Using Spatially Enabled Governance to Synchronise Spatial and Temporal Resource Management

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Summary

Modern spatially enabled governance concepts are used to reimagine the integration of spatial and temporal resource management to enable adaptive-governance intelligence. Historically, in South Africa, land development, tenure documentation, and rural municipal service provision occur on different time scales and are managed by different organisations at the national, district, and local levels. Achieving affordable spatial and temporal coherence of local, district, and national databases remains challenging. In rural municipalities and communal areas, subdivision of communal areas remains incomplete, much as in urban areas only 2 million of the 5-7 million municipal properties have been registered in the Deeds Registry since 1994.

Harmonising and synchronising databases spatially—from district to erven—temporally, including monthly, quarterly, annual, and five-year cycles— and administratively will enable adaptive learning and effective governance.

The Department of Land Reform and Rural Development (DLRRD) can embed data-driven feedback and iterative learning cycles within the National and Regional Spatial Development Frameworks, drawing on data from the National Spatial Data Observatory (NSDO) to operationalise adaptive learning concepts and achieve efficient governance at local, district, and national scales. Quarterly adaptive-learning sessions among these institutions would consolidate experience into shared practice and strengthen governance coherence.

By linking geospatial observation with fiscal and planning systems, the NSDO enables the feedback loops required for real-time institutional learning. Monthly dashboards that integrate land-use change, climate anomalies, and expenditure exposure allow evidence-based timing of interventions. Embedding these insights in IDPs and Spatial Development Frameworks turns data into adaptive-governance intelligence and links monthly reporting into quarterly and annual reports that track performance against the five-year IDPs.

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1.0 Introduction

Historically, in South Africa, land development, tenure documentation, and rural municipal service provision occur on different time scales and are managed by different organisations at the national, district, and local levels. This fragmentation is not only administrative, but it is also institutional. Section 12 of SPLUMA establishes an interdependent planning system, in which multiple spheres, often neighbouring municipalities, must produce and utilise Spatial Development Frameworks (SDFs) in a manner that results in mutual adjustment, rather than merely parallel compliance. This is a nested, non-linear system that relies on continuous interaction between actors, information feedback, and interdependent decisions, which can result in multiple equilibria rather than a single, one-time "approved plan" (Minnie et al., 2022). Harmonising and synchronising databases to spatially enable this complex interaction, from district to erven, and temporally, including monthly, quarterly, annual, and five-year cycles, as well as administratively, aims to enable adaptive learning and effective governance.

South Africa's spatial governance reveals a constant misalignment between administrative time and developmental time. Administrative time advances through five-year Integrated Development Plans (IDPs), fiscal cycles, and electoral terms. Within this “nested labyrinth”, alignment must occur both vertically across spheres and horizontally across adjacent municipalities when spatial issues are coterminous, and this alignment is achieved through participation, shared information, and mutual influence that leads to mutual adjustment. Developmental time unfolds through demographic change, market transitions, and ecological feedback. In rural municipalities, property tax rates are dominated by communal areas where land is not subdivided, and individual portions are not surveyed and recorded in the Deeds Registry. In the absence of registered tenure rights, it is difficult for municipalities to establish the market value of residential properties, and it is impossible for land tenants to establish private ownership of the land they occupy, access financing, or build generational wealth. Additionally, municipalities lose significant property tax and municipal service revenue due to unbilled local services, such as power, water, and sanitation.

The Department of Land Reform and Rural Development (DLRRD) can embed data-driven feedback and iterative learning cycles within the National and Regional Spatial Development Frameworks, drawing on data from the National Spatial Data Observatory (NSDO) to operationalise adaptive learning concepts as outlined by Pahl-Wostl (2009) and achieve

efficient governance at local, district, and national scales. Quarterly adaptive-learning sessions among these institutions would consolidate experience into shared practice and strengthen governance coherence.

2.0 Background and Context

Achieving affordable spatial and temporal coherence of local, district, and national databases remains challenging. In rural municipalities and communal areas, subdivision of communal areas remains incomplete, much as in urban areas, only 2 million of the 5-7 million municipal properties have been registered in the Deeds Registry since 1994.

Against this backdrop, the National Spatial Data Observatory (NSDO) is positioned as enabling infrastructure for making SDFS operational at scale. This requires information feedback to support continuous mutual adjustment between nested political and technical actors. The NSDO directly strengthens that requirement by harmonising and synchronising spatial and temporal data across spheres, and by providing a common evidence base that can be used across the "drafting SDF" sub-holon and the "using SDF" sub-holon, including the leaf-holon where Municipal Planning Tribunals rely on SDFs and land-use schemes when considering development applications.

In Figure 1, Section 12 of SPLUMA presents an oversimplified linear system, supporting the notion that the Act contains the essential elements of a theoretical system. Informing the system elements, both implicit and explicit, is derived from Section 12(2) of SPLUMA, quoted here:

> *12 (2a) The national government, a provincial government and a municipality must participate (the actors) in the spatial planning and land use management* ***processes*** *that impact on each other to ensure that the plans and programmes are coordinated, consistent and in harmony (as a developmental state representing a spatial equilibrium) with each other.*
>
> *(2b) A Spatial Development Framework (SDF) adopted in terms of this Act must* ***guide and inform*** *(outcome) the exercise of any discretion or of any decision taken in terms of this Act or any other law relating to land use and development of land by that sphere of government (South Africa, 2013a, sec. 12(2)).*

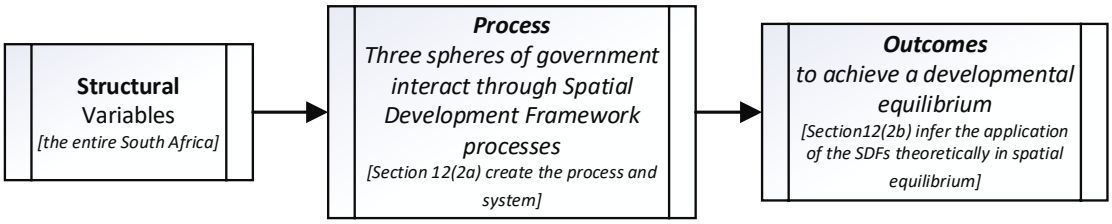

Figure 1 - An oversimplified theoretical linear system created by Section 12 of SPLUMA (Minnie et al., 2022)

In practical terms, this means spatially aligning datasets from district to erven, and temporally aligning reporting across monthly, quarterly, annual, and five-year cycles, so that dashboards become credible inputs into the recurring action situations where alignment is negotiated and revised, not static outputs that sit beside planning.

3. Approach

Underlying the challenge is the simple fact that aerial and satellite mapping have latent misregistration, which achieves an accuracy of 1-3 m (circular error at 95% probability, or CE95). In contrast, the cadastral standard for property surveying is 5 cm CE95. Since 2024, DLRRD has been developing a drone mapping program that has demonstrated high-accuracy 3D mapping, meeting the CD: NGI cadastral mapping requirements of 5 cm CE95. Area mapping of Vista Park, Bloemfontein, achieved a CE95 of 2.7 cm (Minnie, 2024), and independent verification and validation of 5 cm (Abrams, Minnie, and Heimann, 2024) were conducted using 76 ground control points, adhering to ASPRS 2024 accuracy standards.

A second challenge to consistent spatial-temporal mapping is consistent spatial-radiometric calibration, which allows the linking of multiple data sets into a consistent time series. This process of data registration and harmonisation is critical to correlating changes in the human use of the landform in the presence of environmental and climatic changes. In 2025, the Republic of South Africa's Council for Scientific and Industrial Research (CSIR) re-established its Paardenfontein calibration-validation site (Bezuidenhout, 2013, and Faniso–Mnyaka, 2024), which enables both national and international calibration of satellite and aerial sensors.

Third, curating current, accurate municipal service databases remains challenging. Power and water infrastructure may be an exception to a survey requirement, as each legal or illegal power or water connection is connected to a residential or business structure that provides a defined point of consumption. Absent local metering, which has been deemed unsuccessful, associating usage with property elements is impossible. Similarly, surveying will not address the sanitation problem created by shared skip bins, as it will not measure waste generation or disposal per residential unit.

Currently unaddressed at the local level are cellular service rates. Cellular service is a commercial service that may be taxed at the national and local levels. In South Africa, the value-added taxation for cellular service is 15% in contrast to US federal, state, and local taxes that range from 24.5 to 26.8%, depending on the state. In the United States, the Permanent Internet Tax Freedom Act prevents state and local governments from imposing taxes and fees on wireless internet access. Local taxation for cellular service in South Africa may be a previously untapped source of revenue for municipalities that does not require land survey, as it is an extension of existing federal taxation based on billing addresses.

With accurate spatial-radiometric data collected on a recurring basis, we possess the essential mapping tools to subdivide communal land into ervens (property surveys or plats) and maintain spatial and temporal custody at the local, district, and national levels. The foundational elements of a land-tenure market economy are the land survey (plat), the tenure certificate, and a mortgage on the property. In communal areas, a distinction between the property boundaries (erven/plat) and the constructed habitation (buildings) should be included in the survey requirements to properly represent the built property value rather than the land value. In most modern economies, both land and structures are valued and taxed. These documents establish the property value and property base rates. Municipalities will provide utility services, such as electricity, water, and sanitation, and can bill tenured landholders. Without property surveys, taxation, and service revenue billing are difficult, if not impossible.

4. Recommended Program

A recommended program of data curation into the NSDO could logically include the following steps:

a) A baseline survey of land tenure in communal areas is necessary, as is a plan for periodic updates (annual/five-year/To Be Defined). This will enable tenure certification and property taxation.

b) Point-of-service delivery documentation for electricity, water, sanitation, and potentially cellular service is necessary to attribute each property plat and tenure certificate to habitation and municipal service usage.

c) The conflation and curation of a shared database of land tenure, habitation, and municipal services rendered will enable the establishment of property and service rates.

d) Attribution of legal and illegal connections, as well as metering at each point of consumption, is necessary to establish and maintain local municipal control over expended resources and to mitigate unpaid losses from municipal services rendered.

5. Summary

In summary, land tenure certification is a necessary component of moving all South Africans to a common, shared property-based economy and can expand the municipal revenue from taxation to rural municipalities in communal areas. Absent point-of-service monitoring, however, land tenure certification will not specifically address revenue losses from unmetered power, water, and sanitation use. In combination, a conflated database of divided property records (ervens/plats) and point-of-service delivery (address databases) will support more effective municipal management and identify underdeveloped or unreported areas for further examination.

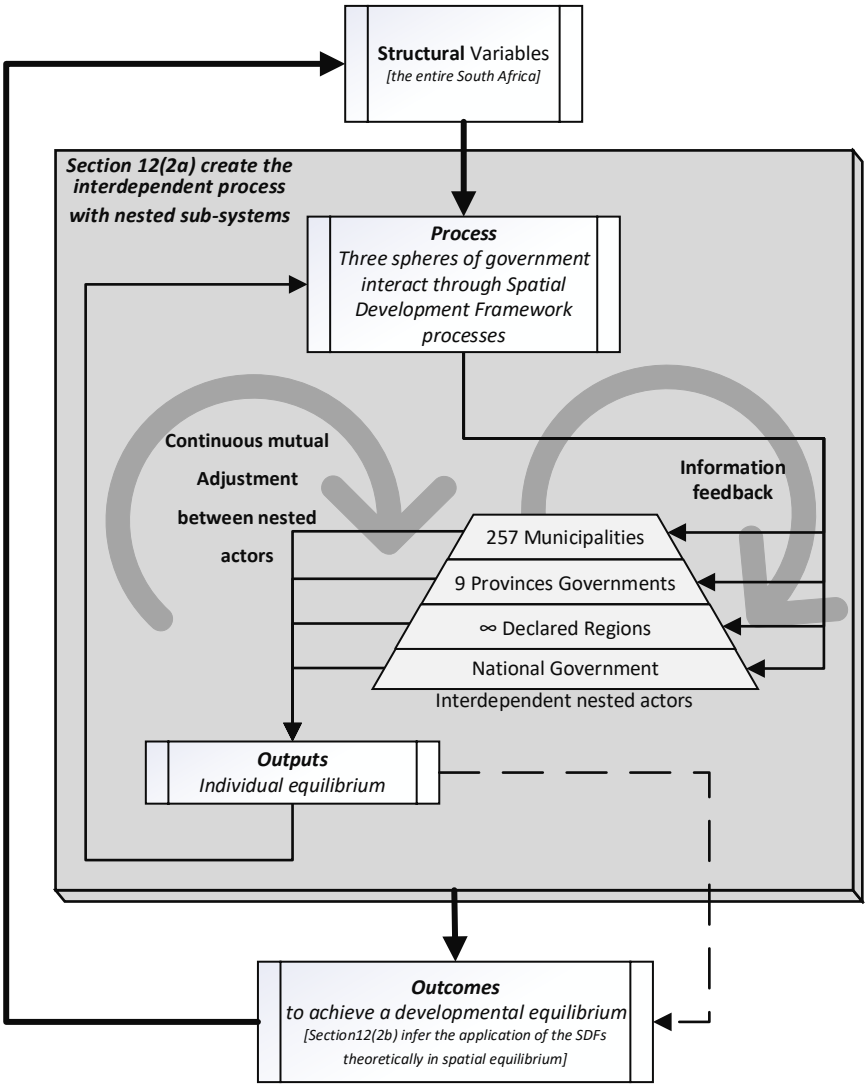

Figure 2 - A nested non-linear system created by SPLUMA to be supported by the NSDO (Minnie et al., 2022)

By linking geospatial observation with fiscal and planning systems, the NSDO enables the feedback loops required for real-time institutional learning. Resulting in the NSDO as a dynamic system that enables interaction between proposed outcomes (Figure 2) that needs to be incorporated into a dynamic loop to ensure mutual adjustment through interdependent decisions. The objective is to achieve mutually influenced multiple equilibria (outputs) representative of inputs from all actors. The combination produces a core theoretical system as required by Section 12(2) of SPLUMA, reflected in Figure 2.

Monthly dashboards that integrate land-use change, climate anomalies, and expenditure exposure allow evidence-based timing of interventions. Embedding these insights not only in Spatial Development Frameworks but also in IDPs and PGDs will transform data into adaptive-

governance intelligence, linking monthly reporting to quarterly and annual reports that track performance against the five-year IDP/PGDSs.

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BIOGRAPHICAL NOTES

Mr. Clinton Heimann, Acting Director General, Department of Land Reform & Rural Development, UNGGIM Co-Chair, UNGGIM Africa – Chair, Registered Town and Regional Planner, SACAA Certified Unmanned Aircraft pilot with BVLOS rating. With over 23 years of experience in spatial planning, rural development, rural agricultural system design, and

infrastructure projects, I am committed to driving transformation in South Africa and Africa, with a specific interest in spatial and land justice, utilising innovative geospatial tools and methodologies within South Africa's urban and rural communities.

Mr. Stephanus (Fanie) Minnie, Director, Spatial Planning and Land Use Management Services / National Drone Programme Department of Land Reform & Rural Development. Registered Professional GISc Practitioner, SACAA Certified Unmanned Aircraft pilot with BVLOS rating and Aviation Safety Management System (SMS) accredited. With 36 years of experience in the built environment related to infrastructure planning, telecommunication engineering projects, GISc projects and Urban and Regional Planning projects and entrusted in 2022 with leading the National Drone Programme, a transformative initiative that enhances spatial analysis and monitoring through cutting-edge remote sensing. Leveraging 3D Oblique imagery, LiDAR, and multispectral mapping, I oversee complex drone operations aligned to ICAO standards that generate actionable insights for spatial planning, infrastructure, and environmental applications.

Dr. Abrams specialises in calibration and independent verification and validation of complex information systems. Examples include establishing absolute spectral calibration systems in the 1980s, establishing 3D geodetic networks with DGNSS class stability and accuracy, and demonstrating and certifying 3D remote sensing systems with sub-meter absolute accuracy across four continents.

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