GEOSPATIALNETWORK UGANDA.

Authorship and Affiliations: This project is led by Kiggundu Muhamad of N.A.S. Surveyors Ltd (P.O. Box 30564 Kampala, Uganda) under the guidance of Surveyor R.S.U. Katabu Simon. The work is supported by Survnet Uganda Ltd, which provides technical partnership. The author is responsible for system design and development, with input from N.A.S. Surveyors and Survnet Uganda. (All authors and affiliations are as stated; no external sources were cited for this project info.)

Data Volumes and Infrastructure

The system manages a large **vector dataset (~20 GB)** of land parcels, including both formal titles and customary *bibanja* rights. This raw data is stored in a spatial database (PostGIS) and served through standard OGC services. For example, an Open Geospatial Consortium Web Feature Service (WFS) provides access to the underlying geographic features (the "source code" behind a map), whereas a Web Map Service (WMS) delivers georeferenced map imagesen.wikipedia.orgen.wikipedia.org. In practice, typical WFS/WMS requests currently deliver on the order of **20 MB of data** per load. (By way of comparison, recent studies note that a simple PNG relief map of a country can be ~20 MBmdpi.com.)

To handle these data volumes efficiently, the system uses spatial indexing and optimized data layouts. For example, one GIS guide notes that *"the single biggest boost to performance is indexing"*, recommending a GIST spatial index on geometry columnsmapserver.gis.umn.edu. We ensure each feature table (e.g. parcels, boundaries) has a proper spatial index and primary key to accelerate queriesmapserver.gis.umn.edu. Tile caching and selective filtering are also employed: vector layers are sometimes split or pre-filtered by area to limit query results. Overall, with 20 GB of vector data, the network can deliver map or feature requests on the order of a few seconds, making the current **typical response time ~5 s**. (This is within the 2–10 s range where interactive maps can still be usable, although ideally sub-1 s would be preferablenngroup.com.)

- **Data infrastructure:** PostGIS database with ~20 GB of land polygons and attributes.
- **Access services:** OGC WFS (for feature queries) and WMS (for map images).
- **Optimizations:** Spatial (GIST) and attribute indexingmapserver.gis.umn.edu, data tiling/splitting, and client-side caching for large layers.
- **Response performance:** Around 5 s per query; Nielsen's usability guidelines suggest operations under ~10 s should display progress feedback to maintain user attentionnngroup.com. (We plan to implement progress indicators for longer tasks.)

Standards and Interoperability

The system is built on open standards to maximize compatibility. It uses OGC protocols (WFS/WMS) as noted, which are widely supported by GIS softwareen.wikipedia.orgen.wikipedia.org. Feature data are exchanged in standard formats such as GML or GeoJSON. This aligns with international best practices: for example, the INSPIRE Directive (EU) establishes a spatial data infrastructure framework that *"enables public sector organisations to share environmental spatial information"* and *"facilitates public access to spatial information"*gov.ie. While Uganda is not under INSPIRE, the same

principles apply: harmonized metadata, service catalogs, and common data models ensure interoperability.

We also consider land administration standards. The ISO Land Administration Domain Model (LADM, ISO 19152) provides a conceptual schema for land rights and cadastral data. LADM *"covers basic information-related components of land administration including those over land, in water, below the surface, and above the ground"*gdmc.nl. In other words, it models parties, rights, and spatial units in a standardized way. Implementing LADM concepts can help integrate *bibanja* (customary rights) with formal registry data. LADM is intended for distributed systems and SDI use: for example, one study notes that LADM promotes *"land administration in a distributed environment with different organizations involved,"* and it explicitly supports developing land administration systems as part of a Spatial Data Infrastructuregdmc.nl.

Key standards and references being used include:

- **OGC WFS/WMS:** Open standards for feature and map servicesen.wikipedia.orgen.wikipedia.org.
- **Spatial Reference Systems:** Consistent use of Uganda's official CRS (ITRF-2005) for all data to avoid reprojection mismatches.
- **LADM (ISO 19152):** Conceptual model for cadastre/tenure domainsgdmc.nl.
- **NSDI Guidelines:** Following the Uganda GIS Standards Manual (2022) developed by the National Planning Authority (drafted to guide information sharing at national scaledocuments1.worldbank.org).
- **INSPIRE Principles:** Although Uganda is not an EU member, INSPIRE's emphasis on common themes, metadata, and web services serves as a useful modelgov.ie.

We also heed interoperability research specific to Uganda. For instance, Musinguzi *et al.* (2012) report that Uganda suffers from *"lack of clear and harmonized policies on the exchange of spatial data across institutions"* and limited collaborationijsdir.sadl.kuleuven.be. To counteract this, our system is designed as an open network where surveyors and land offices can contribute data. We plan to document datasets and use shared schemas so that *"documentation of data, development of policies on data sharing, [and] legislation on [an] SDI"* are addressedijsdir.sadl.kuleuven.be. In summary, we build on OGC/ISO standards and the lessons of INSPIRE/NSDI to ensure the network can scale and interoperate with other Uganda land systems.

Data Privacy and Governance

Customary land data involve personal landholders, so privacy and consent are crucial. Under Uganda's Data Protection and Privacy Act (2019), any processing of personal data (including names or identifiers of land owners) requires prior, informed consentulii.org. The Act defines *"personal data"* broadly as information that can identify a person (e.g. owner name, ID number, occupancy status)ulii.org. In practice, this means the network will only include a beneficiary's consented information. Bibanja holders will explicitly authorize the use of their data; surveys will include a consent clause. Without lawful consent, we cannot share personal details on the system (and the Uganda law mandates we would need to either remove personal identifiers or secure additional legal basis)ulii.orgulii.org.

Additionally, survey data often include location traces and sketches of individuals' holdings. These are treated as confidential: we apply access controls so that only authorized users (e.g. that landowner, or government land officer) can view detailed records. We plan to follow *"privacy by design"*, encrypting sensitive fields in transit and at rest. The system's governance will comply with any future sector-specific regulations. (For example, Uganda's Electronic Signatures Act currently excludes land transactionsdocuments1.worldbank.org, meaning titles still require wet-ink signatures; this reinforces the need for paper backups and careful migration of *bibanja* data.)

Overall, our compliance approach is twofold: (1) **Legal**: adhere to the Data Protection Act by collecting consent and protecting personal dataulii.orgulii.org. (2) **Policy**: develop internal protocols and metadata for all datasets. This complements national policy gaps: as Musinguzi *et al.* note, Uganda needs harmonized policies and data documentation to avoid conflictsijsdir.sadl.kuleuven.be. Our project will contribute by drafting a "Data Sharing Protocol" in consultation with local land authorities, ensuring owners' rights and privacy are respected at every stage.

Project Goals and Societal Impact

The overarching goal is to **improve land tenure security and reduce disputes** by making *bibanja* rights visible and accessible. In Uganda today, customary land certificates are often analog and unindexeddocuments1.worldbank.org, leading to encroachment and conflicts. By digitizing and publishing *bibanja* boundaries (with consent), the system helps community members and surveyors resolve boundary ambiguities. This advances national priorities: the Uganda Land Act (and Vision 2040) emphasize formalizing land rights and embracing an integrated land information systemdocuments1.worldbank.orgdocuments1.worldbank.org.

The specific shared objectives include:

- **Secure Tenure for Rural Communities:** Enable holders of customary land to obtain certificates and have them recognized digitally. This counters the current state where *"Certificates of Customary Ownership are maintained in analogue… and are not digitized or integrated"* into the national registrydocuments1.worldbank.org. Digitization promotes tenure security and protects against natural disasters or fraud.
- **Data Sharing Between Surveyors and Land Offices:** Provide a platform where authorized surveyors, sub-county registrars, and planners can access up-to-date parcel data. This streamlines surveying: land with titles can already be quickly reestablished since the data exists, and *bibanja* plots (once digitized) will allow similar workflows for customary lands.
- **Transparency and Conflict Reduction:** Public availability of consensual land boundaries raises awareness and deters illegal encroachment. As the Cadasta land rights initiative has demonstrated, mapping customary land can secure tens of thousands of tenure rightsesri.com. For example, in Uganda a recent project helped issue *5,500 Customary Certificates*, benefiting over **45,000 people**esri.com. Our system aims to amplify such successes at scale.
- **Community Engagement and Capacity Building:** Beyond technology, we plan outreach programs (inspired by recommendations in Musinguzi *et al.*) to train local leaders in using the systemijsdir.sadl.kuleuven.be. Empowering communities and surveyors with mapping tools ensures the system is used and updated.

These goals combine technical and practical appeal. On the technical side, we implement GIS best practices and standards to ensure a robust SDIgdmc.nlgdmc.nl. On the outreach side, we emphasize the real-world impact: better land management leads to increased agricultural investment, higher credit access (as tenure becomes documented), and social equity (notably, women often benefit from clear land rights when their occupancy is recorded)esri.com. The Cadasta case illustrates that community-centered GIS can *"unlock land tenure rights, economic and social opportunities"* for vulnerable groupsesri.comesri.com. We will highlight such benefits in stakeholder engagement (farmer forums, local councils) to encourage participation.

Scalability, Funding, and Call for Support

Scalability: The network is designed to grow with Uganda's needs. By using open-source GIS software (e.g. GeoServer, QGIS) and commodity hardware, it can start small (single-server) and expand (cloud or local datacenters) as data volume or user load increases. To serve more districts, we plan a modular architecture: each district can host its own node which synchronizes with a central catalog. Interoperability standards ensure that new data sources (e.g. aerial imagery, satellite mapping) can be integrated later.

Funding Needs: Achieving national coverage requires financial and technical resources. Key needs include:

- **Infrastructure Investment:** Servers/storage for larger datasets and backup. Currently 20 GB fits on a moderate cloud VM, but scaling to full national coverage (all districts) will increase storage to perhaps 100–200 GB. High-availability web servers and reliable internet connectivity are also needed for low response times.
- **Data Collection and Digitization:** Field surveying to capture *bibanja* boundaries. This entails training survey teams, GPS/RTK equipment, and data entry personnel. (As noted, populations continue to grow and migratedocuments1.worldbank.org, so systematic land adjudication is an ongoing task.)
- **Training and Support:** Empowering local staff to use and maintain the system. This includes GIS training workshops and development of user manuals in local languages. Past projects stress that *"capacity building"* is essential for SDI successijsdir.sadl.kuleuven.be.
- **Governance and Legal Framework:** Budget for stakeholder meetings to formalize data-sharing agreements, and possibly for legal counsel to ensure compliance with emerging land information laws.

Call for Support: We welcome partnerships and funding from government, NGOs, and the tech community. International donors and technology platforms have shown willingness to invest in land data systems (for example, the UK's FCDO supports land rights programsesri.com). Civil-society groups can join in community mapping efforts. Technologists can contribute via the geospatial community: as one calls to action notes, *"Cadasta cannot do this work alone"* and invites the global GIS community to help *"scale up rights-based mapping and build the next generation of land systems"*esri.com.

In summary, sustained funding will enable the network to expand beyond the pilot phase. By highlighting the socio-economic returns (secured property taxes, investment incentives, conflict reduction), we aim to justify the investment. More immediately, we need seed

funding for the next year's roadmap: server hosting, data digitization (at least in one new district), and user training. Supporting this project aligns with Uganda's Vision 2040 and land sector reformsdocuments1.worldbank.orgdocuments1.worldbank.org, and has the potential to leverage additional resources (e.g. government matching funds, crowdsourcing).

Conclusion: This initiative represents a step toward a fully integrated land administration SDI for Uganda. It leverages international standards (OGC, LADM, INSPIRE principles) and addresses local challenges (customary land rights, policy gaps) in a unified system. The combined technical and social approach – from database indexing to community outreach – ensures a comprehensive solution. By documenting its progress with best practices and citations to seminal worksgdmc.nlijsdir.sadl.kuleuven.beesri.com, this project aims to contribute both a practical system and a replicable model for other contexts.

Sources: This report cites technical and policy literature to support its design. Key references include studies on Uganda's spatial data interoperability challengesijsdir.sadl.kuleuven.beijsdir.sadl.kuleuven.be, World Bank analyses of Uganda's land information systemsdocuments1.worldbank.orgdocuments1.worldbank.org, and GIS standards documentationen.wikipedia.orggdmc.nlesri.com. All statements of fact or prior work are backed by these sources as indicated.