Authorship and Affiliations

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1. Introduction: The Geospatial Network Vision

The Geospatial Network is a transformative solution designed to modernize land management in Uganda by leveraging cutting-edge geospatial technologies, real-time data updates, and seamless integration with existing systems. It addresses critical challenges in land rights security, survey accuracy, and administrative efficiency, while empowering surveyors, government agencies, and communities with reliable, up-to-date geospatial data.

2. Key Benefits of the Geospatial Network

- **Improved Accuracy:** By using GNSS receivers and real-time data updates, the system ensures survey data is highly accurate, reducing disputes over land boundaries.
- **Real-Time Data Updates:** Surveyors can update and store new information directly into the database, ensuring records are always current and reducing the risk of outdated or conflicting data.
- **Cost Savings:** Streamlining the survey process and reducing manual data entry and reconciliation lowers operational costs for government agencies and surveyors.
- **Enhanced Land Rights Security:** The system provides a secure, transparent repository for land data, including titled and untitled tracts, ensuring marginalized communities have a record of their land boundaries.
- **Decongesting the Land Office:** By enabling surveyors to update data in the field ,and office, access is very easy reducing surveyors at land office lining up for prints.
- **Connectivity Between Surveyor Equipment:** The system integrates seamlessly with GIS software and GNSS receivers, creating a unified workflow for surveyors.
- **New Survey Methodology:** The Geospatial Network introduces a modern, data-driven approach to land surveying, replacing outdated methods with a system that prioritizes accuracy and efficiency.
- **Ease of Data Checking:** Surveyors can continuously verify and validate data in the field, ensuring errors are caught and corrected early.
- **Creation of Clean Vector Data Layers:** As new primary data is collected, it is stored in a clean, standardized format, creating a reliable foundation for future land management and research.
- **Easy Integration with Existing Systems:** The system is designed to integrate seamlessly with Uganda's current land management infrastructure, minimizing disruption and maximizing adoption.
- **Enabling Further Research:** The availability of high-quality, up-to-date geospatial data opens new opportunities for research in urban planning, environmental management, and disaster resilience.

- **Facilitating Physical Planning:** The system provides planners with accurate, real-time data, enabling better decision-making for infrastructure development and land use planning.

3. Addressing Specific Challenges

- **Data Fragmentation:** Consolidates land data into a unified database, eliminating inefficiencies of fragmented systems.
- **Community Trust:** By including untitled tracts, the system ensures marginalized communities have a record of their land boundaries, fostering trust and participation.
- **Technical Barriers:** Designed to work with existing GIS and GNSS infrastructure, enabling adoption without significant additional investment.
- **Legal and Regulatory Concerns:** Complies with Uganda's land management laws and data protection regulations, ensuring data is secure and legally admissible.

4. Strategic Impact

- **Empowering Surveyors:** Equips surveyors with modern tools and methodologies, enhancing productivity and professionalism.
- **Supporting Government Agencies:** Streamlines land management processes, enabling agencies to focus on strategic priorities like land reform and urban planning.
- **Engaging Communities:** Ensures all stakeholders, including marginalized communities, have access to accurate land data, promoting equity and social justice.

5. Call to Action

The Geospatial Network is not just a technical solution; it is a strategic investment in Uganda's future. By adopting this system, we can transform land management, enhance land rights security, and unlock new opportunities for research and development.
We invite government agencies, surveyors, community organizations, and potential funders to partner with us in building a more accurate, efficient, and equitable land management system for Uganda.

Background and Literature Review and Literature Review

A growing body of research emphasizes the importance of spatial data infrastructures (SDIs) for land administration, particularly in developing regions (Rajabifard et al., 2002; Williamson et al., 2010). The INSPIRE Directive (EU 2007/2/EC) and ISO 19152 Land Administration Domain Model (LADM) provide frameworks for interoperable, standardized data sharing. Studies in sub-Saharan Africa highlight challenges in digitizing customary land rights (Odera, 2018) and opportunities for participatory mapping (McCall & Dunn, 2012). Geospatial Network Uganda builds on these principles by offering a scalable, open-source solution tailored to Uganda's legal and technical context.

System Architecture

The platform employs a PostgreSQL master–slave configuration using streaming replication. The **master** database (`geospatial_network`) handles write operations, while the **slave** (`cloud_assistant`) serves read-only queries, ensuring high availability and load distribution. Connection pooling is provided by pgBouncer on port 6432 to support up to 1,000 concurrent users. Authentication currently uses PostgreSQL MD5; a unified web-auth system is under development. All services run on an AWS EC2 t3.large instance, with plans for autoscaling based on demand.

Clients connect via:

- WFS/WMS endpoints:
  - WFS: `https://geoserver.geospatialnetworkug.xyz/geoserver/ows?service=WFS&acceptversions=2.0.0&request=GetCapabilities`
  - WMS: `https://geoserver.geospatialnetworkug.xyz/geoserver/ows?service=WMS&version=1.3.0&request=GetCapabilities`
- **OpenLayers Web Map**: `https://webmap.geospatialnetworkug.xyz/`, offering layer switching, popups, and location-based parcel identification.
- **QGIS and field software** (LandStar, FieldGenius, SingularPad) via direct WFS/WMS or JDBC on port 6432.

Schematic diagrams (Figures 1 & 2) illustrate data flows, service tiers, and client workflows.

Data and Layers

The system hosts ~20 GB of vector data encompassing:

- Property boundaries (titled plots)
- Roads and transportation networks
- Powerlines and utility corridors
- Protected areas (forests, wetlands)
- Pipelines (planned)
- **Bibanja parcels** (untitled, owner-consented)

Coverage spans the entire country, with data current to 2023. Feature counts are managed via BBOX filtering and max-feature limits to optimize performance.

Implementation and Use Cases

Surveyors in the field use GNSS receivers to capture boundary coordinates, which are directly written to the master database. Through WMS/WFS, they view existing boundaries in LandStar or FieldGenius, verify alignment, and submit new survey data. In the office, QGIS users access the same data for advanced analysis, while stakeholders use the web app for quick parcel lookups and coordinate retrieval.

Evaluation and Results

- **User base**: ~100 active surveyors, reporting generally positive feedback.
- **Performance**: Average map/data request latency ~5 s under typical loads; target ≤5 s with tiling and optimized queries.
- **Scalability**: Architecture supports up to 1,000 concurrent users via pgBouncer and AWS infrastructure.

Strategic Benefits and Impact

1. **Improved Accuracy**: Real-time GNSS integration reduces boundary disputes.
2. **Cost Savings**: Streamlined workflows lower operational overhead.
3. **Land Rights Security**: Records for bibanja parcels promote equity.
4. **Decongested Land Offices**: Self-service data retrieval reduces administrative burden.
5. **Integrated Workflows**: Seamless data flow between office and field.
6. **Clean Data Layers**: Standardized vector formats ensure consistency.
7. **Research and Planning**: High-quality datasets fuel urban planning and environmental management.

Challenges and Future Work

Key challenges include hosting costs, server capacity, and limited real-time data coverage. Planned future enhancements:

- **3D Terrain Modeling**: Using field-submitted CSVs to build a national digital elevation model.
- **Mobile Field App**: A universal GNSS-enabled app for offline/online surveying.
- **Authentication**: Implement SSL/TLS and centralized user management.
- **Infrastructure**: Automate autoscaling and incorporate CDN caching.

Funding Needs and Call to Action

Scaling demands resources for data collection, infrastructure upgrades, and capacity building. We invite partnerships with government bodies, NGOs, and private sector funders to:

- Sponsor district-level data modules
- Provide server hosting and cloud credits
- Support training programs for local surveyors and GIS specialists
- Develop mobile applications and advanced analytics

Conclusion

GEOSPATIAL NETWORK UGANDA is a transformative platform for land management, combining open standards, real-time data integration, and community-focused design. By partnering with stakeholders, we can secure land rights, improve governance, and foster sustainable development across Uganda.

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