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The governance of global land sector semantic resources – status and pathways

Erik Stubkjær¹, Jennifer Whittal², Simon Hull², Volkan Çağdaş³,
 Charl-Thom Bayer⁴, Laura Meggiolaro⁵, Rohan Bennett^{6,7},
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Knowledge Organization Systems (KOS) enable Semantic Web and Linked Data implementations. KOS in terms of the Linked Land Governance Thesaurus (LandVoc) and the Cadastre and Land Administration Thesaurus (CaLAtHe) render concepts of the ISO 19152:2024 Land Administration Domain Model. These all support more shared and standardized understandings in the land domain. Concept mapping is presented, and an explicit integration of thesauri and knowledge bases is illustrated for education and community engagement. The paper reflects on the integration of CaLAtHe into the LandVoc and AGROVOC context. The establishment of a less strict semantic facility, supporting ad hoc teaching tasks, is motivated.

Keywords: AGROVOC multilingual thesaurus (AGROVOC), Cadastre and Land Administration Thesaurus (CaLAtHe), The Linked Land Governance Thesaurus (LandVoc), Teaching Essentials for Responsible Land Administration (TERLA), concept mapping

1. Introduction

The notion of *semantic resources* is introduced to the geospatial community referring to controlled vocabularies, specifically thesauri, which assist in providing interoperability among datasets in the surveying and construction sectors and supporting a wider e-governance perspective (Çağdaş *et al.* 2021). Compared to the uptake and application of geospatial tools for solving land-related problems and processes (Hull *et al.* 2022) the use of semantic resources lags, despite the paramount importance of a shared understanding of terms among practitioners, researchers and students.

The introduction of thesauri to the largely science and technology-based geospatial domain might be supported by recalling that the zeal of structuring phenomena into hierarchies is as old as Western science: Aristotle (384–322 B.C.) devised a classification scheme for animals, which as Medieval ‘Scala Naturae’ formed the basis for

Carl Linnaeus’ *Systema Naturæ* from 1737, where he divided the physical components of the world into the three familiar kingdoms of minerals, plants and animals. Roget’s *Thesaurus of English Words and Phrases* (1852) provided, according to Roget in his introduction, a *verbal classification ... the same as that which is employed in the various departments of natural history* (Gilchrist 2003). This structuring tradition may be observed also within the International Federation of Surveyors (FIG) community: Barry and Roux (2012) argue that a more rigorous, formally structured, approach to land tenure information systems theory development is desired. It would demonstrate a maturation of the global community, that until relatively recently could be said to be operating in silos established by geo-political, colonial and language divisions. Therefore, they adapt Grover and Glazier’s taxonomy (1986), a hierarchy consisting of worldview, paradigm, grand theory, formal theory, substantive theory, hypothesis, research question, proposition, concept, definition, and symbol.

In the present context of research and education, the notion of *semantic resources* also refers to traditional lecturing material as well as to the *knowledge assets* or *intellectual capital* of an organization. The latter includes e.g. guides, standards, and tools mentioned in the Terms of Reference of the FIG Commission 7 Work plan 2023–26, e.g. the Cadastre 2014 (Kaufmann & Steudler 1998) and ISO 19152:2012 Land Administration Domain Model (LADM) (ISO 2012).

Working with thesauri supports, if not underpins, solving land-related problems or developing new technology. They make clear concepts of the domain of land, the relations among these concepts, and their structuring in various hierarchies. Arguably, no legal, technical, or administrative solution can be adequate without this

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grounding. The ISO 19152-1:2024 LADM (ISO 2024) provides for a normative structure, supplemented by code lists and national profiles. However, at this point it is based in the English language, while worldwide diverse cultures, legal traditions, and different languages exist. Translations of terms between languages can result in confusion, especially where terms are already poorly defined (Hull 2024); therefore, the normative structure is supplemented through thesauri (Stubkjær *et al.* 2018, 2019) as well as various alternative structures as unfolded in the following paragraphs.

Linked Data refers to data published on the Web in such a way that it is machine-readable, its meaning is explicitly defined, and it is mutually linked to external data sets (Bizer *et al.* 2009). It is built upon a set of standards and specifications published by the World-Wide Web Consortium¹ (W3C) such as Resource Description Framework (RDF), RDF Scheme (RDFS), Simple Knowledge Organization Systems (SKOS), Web Ontology Language (OWL), and SPARQL Query Language for RDF (SPARQL). In Linked Data, a resource is accessed by Uniform Resource Identifiers (URI) over the Web, described by RDF based on standardized RDF vocabularies, connected with other semantically related resources by RDF links (Berners-Lee 2006), and queried by SPARQL. The meaning of the concepts used in data and relationships between these concepts may be defined by KOS such as taxonomies, thesauri, or ontologies, which are represented through RDF vocabularies such as OWL or SKOS.

Van den Brink *et al.* (2019) note that the linked data web technology, promoted by the W3C, adds vocabulary management and tooling to the principles, tools, and standards that enable search engine results for consumer shopping. Van den Brink *et al.* (2019) describe best practices, and note unsolved questions related to representing geometry on the Web, regarding recommendable serialization forms and formats, and the use of coordinate reference systems. OGC's GeoSPARQL offers a vocabulary that allows serialization of geometries as Geography Markup Language (GML), but the lack of best practices on the consistent use of the existing spatial data vocabularies prevents interoperability. A proposed update of GeoSPARQL, Version 1.1² has since been achieved.

Other researchers implemented the Linked Data approach to the cadastre and land administration domain. For instance, Saavedra *et al.* (2014) integrated data coming from different cadastral data producers through the Linked Data approach in a Colombian case study. Shi *et al.* (2017) described the publishing and integration of several cross-domain government datasets related to state-owned real estates as Linked Open Data. Ronzhin *et al.* (2019) presented experiences from building a Knowledge Graph by the Netherlands' Kadaster Land Registry and Mapping Agency and demonstrated the advantages of the Knowledge Graph in three different use cases. An updated approach for handling large scale geospatial datasets was presented by Rowland *et al.* (2022). Vilches-Blázquez and Saavedra (2019), presented a framework for generating, enriching, and exploiting geospatial Linked Data from multiple and heterogeneous geospatial data sources. They further provided a case study where land administration information from two Colombian agencies were semantically integrated through knowledge graphs and enriched with

other data according to Linked Data principles (Vilches-Blázquez & Saavedra 2022). Van Aalst (2024) examined the benefits and drawbacks of the implementation of the LADM Edition II for data dissemination in the Netherlands with the Linked Data approach.

The above-mentioned research may indicate that we are facing a new (sub-)discipline. The databases of traditional Geographic Information Systems (GISs) are being replaced by structures (triplestores), which hold concepts that are related through primitive sentences. This implies a new focus on concepts and the corresponding discipline of semantics.

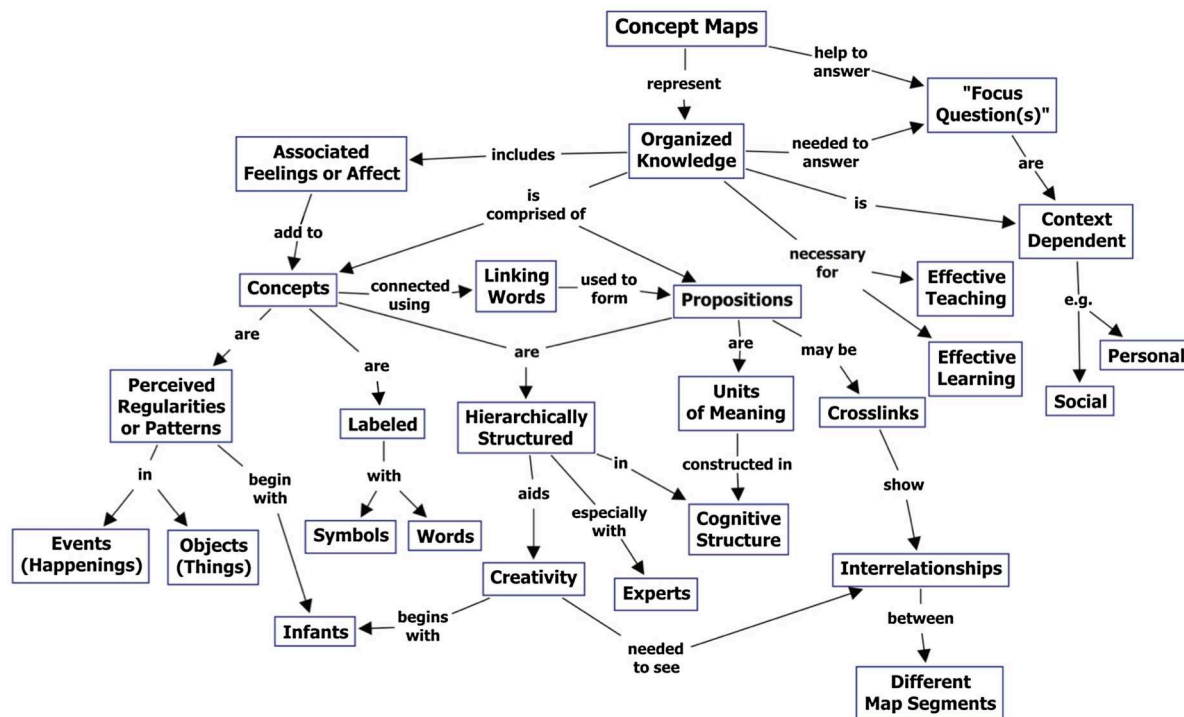
Concept sets in a domain of interest, along with their definitions and relationships, are specified by Knowledge Organization Systems (KOS) in different levels of complexity, such as term lists, taxonomies, classification schemes, thesauri, and ontologies. Researchers have developed various KOS in the form of ontology based on ISO LADM, to realize Linked Data implementations in the domain of cadastre and land administration, e.g. Soon (2013), Sladić *et al.* (2013), Shi *et al.* (2017), as well as Vilches-Blázquez and Saavedra (2022). In addition to these ontologies, several land-related thesauri are available for the FIG community, as outlined by Çağdaş *et al.* (2021). Among these, The Linked Land Governance Thesaurus (LandVoc) and Cadastre and Land Administration Thesaurus (CaLAtHe) are two thesauri developed specifically for the service of the land-related disciplines. The former is related to land governance, while the latter is related to cadastre and land administration.

The governance of these two complementary semantic resources together with code lists and their values, specified according to the ISO LADM formalism, contribute to the improved understanding of linked land administration data. The FIG publication on the Digital Transformation of Land Administration highlights the necessity of clear definitions and uses of terminology, referencing specifically LandVoc as well as the Food and Agriculture Organization of the United Nations (FAO) and FIG glossaries (FAO, UNECE & FIG 2022). The above-mentioned extension of the focus on concepts suggests engaging and organizing colleagues to manage and develop these semantic resources, support their integration into research, and to cooperate with related disciplines in developing courses which introduce the next generation of students to the semantic technology (Jovanovik and Spasić 2019, Čeh and Tekavec 2023).

The scientific contribution of the paper is to further the integration and use of semantic resources within the land sector by

- presenting a method of learning called 'concept mapping',
- motivating a more explicit integration of thesauri and knowledge bases like the Teaching Essentials for Responsible Land Administration (TERLA) in education, training, and community engagement,
- motivating the establishment of a semantic facility, supporting ad hoc teaching tasks, and
- suggesting the integration of CaLAtHe into the LandVoc and AGROVOC context.

The rest of the paper is organized as follows: Section 2 introduces FIG-related semantic resources in terms of three thesauri: AGROVOC, LandVoc, and CaLAtHe. Section 3 illustrates the use of concept mapping and the



1 A concept map showing key features of concept maps (Novak and Cañas 2006)

linking of lecture concepts to thesauri through examples from authors’ own lecturing, to motivate the appropriation of such practices. Section 4 summarizes reflections on thesaurus relations and reports on the outcome; it is followed by Conclusions.

2. FIG-related semantic resources in terms of thesauri

KOS or controlled vocabularies are vital for cataloguing and indexing information resources. They also facilitate communication by providing basic terminology for the domain of interest and enable Semantic Web, Linked Data and Knowledge Graph implementations. Several controlled vocabularies focusing on different aspects of land management have been developed by the land-related disciplines including AGROVOC, LandVoc, and CaLAThe. The content of these controlled vocabularies is described below, as the basis for the discussion in Section 4.

2.1 AGROVOC multilingual thesaurus

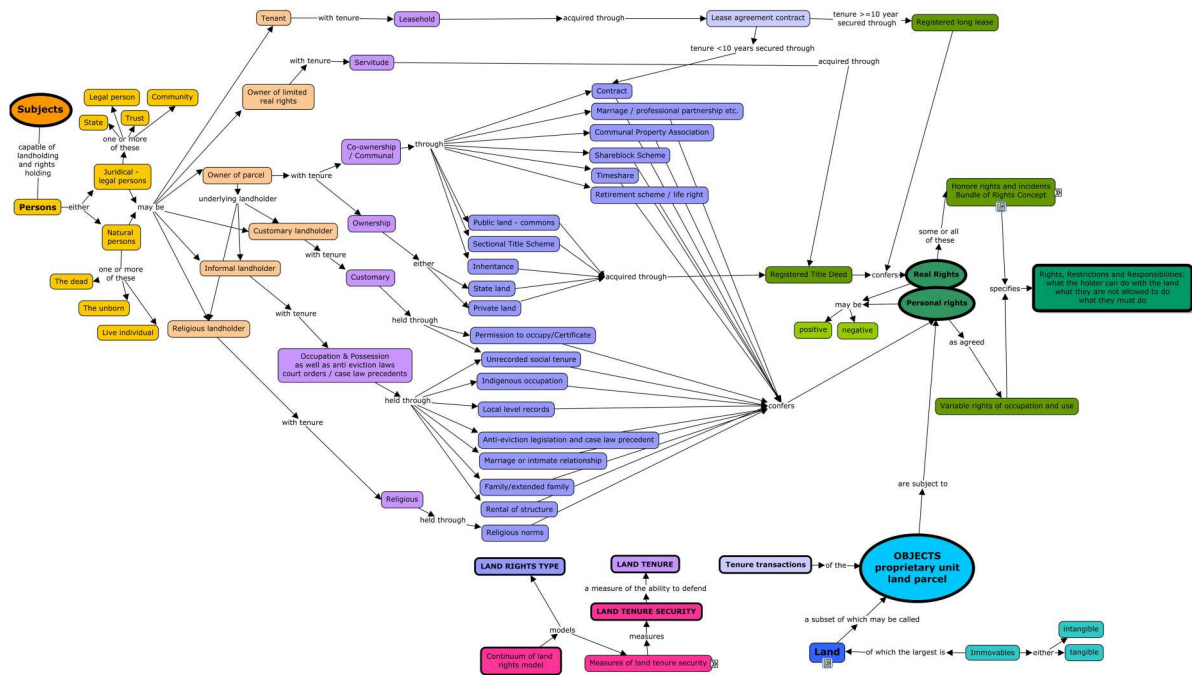
AGROVOC³ is a multilingual thesaurus maintained by the FAO. It includes more than 41,000 concepts and 1,148,000 terms in 42 languages in all areas of interest to the FAO, such as food, nutrition, and agriculture to fisheries, forestry, and the environment. AGROVOC is expressed through the SKOS formalism and published as Linked Open Data. It can be accessed through the SKOSMOS browser⁴ and a SPARQL endpoint.⁵ AGROVOC concepts are organized under the following top concepts: Activities, Entities, Events, Factors, Features, Groups, Location, Measure, Methods, Objects, Organisms, Phenomena, Processes, Products, Properties, Resources, Site, Stages, State, Strategies, Subjects, Substances, Systems, Technology, and Time. AGROVOC is

aligned with other vocabularies such as EUROVOC, National Agricultural Library Thesaurus (NALT), General Multilingual Environmental Thesaurus (GEMET), STW Thesaurus for Economics, and the United Nations Bibliographic (UNBIS) Thesaurus.

AGROVOC is edited by means of the web-based platform, VocBench,⁶ a free and open-source advanced collaboration environment for creating and maintaining KOS. VocBench allows the creation and management of domain-specific sub-vocabularies within AGROVOC. This enables enriching AGROVOC with concepts belonging to other controlled vocabularies. Flexibility is achieved by allowing each sub-vocabulary to have a different concept hierarchy. Currently, several sub-vocabularies have been developed within the AGROVOC frame including the Linked Land Governance Thesaurus (LandVoc) curated by the Land Portal Foundation.

2.2 The Linked Land Governance Thesaurus – LandVoc

LandVoc⁷ is a thesaurus covering concepts related to land governance. LandVoc began in 2013 with addition of new terms and definitions to AGROVOC from existing land glossaries (FAO & Land Portal 2023). In 2012, the land governance sector lacked standardized vocabularies, with only 20 land-related concepts included in the AGROVOC vocabulary. A gap analysis revealed the absence of a structured or uniform approach to using controlled vocabularies for publishing information (Mey et al. 2020) which led to the development of LandVoc in 2016. In 2020 LandVoc became an independent subschema within AGROVOC (Bayer and Meggiolaro 2022). LandVoc builds on existing land glossaries, such as the FAO’s Land Tenure Thesaurus (Ciparisse 2003), the LADM, the Global Land Tool Network (GLTN) and the Global Land Indicators Initiative glossary. It



2 The concept map for Module 4 reflects the introduction to rights, tenure, security of tenure, and ownership. The aspects related to subjects are in shades of orange, those related to objects are shades of blue, and those related to RRRs are in shades of green. The central lilac-purple colours reflect land tenure type, land rights type, and land rights access

can be accessed through the SKOSMOS browser⁸ and the AGROVOC SPARQL endpoint.⁹

LandVoc consists of 310 concepts organized hierarchically under seven top concepts, namely land administration, land equity, land governance, land management, land markets, land rights, and land stakeholders. It is available in English, French, Spanish, Portuguese, Khmer, Vietnamese, Burmese, Thai, Swahili, Hindi, Italian and Arabic. The content of LandVoc is updated periodically according to recommendations of the Community of Experts and in close coordination with the FAO AGROVOC editorial team. LandVoc thesaurus content is licensed under Creative Commons Attribution 3.0 IGO (CC BY 3.0 IGO).

2.3 Cadastre and Land Administration Thesaurus – CaLAThe

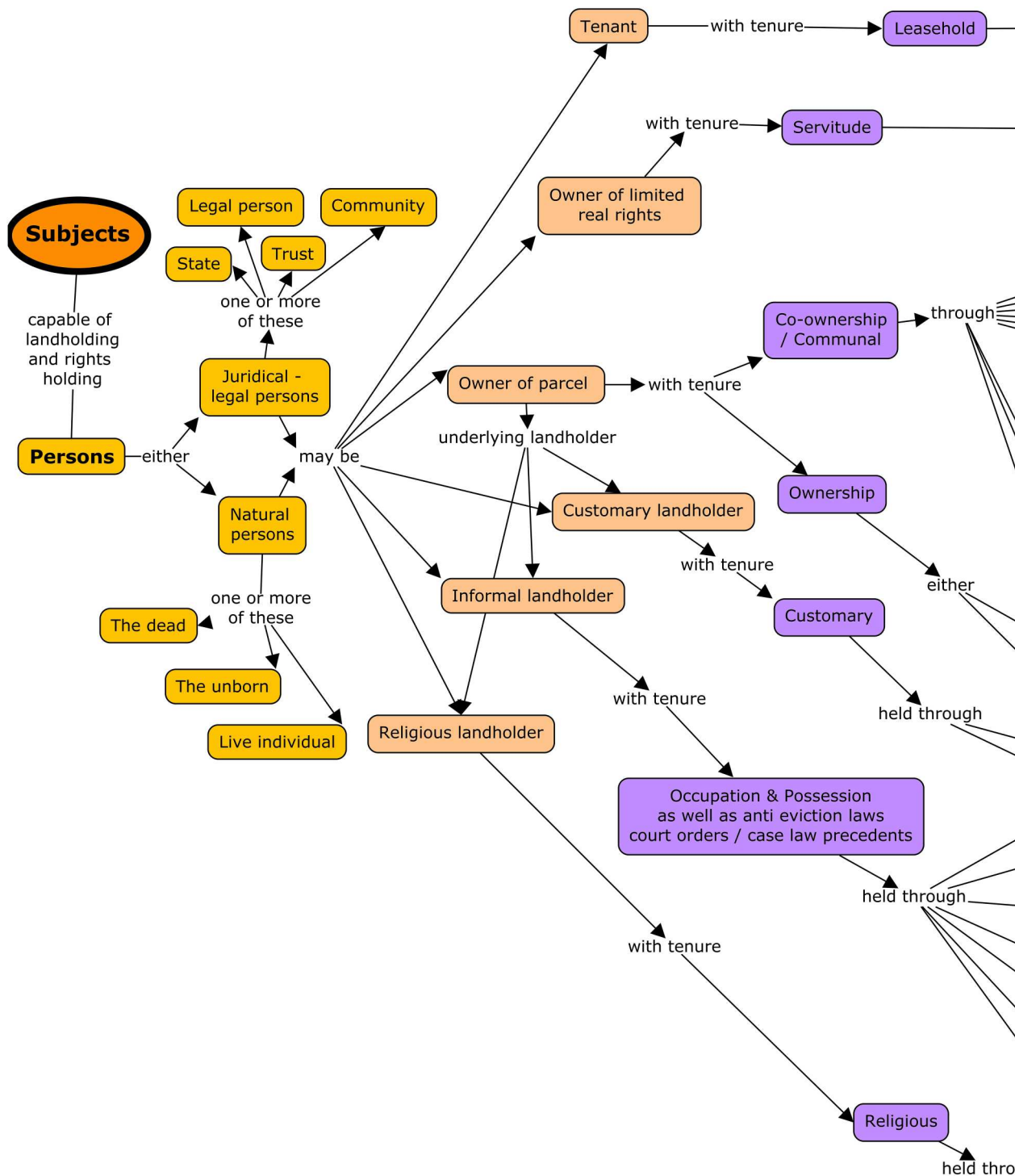
CaLAThe¹⁰ is a domain thesaurus in the SKOS format, issued in 2011 (Çağdaş and Stubkjær 2015). The reviews of a comprehensive number of recent PhD theses (Çağdaş and Stubkjær 2009, 2011) with ontology eliciting in mind (Stubkjær 2001), provided the source for the identification and structuring of domain terms, covering legal, administrative, and technical (surveying and information) aspects. The initial intention was recast into a structuring of basic entities of the domain, namely the concepts.

CaLAThe’s initial version was based on the then draft version of ISO LADM Edition I (ISO 2012). However, it also included terms from other thesauri, such as the AGROVOC, the GEMET with INSPIRE Spatial Data Themes, the STW Thesaurus for Economics, Cycorp’s OpenCyc ontology, and United Kingdom’s Integrated Public Sector Vocabulary. Version 2, issued in 2012, was supplemented with terms representing the dynamic aspect of the domain, based on outcomes from the

European research activity Modelling Real Property Transactions (ESF/COST G9, 2001–05). Version 3 and Version 4, released in 2019, extended CaLAThe with new terms adopted from the Land Division, Condominium, and Survey parts of the OGC Land and Infrastructure Conceptual Model Standard (LandInfra) (Scarponcini and Stubkjær 2017). Version 4 also included code lists of the Survey, Land division, and Condominium sections of the LandInfra standard. Version 5 in 2021 started a multi-lingual itinerary by adding terms in Danish and Turkish, the native languages of the editors. In Version 6, new and revised concept definitions were provided. The intensional definition (also known as the genus-differentia definition) method recommended by ISO 704:2009 ‘Terminology work – Principles and methods’ (ISO 2009) was applied in the preparation of definitions. Moreover, the multilingualism of CaLAThe was further improved by the addition of Malay terms. Version 6 in 2023 complemented CaLAThe with Common law concepts, and Dutch terms were added. The current Version 7 now includes about 250 English language concepts with their definitions and their equivalences in the Danish, Dutch, Malay, and Turkish languages. The concepts are organized through the top concepts that characterize the domain covered, namely Activity, Information, Land, Law, Party, and Survey.

3. The use of thesauri in university education

The emergence of the semantic web and linked data technology has triggered a learning approach called concept mapping. Therefore, concept mapping is introduced to invite lecturers and students to apply this approach. Concept mapping has been applied by one co-author and is illustrated and extended to demonstrate the linking of



3 Section of the concept map showing the subjects and types of landholder and landholding

lecture concept structures to relevant thesauri. A course lectured by another co-author provides the base for similarly linking concept structures of overheads to thesauri. The subsequent section 3.3 motivates a more explicit integration of thesauri and knowledge bases like the Teaching Essentials for Responsible Land Administration (TERLA) in education, training, and community engagement, and calls for glossaries and other semantic resources needed to supplement the TERLA. The complexity of this integration motivates a proposal to establish a semantic facility which supports lecturers in ad hoc teaching tasks.

3.1 Concept mapping

Thesauri record knowledge; the challenge is to articulate that knowledge in a way that adequately translates into personal application, be it in the role as student, lecturer, or scientist. Concept mapping has been proposed as a learning approach, which gradually has gained wider acknowledgment. A concept map is a graphical representation of concepts (nodes) and relationships (in graph theory: edges) between them. The relationships can be conceptual (such as hierarchical) or empirical (such as cause and effect, influence) (Soergel 2009). Concept maps display ideas in a hierarchical structure and tie

- Subjects are capable of landholding and rights holding (Persons)
 - Juridical persons
 - The state
 - Trusts
 - Community
 - Legal person (incl organisations)
 - Natural persons
 - Live natural persons
 - The dead
 - The unborn
- Types of landholder include
 - Tenant
 - Owner of limited real rights
 - Owner of parcel (land object)
 - Customary landholder
 - Informal landholder
 - Religious landholder
- The types of landholding include
 - Leasehold
 - Servitude
 - Co-ownership/communal
 - Ownership
 - Customary
 - Occupation & possession
 - Religious

4 Subject-related concept structure of Module 4 in the course APG3033W Land Law and Cadastral Systems

them together with explanatory nodes and links. Two or more concepts can be linked together with words to form propositions (Machado and Carvalho 2020).

In a concept-map based learning environment, students, individually or in groups, may construct a concept map showing their previous knowledge on a topic, and further develop a knowledge model that reflects their increased understanding (Cañas *et al.* 2023). A recent review by Machado and Carvalho (2020) motivates the inserting of concept maps into university teaching, as it contributes to developing critical thinking skills, promotes meaningful learning, and facilitates student collaboration. Their article further aims to provide educators and researchers with a structured overview of the research on concept mapping as learning and assessment tools implemented with students in higher education. Figure 1 below may introduce the issue. Their review provides a basic introduction to the subject, not repeated here, with reference to several disciplines. Geosciences are mentioned in a review by Xiaogang Ma (2022), who details how to build knowledge graphs by designing conceptual models and mentions the CmapTools.¹¹ Knowledge graph construction requests skills, which are presently lectured primarily by computer scientists. However, like problem-based learning developed from something new and special to become a more general teaching practice, the computer-assisted knowledge construction may similarly become a more general practice.

In the land administration domain, Whittal (2015) used concept mapping through the CmapTools for assessing the role of bachelor degree in Geomatics at the University of Cape Town, which is focussed on land-based

surveying, in preparing graduates for coastal and offshore work nationally and internationally. Some limitations in the undergraduate programme were uncovered, highlighting the importance of further employer-led education and training for graduates employed in the offshore industry. Concept mapping was shown to be a useful tool for understanding the intersection between different bodies of knowledge, and also to model the hierarchy of concepts.

This brief introduction to concept mapping suggests how the knowledge embodied in thesauri might enrich land administration teaching and learning. Concept maps created by individual students will reflect how students perceive the domain knowledge, for example, domain concepts and relationships between those concepts may enable them to gain deeper domain knowledge.

3.2 Application of concept mapping for university courses

Concept mapping has been applied for the representation of the knowledge graph of concepts associated with a suite of three real property law and cadastral courses taught in the third year of the BSc Geomatics in Surveying degree at the University of Cape Town. A complex and inclusive concept map of the entire suite of courses has been developed but is too detailed to present here. Figure 2 focuses only on concepts introduced in Module 4 of the course *APG3033W-Land and Cadastral Survey Law*. These concept maps reflect ontological aspects of the course design and delivery appropriate to teaching and learning in a legally plural African context. The

Table 1 The matching concepts of Module 4 of the *APG3033W-Land and Cadastral Survey Law* course with the concepts of domain-related thesauri

Land and Cadastral Survey Law course concepts	LandVoc	AGROVOC	CaLAtHe
<p>*Subjects are capable of landholding and rights holding (Persons)</p> <ul style="list-style-type: none"> • Juridical persons <ul style="list-style-type: none"> • The state • Trusts • Community • Legal person (incl organizations) • Natural persons <ul style="list-style-type: none"> • Live natural persons • The dead • The unborn 	<p>* land stakeholders</p> <ul style="list-style-type: none"> • - • government • trusts • local communities • - • families, farmers • - • - • - 	<p>* Groups</p> <ul style="list-style-type: none"> • - • government • trusts • community organizations • - • individuals, women, youth • - • - • - 	<p>* Party</p> <ul style="list-style-type: none"> • Natural person role • Governmental org. • - • Social group • Legal person, Organization • Natural person • - • - • -
<p>* Types of landholder include</p> <ul style="list-style-type: none"> • Tenant • Owner of limited real rights • Owner of parcel (land object) • Customary landholder • Informal landholder • Religious landholder 	<p>* land stakeholders</p> <ul style="list-style-type: none"> • tenants, smallholders • - • landowners • Indigenous Peoples • pastoralists, squatters • - 	<p>* land stakeholders</p> <ul style="list-style-type: none"> • tenants, smallholders • - • landowners • ethnic groups • squatters • religious groups 	<p>* Rights holder</p> <ul style="list-style-type: none"> • Lessee • Encumbrance holder • Owner • Collective ownership • Indigenous tenure system • -
<p>* The types of landholding include</p> <ul style="list-style-type: none"> • Leasehold • Servitude • Co-ownership/communal • Ownership • Customary • Occupation & possession • Religious 	<p>* -</p> <ul style="list-style-type: none"> • leases • - • collective ownership • land ownership • customary tenure • occupation • - 	<p>* land ownership</p> <ul style="list-style-type: none"> • leaseholds • - • coownership • ownership • customary tenure • occupancy • - 	<p>* Real right</p> <ul style="list-style-type: none"> • Leasehold • Easement • Co-ownership • Ownership • Customary tenure • - • -

layout is influenced by the triad of Objects, Subjects and Rights, Restrictions and Responsibilities (RRRs) such as reflected in LADM, FFP, and discussed and extended by the Von Benda-Beckmanns to include space–time dimensions (2014). Figure 3 illustrates some of the details related to the Subjects of landholding. The concept mapping was undertaken using the CMapTools software mentioned above.¹²

The full power of CmapTools cannot easily be shown. The software facilitates linking concepts to web pages and teaching materials such as glossaries, readings, notes, and presentations. Moreover, information may be added to a concept, such as a definition or description. This information appears when holding the mouse over the concept, but there is no indication of this hidden information (such as a handle) to alert the user.

The presented course concepts are next linked to concepts of domain thesauri to further motivate and supplement teaching and learning approaches. Course concepts are motivated by course purpose. The linking of course and thesaurus concepts may be based on shared definitions. It should be noted that reflections on the validity of the linking are included into the general teaching and learning process and not explicitly addressed in the following.

A part of the above concept structure, namely the hierarchy of concepts related to Subjects, are rendered in Fig. 4 below. This hierarchy forms the basis for illustrating the

linking of concepts to thesauri of the domain: LandVoc, AGROVOC, and CaLAtHe in Table 1.

The linking of course-specific concepts to thesauri is illustrated also through a lecture with focus on geospatial aspects from the course *International Land Management*, lectured at the Institute of Real Estate Studies, then Helsinki University of Technology, Finland. Course description, overheads, etc. are available at <https://homes.plan.aau.dk/est/Undervisning/HUT03/Index.html> and concepts of the lectures given 08.10.2003 are presented in Fig. 5 below:

The concept structure is like the previous example supplemented with references to the mentioned thesauri: LandVoc, AGROVOC, and CaLAtHe, as well as two further semantic resources: The ISO/TC 211 Multi-Lingual Glossary of Terms, Geolexica, and The Basic Register of The-sauri, Ontologies & Classifications (BARTOC), a database of Knowledge Organization Systems, see Table 2.

3.3 The interplay of thesauri and learning in higher education

The Teaching Essentials for Responsible Land Administration (TERLA) is a set of six modules designed by the Global Land Tools Network (GLTN) and published online in 2019.¹³ The modules provide educators and curriculum developers with broad content on aspects of ‘responsible’ land administration for the development of teaching tools to address current global land issues.

- Spatial feature = Terrain object
 - Settlement
 - Dwelling
 - Unit of real property
 - Area
- Territorial units
 - Region
 - District
 - Diocese
 - Parish
 - County
 - Municipality
 - Jurisdiction
 - Court district
- Location
 - Place name
 - Post address
 - Street name
 - Cadastral parcel identifier
- Marker
 - Sign plate
 - Street sign
 - Boundary mark
- Spatial reference frame
 - Geodetic coordinate system
 - Road network
 - Road segment

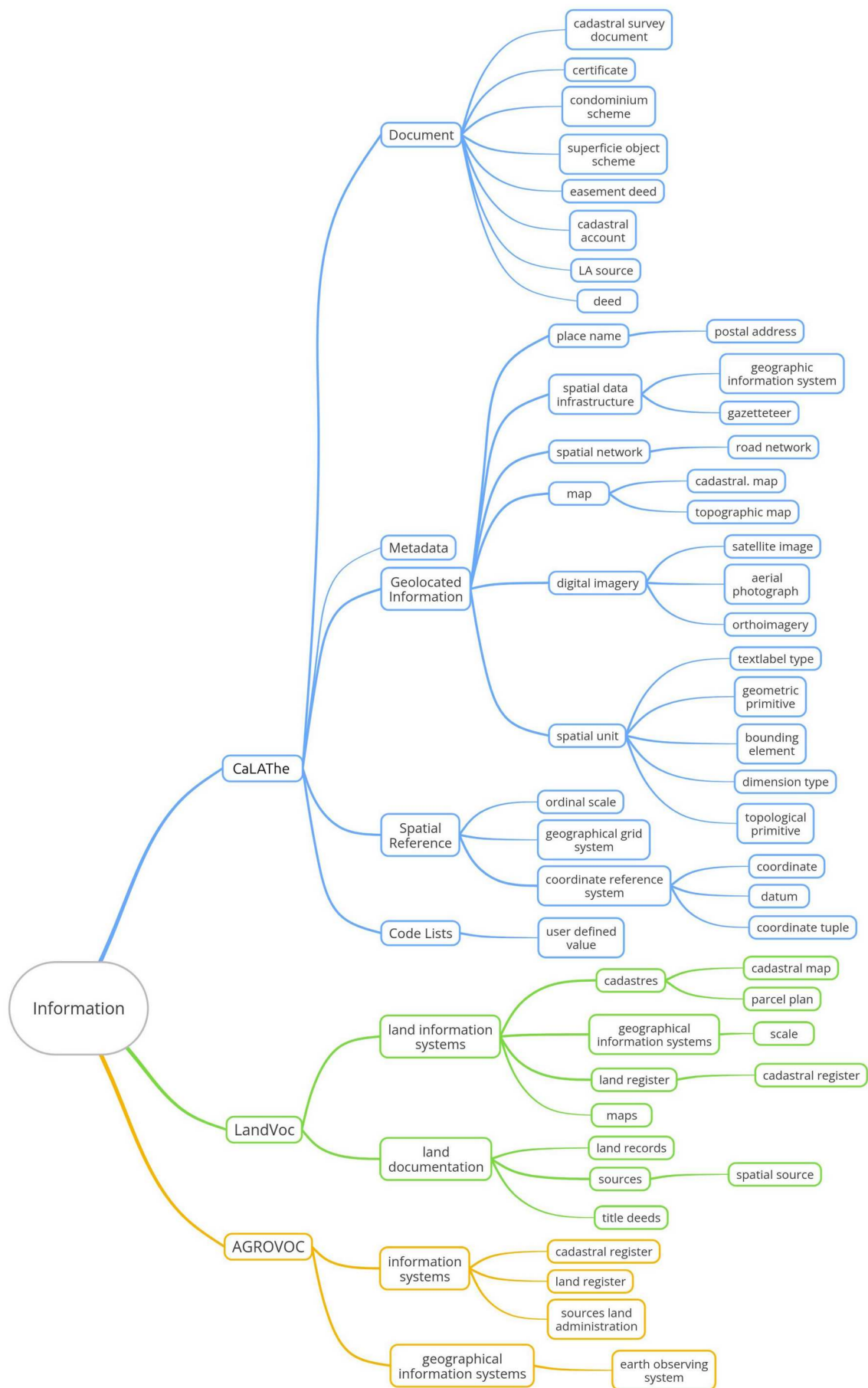
5 The concept structure of *International Land Management*, lectured at the Institute of Real Estate Studies, then Helsinki University of Technology, Finland

More recently, an abridged version (Enemark 2023) has been published. Hull *et al.* (2024, p.16) conducted a review of all six TERLA modules, noting that several concepts associated with land administration require clarity of definition for shared understanding and use. Mattson and Mansberger (2017, p. 1) share this concern: *There are a lot of concepts related to land and sometimes it can be difficult to understand how they are used.* They propose that definitions of different concepts in the land sector should be explored as a starting point for degree programmes in land administration and management. Hull *et al.* (2024, p. 7) echo this concern, noting that in TERLA, *more definitions are needed and where they are provided, they are not always sufficiently robust.* They propose that a glossary of terms should be provided *as a navigational tool [to] help readers grasp the meanings and ... interpret the reading materials* (Hull *et al.* 2024). As a starting point, educators could refer to the comprehensive glossary provided in Williamson *et al.* (2010), noting however the legal tradition of the educator's context (cf. Glenn 2014) and the fact that definitions and use of terms evolve (as shown in Hull 2024). This necessitates educators in the land sector to draw from a wide variety of sources, both decades old and recent, to cultivate an unbiased and broad understanding of concepts.

The orderly management of such a variety of glossaries and definitions is a challenge. First, the semantic resources described in section 2, FAO's AGROVOC and Land Portal Foundations' LandVoc, are based on

substantial efforts spent in achieving the present concept structures and definitions, implying that modifications are only carefully and thoughtfully realized. Next, Steiner and Albert (2017) claim that *For one and the same knowledge domain it is not realistic to assume that only one correct representation of complete consensus exists ... [because] there is a range of alternative ways conceivable to describe and conceptualize the same domain.* They discern *Content validity [which] refers to the correct building of the content of a concept map, ... [from] application validity, [which] refers to the practical usability and usefulness of a target concept map* [i.e. a concept map to be validated]. It appears that application validity refers to the users' previous knowledge and capacity for making sense of the presented knowledge. LandVoc editors structure their knowledge base to bridge heterogeneous knowledge communities and foster interdisciplinarity, while editors of CaLAtThe use resources to improve content validity.

Summarizing, the complexity of thesaurus management calls for a semantic facility, like the technology applied for AGROVOC, which allows individual lecturers and scientists to edit their definitions and concept structures. The facility thus combines thesaurus management and concept mapping and may offer a potential for the preparation and use of knowledge graphs (cf. Vilches-Blázquez and Saavedra 2022). Moreover, as the GLTN e-learning platform is hosting TERLA and the FIG community is a main user of TERLA, further



6 The top concept Information with the uppermost concepts of the CaLAtHe, LandVoc, and AGROVOC thesauri, prepared in the context of the alignment process

Table 2 The matching concepts of International Land Management course with the concepts of domain-related thesauri

International Land Management course concepts	LandVoc	AGROVOC	CaLThe	TC211Geolexica	BARTOC
* Spatial feature	* -	* -	* Spatial feature type	* spatial feature collection	* -
• Terrain object	• -	• -	• -	• -	• -
• Settlement	• -	• -	• Site	• settlement	• -
• Dwelling	• -	• dwellings	• -	• -	• Dwelling Address Classification
• Unit of real property	• property	→housing	• Real property	• -	• Gale Real Estate Thesaurus
• Area	• territory	• property	• -	• -	• LC MARC Geographic Areas
		• area			
* Territorial units		* territory	* Administrative unit		* Administrative Territorial Units Name Authority List (covers e.g. municipality)
• Region		• regional government			
• District		• -			
• Diocese		• -			
• Parish		• -			
• County		• -			
• Municipality		• -			
• Jurisdiction		• -			
• Court district		• jurisdiction			
* Location		* location			* ISA Programme Location Core Vocabulary
• Place name			• Place name	• location	• ISOC Thesaurus of Place Names
• Post address			• Postal address	• place identifier	
• Street name				• postal address	
• Cadastral parcel id					
* Marker	* -	* marker buoys	* Marker	* -	
• Sign plate	• -	• -	• -		
• Street sign	• -	• -	• Street sign		
• Boundary mark	• boundary face	• boundary face	• Boundary mark	• boundary	
* Spatial reference frame		* -	* Spatial reference	* -	
• Geodetic coordinate system		• -	• Coordinate reference system	• geodetic coordinate system	• WGS84 Geo Positioning
• Road network		• -	• Road network	• -	• -
• Road segment		• roads	• -	• -	• -

cooperation is being explored for promoting conceptual understanding in the classroom.

4. The governance of FIG-related thesauri

The LandVoc thesaurus is stored as a subscheme of FAO's Multilingual Thesaurus, AGROVOC. Therefore, investigations reflected on whether CaLaThe should join the AGROVOC context as an alternative subscheme. Several arguments call for the flexibility provided by more subschemes, including the world-wide differences in the land tenure realities of countries and the fact that LandVoc editors structure their knowledge base to accommodate various user interests, while editors of CaLaThe use resources to improve content validity (Çağdaş et al. 2024).

An idea to postpone the subscheme decision, while integrating CaLaThe concepts and structures into AGROVOC and LandVoc and next obtain integration and user experiences as basis for the decision, was given up, also for economic reasons. Instead, an agreement was made to work for integration of the two vocabularies within the LandVoc subscheme.

Presently, LandVoc and AGROVOC concepts are mapped to other vocabularies, including CaLaThe. For example, the concept 'boundaries' records a skos:exact-Match to <http://www.cadastralvocabulary.org/CaLaThe/Boundary>. The first step in the integration process consists of further aligning of the concepts of the two vocabularies, starting from the top and uppermost concepts of LandVoc and CaLaThe. Figure 6 presents the concepts under the top concept Information. Concepts from AGROVOC are included, because the proposed concept structure must be aligned as well with the concept structure of AGROVOC.

Subsequently, concepts lower in the concept hierarchy have to be aligned based on methods provided by international vocabulary standards (such as ANSI/NISO 2005, ISO 2011), advice from the LandVoc Community of Experts¹⁴ are to be invited, and the restructured set of concepts are to be entered into the VocBench platform. FIG Commission 7 (specifically Working Group 7.8) will continue to actively engage with the LandVoc Community of Experts to enhance alignment and shared ownership of semantic vocabulary development in the land governance and administration domain. Strengthening this collaboration will facilitate greater interoperability, coherence and use of the standardized vocabulary, ultimately improving data integration and knowledge exchange across sectors. Final alignment checks will be performed, before the integrated vocabulary can be published and updated in AGROVOC. LandVoc is available in 12 languages and CaLaThe in five languages, which also presents an opportunity to translate the integrated vocabulary into more languages and increases opportunities for access, use and linking knowledge across geographies. The Land Portal will serve as the main facilitator and curator of the vocabulary within the AGROVOC editorial community.

5. Conclusions

Concern for Semantic Web and Linked Data prompted the addressing of interoperability challenges, especially

between semantic resources in terms of thesauri and educational platforms in the land sector, and specifically at the global level. Thus, the SKOS-based thesauri: AGROVOC, LandVoc, and CaLaThe, as well as FIG-supported semantic resources, including The Teaching Essentials for Responsible Land Administration (TERLA) modules were presented, and the need for supplementing the TERLA modules with glossaries was identified and supplemented with suggestions for use of course-specific concept structures and links to relevant thesauri.

Research on the learning approach *concept mapping* was reported, and concept mapping was applied for a suite of three real property law and cadastral courses, and next linked to thesauri of the domain to demonstrate benefits of concept mapping. Concept mapping may supplement the published methodology for the development of LADM country profiles (Kalogianni et al. 2021) regarding the profile scoping and country profile development of the methodology, as well as development parts of LADM Edition II (Kara et al. 2024) and their code lists.

The complexity of thesaurus management calls for a semantic facility, like the technology applied for AGROVOC, which allows individual lecturers and scientists to edit their definitions and concept structures, drawing on the GLTN e-learning platform hosting TERLA. The facility thus combines thesaurus management and concept mapping and may offer a potential for the preparation and use of knowledge graphs (cf. Vilches-Blázquez and Saavedra 2022). Further cooperation is being explored for promoting conceptual understanding.

Finally, an agreement on integrating CaLaThe into the LandVoc thesaurus and corresponding implementation steps was established. The integration will be coordinated by the Land Portal in partnership with FIG Commission 7 and supported by the custodians of CaLaThe and the LandVoc Editorial Community. This approach continues to build bridges between knowledge silos in land governance, fostering interdisciplinary cooperation across diverse fields.

Disclosure statement

No potential conflict of interest was reported by the author(s).

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Notes

1. <https://www.w3.org/>
2. <http://www.opengis.net/doc/IS/geosparql/1.1>
3. <https://www.fao.org/agrovoc/>
4. <https://agrovoc.fao.org/browse/agrovoc/en/>
5. <https://agrovoc.fao.org/sparql>
6. <https://vocbench.uniroma2.it/>
7. <https://landvoc.org/>
8. <https://explore.landvoc.org/landvoc/en/>
9. <https://agrovoc.fao.org/sparql>
10. <http://www.cadastralvocabulary.org/>
11. <https://cmap.ihmc.us/>
12. Software Copyright (c) 1998–2015 Institute for Human & Machine Cognition (IHMC)
13. <https://elearning.glt.n.net/>
14. <https://landportal.org/voc/landvoc/experts-community>

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