-ecological intent that defines working lands, and if we continue to prioritize automation over interpretation, we risk creating models that are technically precise but functionally out of context (Portelli, 2020). Advancing a HITL agenda is not a retreat from technology but a maturation of it. By valuing local narratives alongside spectral observations, GIScience can develop representations that are not only technically accurate but also socially meaningful. Maps of the future should reflect not only the Earth's surface, but also the knowledge and practices of the people who steward it.

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