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Article

Cadastres and land management in Africa: Discussions on their sustainability and lessons through a semisystematic review

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Abstract: The challenge of developing cadastral infrastructure in Africa is inextricably linked to the global issues of sustainable development. Indeed, in light of the constraints inherent to conventional cadastral systems, alternative systems developed through land regulation programmes (LRPs) are compelled to align with the tenets of sustainable development. A discursive study, conducted through a semisystematic literature review, enabled the selection of 53 documents on cadastral systems deployed in multiple countries across the African continent. A number of systems were identified and grouped into four categories: urban, rural, participatory and hybrid cadastral systems. These systems are developed on the basis of standards and sociotechnical approaches, including the LADM, STDM, and FFP, as well as innovative technologies such as blockchain. However, their sustainability is limited by the fact that they are not multipurpose cadastral systems. Consequently, there is an urgent need for studies to develop a global framework that will produce truly significant and sustainable results for all sections of society.

Keywords: cadastral system; land management; sustainable development; semisystematic review; African continent

1. Introduction

Historically, cadastral systems have been a fundamental part of the infrastructure of a country's land administration systems, facilitating the implementation of land policies and land management strategies (FIG Publication No. 60). In Africa, they were mostly introduced at the beginning of the colonial period by the colonizing powers according to their standards, approaches and needs for registering land assets. Conventional cadastral systems, considered essential for effective land administration, have been established in almost all countries. However, these systems have struggled to live up to expectations, with limited territorial coverage and a paradoxical weakening of land rights (Kingwill, 2004). Since the end of the twentieth century, these concerns, coupled with the various problems associated with land, have led decision-makers and experts to formulate sustainable development as a fundamental concept for remedying the ills that undermine all sectors, especially the land sector.

The concept of sustainable development, defined in its most basic form as the capacity to meet the needs of the present without compromising the ability to meet the needs of future generations, was first proposed in the 1970s (Martin, 2002). Since that time, it has been the subject of two United Nations global development programs. First, the Millennium Development Goals (MDG_2000–2015) and second, the agenda 2030 on Sustainable Development Goals (SDG_2015–2030). Of the issues outlined in the

targets, indicators and objectives, the question of land tenure and the basis of its use is of particular importance in the context of these challenges in all societies. Consequently, the complexity of the relationships between people and land is an important issue to be resolved for effective land appropriation and better valuation of land assets.

The valuation of appropriable land assets generates tensions in terms of management, taxation, urban planning, development, peace, etc., and is a growing concern for experts and decision-makers. These appeals found their full resonance at the start of the decentralization process and the promotion of good governance. These circumstances have led to the development of land management tools. A number of systems/tools were developed, forming an action package that was introduced to Africa from the 1980s onward. This was made possible in part by the support of the World Bank and other cooperation agencies (Durand-Lasserve, 1993; Farvacque and McAuslan, 1992; World Bank, 1985). Among these instruments, land information systems (LISs) are highlighted. An LIS should be seen as an environment that brings together a database related to parcels of land as well as the equipment, procedures and methods that enable data to be collected, updated, processed and correlated, with a view to producing and retrieving information (Durand-Lasserve, 1993). The implementation of these techniques has demonstrated a remarkable degree of variability, as observed by van Oosterom et al. (2006): one operates the registration of acts, the other performs the registration of titles, some systems are centralized, others are decentralized, some systems are based on a general limits approach, and others are based on fixed limits. These LISs, in the form of cadastral systems or land registries, are being promoted to record land information in several countries (Çagdaş and Stubkjaer, 2009). However, if they are part of the LIS, definitions vary considerably. For the Commission of the International Federation of Surveyors (FIG), the cadastre, is normally a parcel-based and up-to-date land information system containing a record of interest in land (e.g., rights, restrictions and responsibilities). It usually includes a geometric description of land parcels linked to other records describing the nature of the interests, the ownership or control of those interests, and often the value of the parcel and its improvements. It may be established for fiscal purposes (e.g., valuation and equitable taxation) or legal purposes (conveyancing) to assist in the management of land and land use (e.g., for planning and other administrative purposes) and to enable sustainable development and environmental protection (FIG, Publication N° 11).

Lavigne (1996) defines cadastres as exhausting (over the entire territory), descriptive (description of the property and its boundaries), evaluative (determines its tax value) and/or legal, and permanent (updated) inventories of land ownership. Silva and Stubkjaer (2002) define this as a systematic and official description of land parcels that includes a unique identifier and textual records on attributes for each parcel. Additionally, in 2009, Çagdaş and Stubkjaer emphasized that this approach provides systematic and official descriptions of land parcels or real estate units. It is therefore appropriate to consider the cadastral system as the principal mechanism for the sustainable administration and management of land resources (Chekole et al., 2020a). The cadastral system is analogous to the land administration system and considers the land parcel to be identified (Williamson et al., 2010). The administration of land as a

natural resource is concerned with ensuring its sustainable use and development. Therefore, it is concerned with all the frameworks (social, legal, economic, technical, etc.) within which land managers and administrators must operate to ensure "ownership." (UN/ECE, 1996). These definitions indicate that the cadastral system is not merely a record of cartographic and attribute data for parcels; it also ensures their sustainability. Nevertheless, as with LIS, the implementation of cadastres is based on a number of disparate principles. Some systems are founded on a fiscal basis, others are founded on a legal basis, others are founded on a security basis, and others are founded on a combination of the two. Despite their diversity, these systems all focus on the intermediary relationship between humans and land.

The use of cadastral systems has undergone several generations of intervention in Africa. A historical analysis reveals that they began with the introduction of what (Comby, 2012) called the "watered-down Torrens system" (a derivative of the Torrens system established in 1858 in Australia). This is a cadastral system established to record colonial property and land transactions, as well as to transfer customary rights through the cadastres into modern registers. This was followed by state-led systems such as registers, which were implemented as a conventional land management tool in most states. Subsequently, systems that transcended the conventional framework were introduced (Hull and Whittal, 2020; Williamson et al., 2010). In their original form, cadastres were legal in nature. However, as a consequence of socioeconomic and urban crises, they underwent a transformation, evolving into fiscal and planning systems. This evolution has enabled them to benefit from new techniques and technologies with the aim of untying land rights from human expression by formalizing land acts on systems other than paper (Lavigne Delville, 2002, 2009; Lemmen et al., 2004; Plateau, 1996). It is widely recognized that the cadastral system represents a central approach to land management. If land management is defined as the process of making the best use of land resources, the design of cadastral systems must not only incorporate sustainability as a guiding principle but also be sustainable at the operational level, within territories and for all stakeholders. This operationalization requires an epistemological understanding that could serve as a basis for the sustainability of each cadastral system developed. It is therefore crucial to synthesize the various alternative cadastral systems developed on the continent in response to the limitations of national cadastral systems to gain insight into the sustainable development objectives targeted at the deployment of cadastres in Africa. The study is informed by the following research questions:

- What types of cadastral systems have been deployed in land administrations in Africa?
- What are the standards and sociotechnical approaches of cadastral systems in Africa?
- How do these cadastral systems consider sustainable development?

This research is organized as follows. Section 2 presents the research methodology. The results of the research are summarized in Section 3. Section 4 presents the discussion, lessons learned, and the final section is devoted to the conclusion and recommendations.

2. Methodology

In light of the research objectives, a semisystematic literature review is employed as the methodological approach in this study. In general, this review seeks to understand and synthesize potentially relevant research aspects and implications for the topic under study with the help of meta-narratives (Wong et al., 2013). This type of review is designed to identify and explain all theoretically significant patterns for a given topic through a meta-narrative synthesis (Snyder, 2019). Additionally, this synthesis is designed for topics that have been conceptualized and studied in disparate ways by various groups of researchers in various disciplines. To conduct this research on cadastral systems, we employed an approach that combined exhaustive data collection and the categorization of themes developed in the literature (Omazic and Zunk, 2021).

First, the concepts that can be linked to cadastres were defined. Consequently, the following keywords were identified as relevant for the purposes of this study: cadastres, cadastral system, cadastral tool, alternative cadastral system, land register, land book, land information system, land administration system, land administration, land security system, land security, land data, land title, and land ownership. Boolean methods were then employed in the Google Scholar and Scopus databases to identify all relevant literature up to 2024. These databases were selected for their comprehensive coverage of journals focusing on land globally (Mongeon and Paul-Hus, 2016). Second, a process of sorting the collected citations and documents was carried out via the PRISMA flowchart **(Figure 1).**

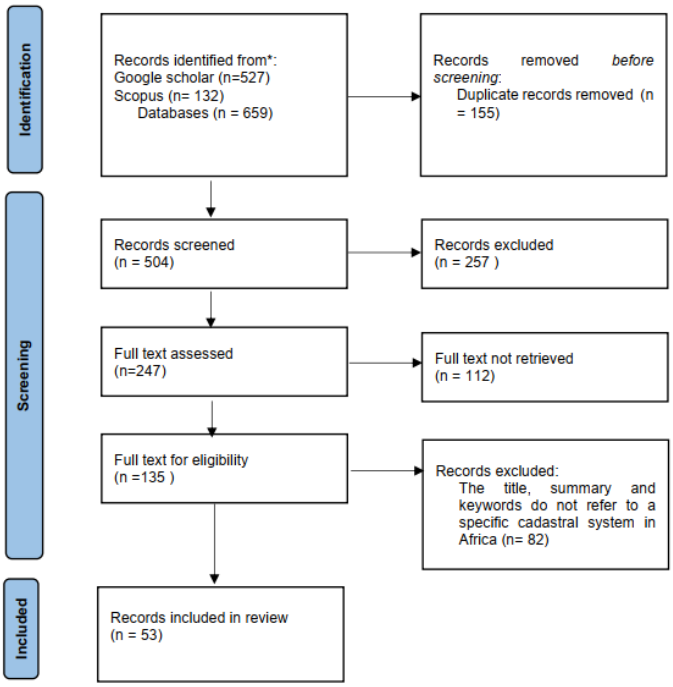

Figure 1. PRISMA flow diagram.

Source: Authors, 2024.

The search was conducted in English and French and encompassed a diverse array of sources and documents pertinent to the research questions. The search returned a total of 659 documents. To guarantee the quality and relevance of the

documents selected for analysis, a set of inclusion and exclusion criteria was applied. Consequently, any duplicates, citations, titles or abstracts that did not pertain to a country on the continent or that did not mention a country in Africa were immediately excluded. Second, the title and summary should not address the administration of land in a country in general but should focus on the specific type of cadastral system in question. A total of 135 texts were selected for more in-depth analysis. A total of 53 documents were selected via a reading grid. The remaining documents were of various types, including scientific articles (68%), books (8%), dissertations/theses (6%), conference proceedings (6%), study reports (10%) and teaching sheets (2%).

The titles, summaries and keywords of all these documents refer to a cadastral system deployed or currently being tested on the African continent.

The selected documents were then subjected to content analysis. This technique enabled us to identify, collate, analyze and synthesize the various systems mentioned in the scientific literature and to analyze the standards and sociotechnical approaches underpinning them.

In terms of sustainability, we propose the hypothesis that no system can be implemented without any vision of sustainability. Therefore, our focus should be on their orientation with respect to sustainability to understand their conceptual and operational scope. In light of the aforementioned considerations, the writing process entailed a comprehensive literature search utilizing the spider approach (Ansah et al., 2023; Webster and Watson, 2002), with the objective of elucidating the identified aspects and addressing any areas of ambiguity. The following section presents the findings of this search.

3. Results

3.1. Identification of cadastral systems in databases

The initial step was to identify the cadastral systems in each country. The proportions of the countries of interest were taken into account on the basis of the publications to quantify the authors' interest in a given system **(Figure 2).**

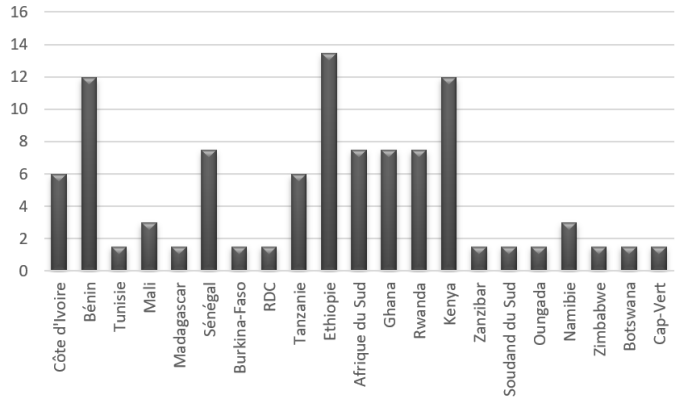

Figure 2. Countries involved in current studies.

Source: Authors, 2024.

This graph shows that, particularly in English-speaking areas (64%), countries such as Ethiopia, Kenya, Ghana, South Africa and Rwanda are the countries where

cadastral tools are deployed and best documented. In the French-speaking area (33%), Benin, Senegal and the Ivory Coast were the standard bearers of these studies. The discrepancy in documentation between English-speaking and French-speaking environments can be attributed to a number of factors, including the colonial legacy of donors and experts involved in cadastral system development projects, the greater emphasis placed on land administration issues by English-speaking universities than their French-speaking counterparts, and the greater level of funding allocated to research in English-speaking contexts than in French-speaking contexts. This literature began in earnest in the 1990s, when nonconventional land information systems were first implemented in African countries. Indeed, the adoption of cadastral tools on the continent was more in line with land regularization programs (LRP-Bizoza and Opio-Omoding, 2021). These programs aimed to ensure the coexistence of different types of land tenure systems, which sometimes require different cadastral approaches in the same territory. De Vries et al. (2014) distinguished between conventional and neo-cadastal systems. The former are based on rules defined by a hierarchical authority, whereas the latter are based on a variety of opinions. These systems are called alternative land registration systems (Kabigi et al., 2021), and several are being developed on the continent, as shown in **Table 1**.

Table 1. Publications on the cadastral system developed.

Cadastral system developed	Countries concerned
Plan Foncier Rural (PFR)	Ivory Coast, Benin, Burkina Faso
Registre Foncier Urbain (RFU)	Benin
Land register/Land books	Mali, Senegal, Ethiopia
Plan Local d'Occupation Foncière (PLOF)/Guichet foncier communal	Madagascar
Plan d'Occupation et d'Affectation des Sols (POAS)	Senegal
Système d'Information sur les Attributions Foncières (SIAF)	Senegal
Système d'information géographique participatif (SIG-P)	Senegal
Land Information System based on Land Administration Domain Model (LIS-LADM)	Benin
Hybrid system based on the Social Tenure Domain Model (STDM)	Democratic Republic of Congo
Village Land Use Plan (VLUP)	Tanzania
Urban Cadastral System	Ethiopia
Community Land Record System (CRS)	South Africa
Blockchain technology	Ghana, Tunisia
Pro-poor land recordation tool (PPLRT)	Kenya, South Sudan, Oungada
Certificates of Customary Right of Occupancy (CCRO)	Tanzania
Unmanned Aerial Vehicles (UAVs) in Land Administration System (LAS)	Ghana, Kenya, Namibia, Rwanda, Senegal, Tanzania
Volunteered Geographic Information (VGI or participatory mapping) in Land administration	Kenya
South Africa Spatial Data Infrastructure (SASDI)	South Africa
Land Registry	Ethiopia
Hybrid land tenure administration	South Africa
Women's Land Tenure Security	Ethiopia

Source: African cadastral systems review; Authors, 2024.

The systems presented in this table encompass a diverse range of types. Some systems are geographically oriented. These systems are designed for use in urban territories, including the Registres Fonciers Urbains (RFU), the Urban Cadastral System, and the Community Land Record System (CRS). They are also suitable for use in rural territories, such as the Plans Fonciers Ruraux and the Village Land Use Plan (VLUP). Additionally, they can be employed in national (centralized) or communal (decentralized) territories. Other systems are clearly oriented toward specific land rights in specific territories. These include the Hybrid System based on the Social Tenure Domain Model (STDM), the Pro-Poor Land Recordation Tool (PPLRT), the Women's Land Tenure Security, and the Certificates of Customary Right of Occupancy (CCRO). Some scholars prioritize the examination of resources, such as the South Africa Spatial Data Infrastructure (SASDI) and the Plans d'Occupation et d'Affectation des Sols (POAS), whereas others prioritize the analysis of methodologies, such as the Volunteered Geographic Information System (VGI) and the Système d'Information Géographique Participatif (SIG-P). A classification of these systems on the basis of their terminologies reveals four main categories.

3.1.1. Urban cadastral systems

A number of systems are being developed for land management in urban areas. An urban area or city broadly refers to any permanent grouping of a relatively large population in the same place. A concentration of inhabitants lived in a relatively small geographical area. The urban setting is most often characterized by a dense cluster of housing, an individualized and differentiated society, functional diversity, capitalization and innovation capacity that are part of multiple interaction networks and form a hierarchy, including increasingly complex nodes as we move from small to large (Pumain et al., 2006). In this sense, habitat is the common denominator of all cities. Habitats include built and unbuilt property, infrastructure and urban superstructure.

The development of a cadastral system in this context responds more to the management needs of these urban properties for various purposes. Zoumarou (2007), in his studies on the adoption of the Registre Foncier Urbain in Benin, reported that the installation of the system in municipalities was aimed at 3 components: urban, land and tax. However, only the tax component was actually implemented by the municipalities, enabling tax issues and collections to jump from 50.49% in 1991 to 79.80% in 2006. The same observation was made by Simmoneau (2012a, 2015), for whom the principal motivation for setting them up, in line with the city intervention strategy, is the financial empowerment of urban authorities. The system in place consists of an addressed parcel map; a tax, land and urban computerized database; and possibly geographic information system (GIS) software, which enables annual tax notices to be sent to landowners (Simmoneau, 2012b). In Ethiopia, the urban cadastral systems developed in the country's regions are at the heart of the administration and management of land ownership, land value, land use and land development (Chekole et al., 2020a). In this respect, the cadastral system provides security not only for landowners but also for investors and lenders, as well as for governments (Chekole et al., 2020a, 2020b). These so-called urban cadastral systems are intended more to

finance and empower the managers of urban centers, to the detriment of urban social strata.

3.1.2. Rural cadastral systems

Unlike urban cadastral systems, rural systems are more community oriented. These include the PFR implemented in Ivory Coast, Benin and Burkina Faso; the PLOF in Madagascar; the POAS and SIAF in Senegal; and the VLUP in Tanzania; all of which have in common the management of farmland for rural households. Indeed, the rural environment is essentially agricultural. Most of these systems are developed in the course of large-scale land certification programs aimed at providing access to secure land rights, agricultural development and sustainable management of the land and the natural resources (fauna, flora, water, etc.) that it supports (Adamie, 2021). As part of the distribution of the CCRO in Tanzania, data are collected by village land councils (VLCs) and village land use and management committees (VLUMCs), with village chiefs acting as guarantors of land registers. Initially (1999), the registers were not computerized before benefiting from tools using Global Positioning System (GPS) technology or spatial imagery through remote sensing and geographic information systems (GIS) from 2016 onward (Kabigi et al., 2021). The cadastral parcel plans are materialized by a set of maps and a written report. The VLUP also proposes land-use zoning to enable local governments to manage territories and populations and to guide social practices related to the environment, property and use of natural resources (Schlimmer, 2020). The same principles apply to the PFR, although geographical boundaries are identified on a precise scale map (1/10,000) when the projects are implemented. However, to compensate for the lack of licensed surveyors, boundary surveys are kept by neighbors, and survey teams collect land rights as perceived and recognized by inhabitants, after which the central administration takes over management (Chauveau et al., 1998; Edja and Le Meur, 2009; Stamm, 2000). In Ghana, users are provided with simple land registers managed by customary land secretaries (CLSs). Madagascar's PLOFs follow a similar principle, but mayors are responsible for issuing land certificates.

3.1.3. Participatory cadastral systems

So-called participatory cadastral systems take advantage of the concepts of democracy and sustainable development. In this way, their adoption framework often makes it possible to go beyond particular interests and adopt a community perspective, taking into account the representation of marginalized groups (Bacqué and Gauthier, 2011). In this vein, Barnaud (2013) suggested that participation is a practice that consists not only of involving all stakeholders in the decision-making process but also, necessarily, of taking their diverse opinions into account. The PPLRT tested in Kenya, the SIG-P in Senegal and the VGI in Kenya and Botswana are examples of this type of register. Hendricks et al. (2019), as part of their analysis of the PPLRT, have shown that these tools, promoted since 2012 by the Global Land Tool Network (GLTN), aim to provide participatory enumeration and geospatial mapping of spatial data in unofficial informal land registers. Siriba and Dalyot (2017) also noted the informal nature of the VGI due to the disparate nonprofessional groups involved in the data collection. These cadastral systems adopt an inclusive approach, aiming to achieve participatory ideals such as the recognition of community land rights, collegiate

decision-making and grassroots empowerment. However, they are also biased in that they focus more on certain social strata (women, the poor, marginalized populations, etc.) than others do, which does not encourage the objective participation of all stakeholders. However, they are also biased in that they focus more on certain social strata (women, the poor, marginalized populations, etc.) than others do. This does not encourage the objective participation of all stakeholders, especially those social strata that are not necessarily vulnerable in the sense of the systems' promoters but also experience difficulties in accessing land rights. This includes underemployed or unemployed men, landowners who have no interest in participating in the programmes, and so on.

3.1.4. Hybrid cadastral systems

Hybridity highlights the interconnections among several concepts, approaches and tools. Thus, a hybrid cadastral system is one that brings to the fore both "traditional" and "modernity", "formal" and "informal", "social" and "legal", and "local" and "national", with the participation of several stakeholders. For example, the CRS documented in South Africa is based on this approach (Barry and Kingwill, 2020). The CRS is managed by volunteers from informal settlements, and the data are both digital and paper-based. It is managed by a triad of volunteers, nongovernmental organizations and municipalities. In a case study of hybrid land registration systems, Barry (2020) noted that the South African National Civic Association, which is more politically militant because it is aligned with the African National Congress (ANC, the ruling party), created a nongovernmental tenure administration in the municipality of Dunoon, which initially acted in opposition to the official registration system and then in harmony with it, even rigorously maintaining the official procedural and documentary requirements. Therefore, while hybrid system data can be rigorous, this is generally not the case, as Mahamba (2022) found on the Masiani project in North Kivu (Republic Democratic of Congo), where the system is required to formalize current land tenure practices while being uncoupled from the regional cadastral system, thus not favoring the provision of title deeds to registered properties.

All these systems are based on internationally approved sociotechnical standards/models for the production of land information.

3.2. Sociotechnical land tenure standards and approaches

The question of norms and approaches is a transversal issue closely linked to the data, legal and political aspects of systems (Stocker et al., 2022). Norms are important in determining what types of information a cadastral system should be looking for. According to the literature, the land administration domain model (LADM) and social tenure domain model (STDM) are the main norms currently being integrated into African cadastral systems.

3.2.1. LADM

Developed in 2012, the LADM is a conceptual ISO standard and serves as a framework for countries to create their own functional administrative model (FIG, 2012). It has been developed to accelerate the sharing of information and the digitization of cadastral systems worldwide, particularly in developing countries. Since then, each country has developed its own national and/or regional profile, all of

which must contain information on rights, restrictions and responsibilities (RRR-Okembo et al., 2022). In Kenya, for example, the local domain model (LDM) was developed as the LADM standard. The model is designed to capture information from indigenous communities in a variety of ways, from sketches to verbal communication via a computer software interface. It is designed to meet the requirements related to the registration of women's rights, community land rights, seasonal occupation of land by pastoralists and informal occupation (Okembo et al., 2022). In Benin, the LADM was adopted after the 2013 and 2017 land reforms to include both cadastral parcels whose ownership is guaranteed by the state and cadastral parcels whose ownership is presumed so that users can always understand the level of legal security their parcel provides (Mekking et al., 2021).

3.2.2. STDM

The STDM was developed in 2006 by UN-Habitat and GLTN in response to the shortcomings of conventional administration systems—their inability to manage customary and nonformal land tenure systems in developing countries (GLTN, 2015; Moreri et al., 2018). It is a software package comprising a number of GISs and other applications for recording, visualizing and manipulating geospatial data and other information. According to its designers, it fills the gap left by the formal system by recognizing rights as soon as ownership is not contested. However, other authors believe that they should be more inclusive, registering even disputed plots and including women, young people and civil society in the registration of land rights (Mahamba, 2022; Siriba and Dalyot, 2017). In terms of rights, the STDM is intended to be a tool for broadening the range of rights and claims, with the aim of extending land tenure security to as many people as possible in rural and urban areas, regardless of the level of formality, legality or technical accuracy (Siriba and Dalyot, 2017).

All the standards, whether conventional, LADM or STDM, developed over the past decades are highly technical and less conceptual. Therefore, to have a global framework for the development of cadastral systems, the 'fit-for-purpose' approach has been introduced in several national administrations of African countries.

3.2.3. The FFP approach in African countries

The FFP approach for land administration systems was launched by the FIG and the World Bank in 2014 (FIG, Publication no. 60). The FFP is an approach for collecting and organizing data to document land rights that, among other things, advocates flexibility, relaxed precision standards for spatial data relating to evidence of delimitation, and participatory methods for land delimitation and land tenure data collection and processing (Enemark et al., 2014). Its objective is to provide rapid and affordable data acquisition for land administration purposes that meet social needs (Flores et al., 2021). This approach has already been tested in a number of countries, including Ethiopia, Kenya, South Africa, Rwanda, Botswana, Uganda, Ghana, Benin, Ivory Coast, Cape Verde, Mozambique, Namibia, Nigeria and Zimbabwe. In this context, each country considers the strategic choices to be made between cost, time, quality and the technologies to be used. In Kenya, for example, faced with the challenges of governance, the adoption of the approach has focused its strategic choices on data quality and accessibility (Flores et al., 2021). In Benin, the choice is rapid production and low cost. Others, such as the Ivory Coast, are exploring public–

private partnerships (PPPs) as an active source of participation in improving land tenure systems in terms of cost and data quality (Garcia-Moran et al., 2021). Whatever the choices, they all aim to ensure that parcel data from different sources and of varying levels of quality are linked.

In addition to the interest of systems in evolving approaches to land data production, they are also keeping pace with technological developments.

3.3. The use of technologies in African land administration

In Frontier Technologies for Securing Tenure (IFAD, 2023), a number of significant technologies were identified for management purposes, including devices, image-based solutions, machine learning, geographic information systems and blockchain technology. Among these technologies, blockchain is distinguished by its capacity to serve as a land register, whereas the others are limited primarily to the collection of contact details. Nevertheless, only a limited number of countries on the continent have conducted preliminary experiments with this technology. Blockchain technology is a peer-to-peer network comprising a chain of units that establishes a relationship of equality between them. This traceability solution is regarded as a crucial component in regulating reliability and guaranteeing the transparency of data. The objective is to increase the transparency, reliability and security of land data (de Vries et al., 2020). This approach can enhance the quality, accuracy and integrity of data through the utilization of a consensus mechanism between stakeholders, facilitating convenient access to information and preventing fraud, corruption, land record manipulation and multiple land sales (Ansah et al., 2023). The utilization of this technology facilitates transparent access to land information, thereby eliminating superfluous bureaucratic procedures and unqualified intermediaries and consequently reducing the complexity and duration of the land expropriation process. In light of these attributes, it seems reasonable to posit that this could be a potential solution to the issue of dual land tenure systems. However, its implementation in a country such as Ghana, where 80% of land transactions are informal, has yielded only a limited number of tangible outcomes. In Tunisia, this technology has only been proposed as a means of chaining the production of land data within land services, which limits the potential scope for its adoption (Ben Amor and Mkadmi, 2023). Some authors posit that the primary challenge presented by blockchain technology is its potential to challenge the sovereignty of land administration systems. Indeed, in numerous jurisdictions globally, land administration remains a state-sanctioned activity (FIDA).

4. Discussion

A conceptual analysis of sustainable development is carried out to understand the factors that can underpin the sustainability of cadastres in Africa.

4.1. Essence of sustainable development and implementation of cadastres

In essence, sustainable development is development based on three fundamental pillars: social, economic and environmental. In line with Hagel (2013), the way in which the concept of ‘sustainable development’ is often represented shows that the three spheres are interdependent, influence each other and interact. For Habib (2024),

it is the responsibility of the community to manage land in a way that meets the needs of the population in terms of land security, peace building and the provision of sustainable solutions for social, economic and environmental development. However, a closer look at the different systems categorized reveals that they are oriented toward one specific aspect of sustainability. These are social, economic or environmental aspects that rarely overlap, as illustrated in **Figure 3** below.

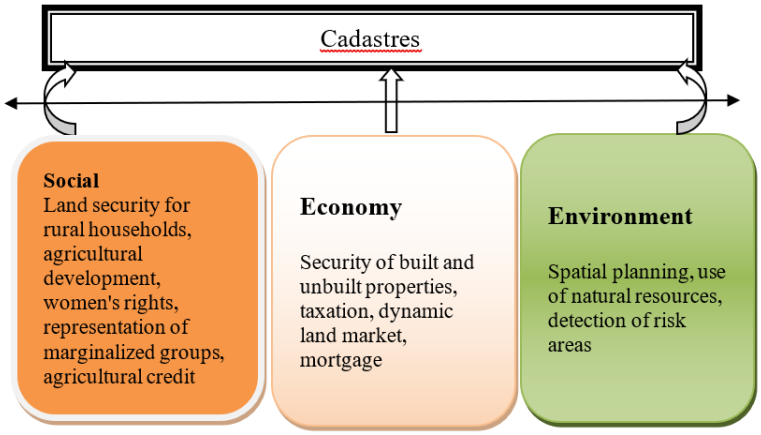

Figure 3. Sustainable aspects of cadastres.

Source: Sustainability of the cadastral systems used, Authors, 2024.

Figure 3 shows that, from a social perspective, the systems in question support land tenure security for rural households, agricultural development, women's land rights and the representation of marginalized groups. From an economic perspective, they contribute to the security of built and unbuilt property, land taxation, land market dynamics and the mortgaging of assets. From an environmental perspective, they are used for land-use planning purposes, for the use of natural resources, for the detection of areas at risk, etc. However, as they possess their own intrinsic characteristics and are not necessarily versatile, they cannot be defined as sustainable. As posited by Ting and Williamson (1999), multipurpose cadastral systems are increasingly regarded as indispensable for economic development, environmental management and social stability across all countries.

In the context of global sustainable development objectives, the advancement of cadastral systems, including those with multipurpose functionality, must align with the requisite standards.

4.2. Sustainable development goals (SDGs) and cadastral systems

The objective of adopting the 17 SDGs, 169 targets and nearly 230 measurement indicators in 2015 (Nations Unies, 2015b), is to complete the efforts begun under the Millennium Development Goals (MDGs) in 2000 by 2030. These objectives are related to three dimensions: economic growth, social inclusion and environmental protection (Nations United, 2020; Gérardin et al., 2016). In accordance with the scope of many of these objectives and targets, cadastral systems are fundamental to national spatial data infrastructures (UN-GGIM, 2016). Cadastral systems are therefore linked to a number of predefined sustainability objectives, targets and indicators (see **Table**

2), which must be known and taken into account in a comprehensive manner before development can be supported.

Table 2. SDGs listed in relation to cadastral systems, authors, 2024.

Goals	Touch targets	Indicators
Goal 1: Eradicate poverty in all its forms, everywhere in the world	1.4. By 2030, ensure that all men and women, especially the poor and vulnerable, have equal rights to economic resources and access to basic services, land ownership, control over land and other forms of property, inheritance, natural resources and new technologies and financial services adapted to their needs, including microfinance.	Proportion of total adult population with secure land rights and legally authenticated documents who consider their land rights secure, by gender and type of tenure.
Goal 2: Eradicate hunger, ensure food security, improve nutrition and promote sustainable agriculture	2.3 By 2030, double the agricultural productivity and incomes of small-scale food producers, especially women, indigenous people, family farmers, pastoralists and fishers, including by ensuring equal access to land, productive resources and factors of production, knowledge, financial services, markets and opportunities for value addition and off-farm employment.	2.3.1 Production volume per work unit according to the size of the farm, pastoral or forestry operation 2.4.1 Proportion of agricultural land used productively and sustainably
Goal 5: Achieve gender equality and empower all women and girls	5.a. Undertake reforms to give women equal rights to economic resources, as well as access to ownership and control of land and other forms of property, and to financial services, in compliance with domestic legislation.	5.a.1 a) Proportion of total agricultural population with ownership or guaranteed rights to agricultural land, by gender; b) proportion of women with ownership or guaranteed rights to agricultural land, by type of right. 5.a.2 Proportion of countries with a legal framework (including customary law) guaranteeing women the same rights as men in terms of access to ownership or control of land
Goal 11: Ensure that cities and human settlements are inclusive, safe, resilient and sustainable	11.1 By 2030, ensure access for all to adequate, safe and affordable housing and basic services, and clean up slums 11.3 By 2030, strengthen sustainable urbanization for all and capacities for participatory, integrated and sustainable planning and management of human settlements in all countries	11.1.1 Proportion of urban population living in slums, informal settlements or inadequate housing 11.3.2 Proportion of cities with a structure for the direct participation of civil society in city management and planning, operating regularly and democratically
Goal 16: Promote peaceful and inclusive societies for sustainable development, ensure access to justice for all, and build effective, accountable and inclusive institutions at all levels.	16.7 Ensure that decision-making is characterized by dynamism, openness, participation and representation at all levels.	16.7.2 Proportion of the population who feel that decision-making is open and responsive, by gender, age, disability status and population group
Goal 17. Strengthen and revitalize the Global Partnership for Sustainable Development.	17.1 Improve domestic resource mobilization, particularly through international assistance to developing countries, with a view to strengthening national capacities to collect taxes and other revenues.	17.1.2 Proportion of the national budget financed by national taxes

As evidenced in **Table 2**, cadastral systems represent a crucial component in the pursuit of sustainability, as outlined in the Sustainable Development Goals (SDGs), given their alignment with six fundamental objectives pertaining to land management. These are Goals 1, 2, 5, 11, 16 and 17, with their specific targets and measurement indicators, which are indispensable for sustainable development if it is to achieve the desired sustainable management. Furthermore, previous research by Chekole et al. (2020a) identified Goals 1, 8, 11 and 16 as playing a significant role in the context of cadastral systems and the SDGs. It was concluded that Goal 8 and its associated indicators did not effectively assess the contribution of land management systems to economic growth. This was in contrast to Goal 17, which employed financial indicators, particularly those linked to national budgets, which could be disaggregated

into communal, regional, prefectural, and other levels. Notably, the authors did not consider Goals 2 and 5, which include targets and indicators for agricultural productivity and equality. Without effective land management, it is impossible to eliminate hunger or ensure equal rights, regardless of whether the population is urban or rural. Holden and Tilahun (2020) and Muchomba (2017) acknowledge this when they state that, as a result of reforms and large-scale land certification, women are less disadvantaged in terms of land rights and are able to allocate more household resources to health and nutrition, as they no longer have to spend time claiming land rights. While Objective 16 effectively highlights the importance of decision-making, there is a need to address the issue of citizens' participation in decision-making processes, such as calls for tenders, without necessarily having a comprehensive understanding of the underlying issues owing to the limitations of the information they are provided with. In light of these considerations, Hull and Whittal (2017) posit that the objectives must originate from the needs of citizens or communities and resonate with them in a meaningful way. Consequently, land administration reforms and the development of cadastral systems must pursue the threefold objectives of success, sustainability and significance (3S).

5. Lessons from this study

A review of the literature on cadastral systems revealed that authors have paid considerable attention to alternative systems. These systems focus on a few selected aspects of sustainable development and therefore do not take all dimensions into account. This state of affairs is unlikely to facilitate the creation of multipurpose cadastral systems and an overall synergy of action that would make it possible to achieve all the objectives associated with the concept of sustainable development. In view of these challenges, several authors have proposed assessment frameworks for achieving sustainable cadastral development in Africa. In their 2020 publication, Hull and Whittal make ten recommendations (see Appendix A) for achieving sustainable development in the context of customary land rights. The aim of these recommendations is to align development objectives with the needs of land rights holders. In addition, Chekole et al. (2020b) and Getie et al. (2022) presented an evaluation framework that identifies best practices and indicators for the ideal implementation of the cadastral system in an urban and rural context (see Appendix B and Figure A1). The aim of these proposals is to provide a framework within which cadastral systems can be used to achieve social stability, economic development and environmental protection simultaneously. It is not yet possible to draw conclusions until all the above proposals have been implemented. Nevertheless, a more detailed study is needed, particularly with respect to the normative implications of cadastres, the logic of economic and environmental efficiency and the security provided by these systems in the context of legal pluralism. The ultimate goal would be to bring all the indicators together in a multipurpose cadastral approach, although Getie et al. (2022) argue that this would not be an easy task.

6. Conclusion

This study on the sustainability of cadastral systems in the field of land management, on the basis of a semisystematic review of the literature, identified a range of alternative cadastral systems and tools, which have been classified into four categories. The aforementioned urban, rural, participatory and hybrid cadastral systems are established in accordance with a number of standards and sociotechnical approaches, including conventional systems such as Torrens, the LADM, the STDM and the FFP. The specificities inherent to the various deployments of these systems affect certain dimensions of sustainable development. These include land management in urban areas, particularly in terms of economic aspects; agricultural land management through the recognition and allocation of rights to farmers and rural communities; participatory management with an emphasis on the granting of rights to disadvantaged people; and hybrid management, which creates links between different types of tools, concepts and approaches. This demonstrates that the systems are oriented either toward the social dimension of sustainable development or toward its economic or environmental dimension and are rarely comprehensive. In light of the various identification, evaluation and validation frameworks proposed by numerous authors, particularly with respect to customary, rural and urban land, it can be argued that cadastral systems deployed in regions, communes, towns or rural areas in African countries can more effectively address sustainable development if they adopt a holistic approach and are multipurpose. However, the implementation of multipurpose cadastral systems is unlikely to succeed in environments where there is a lack of political will, a disparate institutional framework, limited social mobilization and a prevalence of individual interests pursued through fraud and corrupt practices. A more profound study of the political, institutional, social and economic aspects is needed to develop systems that will yield significant and genuinely sustainable outcomes for the population.

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Appendix A

Recommendations of Hull and Whittal (2020) for sustainable cadastral systems.

1. Theory alignment: Aligning cadastral system development theory with customary rights holders' experiences.

2. Disaster management: The development of cadastral systems, as a component of land administration, has an important role in postdisaster recovery.

3. State independence: The success of cadastral initiatives must be semiindependent so as not to be dictated by political and donor considerations.

4. breakdown silos: Cadastral services and land administration must commit to breaking down governance silos if they are to be independent.

5. Redefining cadastral systems: Extend the cadastre to other types of land and rights by linking the cadastre and register wherever possible.

6. Capacity and support: Capacity building must be an integral part of the development process.

7. Ensuring safety: Integrating safety issues into development planning.

8. Independent review: An independent review process must be set up and integrated into the development plan from the outset.

9. Coherent land policy: Assessing cadastral systems against the framework for successful, sustainable and meaningful development

10. Use the '3S' framework: Cadastral systems that aim to be successful, sustainable and significant must be assessed against any additional elements that are important in their context.

Appendix B

An evaluation framework for the urban cadastral system for Chekole et al. (2020).

- Political: Existence of political will in support of the cadastral system
- Policy: Existence of government policy for the cadastral system
- Legal and institutional: Existence of a legal basis, such as laws, regulations, standards
- Social: Society must benefit from cadastre policy and recognize its necessity.
- Economical: The cadastral system process should be self-financing and should ensure cost recovery.
- Environmental: Cadastral system policies need to support duties such as environmental protection and monitoring of land resources.
- Public–private partnership: Partnerships between the public and private sectors under the conditions of well-determined limits on both duties and responsibilities are important
- Technical: cadastral policy must adopt and personalize international technical standards.

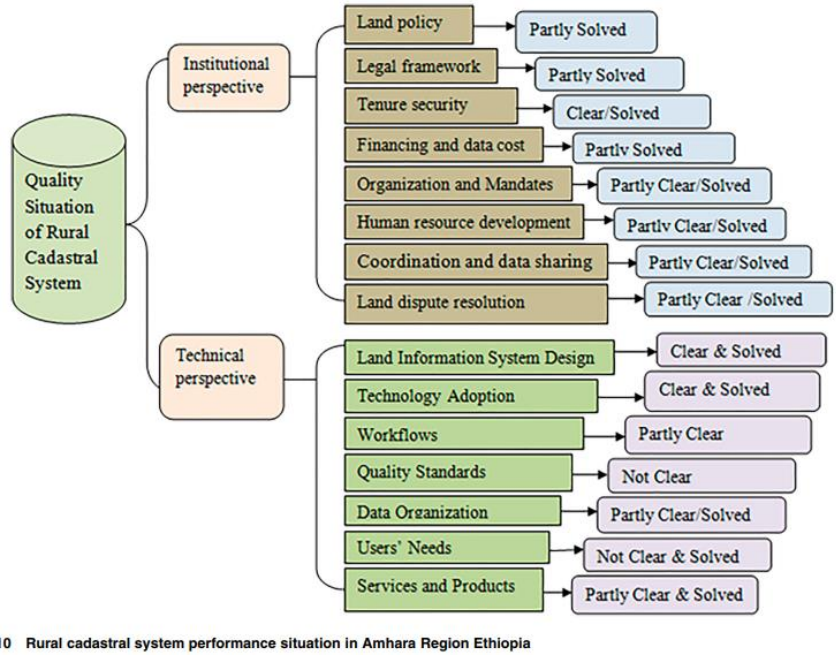

Figure A1. Developing a framework for assessing the efficacy of the rural cadastral system for Getie al. (2022).