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Documentation on extended Land Administration Domain Modeling (LADM)

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Executive Summary

This is the fourth deliverable report (D 3.4) of the 'its4land' project Work Package WP3, which has as a scope to describe the approach developed for extending the Land Administration Domain Model (LADM), to meet the needs for reliable cadastral information of the indigenous African populations. Currently, not all the exclusive characteristics, forming the human – land relations, can be satisfactorily defined within the ISO 19152 LADM framework. Thus, consistent local information registration, in a standardized format, and its integration into the LADM framework, were considered as core tasks in need to be handled.

In the previous deliverable (D.3.1), it was demonstrated how the indigenous information related to land administration was formalized into a domain model, the Southern Kenyan Maasai ontology (SKMO). In current deliverable we demonstrate how the formalized indigenous knowledge can be handled through an enhanced version of the LADM, for cadastral purposes.

The purpose of D3.4 report is to:

- Briefly present the revised parts of the first version of the SKMO. SKMO was presented in detail in our previous Deliverable D3.1
- Describe the approach for extending the LADM, to meet the land administration needs of indigenous African populations.
- Provide an accessible guide for the Adaptor Model
- Present example implementations from Kenyan case study.

The developed models described in this report can be accessed at:
https://share4land.itc.utwente.nl:5566/fsdownload/blllSLX5n/Domain_Modelling

Contents

Abbreviations

LADM	Land Administration Domain Model
SKMO	Southern Kenyan Maasai Ontology
MSKDM	Maasai of Southern Kenya Domain Model
EDM	Ethiopian Domain Model
DDL	Distributed Description Logics
OWL	Ontology Web Language
RRR	Right, Restriction, Responsibility

1. Introduction

Its4land is a European Commission Horizon 2020 project funded under its Industrial Leadership program, specifically the ‘Leadership in enabling and industrial technologies – Information and Communication Technologies ICT (H2020-EU.2.1.1.)’, under the call H2020-ICT-2015 – and the specific topic – ‘International partnership building in low and middle-income countries’ ICT-39-2015.

Its4land aims to deliver an innovative suite of land tenure recording tools that respond to sub Saharan Africa’s immense challenge to rapidly and cheaply map millions of unrecognized land rights in the region. ICT innovation is intended to play a key role. Many existing ICT-based approaches to land tenure recording in the region have failed: disputes abound, investment is impeded, and the community’s poorest lose out. its4land seeks to reinforce strategic collaboration between the EU and East Africa via a scalable and transferrable ICT solution. Established local, national, and international partnerships seek to drive the project results beyond R&D into the commercial realm. its4land combines an innovation process with emerging geospatial technologies, including smart sketchmaps, UAVs, automated feature extraction, and geocloud services, to deliver land recording services that are end-user responsive, market driven, and fit-for-purpose. The transdisciplinary work also develops supportive models for governance, capacity development, and business capitalization. Gender sensitive analysis and design is also incorporated. Set in the East African development hotbeds of Rwanda, Kenya, and Ethiopia, its4land falls within TRL 5-7: 3 major phases host 8 work packages that enable contextualization, design, and eventual land sector transformation. In line with Living Labs thinking, localized pilots and demonstrations are embedded in the design process. The experienced consortium is multi-sectorial, multi-national, and multidisciplinary. It includes SMEs and researchers from 3 EU countries and 3 East African countries: the necessary complementary skills and expertise is delivered. Responses to the range of barriers are prepared: strong networks across East Africa are key in mitigation. The tailored project management plan ensures clear milestones and deliverables, and supports result dissemination and exploitation: specific work packages and roles focus on the latter.

1.1. Connection with Deliverable D3.1

In Deliverable D3.1 we have described the reasons and the approach for developing a formal model for capturing information related to land administration, communicated by the local Kenyan Maasai community. The model was primarily characterized as an ontology. However, due to its case-specific character and refinement, from now on it is reported as a domain model. The same applies for the newly developed model for Ethiopia (the model is still under validation, and detailed information is not provided in the current version), while an upper-level model, which can be developed in the future, capturing widely the human – land relations in rural African areas, could be characterizes as the Rural Land Administration Ontology for African Countries. Thus, the terms used from now on, referring to the case-specific models, are the Maasai of Southern Kenya Domain Model (MSKDM, instead of SKMO) and the Ethiopian Domain Model (EDM), for Kenya and Ethiopia accordingly.

1.2. Land Administration Domain Model (LADM)

The ISO 19152 international standard for land administration, known also as LADM has as a scope the systematic description of formal or informal human-land relations, for land administration purposes.

The four main packages of the LADM, namely i) spatial sources (surveying), and spatial representations (geometry and topology), ii) spatial units (parcels, and the legal space of buildings and utility networks), iii) parties (people and organizations); iv) basic administrative units, rights, responsibilities, and restrictions (ownership rights), are materialized through the main classes i) LA_SpatialSource, ii) LA_SpatialUnit, iii) LA_Party and iv) LA_BAUnit and LA_RRR, accordingly [1]. All the classes bear some attributes which help the encoding of the information inserted to the LADM as instances (see Table 1).

Table 1. Basic classes of the main LADM packages.

Package name	**LADM class**	**Attributes**
Spatial unit	LA_SpatialUnit	area, dimension, extAddressID, label, referencePoint, suID, surfaceRrelation, volume
Spatial unit	LA_Level	id, name, registerType, structure, type
Spatial unit	LA_SpatialSource	measurements, procedure, type
Party	LA__Party	extPID, name, pID, role, type
Basic Administrative Unit	LA_BAUnit	name, type, uID
Basic Administrative Unit	LA_RRR	description, rID, share, shareCheck, timeSpec

These high level LADM classes will be used as the linking nodes between the indigenous knowledge, registered in the independent domain models (i.e. MSKDM, EDM), and the LADM.

1.3. The Domain Models

The specialized concepts in the two domain models (MSKDM, EDM) are subsumed by 8 common high-level classes. The high-level classes are designed to directly or indirectly capture salient concepts revealing human-land relations. Under these eight high-level classes, significant numbers of sub-classes (i.e. the class *EnvironmentalCharacteristic* of the MSKDM has 7 subclass levels with total 202 subclasses) describe the unique characteristics of each system by incorporating indigenous knowledge. This system of classes and sub-classes encodes knowledge deriving from activities such as community-based resource mapping, and transforms that knowledge into a valuable source of information for land administration purposes. Within the scope of its4land's SmartSkeMa tool this transformation is realized in part through the automated interpretation of sketch maps as sources of land tenure information. The 8 high level classes are summarized in the Table 2. All the high-level classes are immediately sub-classes of the class *Thing*.

Table 2. High level classes of the MSKDM.

High-level classes	Class description
EnvironmentalCharacteristic	characteristics relating to vegetation, land, and climate
SocialUnit	social structures and roles
Activity	primarily geographical-scale activities and ceremonial activities
HomesteadComponent	objects that make up parts of a homestead and interior furnishing
Material	substances used in built structures
Shape	geometric figures
Livestock	domestic animals used for farming
InfoSource	Metadata for source information

Especially for the MSKDM, new features of the revised model version are the *ObjectProperties*, which provide valuable information when linking pieces (i.e. *Individuals* of classes) of the registered concepts within the model (see Table 3). The number of linkages was purposefully kept low (only the absolutely necessary and meaningful connections were made), in order to avoid future functional conflicts when connecting the current model with other independent domain models and ontologies.

Table 3. MSKDM ObjectProperties.

ObjectProperty	Domain	Range
hasMaterial	Engeberi (roof), HumanDwelling EnclosureForAnimal Infrastructure Olohurie (shelter)	Material
hasShape	Boundary ArtificialArea Landmark WildlifeEcosystem GrazingLand LandFormation Enkutoto (Neighborhood) NaturalReserve Olcampa (Individual parcel of agricultural land)	Shape
hasSource (inverse of isSourceFor)	Activity HomesteadComponent Shape SocialUnit EnvironmentalCharacteristic Livestock	MSKOSource
isSourceFor (inverse of hasSource)		

1.4. The Adaptor Model

The information contained in the developed independent domain models can be used as a valuable source of information for a bottom-up land administration tool, within the LADM framework. The independence preservation of the contributing components is a key functionality of the Distributed Description Logics (DDL) approach, which is considered for the abovementioned scope. Inter-domain model connections are formed within a new independent tool, named as the “Adaptor Model", which has been implemented to bridge the relevant concepts between the developed domain models and the LADM [2].

2. Methodology

2.1. Conceptual Integration

The main classes of the LADM model are the **LA_SpatialUnit**, **LA_Party**, **LA_BAUnit** and **LA_RRR**. In the domain models describing the indigenous knowledge, the higher-level classes that provide information about human-land relations are the **Activity**, **EnvironmentalCharacteristic** (with significant number of sub-classes in both MSKDM and EDM, i.e. ClimateCharacteristic, Land Agreement, LandFormation, Landmark, LandQuality, AgriculturalLand, ArtificialArea, Boundary, DomesticEcosystem, GrazingLand, NaturalReserve, WildlifeEcosystem, SoilType, VegetationCharacterstic etc.), **HomesteadComponent** and **SocialUnit**.

The information injection from the domain models (MSKDM and EDM) into the LADM is performed through a case-specific independent tool, the Adaptor Model (see Figure 1). As already mentioned in the introduction, the indigenous information about human – land relations, was acquired through oral communication (i.e. interviews and workshops) with stakeholders of various socio-economic statuses, during scheduled workshops in the year 2017, and a first level of model validation was performed using sketch maps, drawn by members of the local community.

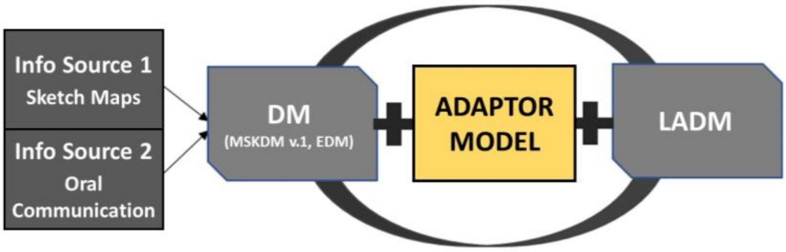

Figure 1. Conceptual integration of the domain models with LADM.

2.2. Physical Integration – the Adaptor Model

The Adaptor Model developed for the Kenyan case study contains, all-in-all, 38 classes (Figure 2), 4 *ObjectProperties* and 4 *DataProperties* (Table 4). Primarily, existing LADM concepts were used. However, the model was enhanced by introducing new concepts, inserted through the Adaptor Model [2]. These new concepts, attempted to capture the role of the dynamically changing climatic and vegetation characteristics, to the human – land relations.

The Adaptor Model developed for the Ethiopian case study currently consists of a similar number of classes, *ObjectProperties* and *DataProperties*, however this is not considered as the final version, since it is still under revision.

Table 4. *Object* and *DataProperties* in the Adaptor Model.

ObjectProperty	DataProperties
CondRestrictionHindersRight	hasBeginLifeVersion
CondRightFavorsRight	hasEndLifeVersion
RightFavoredByCondRight	hasShare
RightHinderedByCondRestriction	hasTotalShare

Figure 2. Graphical representation of the Adaptor Model classes structure, for the MSKDM.

2.2.1. Original LADM concepts

The domain models (MSKDM and EDM) and the LADM were developed using the Ontology Web Language (OWL) [3], within Protégé [4] to ensure models' coherence and unambiguity.

The connection between these models are created through the Adaptor Model, developed within the same environment (Protégé). The Adaptor Model relates the core LADM concepts with the domain model classes through a relationship "*is a"* (see Table 4). This connection is made in order to enable proper specification of the LADM ObjectProperties which can form meaningful relations between different individuals of the domain models. However, in some cases these connections should be done indirectly, due to emerging conflicts. This will be explained in the following lines.
Indicatively, through the Adaptor Model is formed the connection "an InfoSource (domain model class) is a SpatialSource (LADM class)". This connection provides guidance for which relations are allowed and meaningful to be made, within the LADM framework. These relations refer to connections between the *Individuals* of InfoSource classes using existing LADM *ObjectProperties*. For example, the SpatialSource class is specified as *Domain* class for the LADM *ObjectProperties* "hasBAUnitSpatialSource", "describesBFace", "describesBFaceString", "describesPoint", describesSpatialExtent", etc. The established InfoSource - SpatialSource relation indicates that the indigenous information registered under the InfoSource class (high-level class of the domain models) can provide meaningful information for land administration purposes, when creating specifications using these rules (*ObjectProperties*).

Table 4 refers to the MSKDM and presents not only the connections performed within the Adaptor Model, but also the relevant LADM *ObjectProperties*.

Table 4. MSKDM – LADM connection performed within the Adaptor Model, and relevant *ObjectProperties*.

MSKSM class	**Relation**	**LADM class**	**LADM *ObjectProperties***
InfoSource	is a	LA_Source	describesBFace describesBFaceString describesPoint describesSpatialExtent hasAdminSourceBAUnit hasAdminSourceParty hasBAUnitAdminSource hasBAUnitSpatialSource hasSpatialSourceParty
DomesticEcosystem, Artificial Area, AgriculturalLand HomesteadComponent, Shape, Boundary, Fragmented Pastureland, WildlifeEcosystem GrazingLand, Neighborhood, Landmark	is a	LA_BAUnit	hasAdminSourceBAUnit hasBASpatialUnit hasBAUnitAdminSource hasBAUnitRRR hasBAUnitSpatialSource hasRRROnBAUnit
Shape, Polyline (is a AbstractCurve), Line (is a AbstractCurve), Point (is a AbstractPoint), Circle (is a Abstract-Region), Rectangle (is a AbstractRegion), Polygon (is a AbstractRegion)	is a	LA_SpatialUnit	describesSpatialExtent
Boundary	is a	LA_BoundaryFaceString	describesBFaceString
Activity	is a	LA_RRR	hasAdminSourceRRR

			hasBAUnitRRR hasRRR hasRRROnBAUnit isSsupportedBy
SocialUnit *	is a	LA_BAUnit or LA_Party	hasAdminSourceParty hasRRR hasResponsibilityParty hasRestrictionParty hasRightParty hasSpatialSourceParty isRegisteredAs

*SocialUnit class is treated in a special approach, as described in following lines, due to emerging conflict.

A special case in the abovementioned list suggests the class SocialUnit (MSKDM class), which can be interpreted either as a Party (LA_Party) or as a Basic Administrative Unit (LA_BAUnit). When modeling the SocialUnit, in the Adaptor, as sub-class of both LA_BAUnit and LA_Party, a conflict appears to the finally produced combination model (MSK-LADM), when querying *Individuals* of the SocialUnit class or its sub-classes.
Based on the LADM documentation [1], the LA_Party LADM class is associated to the LA_BAUnit (sub-class of the "RolePlayer" LADM class) "*to cater for the fact that a basic administrative unit can be a party (e.g. a basic administrative unit holding an easement on another basic administrative unit)*". Consequently, in the Adaptor Model the SocialUnit class is primarily connected to the LA_BAUnit of the LADM class through the "is a" relation.

The connection of the MSKDM class SocialUnit with the LADM class Party is performed indirectly, at the finally produced combination model MSK-LADM, through *ObjectProperties* and inferred relations. As an example, we use an *Individual* (i.e. RanchGroupMember1) of the SocialUnit sub-class "Rancher". In LADM, the *ObjectProperty* "hasRight", by default, receives as *Domain* of the LADM class "Party" and as "Range" of the LADM class "Right". Having the information that the SocialUnit can behave as a "Party", we can form within the Protégé environment the assertion "RanchGroupMember1 – hasRight …". Likewise, the "RanchGroupMember1" becomes a "Party" indirectly, through an inferred relation, overcoming the initial issue of conflict (see Figure 3).

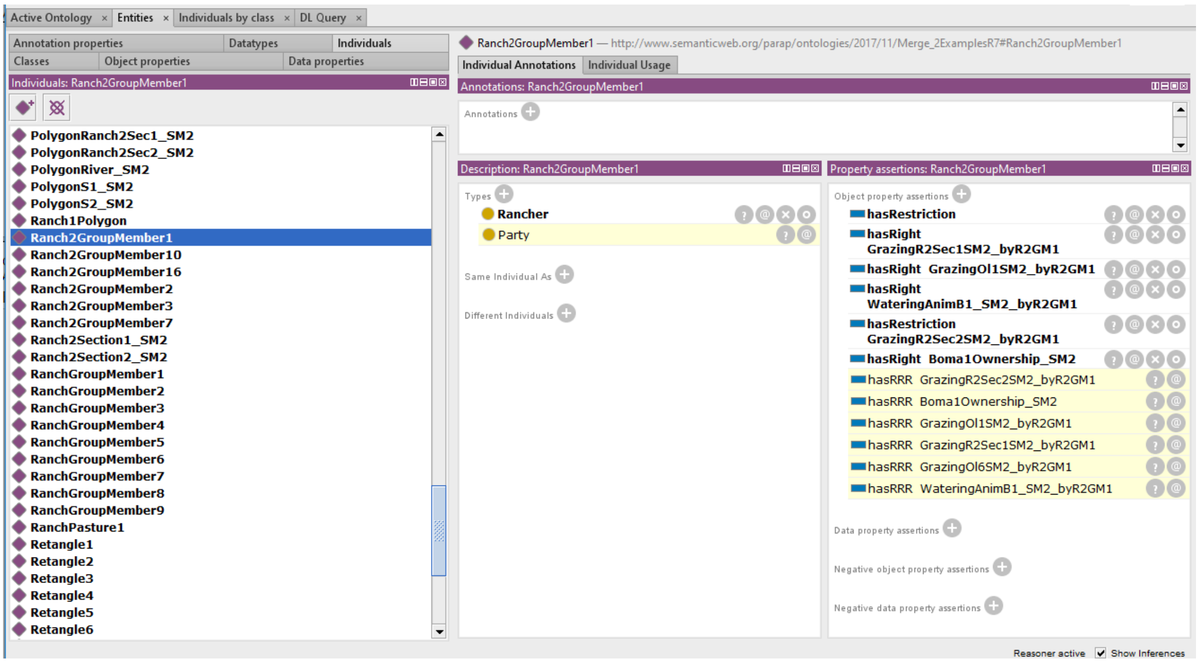

Figure 3. The Individual “RanchGroupMember1” becomes indirectly of type Party.

2.2.2. Novel Concepts

Not all MSKDM concepts were satisfactorily interpreted into the LADM [2]. In particular, for the case of the Kenyan Maasai community, dynamic (i.e. changing) climatic and vegetation characteristics play a central role in understanding the human – land relations. Thus, we propose to extend the LADM with the innovative notion of conditional rights, restrictions and responsibilities (RRR). For example, the mutually agreed right to a particular activity (such as grazing) on a particular region of land may only apply if *dry weather during the dry season* makes grazing difficult or impossible in other regions. Thus, the right to an activity is conditional on specific, periodically changing climatic circumstances. In order to accurately capture and describe real-world Maasai land use patterns we require such conditional RRR.

In the Adaptor Model we introduce one new class ConditionalRRR, with subclasses ConditionalRight, ConditionalRestriction (Figure 2). These two classes are related to the Right class of the LADM model through the *ObjectProperties* ConditionalRightFavorsRight and ConditionalRestrictionHindersRight respectively. The ConditionalRight class is also related to LADM class Party through the *ObjectProperty* PartyFacesCondRRR.

The (logic-based) interpretation of a conditional RRR is that, if the condition C is TRUE in situation s, denoted as C(s), then the corresponding RRR, R, applies to situation s, is denoted as R(s), with $C(s) \rightarrow R(s)$.

Importantly, observe that, given such a conditional RRR, if condition C does not hold, i.e. $\neg C(s)$, then it is not the case that the RRR necessarily does not hold, $\neg R(s)$. Intuitively, a right or restriction (such as grazing) may apply under various different conditions. If any of those conditions hold then the RRR applies (i.e. the *Restriction* applies), and if none of the conditions hold then the model expresses the case that it is unknown whether the RRR applies (i.e. we cannot have concrete information on whether or not the *Restriction* applies).

3. Results

3.1. Use Cases from the MSKDM

A hypothetical example on how spatial and non-spatial indigenous information, registered in the MSKDM can be injected and used under the LADM framework using the Adaptor Model is presented in the following lines.

A real sketchmap (Figure 4), drawn by members of the Maasai community during field work in early 2017 and further information acquired through oral communication, are used as data source. On the sketchmap, we have overlaid annotations to highlight various features for the example. The red lines represent boundaries of a specific ranch (which are not necessarily indicated by some fence or barrier), in which nine homesteads (bomas) are located, represented by circular shapes. A rectangular formation, representing an olopololi, is located next to each boma, which is a fenced area used for grazing especially during dry periods. Other visible significant spatial characteristics are marshlands, mountains, paths, water points, a river with an estimated buffer zone, and a public building (school). All information is decoded and registered into the MSKDM and transformed into a format suitable to be used by the LADM via our Adaptor.

Figure 4. Sketch map created by members of the Maasai community during field visit in Kenya (left: original, right: with added annotations by authors).

SCENARIO 1

Impact of climate. From the field visit we have learned that the entire ranch area can be used by any ranch member. The only exceptions are fenced rectangular areas, used for grazing purposes (olopololis), located next to households (bomas) indicated by circular features. Olopololis can be accessed only by their owners who are the residents of the adjacent boma. This information is in agreement with the information described also by [5].

…" *Individual ranchers would release their livestock to graze in group ranch pastures during the wet season and retreat into their fenced and exclusive ranches in the dry, while denying group members the use of their ranches during this time. The individual ranchers were in effect using the group ranch as a wet season grazing area and setting aside their own land as dry season grazing areas i.e. olopololis. These olopololis were exclusive, accessible only to the individual ranch owners themselves*."

In this scenario, we capture the impact of climate to the potential of land use as conditional RRR (see Figure 5).

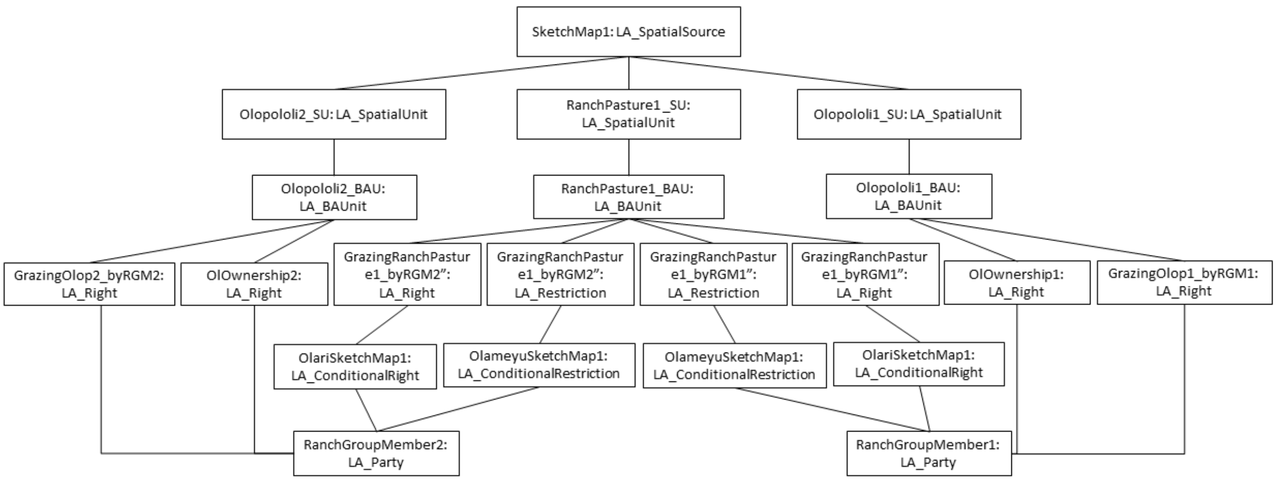

Figure 5. Human-land relation LADM diagram with conditional RRR based on climate (Scenario 1).

Conceptually, the emerging indigenous information can be interpreted though LADM as follows:

- *RanchGroupMember1*, resident of *Boma1*, is the owner of *Olopololi1*
- *RanchGroupMember1* is allowed to graze animals within the whole *RanchPasture1* except from the other private Olopololis, i.e. the *Olopololi2*
- *RanchGroupMember1* cannot graze animals within the *RanchPasture1* due to the restriction imposed by climatic conditions. During dry period there is not enough vegetation to satisfy the animals' needs.
- *RanchGroupMember2*, resident of Boma2, owns *Olopololi2*.
- *RanchGroupMember2* is also allowed to graze animals within the *RanchPasture1*, except from the other private Olopololis, i.e. the *Olopololi1*

SCENARIO 2

Impact of wildlife. From field visits we have learned that a wildlife corridor exists along the river. Thus the area is very dangerous for the locals themselves, as well as for their herds. Several cases of conflict were reported during our field studies, while other studies have reported that wildlife-herd conflict is a major issue for Maasai community.

In this scenario, we capture the restriction, applied to RanchGroupMember1, of access to the area around the river, characterized as a wildlife passage (Figure 12). Indicatively, from the *SketchMap1* we get the spatial information for the existence of a *WildlifePassage*. Within the LADM environment, the *WildlifePasage* is inserted as both a *SpatialUnit* and a *BasicAdministrativeUnit*, on which specific *Restriction* applies. The Restriction refers to the RanchGroupMember1, for the action of *Grazing* within this area. This example can be characterized as a case-specific unofficial regulation (i.e. not recognized by public administrations) applied by the ranch group members.

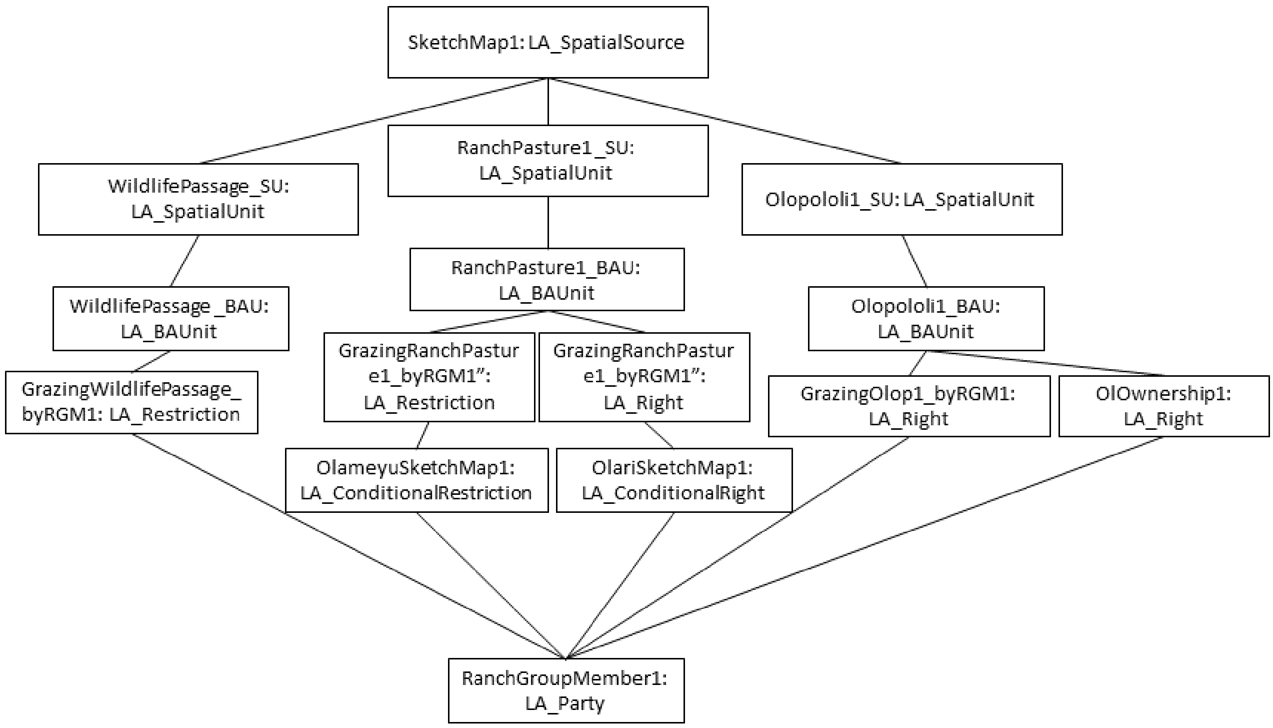

Figure 6. Human-land relation LADM diagram with RRR based on seasonal wildlife movement patterns (Scenario 2).

The abovementioned concepts can be formalized in the MSKDM, Adaptor and LADM as indicated in Table 5.

Table5. Table description.

Concept	MSKDM class	Adaptor	LADM
SketchMap_1	Instance of class MSKOSource	MSKOSource is a LA_Source	Instance of class LA_SpatialSource or LA_AdministrativeSource
RanchGroupMember1	Instance of class Rancher (Thing> SocialUnit>Rancher)	SocialUnit is a LA_Party	Instance of class LA_Party
Boma1	Instance of class Boma (Thing>EnvironmentalCharacteristic> LandCharacteristic>LandUseType>ArtificialArea>HumanDweling> Boma)	ArtificialArea is a BAUnit	Instance of class BAUnit
Olopololi1	Instance of class olopololi (Thing>EnvironmentalCharacteristic> LandCharacteristic>LandUseType>ArtificialArea> EnclosureForAnimal>Olopololi)	ArtificialArea is a BAUnit	Instance of class BAUnit
RanchPasture1	Instance of class Pasture OR Instance of class Ebalbal (Thing>EnvironmentalCharacteristic> LandCharacteristic>LandUseType>GrazingLand> Pasture) (Thing>EnvironmentalCharacteristic> LandCharacteristic>LandUseType>GrazingLand> Ebalbal)	GrazingLand is a BAUnit	Instance of class BAUnit
GrazingOlop1_byRGM2	Instance of class Perper(grazing) (Thing> Activity>AgropatoralActivity>Perper)	Activity is a LA_RRR	Instance either of class LA_Right, OR LA_Restriction
GrazingOlop1_byRGM1	Instance of class Perper(grazing) (Thing> Activity>AgropatoralActivity>Perper)	Activity is a LA_RRR	Instance either of class LA_Right, OR LA_Restriction
GrazingOlop2_byRGM2	Instance of class Perper(grazing) (Thing> Activity>AgropatoralActivity>Perper)	Activity is a LA_RRR	Instance either of class LA_Right, OR LA_Restriction
GrazingOlop2_byRGM1	Instance of class Perper(grazing) (Thing> Activity>AgropatoralActivity>Perper)	Activity is a LA_RRR	Instance either of class LA_Right, OR LA_Restriction
GrazingRanchPasture1_byRGM1	Instance of class Perper(grazing) (Thing> Activity>AgropatoralActivity>Perper)	Activity is a LA_RRR	Instance either of class LA_Right, OR LA_Restriction
GrazingRanchPasture1_byRGM2	Instance of class Perper(grazing) (Thing> Activity>AgropatoralActivity>Perper)	Activity is a LA_RRR	Instance either of class LA_Right, OR LA_Restriction
GrazingWildlifePassage_byRGM1	Instance of class Perper (grazing) (Thing> Activity>AgropatoralActivity>Perper)	Activity is a LA_RRR	Instance either of class LA_Right, OR LA_Restriction
GrazingWildlifePassage_byRGM2	Instance of class Perper(grazing) (Thing> Activity>AgropatoralActivity>Perper)	Activity is a LA_RRR	Instance either of class LA_Right, OR LA_Restriction
RanchGroupMember2	Instance of class Rancher (Thing> SocialUnit>Rancher)	SocialUnit is a LA_Party	Instance of class LA_Party
Boma2	Instance of class Boma (Thing>EnvironmentalCharacteristic>LandCharacteristic>	ArtificialArea is a BAUnit	Instance of class BAUnit

	LandUseType>ArtificialArea>HumanDweling>Boma)		
Olopololi2	Instance of class olopololi (Thing>EnvironmentalCharacteristic>LandCharacteristic> LandUseType>ArtificialArea>EnclosureForAnimal>Olopololi)	ArtificialArea is a BAUnit	Instance of class BAUnit
OlOwnership1	Instance of class UnofficialLandUseRight (Thing>EnvironmentalCharacteristic>LandCharacteristic> LandAgreement>UnofficialLandUseRight)	UnofficialLandUseRight is a LA_Right	Instance of class LA_Right
OlOwnership2	Instance of class UnofficialLandUseRight (Thing>EnvironmentalCharacteristic>LandCharacteristic> LandAgreement>UnofficialLandUseRight)	UnofficialLandUseRight is a LA_Right	Instance of class LA_Right
BomaOwnership1	Instance of class UnofficialLandUseRight (Thing>EnvironmentalCharacteristic>LandCharacteristic> LandAgreement>UnofficialLandUseRight)> LandAgreement>UnofficialLandUseRight)	UnofficialLandUseRight is a LA_Right	Instance of class LA_Right
BomaOwnership2	Instance of class UnofficialLandUseRight (Thing>EnvironmentalCharacteristic>LandCharacteristic> LandAgreement>UnofficialLandUseRight)	UnofficialLandUseRight is a LA_Right	UnofficialLandUseRight is a LA_Right
OlameyuSketchMap1	Instance of class Olameyu_(DrySeason) (Thing>EnvironmentalCharacteristic>ClimaticCharacteristic> Olameyu_DrySeason)	ClimaticCharacteristic is a LA_ConditionalRRR	Instance of class LA_ConditionalRight OR LA_ConditionalRestriction
OlariSketchMap1	Instance of class Olari_(WetSeason) (Thing>EnvironmentalCharacteristic>ClimaticCharacteristic> Olari_WetSeason)	ClimaticCharacteristic is a LA_ConditionalRRR	Instance of class LA_ConditionalRight OR LA_ConditionalRestriction

4. Limitations and potential refinements

The flexible structure of the domain models facilitates knowledge sharing among different models, without intervention to the models themselves. Currently, the *Adaptor Model* is developed based on case-specific needs for each of the developed indigenous information domain models. Since the adaptor models for both MSKDM and EDM serve the same purpose and given the fact that for the analyzed systems the top-level classes coincide, a universal Adaptor Model can possibly be developed. However, important issues should be taken into consideration [6] such as:

- The development of a universal Adaptor Model may potentially require partial restructuring of the existing high-level domain models' classes, for consistency reasons within the universal Adaptor Model.
- Potential conflicts in semantics should be treated with caution
- Redundancy issues should be taken into consideration

A second-level validation stage of the indigenous information domain models, with the contribution of the local communities, already scheduled in the near future, will contribute to the domain models' refinement and will provide better insight about the potential of a universal Adaptor model development.

5. Conclusion

Current report presents the approach applied for extending the LADM, in an attempt to incorporate exclusive characteristics of human – land relations addressed in East African countries. Various concepts, revealing directly or indirectly aspects of the human – land relations were formally organized in domain models (currently for the Kenyan and Ethiopian study sites, namely MSKDM and EDM). The LADM and the domain models were developed using the OWL within Protégé environment. The flexibility of OWL objects, as expressed by the Distributed Description Logics approach, enables the connection of independent components (i.e. the domain models), by bridging relevant concepts.

Following this approach, two Adaptor Models were developed (for the Kenyan and Ethiopian study sites), both consisted of 38 classes, four *ObjectProperties* and four *DataProperties*. In current deliverable is presented only the model referring to the Kenyan study site, since the domain model of the Ethiopian study site is still under revision, and thus the relevant Adaptor model might undergo revisions too.

Through the Adaptor Model for the Kenyan study site are introduced to the LADM the innovative concepts of conditional rights, restrictions, responsibilities (*ConditionalRRR*), which attach a dynamic character to the traditional concepts of LADM RRRs, based on prevailing environmental framework (i.e. the climatic conditions).

The functionality of the Adaptor Model for the Kenyan study site was tested using real sketchmaps created by the local Maasai community. In current report are presented two scenarios from one of these sketches. The concepts appearing in 30 real sketchmaps were adequately interpreted by the domain model and were properly translated into suitable information for the LADM.

Currently each case-specific domain model requires a distinct adaptor model in order to have its concepts translated into LADM concepts. Development of more relative domain models for other Eastern African study sites and refinement of the current ones might enable the development of a universal Adaptor model, facilitating interoperability and land administration information acquisition. However certain issues should be regarded with great caution.

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