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Monitoring Indicators of International Guidance Documents and Frameworks through LADM

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Key words: Land Administration, Land Governance Assessment Framework (LGAF), Global Land Indicators Initiative (GLII), Land Administration Domain Model (LADM).

SUMMARY

Evaluating the performance of a land administration system (LAS) is a critical task as it can provide input for improving the operational system. Through such an evaluation, the strengths and weaknesses of the existing system can be identified, and actions can be taken to improve it. Efforts have been made to develop frameworks and best practices for the assessment and comparison of the performance of LASs. Amongst the most prominent are the 'Land Governance Assessment Framework' (LGAF) of the World Bank and the 'Global Land Indicators' proposed by the Global Land Tool Network (GLTN) and the United Nations Human Settlements Programme (UN-Habitat) in its Global Land Indicators Initiative (GLII). The GLII indicators are closely related to the UN-Sustainable Development Goals (SDGs) indicators on land tenure security, namely SDGs 1.4.2 (%adults with secure tenure rights), 5.a.1 (%agricultural population with secure rights over agricultural land), and 5.a.2 (women's equal rights to land ownership).

The Land Administration Domain Model (LADM), an International Standard (ISO, 2012), can be used to monitor global indicators proposed by various international organizations and to evaluate the performance of LADM-based LASs, as LADM Edition II now provides full support for all land administration (LA) functions including marine georegulation, valuation information and spatial plan information. Interface classes to the LADM are designed to support the generation and management of products and services, such as the monitoring of global performance indicators for LASs.

This paper is a follow-up on Chen et al. (2024), which was focusing on formalizing SDG land related indicator using LADM. The objective of this study is to explore the extent to which LADM can be used to also monitor the indicators of LGAF and GLII. To this end, the indicators are categorized according to their degree of association with LADM (i.e. full computational association, partial computational association, indirect association, association with other standards and non-association), and interface classes are created based on the results. The results show that LADM can be used to monitor a significant portion of the indicators of LGAF and GLII, although most of the indicators are related to a country's national legislation, its implementation and organizational decisions and capability.

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1. INTRODUCTION

The evaluation of the performance of a land administration system (LAS) is an important task, as it may identify the strengths and weaknesses of the existing system and provide the basis for improving it.

The evaluation of LASs is a complex task, initially due to the diversity of perceptions of land within societies (Steudler et al., 2004). Efforts have been made to develop frameworks and best practices for evaluating and comparing the performance of LASs (Williamson and Ting, 2001; Steudler et al., 2004). Global initiatives such as the World Bank, the United Nations (UN) (e.g., UN-Habitat, UN-GGIM, FAO) and the Global Land Tool Network (GLTN) have published agendas, guidelines and frameworks that focus on land administration (LA) beyond 2010. For example, the World Bank published the 'Land Governance Assessment Framework' (LGAF) in 2013, the UN announced the 'Sustainable Development Goals' (SDGs) (UN, 2015), and the UN published the 'New Urban Agenda' (NUA) (UN, 2017). The 'Framework for Effective Land Administration' (FELA) was published by the United Nations Committee of Experts on Global Geospatial Information Management (UNGGIM, 2020); GLTN and UN-Habitat published the 'Assessment of the Uptake of the Set of 15 Indicators by the Global Land Indicators Initiative (GLII) in Global and Regional Frameworks and by Land Actors' (UN Habitat/GLTN, 2021) and the Food and Agriculture Organization of the United Nations (FAO) published the revised version of the 'Voluntary Guidelines on the Responsible Governance of Tenure' (VGGT) (FAO, 2022). This current study will focus on the World Bank's LGAF, and indicators as identified by the GLII.

The LGAF can be used to identify and monitor good practices in the land sector. The LGAF is motivated by the fact that land policy analysis and interventions are often fragmented. They tend to focus only on specific aspects such as land registry or surveying. This not only lacks important synergies with other parts of the system, but may ultimately prove to be ineffective and unsustainable (World Bank, 2013). The LGAF is structured around five key thematic areas: (a) how land rights are defined and enforced; (b) how land is managed, used and taxed; (c) how public land is managed; (d) how information on rights is maintained and accessed; and (e) how land disputes are managed and resolved (World Bank, 2013).

The GLII was established under the GLTN in 2012 with the aim to support efforts to harmonize monitoring efforts around land tenure and governance. The GLII seeks to derive a list of globally comparable harmonized land indicators, using existing monitoring mechanisms and data collection methods as a foundation. The initiative is supporting global and regional frameworks such as the VGGTs, agreed by 193 Member States and supported by civil society (UN-Habitat/GLTN, 2017). In 2021 UN-Habitat and GLTN published an assessment document to '*better understand how GLII land indicators are being used by GLII partner and non-partner organizations, and by extension, to appreciate the impact of GLII indicators on*

the larger regional and global effort to promote monitoring of land tenure security for men, women and youth' (UN-Habitat/GLTN, 2021).
The Land Administration Domain Model (LADM) was published as a standard by the International Organization for Standardization (ISO) in 2012 (ISO, 2012). The focus of the LADM Edition I (ISO, 2012) is on the part of land administration that is interested in rights, responsibilities and restrictions concerning land (or water) and its geometric (geographic) components (Lemmen et al., 2015). The systematic revision of LADM Edition I within ISO has been initiated in 2018, and the domain experts have decided that LADM Edition II should be structured as a multi-part standard. Part 1, ISO 19152-1 *Generic conceptual model*, presents '*the fundamental notions and defines the basic components and relations shared by all objects created by land administration / georegulation*' (ISO, 2024a), is published as an international standard in January 2024. Part 3, ISO 19152-3 *Marine georegulation*, provides '*the concepts and structure for standardization for georegulation in the marine space*' based on the International Hydrographic Organization's (IHO) S-121 (ISO, 2024b), is published as an international standard July 2024. The systematic revision and development processes are ongoing for ISO 19152-2 *Land registration*, ISO 19152-4 *Valuation information* and ISO-19152-5 *Spatial plan information*, all of which are at the Draft International Standard (DIS) stage at the time of writing of this paper (August 2024) (Kara et al., 2024). The LADM can be used to monitor global indicators proposed by various international organizations, including the World Bank's LGAF and indicators identified by the GLII, and to evaluate the performance of LADM-based LASs. Since the LADM Edition II provides full support for all the functions of the LA, it can be used to evaluate the value and use of land-related indicators. For this purpose, interface classes to the LADM can be created to support the generation and management of products and services (ISO, 2012), such as the monitoring performance of global indicators for LASs.
The objective of this study is to explore the extent to which LADM can be used to monitor the indicators of LGAF and GLII. To this end, the indicators are categorized according to their degree of association with LADM (i.e. full computational association, partial computational association, indirect association, association with other standards and non-association) as proposed by Chen et al. (2024), and interface classes are created for the full computational associations. This paper is organized as follows: Section 2 briefly introduces the LADM Edition II, World Bank's LGAF and the GLII's Global Land Indicators. Section 3 analyzes the LGAF indicators and their relationship to LADM. Section 4 examines the GLII and their relationship to LADM. Considering the results of the analyses, interface classes to LADM are created to monitor the indicators in Section 5. The last section concludes this study.

2. BACKGROUND AND RELATED RESEARCH

This section briefly introduces LADM Edition II. This is followed by the main objective and content of LGAF. Lastly, the main objective of GLII and the content of the Global Land Indicators are presented.

2.1 LADM Edition II

LADM Edition I focuses on the land tenure function of LA. The land value and land use functions are not included in detail in the first edition, but external classes ExtValuation and ExtLandUse are proposed, respectively. It is worth noting that the external classes indicate what data content LADM expects from external resources (Lemmen, 2012).

In response to requests from the international LA community, the decision was made to refine the existing content and extend the scope of Edition I of the LADM. This begins with gathering feedback from ISO/TC 211 member states on the need for updated and expanded capabilities of the LADM. In addition, to revise LADM Edition I, several FIG LADM workshops were organized to discuss options for improvements and extensions among experts, see Kara et al. (2024). From those, the integration of valuation information (Part 4) and spatial plan information (Part 5) within the LADM has been considered appropriate, together with the provision of LA in 3D (spatial units below, on and above the surface of the earth) on land (Part 2) as well as at sea (Part 3). In addition, the need for further, refinement of rights, restrictions and responsibilities (RRRs), a refined survey model, new subclasses for spatial units, a set of possible representations of spatial units in 2D, 3D or mixed dimension, identifying legal spaces in buildings, refined legal profiles have been considered. Figure 1 shows the extended scope of LADM Edition II. For the scope and content of the conceptual model of Part 1 (Generic conceptual model), Part 2 (Land registration), Part 4 (Valuation information) and Part 5 (Spatial plan information), see Kara et al., 2024.

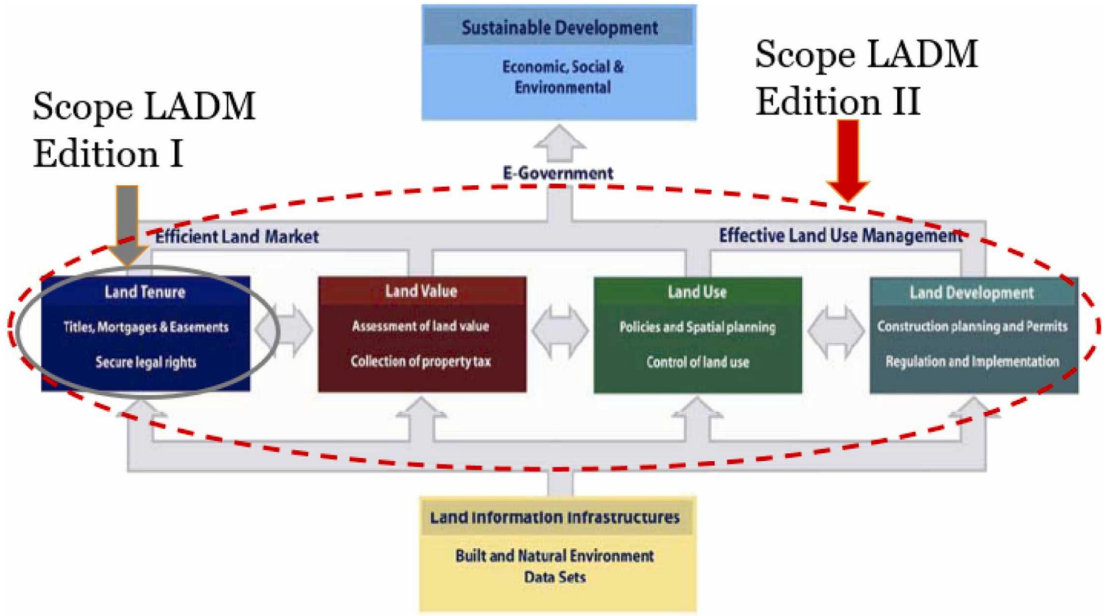

Figure 1. The extended scope of LADM (adapted from Enemark 2006)

LADM Part 2, Part 4 and Part 5 have not yet been published as an ISO standard, but are in one of ISO's mature states: Draft International Standard (DIS). All three parts are expected to be published as an international ISO standard in 2025. The UML of all three parts is available on the GitHub page of the ISO Harmonized Model Maintenance Group (ISO HMMG) at https://github.com/ISO-TC211/HMMG. Since the conceptual models of the mentioned parts are at a mature stage, they can be used to develop interface classes, for example, to monitor the efficiency of LASs in different contexts, including land tenure, value, and use.

2.2 World Bank's LGAF

According to World Bank (2013), the need for a systematic assessment of land governance arises from three factors: (1) land has emerged as a key factor for sustainable growth and poverty reduction, (2) there can be a wide gap between legal provisions and their actual implementation, namely institutional fragmentation, and (3) progress depends on the ability to forge consensus among experts in a participatory and deliberative process based on comprehensive analysis. The LGAF was developed by the World Bank in partnership with FAO, UN-Habitat, International Fund for Agricultural Development (IFAD), International Food Policy Research Institute (IFPRI), the African Union, and bilateral partners (World Bank, 2024). It is worth noting that the LGAF has been revised to take into account the VGGTs and the lessons learned from the implementation of the LGAF (World Bank, 2013).

The LGAF process is coordinated and implemented by country experts. The broad steps of the LGAF are: (1) collection of qualitative and quantitative background information, (2) stakeholder panels to rank dimensions; invitation is based on area of expertise, (3) LGAF report with identification of priority policy areas for follow up, (4) validation of rankings and discussion of actionable policy priorities, and: (5) follow up with work plan (World Bank, 2024). The core approach of the LGAF is to provide scores for each dimension through panels of experts (World Bank, 2024). Each panel discusses a specific thematic area and includes a diverse group of individuals who are subject matter experts on different aspects of the issues in the area under study (e.g., lawyers, academics, experts working for non-governmental organizations, government officials, land professionals, etc.). Between 3 and 8 members can be selected for each panel to bring together a variety of perspectives and substantive expertise needed to provide a meaningful assessment (World Bank, 2024). The dimensions are divided into 9 panels on the following topics: (1) land tenure recognition, (2) rights to forest and common lands & rural land use regulations, (3) urban land use, planning, and development, (4) public land management, (5) transparent process and economic benefit, (6) public provision of land information: registry and cadastre, (7) land valuation and taxation, (8) dispute resolution, and: (9) review of institutional arrangements and policies (World Bank, 2024). The implementation manual of the LGAF (World Bank, 2013) identifies 27 main indicators and associated 108 dimensions. For each dimension, an evaluation consisting of four different levels should be provided. See Table 1 for more details on LGAF indicators. Lastly, 39 countries all around the world, mostly African countries, implemented the LGAF, according to World Bank (2024).

2.3 GLII's Global Land Indicators

The need to step up monitoring of land governance issues drove the establishment of the GLII in 2012 by the Millennium Challenge Corporation, the World Bank, and UN-Habitat. The platform is hosted and facilitated by GLTN/UN-Habitat. GLII includes over 50 institutions around the world ranging from UN Agencies, inter-governmental organizations, international nongovernmental organizations, academia, private sector, researchers and training institutions, and farmer organizations (GLTN, 2024).

One of the mandates of the GLII is to develop nationally applicable and globally comparable land indicators and data protocols for land monitoring (GLTN, 2024). GLII and its partners have built stronger national processes for comparable and comprehensive monitoring of land governance at scale in relation to global and regional land governance frameworks: the VGGTs, the SDGs, the NUA, the African Union Framework and Guidelines for Land Policy

in Africa (AU-F&G), and other initiatives. The platform identified a set of 15 land indicators developed and validated by GLII partners, including a number of indicators included in the SDGs monitoring framework under SDGs 1, 2, 5, 11, 15 and their link to SDG 16 (GLTN, 2024). The GLII's 15 nationally applicable and globally comparable land indicators that go beyond the SDGs' land provisions and cover four key areas of land governance: (1) land tenure security for all, (2) land and conflict, (3) land administration services, and: (4) sustainable land use management (GLTN, 2024).
Three main levels of reporting and analysis are envisaged for the 15 GLII indicators: (1) country-level reporting by national governments (GLII indicators with number 1, 2, 6, 7, 8 11, 12), (2) country-level reporting assisted by international data initiatives (GLII indicators with number 3, 4, 8, 9, 10, 13), (3) global monitoring (GLII indicators with number 5, 14, 15) (UN Habitat/GLTN, 2017). It was noted that use of the indicators among partners was highest for the five GLII indicators related to land tenure security (indicators 1.1 to 1.5) (UN Habitat/GLTN, 2021). The GLII indicators are closely related to the SDG indicators on land tenure security, namely SDGs 1.4.2, 5.a.1, and 5.a.2 (UN Habitat/GLTN/GLII, 2022). See Table 2 for more details on GLII indicators.

3. ANALYSIS OF THE INDICATORS AND THEIR RELATIONSHIP TO LADM

3.1 LGAF Indicators and their Relationship to LADM

The World Bank's LGAF includes 107 dimensions associated with 27 indicators grouped under 9 different themes. In the Appendix, Table 1 presents the LGAF themes, land governance indicators, LGAF dimensions and their relationship to LADM. Rows highlighted in green represent *full computational association* with LADM, while turquoise represents *partial computational association*. *Indirect association* is shown in yellow, *association with other standards* is shown in pink, and *non-association* is shown in gray. For the descriptions of associations, see Chen et al. (2024). It should be noted that the first two steps (i.e., keywords extraction and matching with LADM) as proposed by Chen et al. (2024) are not included in this paper, since all indicators of LGAF and GLII are directly related to land management.
A brief explanation of how LADM is related to the related dimensions of LGAF is given in the last column of Table 1. According to the analyses performed, 10 dimensions are found to have a full computational association with LADM, 11 dimensions have a partial computational association. 31 dimensions are found to have an indirect association, while a few dimensions related to actual land use (ISO 19144-3) are found to be partially associated with other standards (which are not included in the statistics given here as they are counted in other categories). On the other hand, 55 dimensions are found to be related to a country's national legislation and its implementation. These dimensions are considered to be in the context of operating a system based LADM. Lastly, it should be noted that these results may not be the final result, the evaluation can be revised considering the feedback given in the workshop, by reviews, and so on.

3.2 GLII Indicators and their Relationship to LADM

The GLII has identified 15 requirements that are grouped into four different themes. In the Appendix, Table 2 shows the GLII themes, the GLII indicators, and their relationship to the LADM. The same color scheme is used to color Table 2.

A brief explanation of how LADM relates to the related indicators identified by the GLII is given in the last column of Table 2. According to the analyses performed, 3 indicators are found to have a full computational association with LADM: 3 indicators have a partial computational association, and 3 indicators have an indirect association. 6 indicators are found to be associated with the national legislation of a country and the implementation of the legislation. These indicators are considered to have no association with LADM.

These results are not final, the evaluation may be revised taking into account the feedback given in the workshop, by reviews, and so on.

4. MONITORING THE INDICATORS THROUGH LADM

After the publication of LADM as an international ISO standard, it is developed to country profiles or really implemented by many countries, academics, companies, etc., see Lemmen et al. (2020). One of the approaches that can be followed to develop a LADM-based product or service is to create interface classes to LADM. Annex L of LADM Edition I indicates that interface classes can be considered as user-defined and outside the scope of LADM (ISO, 2012). Annex L of the LADM Edition I provides three examples of interface classes for party portfolio, spatial unit overview, and mapping spatial units (e.g., cadastral maps). It is expected that the LADM Edition II Part 2 Land registration will include some more interface class examples. Based on the examples used, six interface classes are developed to monitor indicators of LGAF and GLII. These interface classes are presented in this section.

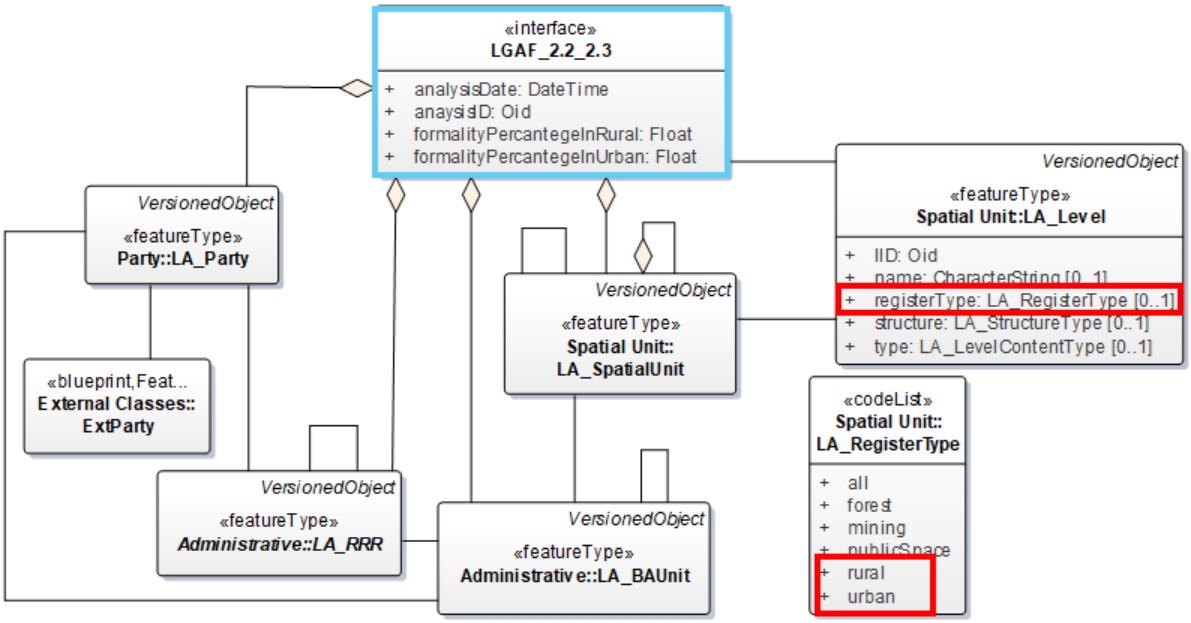

Figure 2. Monitoring LGAF dimensions 2.2 (formally registered land in rural) and 2.3 (formally registered land in urban) via LADM using the interface class approach

Figure 2 shows how LGAF dimensions 2.2 "*Individually held land in rural areas is formally registered*" and 2.3 "*Individually held land in urban areas is formally registered*" can be monitored through LADM using the interface class approach. These dimensions are aligned with ISO 19152-1 and ISO 19152-2. All of the interface classes in this section have analysisDate and analysisID attributes, since the assessment may change over time and a new analysis may be required, for example, every year or so. The registerType attribute of LA_Level can be used to specify whether the land is in an urban or rural area. Therefore, an association relationship is specified between LA_Level and the interface class. The information from LA_Party, LA_RRR, LABAUnit and LA_SpatialUnit is aggregated in the interface class 'LGAF_2.2_2.3' to calculate the formality percentage in rural and urban areas.
The importance of equal rights for women is underlined in several evaluation frameworks. The SDGs also have a few goals that can be related to LA. Chen et al. (2024) developed interface classes, operations and methods to support automatic calculation of the proportion of secure tenure rights (on land and agricultural land) by sex (see SDGs 1.4.2 and 5.a.1).

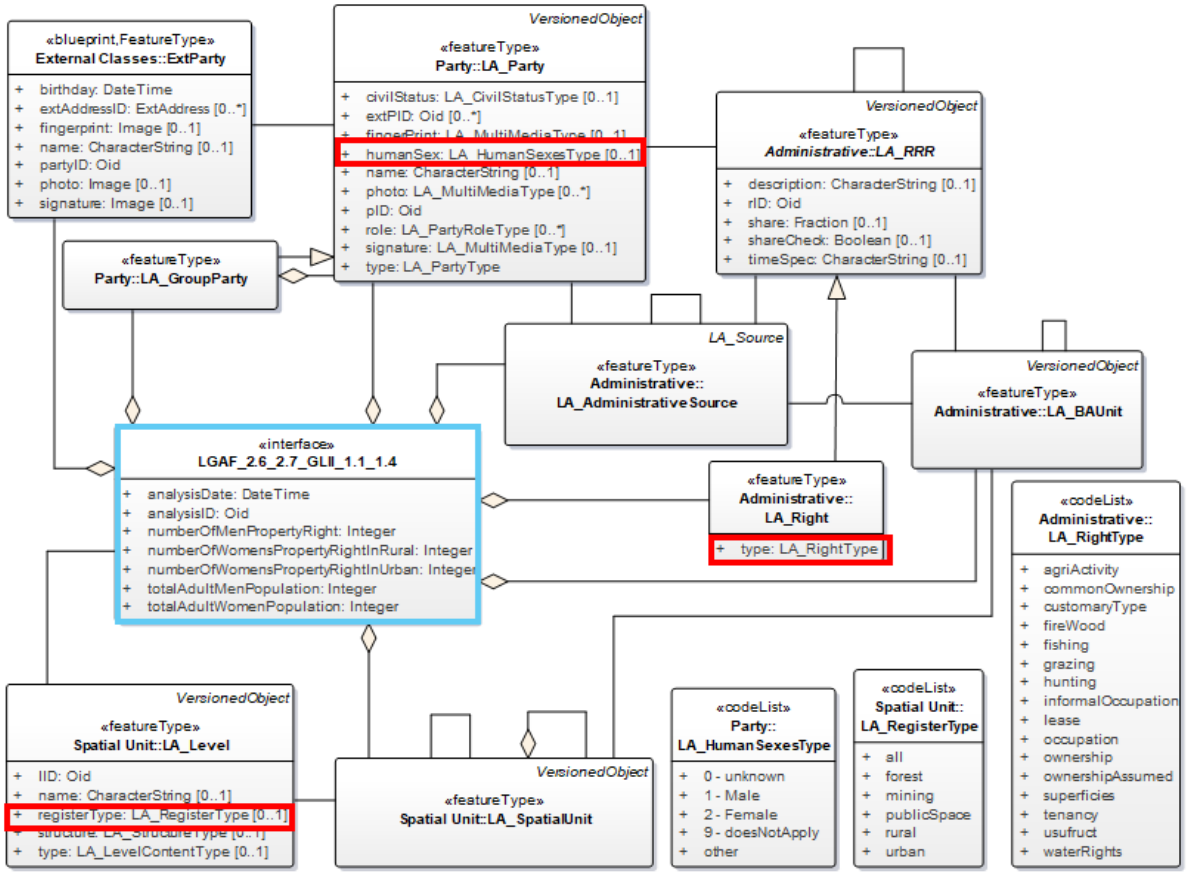

Figure 3. Monitoring LGAF dimensions 2.6 (women's rights are registered), 2.7 (equal rights to women) and GLII indicators 1.1 (legally recognized documentation to land for women and men), 1.4 (equal rights to women) via LADM using the interface class approach

Figure 3 presents how LGAF dimensions 2.6 "*Women's rights are registered and recognized in practice in both urban and rural areas*" and 2.7 "*Women's property rights to land are equal to those by men*" as well as GLII indicators 1.1 "*Percentage of women and men with legally*

recognized documentation and evidence of secure rights to land" and 1.4 "*Level to which women and men have equal rights to land, including rights to use, control, own, inherit and transact these rights*" can be monitored through LADM using the interface class approach. These dimensions and indicators are related to ISO 19152-1 and ISO 19152-2. It should be noted that the interface class developed in this paper shares similar attributes (e.g., total population) with the interface class developed in Chen et al. (2024). Similar to the previous interface class (see Figure 2), the interface class "LGAF_2.6_2.7_GLII_1.1_1.4" has an association relationship with LA_Level to specify whether the land is located in an urban or in rural area. Since human sex type (see Unger et al, 2023 for more information) is an important information to monitor these requirements LA_Party and ExtParty are aggregated into the interface class. In addition, information about the type of right and its source is obtained from the LA_Right and LA_AdministrativeSource classes. Lastly, LA_BAUnit and LA_SpatialUnit are aggregated into the interface class to include information about land. The attributes 'number of men's property right', 'number of women's property right in rural' and 'number of women's property right in urban' are added to the "LGAF_2.6_2.7_GLII_1.1_1.4" to monitor the above requirements. Furthermore, it is worth noting that GLII's indicator 1.5 "*Numbers and proportion of indigenous and community groups with land claims that have legally recognized documentation or evidence of secure rights, and percentage of land areas claimed and utilized that have been legally secured*" can also be partially monitored through this interface class, as LADM allows the representation of rights of indigenous and community groups with the LA_GroupParty and LA_Right classes.

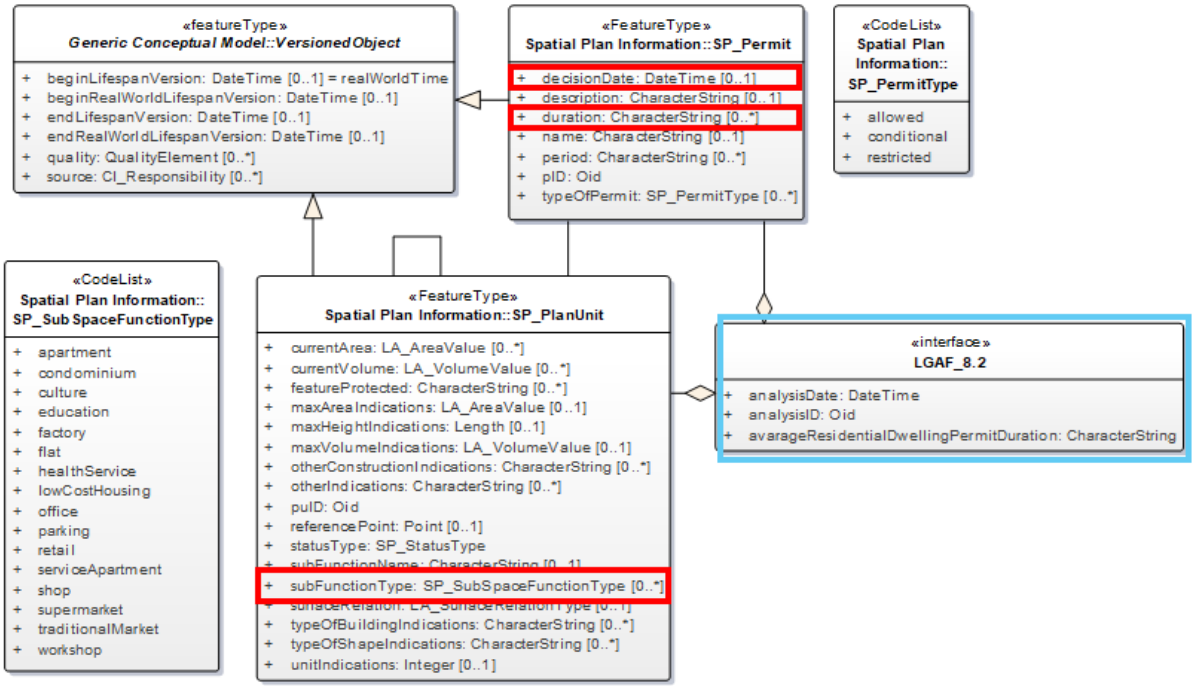

Figure 4. Monitoring LGAF dimension 8.2 (time required for building permit) via LADM using the interface class approach

Figure 4 shows how LGAF dimension 8.2 "*The time required to obtain a building permit for a residential dwelling is short*" can be monitored through LADM using the interface class

approach. This dimension is related to ISO 19152-5. The permit duration and decision date of the permit attributes are included in the SP_Permit class, which is also related to the class VersionedObject, which includes real and database time. The LGAF_8.2 interface class has an aggregation relationship with LA_Permit. As this dimension is related to residential dwelling, an aggregation relationship is defined between "LGAF_8.2" and SP_PlanUnit. In order to calculate the average permit duration for residential dwellings, the "avarageResidentialDwellingPermitDuration" attribute is added to the "LGAF_8.2".

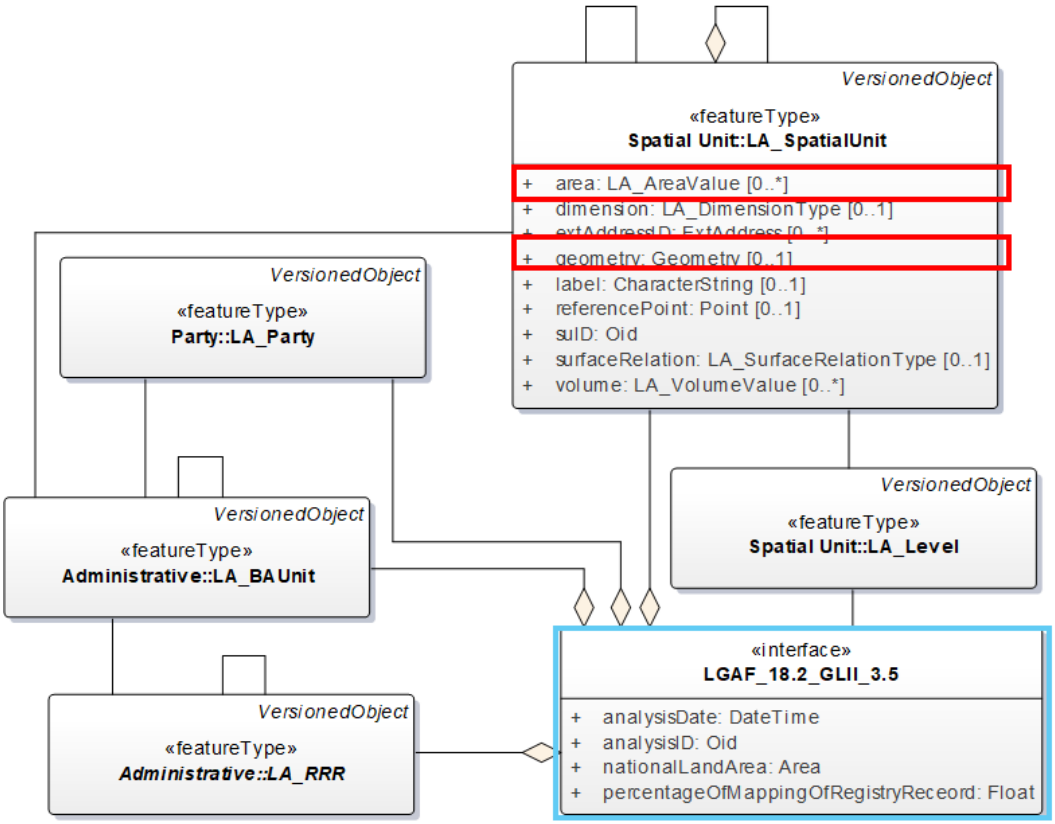

Figure 5. Monitoring LGAF dimension 18.2 (registry records is complete) and GLII indicator 3.5 (rights holders and tenure status are incorporated into cadastral maps) via LADM using the interface class approach

Figure 5 presents how the LGAF dimension 18.2 "*The mapping or charting of registry records is complete*" and the GLII's indicator 3.5 "*Proportion of national land areas with rights holders and tenure status identified that are incorporated into cadastral maps / land information systems*" can be monitored through support by LADM using the interface class approach. This dimension and indicator are related to ISO 19152-1 and ISO 19152-2. The "LGAF_18.2_GLII_3.5" interface class has aggregation relationships with LA_SpatialUnit (for total land area and cadastral maps), LA_Party (for right holders), LA_RRR and LA_BAUnit (for registry records). In addition, LA_Level is linked to the interface class to include all registries into the analysis. The "LGAF_18.2_GLII_3.5" has total "nationalLandArea" and "percentageOfMappingOfRegistryReceord" attributes to monitor the above dimension and indicator.

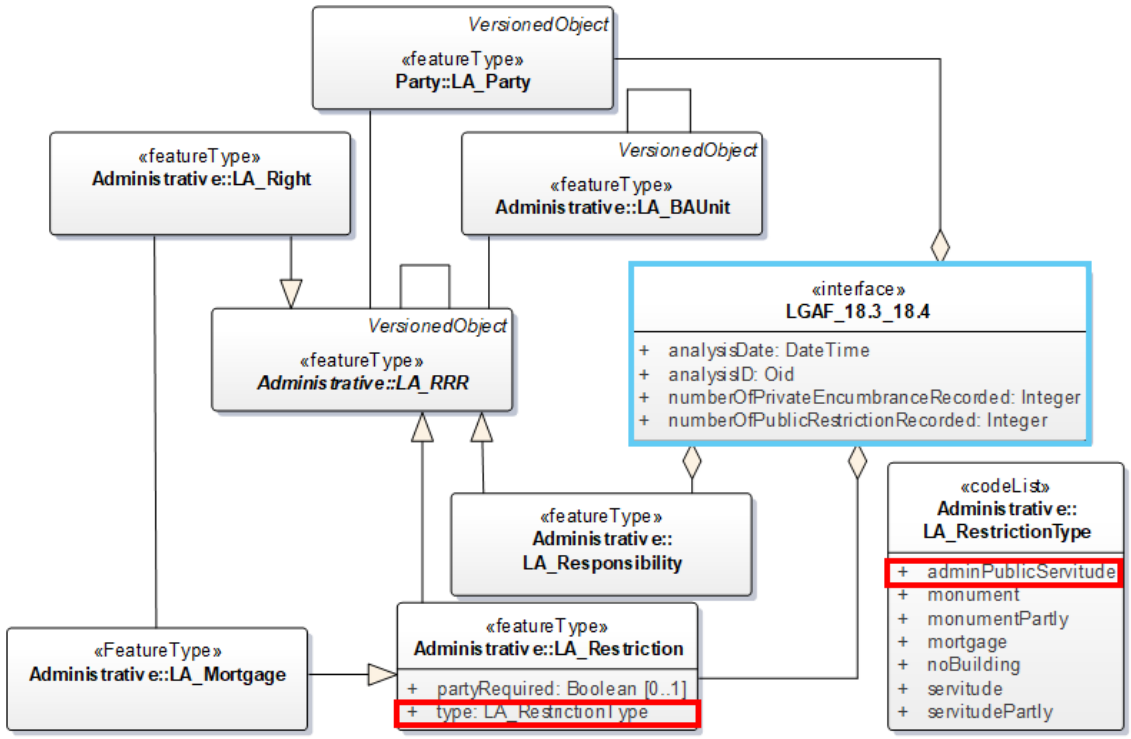

Figure 6. Monitoring LGAF dimensions 18.3 (private encumbrances are recorded) and 18.4 (public restrictions are recorded) via LADM using the interface class approach

Figure 6 shows how the LGAF dimensions 18.3 "*Economically relevant private encumbrances are recorded*" and 18.4 "*Socially and economically relevant public restrictions or charges are recorded*" can be monitored through support by LADM using the interface class approach. This dimension and indicator are related to ISO 19152-1 and ISO 19152-2. "LGAF_18.3_18.4" interface class has aggregation relationships with LA_Party, LA_Responsibility and LA_Restriction to collect all the information to calculate "numberOfPrivateEncumbranceRecorded" and "numberOfPublicRestrictionRecorded".

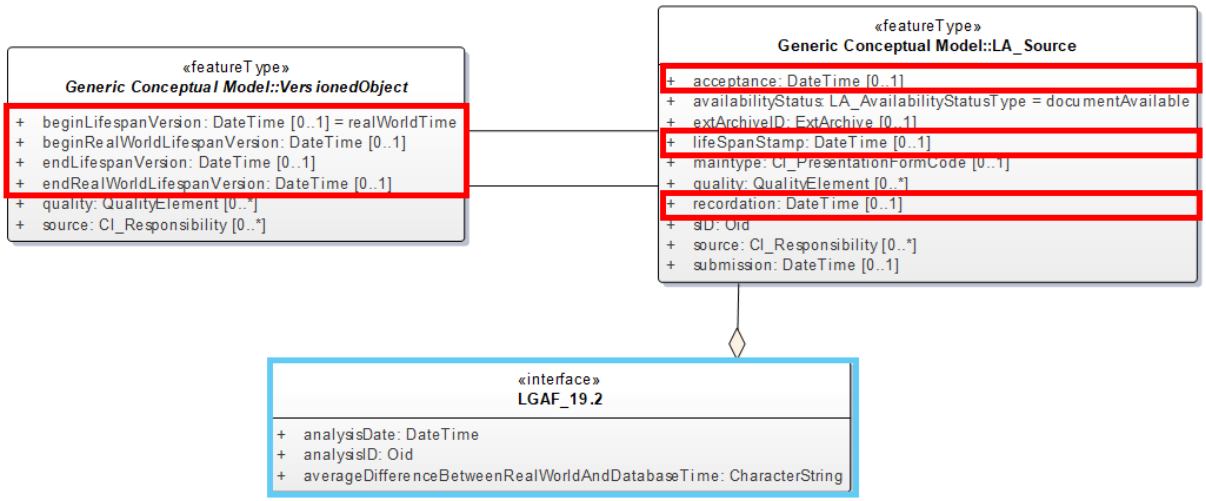

Figure 7. Monitoring LGAF dimension 19.2 (Registry/cadastre information is up-to-date) via LADM using the interface class approach

Figure 7 presents how the LGAF dimension 19.2 "*Registry/cadastre information is up-to-date*" can be monitored through LADM using the interface class approach. "LGAF_19.2" interface class has an aggregation relationship with LA_Source to monitor/search whether registry/cadastre information is up to date via comparing date of source data (LA_Source, VersionedObject) and registration date (real world time, database time, etc).

5. CONCLUSION

This study examines LGAF and GLII indicators considering the conceptual models of LADM Edition II in terms of whether LADM can enable to monitor the performance of LASs through interface class approach using LGAF and GLII frameworks. The findings show that the LADM can be used to monitor a significant portion of the LGAF and GLII indicators, although most of the indicators are related to national legislation, its implementation, and organizational decisions and capacity. A country, for example, may develop a country profile for land disputes based on LADM and effectively manage the disputes. However, indicators related to land disputes are not considered monitorable with LADM Edition II in this paper, as they are not conceptually modeled in LADM. In other words, the evaluation of indicators with LADM depends on many situations (e.g. country implementation, data accuracy, timeliness, etc.). On the other hand, LADM can make it easy to monitor the performance of LA through the indicator. It should be noted that the number of countries reporting to LGAF and GLII is relatively limited. The number of reporting countries should be improved and LADM indicator modeling can facilitate this. Some of the examples in this paper could be added to Annex I (Interface Class) of ISO 19152-2.

Figure 8. LGAF and GLII country reports (Source: World Bank, 2024; GLTN, 2024)

In this paper, interface classes are designed only for LGAF and GLII indicators that have full computational association with LADM. It is also possible to design interface classes for

partial computational association and indirect association. Furthermore, it should be noted that the classification of LGAF and GLII indicators still can be changed/revised considering the feedback given in the workshop and so on. In addition, operations and methods can be specified to track the performance of LASs based on the indicators in an automated and formalized manner. Finally, the approach used in this study can be extended in the future with FELA, VGGT and related literature (e.g., Steudler et al., 2004; Dawidowicz and Źróbek, 2018; Chehrehbargh et al., 2024).

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BIOGRAPHICAL NOTES

Abdullah Kara holds a Ph.D. degree (2021) from Yıldız Technical University (YTU) with a thesis on the extension of the Land Administration Domain Model (LADM) with valuation information, which is used as a basis for the development of LADM Part 4 - Valuation information. He worked as a post-doctoral researcher (2021-2024) at the GIS Technology Section, Delft University of Technology. He works as an assistant professor at Gebze Technical University starting from 2024. He has been actively involved in FIG working groups.

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APPENDIX

Table 1. LGAF indicators and their relationships with LADM

Land Governance Indicator	LGAF Dimension	LADM
Land Tenure Recognition		
1. Recognition of a continuum of rights	Individual rural land tenure rights are legally recognized.	This dimension is related to the national legislation of a country and to the implementation of the legislation. LADM supports representing individual tenure rights in rural and urban areas (see LA_Party, LA_RRR, LA_SpatialUnit and LA_Level) as well as customary, informal and Indigenous rights (see also Social Tenure Domain Model (STDM), specialization of LADM) in Annex I of (ISO, 2012) and Annex B in part 2 of edition 2. The result of national legislation may end up in the LA_RightType code list, and by inspecting the code list values and their actual occurrences in the LA_Right records, these dimensions can be assessed.
	Customary tenure rights are legally recognized.	
	Indigenous rights to land and natural resources are legally recognized and protected in practice, where relevant according to international treaties.	
	Urban land tenure rights are legally recognized.	
2. Respect for and enforcement of rights	Accessible opportunities for tenure individualization exist.	A LADM based LAS can enable analyses to check whether tenure individualization exists. Information from different registries (e.g., population, company etc.) can be required to make such analysis.
	Individually held land in rural areas is formally registered.	A LADM based LAS can be used to monitor these dimensions with LA_Party, LA_SpatialUnit, LA_BAUnit and LA_Level, see Section 4.
	Individually held land in urban areas is formally registered.	
	The number of illegal land sales is low.	A LADM based LAS can provide total number of transactions, but extra information is required to monitor these dimensions.
	The number of illegal lease transactions is low.	
	Women's rights are registered and recognized in practice in both urban and rural areas.	A LADM based LAS can keep track of these dimensions, see Section 4 (LA_Level, LA_Party).
	Women's property rights to land are equal to those by men.	
Rights To Forest and Common Lands & Rural Land Use Regulations		
3. Rights to forest and common lands	Rural group rights are formally recognized.	This dimension is related to the national legislation of a country and to the implementation of the legislation. The result of national legislation may end up in the LA_RightType code list, and by inspecting the code list values and their actual occurrences in the LA_Right records, these dimensions can be assessed.
	Even where ownership is with the state, arrangements to ensure users' rights to key natural resources (incl. fisheries) on land are legally recognized and protected in practice.	
	Multiple rights over the same common land and natural resources on these lands can legally coexist.	This dimension is related to the national legislation of a country and to the implementation of the legislation. LADM does support monitoring of this, so by

		checking the actual data, one can see whether or not these types of rights are actually occurring.
	Most communal and/or indigenous land is mapped (demarcated and surveyed) and rights are registered.	A LADM (or STDM) based LAS can help to check how many land parcels are mapped, which rights on that parcel are registered, and who owns the right. Information from different registries (e.g., population etc.) can be required to make such analysis.
4. Transparency of land use rezoning in rural areas	Restrictions regarding rural land ownership are justified.	These dimensions are related to the national legislation of a country and to the implementation of the legislation.
	Restrictions regarding rural land transferability are justified	
	Rural land use plans and changes in these plans (incl. rezoning) are based on public input and burden sharing.	These dimensions are related to the national legislation of a country and to the implementation of the legislation. With ISO 19152-5 Spatial plan information and related source documents this information could be analyzed.
	Rural land use changes to the assigned land use in a timely manner. use plans/rezoning for specific rural land classes (forest, pastures, wetlands, national parks etc.) are in line with actual use	
	There is a clear public process for rezoning of land use classes that result in changes regarding to environmental protection.	
	Use plans for specific rural land classes (forest, pastures, wetlands, national parks etc.) are in line with actual use.	ISO 19152-5 Spatial plan information is capable of representing land use types originated from zoning plans. Land use types in zoning plans (ISO 19152-5) and cadastral maps (ISO 19152-2) can be overlaid and the result map can be used to check differences. However, land use maps are required for actual use. Therefore, information from ISO 19144-3 Land Use Meta Language (LUML) is required (or other land use standards)
Urban Land Use, Planning, and Development		
5. Restrictions on rights: land rights are not conditional on adherence to unrealistic standards	Restrictions regarding urban land ownership and transferability are justified.	This dimension is related to the national legislation of a country and to the implementation of the legislation.
	Restrictions regarding urban land use are justified and enforced (including risk prone and protected areas).	This dimension can be partially monitored by reviewing the source documents behind spatial plans (from national to local level).
6. Transparency of land use restrictions	There is a clear decision making process for expansion of urban land and associated land use change that respects existing rights and information on change is publicly available.	These dimensions are related to the national legislation of a country and to the implementation of the legislation. Note that ISO 19152-5 Spatial plan information is capable of representing land use types originated from zoning plans. Land use types can be obtained from ISO 19144-3 Land Use Meta Language.
	In urban areas, land use plans and changes in these plans are based on public input.	
	Urban land use changes to the assigned land use in a timely manner.	
7. Efficiency in	A policy is in place and progress is being made	These dimensions are related to the

the urban land use planning process	to ensure delivery of low-cost housing and associated services to those in need.	national legislation of a country and to the implementation of the legislation. If all land use plans are represented as proposed in LADM Part 5 then spatial expansion can be traced by means of temporal characteristics of LADM. Using LADM Part 5 one could check how often plans are updated/replaced and inspect related source documents to analyze the efficiency.
	Land use planning effectively controls urban spatial expansion in the largest city in the country.	
	Land use planning effectively controls urban development in the four largest cities in the country, excluding the largest city.	
	Planning processes are able to cope with urban growth.	
8. Speed and predictability of enforcement of restricted land uses	Applications for building permits for residential dwellings are affordable and effectively processed.	This dimension is related to the national regulations and pricing. The process time of building permit applications can be calculated via SP_Permit and source document.
	The time required to obtain a building permit for a residential dwelling is short.	A LADM based LAS can keep track of this dimension with SP_Permit and VersionedObject classes, see Section 4.
9. Tenure regularization schemes in urban areas	Formalization of urban residential housing is feasible and affordable.	These dimensions are related to the national legislation of a country and to the implementation of the legislation.
	In cities with high levels of informal tenure, a clear, well-documented process to address tenure security, infrastructure and housing, exists.	
	A condominium regime provides for appropriate management of common property (rules for common property for management of driveways, parking, gardens, stairways, etc.)	Using ISO 19152-2, one can inspect the actual right types, specific for urban areas, e.g. apartment right.
Public Land Management		
10. Identification of public land and clear management	Public land ownership is justified and managed at the appropriate level of government.	These dimensions are related to the national legislation of a country, to the implementation of the legislation. Note that a LADM based LAS can keep track of this dimension (if all public land is recorded) with LA_Party, LA_BAUnit and LA_SpatialUnit.
	There is a complete recording of publicly held land.	
	The inventory of public land is accessible to the public.	
	The management responsibility for public land is unambiguously assigned.	
	Sufficient resources are available to fulfill land management responsibilities.	
	The key information on public land allocations to private interests is accessible to the public.	LADM can be able to check if the associated parties are public organizations (e.g., government).
11. Justification and time-efficiency of expropriation processes	There is minimal transfer of expropriated land to private interests.	Expropriation can be recorded as a source in LA_Source but since it is not explicitly modelled in LADM these dimensions are not considered as monitorable by LADM. By analyzing source documents, the number of transfer amount from expropriated land to private interests and elapsed time for destined use can be detected. See (12).
	Expropriated land is transferred to destined use in a timely manner.	
12. Transparency and fairness of expropriation procedures	Compensation is paid for the expropriation of all rights regardless of the registration status.	LADM can be extended with a country profile to cover expropriation information (e.g., compensation, appeal, etc.). Source document related to expropriation is recorded in LADM
	There is compensation for loss of rights due to land use changes.	
	Expropriated owners are compensated promptly.	

	There are independent and accessible avenues for appeal against expropriation.	
	Timely decisions are made regarding complaints about expropriation.	
13. Transparent process and economic benefit	Public land transactions are conducted in an open transparent manner.	These dimensions relate to a country's national legislation and its implementation. LADM content could be (partially) public to demonstrate transparency and fairness of procedures. If made public, the LADM content can be served, analyzed or visualized.
	Payments for public leases are collected.	
	Public land is leased and/or sold at market prices.	The leased and sold land public lands and their prices can be represented with LADM (LA_Party, LA_BAUnit, VM_TransactionPrice and VM_Valuation), however expert opinion may be required to detect whether land is sold/leased at market price.
	The public captures benefits arising from changes in permitted land use.	A LADM based LAS can enable detection of changes in permitted land use through Part 5 (SP_PlanUnit), Part 2 (LA_BAUnit, LA_SpatialUnit) and their values with Part 4 (VM_Valuation). However, extra information and analyses are required to monitor these dimensions.
Transfer of Large Tracts of Land to Private Investors		
14. Private investment strategy	Policy and regulations are in place to unambiguously and publicly identify public/ communal land that can be made available to investors, in agreement with legitimate land rights holders.	These dimensions are related to the national legislation of a country and to the implementation of the legislation.
	A policy process is in place to identify and select economically, environmentally, and socially beneficial investments and implement these effectively.	
	Public institutions involved in transfer of large tracts of land to private investors are clearly identified; without institutional and administrative overlap.	
	Public institutions involved in transfer of large tracts of land to private investors share land information and effective inter-ministerial coordination mechanisms are in place to timely identify and solve competing land use assignment (incl. sub-soil).	
	Investors' compliance with business plans is regularly monitored and remedial action is taken if needed.	
	Safeguards are established and applied to prevent that investments involving large tracts of land infringe on or extinguish existing legitimate tenure rights.	
	Cases where resettlement is possible are clearly circumscribed and procedures to carry it out are in place.	LADM could help providing information to analyze this dimension.

15. Policy implementation is effective consistent and transparent and involves local stakeholders	Sufficient information is required from investors for government to assess the cost-benefits of the proposed investments.	These dimensions are related to the national legislation of a country and to the implementation of the legislation.
	A clearly identified process is in place for approval of investment plans and the time required is reasonable and adhered to.	
	There are free, direct and transparent negotiations between right holders and investors; legitimate rights holders have always access to information.	
	Contractual provisions are publicly available and include benefit sharing mechanisms with legitimate right holders.	
16. Contracts are made public, and agreements are monitored and enforced	Accurate information on spatial extent and duration of approved concessions is publicly available so as to minimize overlap and facilitate transfers.	LADM could help providing information on the spatial extent to analyze this dimension.
	Compliance with safeguards is monitored and enforced effectively.	These dimensions are related to the national legislation of a country and to the implementation of the legislation.
	Avenues exist for legitimate right holders to air complaints if investors do not meet contractual obligations and decisions are timely and fair.	
Public Provision of Land Information: Registry and Cadastre		
17. Mechanisms for recognition of rights	There is an efficient and transparent process to formalize possession that is in line with local practice and understanding).	These dimensions are related to the national legislation of a country and to the implementation of the legislation.
	Non-documentary evidence is effectively used to help establish rights.	
	Long-term unchallenged possession is formally recognized.	
	First-time registration on demand includes proper safeguards and access is not restricted by high formal fees.	
	First-time registration does not entail significant informal fees.	LADM content could support this (transparency), what is actually disclosed is a national decision.
18. Completeness of the land registry	The cost of registering a property transfer is low.	This dimension is related to the national legislation of a country.
	The mapping or charting of registry records is complete.	A LADM based LAS can support checking whether the mapping of registry records is complete via LA_SpatialUnit, LA_BAUnit, LA_RRR and LA_Level, see Section 4.
	Economically relevant private encumbrances are recorded.	A LADM based LAS enables recording private encumbrances via LA_RRR and LA_Party, see Section 4.
	Socially and economically relevant public restrictions or charges are recorded.	It is possible to record public restrictions in LADM via LA_RRR, see ISO 19152-2 Annex E for details.
	There is a timely response to requests for accessing registry records.	Depending on the Land Registry and Cadastre regulations and their implementation, it may change.
	The registry is searchable.	A LADM based LAS enables all kind of

		search (e.g., geometrical, temporal, textual and so no)
	Records in the registry are easily accessed.	Depending on the land registry and cadastre regulations and their implementation, it may change.
19. Reliability: registry information is updated and sufficient to make meaningful inferences on ownership	Information regarding land rights maintained in different registries is routinely synchronized so as to reduce transaction cost for users and ensure integrity of information.	Depending on the land registry and cadastre regulations and their implementation, it may change.
	Registry/cadastre information is up-to-date.	A LADM based LAS can enable to search whether registry/cadastre information is up to date via comparing date of source data (LA_Source, VersionedObject) and registration date (real world time, database time, etc). Informal transactions can't be traced.
20. Cost-effectiveness and sustainability	The registry is financially sustainable through fee collection.	It depends on the financial regulation of national land registry and cadastre.
	Investment is sufficient cope with demand and provide high quality services.	
21. Fees are determined transparently to cover the cost of service provision	The schedule of fees is publicly accessible.	These dimensions are related to the national legislation of a country and to the implementation of the legislation.
	Informal payments are discouraged.	
	Service standards are published and monitored.	
Land Valuation and Taxation		
22. Transparency of valuations	There is a clear process of property valuation.	A LADM based LAS enables to record all input and output data used and produced in valuation processes, see ISO 19152-4 Valuation information. However, this dimension is related to the national legislation of a country and to the implementation of the legislation.
	Valuation rolls are publicly accessible.	This dimension is related to the national legislation of a country and to the implementation of the legislation.
23. Collection efficiency	Exemptions from property taxes are justified and transparent.	These dimensions are related to the national legislation of a country and to the implementation of the legislation.
	Property holders liable to pay property tax are listed on the tax roll.	
	Assessed property taxes are collected.	
	Receipts from property taxes exceed the cost of collection.	
Dispute Resolution		
24. Assignment of responsibility	There is clear assignment of responsibility for conflict resolution.	These dimensions are related to the national legislation of a country and to the implementation of the legislation.
	Conflict resolution mechanisms are accessible to the public.	
	Decisions made by informal or community based dispute resolution systems are recognized.	
	There is a process for appealing dispute rulings.	
25. The share	Land disputes constitute a small proportion of	These dimensions are related to the

of land affected by pending conflicts is low and decreasing	cases in the formal legal system.	national legislation of a country and to the implementation of the legislation.
	Conflicts in the formal system are resolved in a timely manner.	
	There are few long-standing land conflicts (greater than 5 years).	
Review of Institutional Arrangements and Policies		
26. Clarity of mandates and practice	Policy formulation, implementation, and arbitration are properly separated.	These dimensions are related to the national legislation of a country and to the implementation of the legislation. Also, organizational structure affects the evaluation of these dimensions.
	The responsibilities of the ministries and agencies dealing with land do not overlap (horizontal overlap).	
	Administrative (vertical) overlap is avoided.	
	Information on land ownership and use is shared among responsible institutions and relevant parts are freely accessible to the public.	
	Overlaps of rights (based on tenure typology) are minimial and do not cause friction.	
	Ambiguety in institutional mandates (based on institutional map) does not cause problems.	
27. Equity and non-discrimination in the decision-making process	Land policies and regulations exist and are developed in a participatory manner.	These dimensions are related to the national legislation of a country and to the implementation of the legislation. Also, organizational structure affects the evaluation of these dimensions.
	There is meaningful incorporation and monitoring of equity goals in land policy.	
	The implementation of land policy is costed, matched with benefits and adequately resourced.	
	There is regular and public reporting indicating progress in policy implementation.	

Table 2. GLII indicators and their relationships with LADM

GLII Indicator		**LADM**
Tenure Security		
Indicator 1.1 Documented land rights	Percentage of women and men with legally recognized documentation and evidence of secure rights to land.	A LADM based LAS enable to specify this indicator using LA_Party, LA_RRR, LA_Source,
Indicator 1.2 Perceived tenure security	Percentage of women and men who perceive that their rights to land are protected against dispossession or eviction.	This indicator is related to the evaluation of right holders.
Indicator 1.3 Tenure security under a plurality of tenure regimes	Level of legal recognition and protection of land rights and uses derived through either statutory or customary regimes	This dimension is related to the national legislation of a country and to the implementation of the legislation. LADM supports representing individual tenure rights in rural and urban areas (see LA_Party, LA_RRR, LA_SpatialUnit and LA_Level) as well as customary, informal and Indigenous rights (see also Social Tenure Domain Model (STDM) (Annex I in Edition 1, Annex B in part 2 of Edition 2), specialization of LADM). Historical source document and current status of land right can be recorded in different levels (LA_Level) in LADM.
Indicator 1.4 Equal rights of women	Level to which women and men have equal rights to land, including rights to use, control, own, inherit and transact these rights	A LADM based LAS can keep track of this dimension, see Section 4 (LA_Level, LA_Party).

Indicator 1.5 Indigenous land rights	Numbers and proportion of indigenous and community groups with land claims that have legally recognized documentation or evidence of secure rights, and percentage of land areas claimed and utilized that have been legally secured.	A LADM based LAS can partially keep track of this dimension, see Section 4 (LA_Party, LA_GroupParty, LA_Source, LA_BAUnit, LA_SpatialUnit).
Land Disputes and Land Conflicts		
Indicator 2.1 Frequency of land disputes and conflicts	Percentage of women and men, Indigenous Peoples and local communities who have experienced land, housing or property disputes or conflicts of different types in the past X years	A LADM based LAS may support the calculations for this indicator. For example, both historic ownership (Level 1), current ownership (Level 2) can be stored in LADM
Indicator 2.2 Availability of dispute-resolution mechanisms	Percentage of women and men, indigenous and local communities that have access to effective dispute resolution mechanisms	This indicator is related to the national legislation of a country and to the implementation of the legislation.
Indicator 2.3 Land dispute-resolution effectiveness	Percentage of women and men, indigenous and local communities who reported a conflict or dispute in the past X years that have had the conflict or dispute resolved.	This indicator is related to the national legislation of a country and to the implementation of the legislation.
Land Administration Services		
Indicator 3.1 Land administration efficiency	Range of times and costs to conduct land transactions	This indicator is related to the national legislation of a country and to the implementation of the legislation.
Indicator 3.2 Transparency of land information	Level to which land information is available for public access	This indicator is related to the national legislation of a country and to the implementation of the legislation.
Indicator 3.3 Land administration availability	Level to which all users, including women and vulnerable groups, have equal access to land administration services	This indicator is related to the national legislation of a country and to the implementation of the legislation.
Indicator 3.4 Mobilization of land-based taxes	Government tax derived from land-based sources as a percentage of total government revenue.	This indicator is related to the national legislation of a country and to the implementation of the legislation. LADM can support taxation via providing information on land (LA_SpatialUnit, LA_BAUnit) and their values (VM_Valuation).
Indicator 3.5 Land area mapped	Proportion of national land areas with rights holders and tenure status identified that are incorporated into cadastral maps / land information systems.	A LADM based LAS enables the calculation the proportion defined in this indicator using LA_Party, LA_SpatialUnit and total national land area.
Sustainable Land Use		
Indicator 4.1 Aggregate national changes in land-use sustainability	Changes in the geographical extent of sustainable land use, measured by: i) land cover/land use change; ii) land productivity change; and iii) soil organic carbon change.	This indicator is related to the national legislation of a country and to the implementation of the legislation. If LADM Part 5 is fully implemented, then changes in planned land use can be specified.
Indicator 4.2 Progress in sustainable land-use planning	Proportions of rural and urban administrative districts or units in which land-use change and land development are governed by sustainable land-use plans that take account of the rights and interests of the local land users and landowners.	LADM part 5 could be used to analyze the actual registered plans (and the dates)