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Executive Summary

This document introduces the Southern Kenyan Maasai ontology (SKMO) version 1.0. The purpose of this document is to:

- describe the methodology for developing the SKMO;
- provide an accessible, high-level guide into the classes and structure of the ontology;
- provide illustrative examples that relate important classes in the ontology to real sketches collected in the field.

We present three products that accompany this deliverable:

- Southern Kenyan Maasai Ontology (SKMO) [version 1.0] in OWL format;
- Reference Report to SKMO version 1.0: a comprehensive, detailed reference report defining each ontology concept and citing academic literature sources connected with each ontology concept - the reference report contains the full academic reference listing (rather than in this guide);
- an image portfolio of extracts of the ontology, visualised as graphs, for further assisting the reader in understanding and navigating the ontology.

Contents

EXECUTIVE SUMMARY	4
1. INTRODUCTION	6
1.1. SEMANTICS AND SKETCH MAPS	7
1.2. SOUTHERN KENYAN MAASAI ONTOLOGY (SKMO)	8
2. METHODOLOGY	9
2.1. ACCESSING SOURCE MATERIAL AND EXPERT KNOWLEDGE	9
2.2. RATIONALE FOR MODELLING THE DOMAIN AS AN ONTOLOGY	9
2.3. ONTOLOGY DEVELOPMENT PROCESS	10
3. SKMO STRUCTURE	12
3.1. OVERVIEW OF THE SKMO	12
3.2. ENVIRONMENTCHARACTERISTIC CLASS	13
LANDCHARACTERISTIC	14
LANDUSETYPE	15
ARTIFICIALAREA	16
3.3. ACTIVITY CLASS	17
3.4. SOCIALUNIT CLASS	18
4. LIMITATIONS AND POTENTIAL REFINEMENTS	20
5. CONCLUSIONS	21
APPENDIX	22

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 inexpensively map millions of unrecognised and/or unrecorded land rights in the region and register them in formal land administration systems. ICT innovation is intended to play a key role. Many existing ICT-based approaches to land tenure recording in the region have not been successful: 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 Sketch Maps, 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 capitalisation. 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 contextualisation, design, and eventual land sector transformation. In line with Living Labs thinking, localised 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.

This document is directly linked to WP3 – “Draw and Make” of the its4land project. The primary objective of the work package is to develop a software tool (the Smart Sketch Maps or SSM system) for recording land tenure information within the context of rural and peri-urban communities based on hand-drawn sketch maps. The tool is composed of several components including a specialized domain model and a visual language for sketching, a system for automated recognition and extraction of objects in sketch maps, qualitative representation, and qualitative alignment of sketched information with underlying geo-referenced datasets. All these component come together to provide a single function: integrating the user’s sketch into a base topographic dataset.

Work packages in the its4land project are organized into distinct tasks. D3.1 is an outcome of work performed as part of task T3.1 of WP3. This document gives an overview of this work by describing the main aspects of the detailed ontology of the Maasai culture based on literature research and data collected in the field in Kajiado county, southern Kenya.

The objective of T3.1 is to elicit and document the spatial concepts that users (e.g. pastoralists) consider important for their everyday activities. While city maps consist primarily of streets and artefacts (i.e. human-made) landmarks, we expected that sketch maps

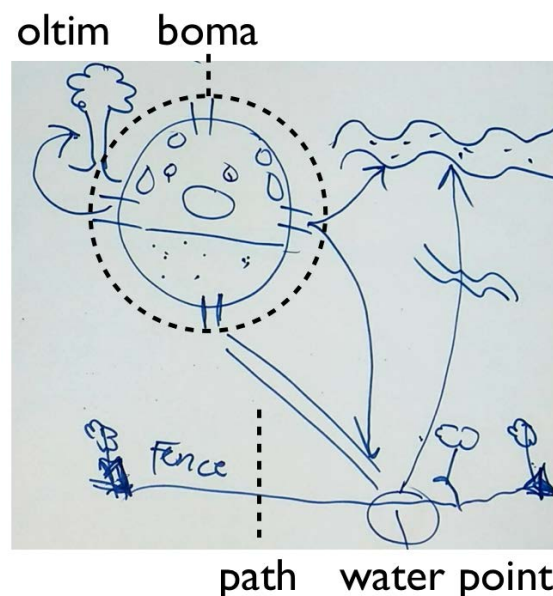
in rural East Africa will contain many natural landmarks, and spatial relations and features derived from activities concerning land use and tenure concepts. Task T3.1 analyses sketched objects and their spatial relations, proposes a suitable terminology to analyse relevant information in sketch maps, and formally documents them in an ontology.

1.1. Semantics and Sketch Maps

What makes smart sketch maps “smart” is that explicitly drawn spatial objects are identified and assigned a semantic (i.e. conceptually meaningful) category. When a person is communicating an object or land use boundary in the form of a sketch they may represent (“draw”) the object as a point, line, or contour. Importantly, the object being communicated is not a geometric object; it is a much richer concept that has complex relationships with other meaningful concepts.

Consider the sketch in Figure 1 drawn during a field exercise. In particular, observe the large complex structure, called a *boma*, where people live. The *oltim* is, culturally, a highly significant gate. When the *oltim* is positioned at the entrance to the *boma* (e.g. in the evening) this indicates that the *boma* is closed and should not be entered. The sketch includes a prominent path that leads to a water point. The sketcher is communicating key objects in their locale of regular activities, and the qualitative position of these objects relative to each other.

Figure 1. Example of a Maasai sketch communicating an aspect of land use



We make the following claim about sketches communicating land use:

Information that is being communicated in the sketch is about objects (e.g. boma, boundary, territory, lakes, paths) and particular qualitative spatial relationships between those objects (e.g. eastward, left of, near, between, inside, passing through). In contrast, the information being communicated is not about points, lines, polygons, and exact numerical distances, dimensions, and angles.

Thus, to capture the information that is being communicated by the human sketcher we require a domain model that anticipates the objects and relationships that will be communicated. It is not sufficient for a software analysis system to “see” (i.e. interpret) the

sketch as a collection of points, lines, and polygons: we need to build-in domain specific concepts so that the software analysis system can “see” boma, lakes, agricultural activities, and so on.

We also need to be able to query the corpus of sketches in an intelligent manner, for example:

Find all sketches in which a human dwelling is relatively far from any body of water.

Find all sketches in which grazing land is shared between different tribes.

As a further example, consider a scenario in which the government is considering building a large road to transport materials between different cities:

Does this region intersect with any activities of local Maasai communities?

To address such queries, and to correctly interpret the semantics of a sketch, a domain model needs information such as:

- a boma is a type of community residence, which is a human-made structure
- a lake is a type of water body

1.2. Southern Kenyan Maasai Ontology (SKMO)

The southern Kenyan Maasai domain model is a collection of:

- concepts that are required to interpret southern Kenyan Maasai sketches of land use (e.g. objects that are likely to appear in sketches such as boma, trees, paths, etc.);
- concepts that are required to express land use information (e.g. social structures, types of relationships between different social communities, and so on).

The domain model provides a common ontological perspective so that a variety of sketches can be compared and automatically interpreted via a uniform conceptual “language”. Our domain model is formal (i.e. unambiguous; can be automatically interpreted and processed in software) and thus provides a uniform language for querying across a large number of sketches.

This document presents a guide to the first release of our Southern Kenyan Maasai land use domain model, and our development methodology. Domain models are necessarily “permanently under construction”, and thus the presented model will inevitably undergo further refinements. Our aim is to make this current version readily accessible to users and other researchers with the intention that they adapt, extend, improve, and refine as needed.

2. Methodology

2.1. Accessing Source Material and Expert Knowledge

We obtained source material for the ontology through:

- a review of academic literature relating to Maasai culture;
- on-site field study visits to Kenya (2016, 2017).

We have reviewed approximately 40 academic documents including research journal articles and Maa (Maasai language) dictionaries. The full reference listing (and citations corresponding to each SKMO concept) is available in the appendix which is also available as an independent report¹.

We have conducted workshop exercises and interviews on two separate trips to Kenya. Participants were peri-urban, rural, and pastoralist Maasai community members. We gained access via our Kenya partners based at TUK. Through these workshop exercises we collected 30 sketches that we used to identify salient concepts. The correspondences between specific SKMO concepts and the collected sketches are detailed in the reference report.

The groups of participants included 18 male and 14 female members of the Maasai community of Kajiado county. There were more participants in the age range 20 – 30 years than in other age ranges as can be seen in the table below.

Table 1. Participants by gender and age ranges

ESTIMATED DISTRIBUTION IN AGE RANGES	20-30	30-40	40-50	50+	TOTAL
MEN	8	2	5	3	18
WOMEN	7	6	1	0	14

2.2. Rationale for Modelling the Domain as an Ontology

We opted for expressing concepts and relationships in the form of an ontology to ensure that the domain model was formal, and thus can be readily and unambiguously parsed by off-the-shelf software tools.

Alternative well-known domain modelling representations include the Unified Modelling Language (UML - particularly class diagrams) and entity-relationship (ER) diagrams. We opted for ontologies over UML or ER diagrams for the following three reasons:

- The theoretical framework underlying ontologies is more comprehensive and supports logic-based reasoning. This means that our ontologies can be consistently contextualized to different local situations (e.g. we can adapt the SKMO to new cultural contexts such as land use and tenure concepts in rural Ethiopia – in Amhara in

¹ Mina Karamesouti, Carl Schultz, Malumbo Chipofya, Jan Sahib, Cristhian Eduardo Murcia Galeano, and Angela Schwering. Reference report: Southern Kenya Maasai Ontology (SKMO). Institute for Geoinformatics, University of Muenster. Muenster, July 2017.

particular). This consistency in turn ensures that we are able to link the different local ontologies to the LADM model in uniform manner.

- UML and ER diagrams are diagrammatic graph-based approaches. In contrast, ontologies have their foundations in Description Logics (within field of Knowledge Representation and Reasoning, which is a subfield of Artificial Intelligence). Description logics have been intensively studied for three decades and have a rigorous mathematical foundation.
- Ontology reasoning tools are available that can determine whether the ontology is consistent, and make certain inferences, owing to its foundations in (description) logic. The computational properties of reasoning and inference using ontologies have been extensively researched and are well understood (e.g. querying, consistency checking). Many off-the-shelf software tools are available.
- There is no obvious disadvantage in developing an ontology, as they can be readily visualised as UML or ER diagrams, e.g. using freely available plug-ins for popular ontology editors such as Protégé.²

2.3. Ontology Development Process

We developed the ontology using the Protégé ontology development environment, and maintain it in the Ontology Web Language (OWL) format. Protégé is a popular, freely available and open source integrated ontology development environment that can be used to view SKMO. The OWL format is a research and industry standard format for ontologies, and many software tools and libraries are available that can process OWL.

Our ontology development approach is driven by functional requirements: concepts are included and related with the intention of capturing information communicated in sketches. For example, vegetation and livestock could potentially be grouped under a common super class Living Entity although such a distinction was not deemed necessary.

We developed the ontology incrementally. As we collected concepts from the previously described sources, we grouped them according to functional requirements for sketch interpretation. As semantic distinctions emerged we introduced more general ontology classes. We cross-checked concepts gathered from academic literature with the sketches collected in the field to determine whether certain concepts may be redundant, or alternatively, played a more prominent role in sketch interpretation than we had initially realized.

Our criteria for determining when a first version of the ontology is adequate are: all prominent concepts that appear in the collected sketches are incorporated, and concepts from a significant number of literature sources are also incorporated. The current submitted version of our SKMO meets these criteria.

We anticipate that refinements will continue as other aspects of WP3 develop. In Section 4 we present limitations of the current SKMO and issues with certain modelling decisions that we intend to address in parallel with other work package tasks.

We emphasise the cultural context of this project as focusing on Southern Kenyan Maasai. When considering communities other than Southern Kenyan Maasai, many similar terms and

² <http://protege.stanford.edu/>

concepts may occur, however the semantics can differ significantly. For example, the particular semantics of boma may change depending on the cultural context and region or even individual interpretation: there may be a shift in the emphasis of the function as an enclosure for livestock (conceptually closer to *olosingo* in SKMO) or rather as a settlement where people live (conceptually closer to *enkang* in SKMO).

3. SKMO Structure

3.1. Overview of the SKMO

The ontology defines seven general, high-level classes, i.e. immediate subclasses of “Thing”, as illustrated in Figure 2.

The *EnvironmentalCharacteristic* high-level class is rich and complex, containing many levels of subclasses. The three immediate *EnvironmentalCharacteristic* subclasses capture characteristics relating to vegetation, land, and climate. In particular, many significant concepts are within the subclasses *LandAgreement* and *LandUseType* (subclasses of *LandCharacteristic*). The class *LandAgreement* in particular directly captures several types of tenure on land.

The following high-level classes are deep, having at least two further subclass levels:

- *Activity*: primarily geographical-scale activities (e.g. agriculture, land leasing, tourism, navigation across geographic-scale areas of land) and ceremonial activities (e.g. emanyatta (‘coming of age’ ceremony for men));
- *SocialUnit*: social structures (e.g. oligata (clan), olkabila (large tribe)) and roles (resident, shepherd, rancher, divisional land control board).

The following high level classes are shallow, having only one further subclass level:

- *HomesteadComponent*: objects that make up parts of a homestead such as engishomi (gates, doors), olengati (yard), and interior furnishing;
- *Material*: substances used in built structures or that impact tasks such as emuni (sediment) or engare (water);
- *Shape*: geometric figures such as points, lines, polygons, circles;
- *Livestock*: domesticated animals used for farming e.g. cattle, sheep, zebu.

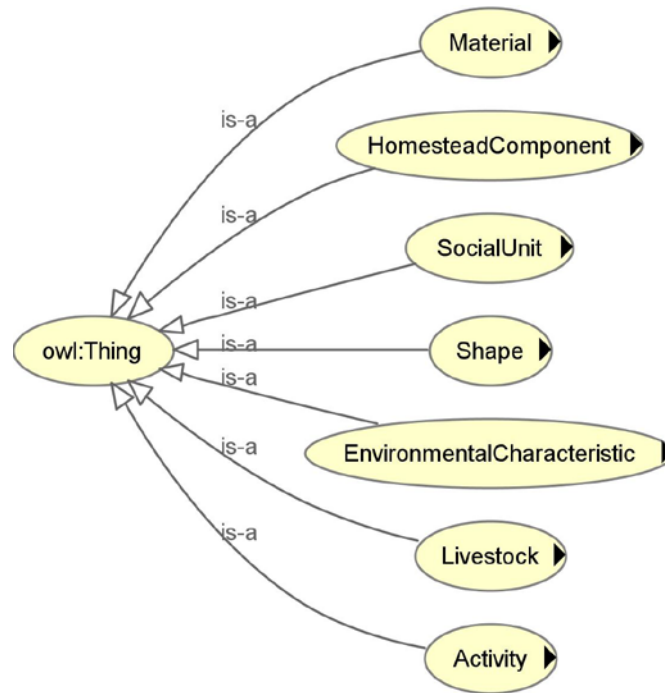
In this guide, the more complex classes will be presented in some detail, i.e. *EnvironmentalCharacteristic*, *Activity*, and *SocialUnit*. For further information on the remaining classes, we refer the reader to the accompanying detailed reference report.

The most significant concepts in the context of land use are:

- classes that describe infrastructure, dwellings, etc. as these are the object from which many activities are referenced;
- classes that describe land agreements, land status, land use, and social relationships.

In the following subsections we will step through each level of abstraction, highlighting important concepts that are central to interpreting sketches.

Figure 2. High-level SKMO classes



The ontology consists of 288 classes. Table 1 presents the basic class statistics to give an indication of the scope and depth of each high-level subclass:

- Number of subclass levels: the depth of the inheritance hierarchy from the given high-level class;
- Number of subclasses: the total number of subclasses that inherit from the given high-level class (either directly or transitively).

Table 2. Number of subclasses and inheritance depth for each high-level concept

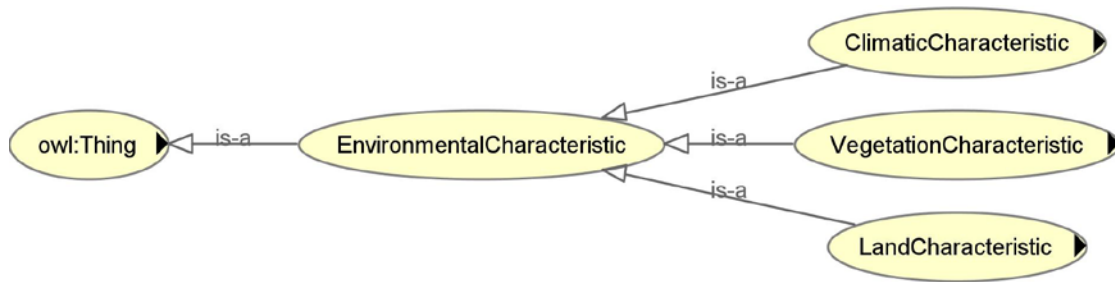
High-level class	Number of subclass levels	Number of subclasses
<i>EnvironmentalCharacteristic</i>	7	202
<i>SocialUnit</i>	3	26
<i>Activity</i>	2	23
<i>HomesteadComponent</i>	1	12
<i>Livestock</i>	2	6
<i>Shape</i>	1	7
<i>Material</i>	1	4

3.2. EnvironmentCharacteristic class

The *EnvironmentalCharacteristic* class generalises concepts covering land, vegetation, and climate (Figure 3). Important concepts within the inheritance hierarchy of the *EnvironmentCharacteristic* class, in particular as subclasses of *LandCharacteristic*, include: dwellings, animal enclosures, types of land use, and many others. We will explore this complex and notable subclass in more depth in the following subsections.

Vegetation and climatic characteristics refer to concepts such as olari (wet season), olameyu (dry season), mugumo trees, oit ekitum (acacia forest) and oltim. Many activities are intrinsically connected to climate, and vegetation plays a significant role in agricultural activities and in defining landmarks used to communicate spatial information about land use and tenure. The quality of the land and soil types are included in the current model as well, since they relate to natural resource availability and consequently to the potential for land use. Land use potential, especially as grazing land, determines the movements of the Maasai pastoralists and therefore the locations that are used as permanent residences.

Figure 3. EnvironmentalCharacteristic subclasses



LandCharacteristic

The *LandCharacteristic* class generalises concepts of (a) describing land, (b) land use, and (c) land agreements (Figure 4). In particular we highlight the following subclasses:

- *LandAgreement*: agreements that regulate land use e.g. paga (communal restricted land), ranch subdivision, government-recognised land use rights, fenced individually-owned land.
- *Landmark*: salient features in the environment that define boundaries or are frequently used to conceptually structure space in sketches e.g. mountain, oltepesi (highly culturally significant tree that functions as a meeting place for women), national reserve, olare (watering place).
- *LandQuality*: describing land and the activities that it affords; primarily describes the land itself, but subclass concepts may also incorporate social dimensions e.g. orkojta (non-degraded grazing land), olupurkel (arid desert), orpora (degraded restricted land).

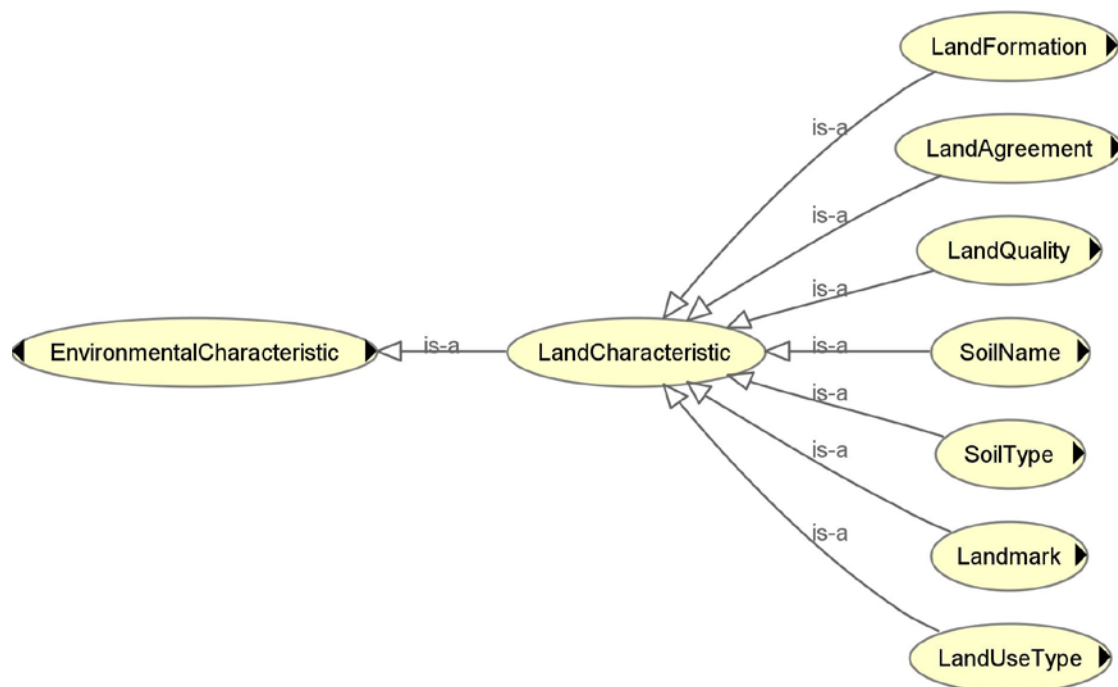
We explore the *LandUseType* subclass in more detail in the following section.

Two main concepts related to the Kenyan Maasai land ecosystem are the domestic ecosystem and the wild ecosystem. In terms of conservation policy, the aforementioned areas can be classified as protected or non-protected. The main issue that confronts these ecosystems is the functional and structural fragmentation, leading to multi-layered (social, ecological, economic) system sustainability issues, but also to severe conflicts among the various social groups residing in the broader area, formerly characterized as the Maasailand. Although individualization of land might be related to a phenomenal security and provide additional income to few residents, through land leasing, land subdivision and the consequent land fragmentation often nurture serious conflicts.

More specifically, for the study area (Kajiado District) the main land use patterns identified over the last decades are the pastures, the agricultural land, the urban areas and the wildlife reserves. During the last 30 years these land use has changed from a sparsely settled pattern, with dominant the grazing lands and forested lands, to a heavily settled pattern, where

agricultural cultivations and urban system expand, in detriment to former land use status, and overlooking the basic land use and land management principles of the traditional Maasai societies, leading to a serious social dichotomy. Although it is attempted by international organizations to re-define and re-introduce these principals in the current system, in an attempt to re-establish socio-ecological equilibrium, turbulences due to land use changes persist. One significant aspect related to these changes is the steady transformation of the wide commonly used land, based on the traditional Maasai principles, into individual parcels of land and fenced areas. Among the Maasai communities, the concept of sharing natural resources is not just symbolic. Rather, it works as a safety net for difficult periods, such as extended droughts. Consequently, the main land use types (i.e. agricultural areas, grazing land, artificial land, ranches, boundaries) as well as the ownership status (i.e. private, public etc), were considered as core components for the current ontological model.

Figure 4. LandCharacteristic subclasses



LandUseType

The *LandUseType* class captures semantic categories assigned to regions in the context of geographic information science and land use (Figure 5). In particular we highlight the following subclasses:

- *GrazingLand*: pasture used to feed livestock, plays a significant role in Maasai movement patterns.
- *Boundary*: physical boundaries and fences e.g. enkikarat (rounded fence).
- *AgriculturalLand*: land used for profit and sustenance e.g. shamba (cultivated plot), fenced irrigated areas, emparet (field garden).
- *NaturalReserve*: government regulated areas, e.g. national parks and game reserves.

We explore *ArtificialArea* in more detail in the following section.

Figure 5. LandUseType subclasses



ArtificialArea

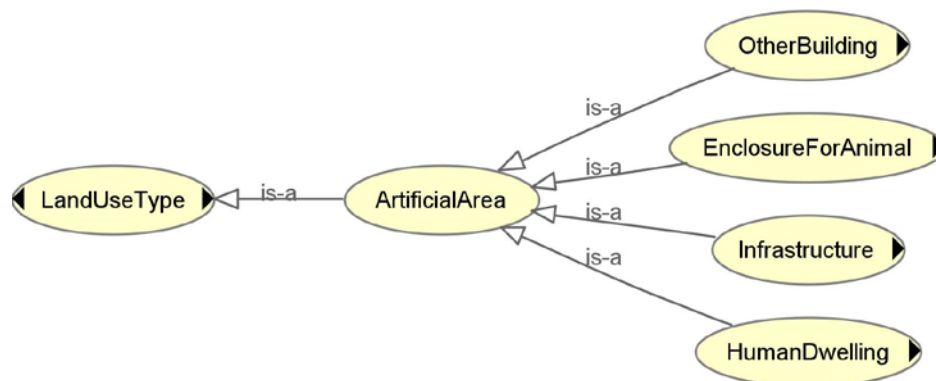
The *ArtificialArea* class captures concepts of (Figure 6):

- *EnclosureForAnimal*: structures and areas primarily dedicated to particular livestock activities or housing e.g. olopololi (grazing field set aside for calves), olokeri (enclosure for sick animals), olosingo (cattle shed).
- *HumanDwelling*: places where people reside e.g. boma (village or collection of households), manyatta (warrior settlement), kraal (small settlement surrounded by a circle of thorn bushes), olcampa (ranch), engitagata (a hut where elders meet)
- *OtherBuilding*: buildings that have a primary function other than as a human dwelling or animal enclosure e.g. police department, school, hospital.
- *Infrastructure*: salient human-built structures that relate to activities or are used for spatial orientation, landmarks, boundaries e.g. dam, railway line, beacon, road, trash pit, gateways.

The Maasai pastoralists are one of the traditional nomadic Nilo-Saharan groups, highly dependent on livestock, natural resource availability and social organization. Spatial organization of the Maasai communities is one of the critical components that need to be described in an ontological model aiming at formalizing the Maasai community system. Main characteristics are the multi-household organizations and the commonly used territories, primarily for grazing.

The nomadic way of living of the Maasai pastoralists gives the homestead a very particular role. Different kinds of permanent or temporary homesteads were enlisted in current ontological model. They are distinguished based on the construction material, the role that they serve in the community, and the social roles of people that reside in them. Characteristics of the human and animal homesteads, animal enclosures, as well as their main components, provide important spatial information and were thus incorporated into the ontological model.

Figure 6. ArtificialArea subclasses



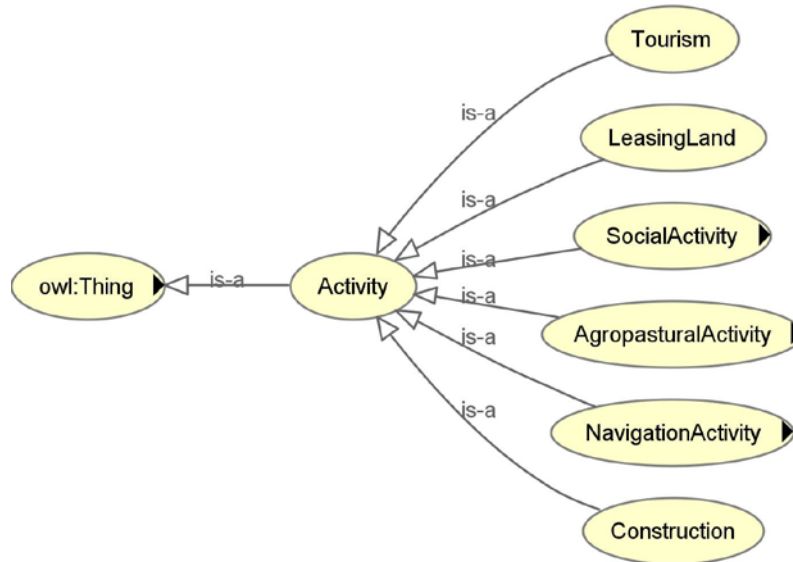
3.3. Activity class

The *Activity* class (Figure 7) covers concepts including agropastoral activities, tourism, cultural ceremonies (emanyatta), geographic-scale navigation (e.g. travelling from a primary settlement, such as a boma, to a water point), leasing activities and construction.

Agropastoral activities are a major source of income for rural Maasai communities, while supplementary income might derive from land leasing for cultivation, conservation (wild life) or touristic use. The fragmentation of the communally used grazing lands seems to be a serious cause of conflicts due to competing activities. Thus, the concept of activities was

incorporated in the ontological model. The way that pastoralism is performed, and consequently the areas that are used, usually depends on the size of the herd, the household wealth, the social constraints as well as the climatic conditions.

Figure 7. Activity subclasses



3.4. SocialUnit class

The *SocialUnit* class (Figure 8) captures concepts relating to social structures e.g. oligata (clan), olkabila (large tribe), and social roles e.g. resident, shepherd, rancher, divisional land control board.

Two critical concepts related to social organization are the concept of man and woman. The male and female members of the Maasai society have very distinct roles but also social and political rights, while resource control and ownership, in any form, varies significantly among the two genders. Apart from the gender-related distinctions, age-related distinction among society members is evident as well. Different kinds of leadership roles are important in understanding certain activities and land relationships, and were thus incorporated into our model, e.g. leaders who make decisions about the community's functionality, including land use decisions; leaders who control the pastoral processes; multi-level social groups (i.e. oloshon, oligata etc.). The interaction of individuals within the various social groups appears to be a key aspect of Maasai societies.

Figure 8. SocialUnit subclasses



4. Limitations and potential refinements

Many objects in a sketch can play multiple roles. For example, particular environmental features such as lakes have an environmental component (e.g. a water body) but may also play the role of a landmark. E.g. an *oltim* is a particular type of plant, and also has a very culturally significant role that can block the gateway into a *boma*.

Many concepts in our SKMO version 1.0 should describe orthogonal abstract concepts that can be combined via multiple inheritances. Continuing with previous example, an *oltim* is primarily a gate, but is also a particular type of vegetation, and so the concept should inherit from both the gateway and vegetation concepts.

Another example of concepts that require further development iterations towards more orthogonality is the *Landmark* class: this should rather describe abstract landmark concepts that can be combined (via multiple inheritance) with many other concepts from different branches of the inheritance hierarchy, e.g.:

Landmark

- *LargeScaleLandmark*
- *SmallScaleLandmark*

EnvironmentalFeature

- *Mountain*
- *Tree*
- *Lake*

The two classes *EnvironmentalFeature* and *Landmark* should not be disjoint so that sketch features can be identified as instances of both environmental features and landmarks as needed.

Finally, a further SKMO verification phase with Southern Kenya Maasai community members, and other experts and scholars in Maasai culture, would be highly desirable. This is one of our key motivations for making the SKMO publicly available: so that it may undergo further refinement in the wider research community.

5. Conclusions

We have presented an overview of our Southern Kenyan Maasai ontology (SKMO) designed to capture concepts related to land use. This document is intended as an accessible guide to the ontology and our development methodology. We also provide a reference report, with a complete reference listing, for further details on each concept within the SKMO.

The source material for the ontology is from academic research literature and sketch data collected through sketching workshops that we ran with Maasai community members during two field studies in Kenya (2016, 2017). We decided to express this domain model as an ontology (rather than other popular graph-based representations such as UML diagrams or ER diagrams) primarily due to the rich and rigorous mathematical foundation and support for automated consistency checking and reasoning. We have employed an incremental, iterative development process.

At the most general abstraction level, the ontology divides concepts into seven categories: activity, social unit, homestead component, material, shape, livestock, and environmental characteristic. The environmental characteristic class is deep and complex, and in particular, has a land characteristic subclass capturing concepts for describing land, land use, and land agreements. Within the land use subclass we highlight the artificial area subclass, which captures important concepts about built structures such as human dwellings, which play a prominent role in many sketches about land use.

Appendix

REFERENCE REPORT: SOUTHERN KENYA MAASAI ONTOLOGY (SKMO)

Mina Karamesouti, Carl Schultz, Malumbo Chipofya, Jan Sahib,
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July 2017

Introduction

its4land EU Horizon 2020-programme, attempts to address the issue of fast and cheap development of Land administration systems. Existing recording and mapping approaches have failed (disputes abound, investment is impeded, and the community's poorest lose out mapping of millions of unrecognized land rights in Kenya). The approach attempted to be developed from the its4land program incorporates technologies and processes that maintain information about people, land, and tenures. These are recognized as crucial tools for delivering sustainable economies, environments, and social cohesion. Land tenure recording helps to deliver tenure security, dispute reduction, investment opportunities, and contributes to good governance.

its4land combines an innovation process with emerging geospatial technologies, including smart sketchmaps, UAVs, automated feature extraction, and geo-cloud 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. Established local, national, and international partnerships drive the project results beyond R&D into the commercial realm.

The limited spatial heterogeneity, in terms of geomorphology and constructed environment, but also the traditional Maasai perception on land use and land ownership (commonly used land), do not favor deterministic approaches for land tenure recording. For this reason, the use of innovative geo-spatial technologies is being attempted to support multi-aspect approaches to spatial analysis [1]. Real-life information will be used to develop an ontological model, aiming to formalize the Maasai community system as well as its main functions.

Comprehensive background knowledge on concepts related to socio-ecological and functional structures, local landscapes and spatial features of the Maasai communities, as well as knowledge and understanding of local terminology was considered mandatory. Main sources for the linguistic information were primarily the online publicly available Maa language dictionaries by Payne and Ole-Kotikash [2] (referred herein as **Dictionary A**) and by Richmond [3] (referred herein as **Dictionary B**). The information of these dictionaries was cross-referenced in many cases with literature but also with direct contact with the locals. Initially, two broad categories were distinguished, one referring to the social characteristics and the other referring to the broader environment within which Maasai communities live. These two categories were subsequently enriched. The findings are presented in the following tables, divided into two main types, **terms** and **concepts**. Terms and concepts are classified based on the social aspects and the environmental aspects of the Maasai way of life. For the social aspect we have considered the roles of individual members of the community as well as the main activities that are carried out as part of everyday life. For the environmental aspect

we have considered climatic factors, vegetation and land. The class related to land is the broadest, since it incorporates not only biophysical land characteristics, but also characteristics related to land use type, land organization and land agreement, as addressed in the Maasai community. The livestock was another class, since animals play an important role in pastoral nomadic society.

Some terms in the ontology might describe more than one concept. This is because such terms have been used with different meanings in the literature and/or in the information obtained through our contact with local communities. As a result, a term may appear in more than one categories (e.g. the terms *enkang* and *olmarei* which might refer to social units or to a household [4, 5]) indicating that it can be used with different semantics depending on the context.

Society

Two critical concepts related to social organization are the concept of man and woman. The male and female members of the Maasai society have very distinct roles but also social and political rights. Resource control and ownership, in any form, varies significantly among the two genders [6, 7]. Apart from the gender-related distinctions, age-related distinction among society members is evident as well [6]. Different kinds of leaders who make decisions on community's functionality, including land use decisions, leaders who control the pastoral processes, but also multi-level social groups (i.e. *oloshon*, *oligata* etc), were considered worth mentioning as other critical concepts in our model [6]. The interaction of individuals within the various social groups appears to be a key aspect of the Maasai societies.

Table 3 . Terms related to society, with the relevant explanation, and the sources: Dictionary A (A), Dictionary B (B), sketches (C), and literature

TERMS - Society			
Term	Explanation	Source	Other Comments
<i>oligata</i> <i>olgilata</i>	Clans	A, [6, 8-10]	[6] - <i>olgilata</i>
<i>en-gishomi</i>	Clan	B	
<i>oloshon</i>	(sub-tribe sections) or [11] - territorial section	[10, 11]	
	Social groups / Ranches / Group ranches	[12, 13]	
	Group representatives	[12]	
	Management committee	[12]	
	Narok County Council - management authority	[14]	
<i>olegwanan</i>	Elder members who decide about land uses	A	
<i>olmarei</i> *	Family	A, [4, 5, 12]	
	Family/ Descendants - Woman - Man - Young members	[12]	
<i>orok kiteng</i>	Descendants	A	
<i>odo mongi</i>	Descendants	A	
<i>Oloiboni</i>	Spiritual leader	A, [6, 9]	

iloibonok	[6] - iloibonok - ritual leader – diviner [9] - oloiboni, ritual expert		
wazee	Highly respected member	[15]	
ol-arikoni	Leader	B	
Alaigwanani olaiguenani	Political leader Age-set spokesman or chief	A, [6]	
laigwanak	Head of clans	A	
ol-abikoni	Inhabitant, resident	B	
ol-meeri	Native other than Maasai	B	
el-latia	Neighbour	B, [8]	
ol-morani moran ilmuran olmurrani	Warrior	B, C, [4, 6-9, 12, 16]	C, [8] - moran [9] - olmurani [12] - ilmurrani
ol-jogut olcekut	Shepherd, herder, pastoralist	B, [9, 12]	[9] – olcekut: herder
	Hired herders	[14, 17]	
ol-aikitalani	Sheriff	B	
	Ranch manager	[8]	
	Individual ranchers - herders	[10, 12]	
	Livestock-poor individuals	[12]	
	Livestock-rich individuals	[12]	
olkarsis	Rich pastoralist	[6]	

Table 4. Concepts related to society, and the sources: Dictionary A (A), Dictionary B (B), sketches (C), and literature

OTHER CONCEPTS - Society	
Concept	Source
Urban population in the study site is growing.	[12]
Rich herders were against subdivision - large herds could not be sustained under smaller sized parcels.	[12]
Ilmurrani are the young warriors between 15 and 25 years old.	[9, 12]
women do not have access to resources and therefore cannot wield power.	[9]
All members of Oloshon (sub-tribe sections) have exclusive claims to rangeland territories for grazing and on water resources. Natural resources were commonly used.	[10, 11]
Women are not considered group ranch members - have no land rights unless in special cases.	[12]
Elder members responsible for decision making.	[12]
Elders were leading members.	[12]
Elders were against land subdivision - reduced land for grazing.	[12]
Marriage is an important means by which individuals build up alliances in the pastoral economy.	[9]
People who go away to work in the cities, without regular return visits are	[9]

treated as though they no longer exist - as if they were dead – have no rights.	
The preferred way to act politically amongst the Maasai involves the use of influence. As a result, women may be able to influence the decisions reached by their husbands regarding stock.	[9]
Main distinction - men care about cattle while women care about children.	[9]
Politics is conducted through the interactions of everyday life.	[9]
Extensive exchange networks underlie patterns of caring for cattle and ensure the long-term viability of the family herds. These patterns involve a system of "delayed-return".	[9]
Young members - grazing areas closest to the household.	[14]
Older boys and young men - move cattle across different niche grazing areas.	[14]
older men and most experienced herders graze animals during extreme drought and flood periods to assist with herding.	[14]
Solidarity is a fundamental organizing principle.	[12]

Animals

As indicated in previous group of terms, the household organization is tightly related not only to the position of the individuals in the social hierarchy, but also to the livestock. Various enclosure types are created for different kinds of animals. Young or sick animals are kept separately from the rest livestock (i.e. in olokeri), while the size of the herd might be indicative of social power and power to manage land resources [9]. For this reason some of the most popular animal species were included in current ontological model, since they can indirectly provide information for some important spatial organization components of the Maasai community.

Table 5. Terms related to animals, with the relevant explanation, and the sources: Dictionary A (A), Dictionary B (B), sketches (C), and literature

TERMS - Animals			
Term	Explanation	Source	Other Comments
	Livestock	[9, 12]	
	Seasonal livestock	[10]	
	zebu	[10, 18-20]	
en-gine	goat	B, C	C – the concept of goats exists also in sketches but without local term
il-lukunguni	poultry	B, C	C – the concept of chicken exists also in sketches but without local term
en-ger in-dare	sheep	B, C	C – the concept of sheep exists also in sketches but without local term
	cow	C	C – the concept of cow, calf exists also in sketches but without local term
<i>inkishu</i>	cattle	[9]	

Table 6. Concepts related to animals, and the sources: Dictionary A (A), Dictionary B (B), sketches (C), and literature

OTHER CONCEPTS - Animals	
Concept	Source
Zebu cattle - is the main cattle breed	[19], [18], [10], [20]
Ownership of stock is a crucial factor in deciding who has political control in the society	[9]
Stock associates can only be built up with others if one has a herd of animals.	[9]
Herd size reduction might be necessary in some areas	[12]

Activities

Agropastoral activities are the main source of income for Maasai communities, while supplementary income might derive from land leasing for cultivation, conservation (wild life) or touristic use [17, 21]. The fragmentation of the communally used grazing lands, due to the alternative activities, seems to be a serious cause of conflicts [17, 22]. Thus, the concept of activities was incorporated in the ontological model. The way that pastoralism is performed, and consequently the areas that are used, usually depends on the size of the herd, the household wealth, the social constraints as well as the climatic conditions [5, 12, 14, 17, 20].

Table 7. Terms related to activities, with the relevant explanation, and the sources: Dictionary A (A), Dictionary B (B), sketches (C), and literature

TERMS - Activities			
Term	Explanation	Source	Other Comments
e-turishoi e-tur enturore enkop	Cultivate, plough B - el-lidare , en-durgore (harvest)	A, B, [5]	
eunoto	The planting	[9]	
	Collecting wood	[9]	
	Chopping wood	[9]	
ol-amayio olkiyioi	Hunt	A, [23]	[23]
a-irrita	Look after the herd	A	
o-ramatei	Manage the cattle	A	
ronco	Drive the cattle to distant place for some months, seasonal pastoralism	B, [9, 17], [10], [20]	
	Transhumant pastoralism	[10]	
	Subsistence pastoralism	[12]	
Shoo perper	Grazing around A – perper – grazing around home	A, B, [6]	[6] – the right of “pasturing”
	Dry season grazing	[12]	
en-gias	Occupation	B	
	Washing cattle	C	
lagitim	Travel to get water for cattle	A	
emanyattas	Cultural events (coming of age ceremony)	A, C, [4, 9]	
Ilmala	Influence through a discussion of deputations	[9]	
	Tourism	[21]	
	Seasonal migration	[10]	

Table 8. Concepts related to activities, and the sources: Dictionary A (A), Dictionary B (B), sketches (C), and literature

OTHER CONCEPTS - Activity	
Concept	Source
Two types of lion hunting are identified: <i>Olamayio</i> – for prestige to the warrior, and <i>Olkiyioi</i> – to protect the herd.	[23]
The moran (or olmorani) is responsible to protect the neighborhood. For this reason, he lives in the emanyata (or manyatta), which is a camp outside the enkang	[4]
Common seasonal pastoralism practice during times of drought, is to move livestock to temporary camps, which are closer to areas of underutilized forage	[20]
Grazing animals into protected areas (PAs) , where both forage quantity and quality are higher is a common strategy during drought	[20]

Men spend most time away from enkan, checking the cattle or visiting other inkang'itie (enkan-plural)	[9]
During dry period herds are splitted among relatives and are droved in long distances to find water and food - [17]Joint herding usually occurs during drought	[9, 17, 24], [20]
Herd mobility is a central management strategy	[22]
Livestock exchanges reduce risks and improve recovery through herd ownership associations	[14]
Grazing differentials among group ranche members	[12]
During wet period majority of livestock walks less than 4 km away from boma	[7, 18]
During droughts herders withtheir livestock have to walk for 5 - 15 km from their enkan (or boma) to the watering places, in order to water their animals (half hour to 5 hours)	[18], [5, 25, 26]
Tourism industry promises more reliable and higher salaries	[14, 17]
Maasai pastoralists reside with their livestock (cattle, sheep, and goats)	[20]
Tourism - Maasai pastoralista do not always receive the enefits (income) from the wildlife tourism industry - not all landowners receive cash benefits equally	[21]
New income opportunities come from leasing pastures and cultivating	[14], [12, 17]
Herder's opinion...As much as I would like to be a pastoralist, farming is more suitable for this area. For instance, I grow tomatoes. The problem is that we don't have the know-how and water levels are decreasing. Farming is also safer.	[27]

Spatial organizations

The Maasai pastoralists are one of the traditional nomadic Nilo-Saharan groups, highly dependent on livestock, natural resources' availability and social organization. Spatial organization of the Maasai communities is one of the critical components that need to be described in an ontological model aiming at formalizing the Maasai community system. Main characteristics are the multi-household organizations and the commonly used, for grazing purposes, territories (Table 1, 2).

Table 9. Terms related to spatial organizations, with the relevant explanation, and the sources: Dictionary A (A), Dictionary B (B), sketches (C), and literature

TERMS - Spatial organizations			
Term	Explanation	Source	Other Comments
Enkan	City – area where a family resides [4] – multi-household (6-12 households)	A, B, C, [11], [4], [5], [9], [12]	B – eng-ang (village, town) C – enkan [9] - village, settlement, home [12]- enkan
En-aitas	habitat	B,	
Kraal	Settlement surrounded by thorn bush fences Afrikaans word used also as enclosure for	A, B, [24]	[24] – group of settlements =

	animals		enkutoto
e- mingani	deserted kraal	B	
i-nuruan	deserted kraal	B	
Olmarei	Household	[8], [28], [4]	[28] - one or more households (olmarei) [4]-enkang > olmarei (enkang has several olmarei)
<i>elatia/enkutoto</i> <i>inkutoto</i>	Neighbourhood/locality [28] - Cluster of bomas in favored localities	[8], [24, 28]	
<i>Oloshon</i> <i>Olosho</i>	Largest grazing unit [6] - primary unit of territorial political system [11] - territorial section commonly used	[6, 8, 11]	[11] - olosho

Table 10 . Concepts related to spatial organizations, and the sources: Dictionary A (A), Dictionary B (B), sketches (C), and literature

OTHER CONCEPTS - Spatial organizations	
Concept	Source
The main sections (oloshon) in the Greater Amboseli Ecosystem are the Ilkisonko section and the Kaputei, Matapaato sections	[10]
In south Kajiado District is situated the Kuku Group Ranch	[29]
Other broader districts are the Kajiado and Narok districts	[10]
Shompole Group Ranch	[4]
Olkirmatian Group Ranch	[4]
The Western edge of the Ilkerin hills was used as a barrier for land encroachment	[9]

Land Use & Land Ownership

Two main concepts related to the Kenyan Maasai land ecosystem are the **domestic** ecosystem and the **wild** ecosystem, while in terms of conservation policy, the aforementioned areas can be classified as **protected** or **non-protected** [10]. The main issue confronting these ecosystems are **functional and structural fragmentation**, leading to multi-layered (social, ecological, economic) system sustainability issues, but also to severe conflicts among the various social groups residing in the broader area, formerly characterized as the Maasailand [10, 27, 30, 31]. Although individualization of land might be related to greater security and provide additional income to few residents, through land leasing, land subdivision and the consequent land fragmentation often nurture serious conflicts [10, 31].

More specifically, for the study area (Kajiado District) the main land use patterns identified over the last decades are the **pastures**, the **agricultural** land, the **urban** areas and the **wildlife** reserves [17, 32]. During the last 30 years these land use has changed from a sparsely settled pattern, with dominant the grazing lands and forested lands, to a heavily settled pattern, where agricultural cultivations and urban system expand, in detriment to former land use status, and overlooking the basic land use and land management principles of the traditional Maasai

societies, leading to serious social dichotomy [9, 10, 12, 14, 27, 33]. Although international organizations attempt to re-define and re-introduce these principals in the current system [34], in an attempt to re-establish socio-ecological equilibrium, turbulences due to land use changes persist [35]. One significant aspect related to these changes, is the steady transformation of the wide **commonly used land**, based on the traditional Maasai principles, , into **individual** parcels of land and fenced areas [12, 14, 36]. Among the Maasai communities, the concept of **sharing natural resources** is not just symbolic, rather it works as a safety net for difficult periods, such as the extended droughts [17]. Consequently, the main land use types (i.e. **agricultural areas, grazing land, artificial land, ranches, boundaries**) as well as the ownership status (i.e. **private, public** etc), were considered as core components for the current ontological model.

Table 11. Terms related to land use, with the relevant explanation, and the sources: Dictionary A (A), Dictionary B (B), sketches (C), and literature

TERMS - Land use			
Term	Explanation	Source	Other Comments
	Domestic ecosystem	[10]	
	Wild ecosystem (wildlife conservation)	[10]	
	Protected areas - Reserves	[14], [10]	
	National Park	[12], [10]	
	Game reserve	[12], [10]	
	Amboseli ecosystem	[10]	
	Nairobi National Park	[11]	
	Tsavo National Park	[11]	
	Masai Mara National Park	[11]	
	Samburu National Park	[11]	
	Non-protected areas	[10]	
	Structural / functional fragmentation	[10]	
	Fenced irrigated agricultural areas	[21]	
	Greenhouses growing flowers	[11]	
emparnati	Permanent grazing settlement land use system	[10]	
enkaroni	Seasonal grazing settlement land use system	[10]	
	Land scarcity	[12]	
	Extensive / Intensive pastoralism	[10]	
	Sedentarized agropastoralism (herders settle permanently)	[10, 24]	
	Nomadic pastoralism	[9, 17, 27, 37, 38], [10]	
	Fragmentation (of pastoral areas)	[10]	
	Swamps	[10, 21, 22]	
	Inhabited areas (artificial areas)		

Table 12. Concepts related to land use, and the sources: Dictionary A (A), Dictionary B (B), sketches (C), and literature

OTHER CONCEPTS – Land use	
Concept	Source
In Shompole/Olkirmatian Group Ranches, the ecological conditions permit rainfed irrigation of cash crops	[4]
Grazing areas are decreasing while fragmentation of these areas increases	[14]
Amboseli National Park is surrounded by six communally owned group ranches	[11, 21]
sedentarization, subdivision and the reduced pastoral land-use has resulted in a spatial separation of ecosystem processes and the removal of	[10]

livestock grazing and settlement creation from certain areas of the landscape	
Emparnati settlement zones evolved adjacent to newly installed local infrastructure, services, and/or other key resources (e.g., roads and swamps)... and attracted additional services (e.g. shops, grain mills)	[10]
Maasai Mara National Reserve is an unfenced area of ~1500 km ²	[14]
Mara National Reserve (MMNR) is grazed 99 % of the days during the drought and 70 % of the days in the wet season	[14, 17]
Herders now graze their cattle in the park at night	[16]
Loita Hills and plains around were used in the past as wet-season pasture	[9]
The Rift Valley was used in the past by British for farming	[9]
The Mount Kenya was used in the past for settler farming	[9]
During the last 30 years land uses in Kenya have changed from sparsely settled (shrublands and forests), to heavily settled (cultivated and urbanized)	[33]
Three western swamps at the base of Kilimanjaro highlight the effects of segregation compounded by land-use intensification	[10]
Some small-scale maize cultivation may be practiced immediately around the boma, but this is not generally a feature of ranch areas close to MMNR, due to the risks of crop-raiding by wildlife	[28]
Inhabited areas - very densely populated Kisii and Kericho districts - these settlement patterns show that permanent housing is encroaching southward	[39]
National Reserves caused permanent loss of access to key forage and water resources for local herders	[10]
Kilimanjaro and Chyulu Hills are reserve grazing “banks”	[10]
Three western swamps at the base of Kilimanjaro highlight the effects of segregation compounded by land-use intensification	[10]
Swamps are important for humans (for agricultural and domestic water use), livestock (as grazing reserves), and wildlife (for forage and water).	[10]
Large swamp areas have been converted to agriculture, resulting in significant conflicts over water management and grazing in reserves.	[10, 16]
Olopololos grazed in dry period	[12]
Group ranch pastures are used in dry period by everybody	[12]

Table 13. Terms related to grazing-related areas, with the relevant explanation, and the sources: Dictionary A (A), Dictionary B (B), sketches (C), and literature

TERMS - Grazing-related areas			
Term	Explanation	Source	Other Comments
ol-alili	gazing field set apart for calves	A	
ol-alili orng'arua	Reserve in swampy area grazed only in dry season	[40]	
nembirika	basin grazed during wet period	[40]	
endonyo nadosoito	grazed in wet period	[40]	
ebalbal	grazed in wet period	[40]	

engusero ondinyika	valley of arid scrub grazed in dry period	[40]	
oit ekituma	grazed in dry period	[40]	
oloudo	upland grazed in dry period	[40]	
ol-aleli	Enclosure set aside for calves to graze. This is outside of the enk-áŋ , and is enclosed by thornbushes. It may be 1 x 6 km or bigger	A	
	pasture	C	
oloshon	largest grazing unit	[8]	

Table 14. Concepts related to grazing-related areas, and the sources: Dictionary A (A), Dictionary B (B), sketches (C), and literature

OTHER CONCEPTS - Grazing-related areas	
Concept	Source
During dry season, many animals are kept near the enkang	[9]
During dry season herders have to lead animals in long distances to water them. Elder participate in herding during this period as well.	[9]
Grazing orbit /herding orbit - the path that cattle circumnavigate from their enclosures to grazing and water resources and back to their enclosures in a grazing day	[20, 26]

Table 15. Terms related to agricultural areas, with the relevant explanation, and the sources: Dictionary A (A), Dictionary B (B), sketches (C), and literature

TERMS - Agricultural areas			
Term	Explanation	Source	Other Comments
shambas	cultivated plots	A, C	
enkurma	garden field	A, B, C, [9]	
ol-campa	individual parcel of agricultural land	A	
e-mukunta	cultivated garden field	A	
	farming land /farm	C	
em-paret	field - garden	A, C	C-(?) emparet?
ol-ale loo nuesi	game reserve	A	

Table 16. Terms related to land ownership, with the relevant explanation, and the sources: Dictionary A (A), Dictionary B (B), sketches (C), and literature

TERMS - Land ownership			
Term	Explanation	Source	Other Comments
Green cards	this is a kind of indication for official	Unofficial	

	land ownership	source	
	Exclusion is a prime theme in group ranch subdivision	[12]	
	Innitially Maasai herders supported ranch subdivision	[12]	
	Land Tenure - Land rights – title deeds	[11], [12], [10, 32]	
	Communal Land	[12], [10]	
	Individual ownership	[9], [12], [14]	
	Land grab	[12, 38]	
	Eviction of unauthorized settlers	[12]	
	Chasing of non-ranch members	[12]	
	Failure of collective decision making relate to land management	[12]	
	Individual ranchers are seen as menace to group ranches	[12]	
	Individual ranchers represent land grab	[12]	
	Fenced grazing areas only for individual ranchers - olopololis	[12]	

Table 17 . Concepts related to land ownership, and the sources: Dictionary A (A), Dictionary B (B), sketches (C), and literature

OTHER CONCEPTS - Land ownership	
Concept	Source
Legal land tenure rights - title deeds [11, 32] - Massai viewed legal land titles as a means of securing their land from encroachment by immigrant farmers ,but that proved elusive	[11, 32], [12]
programs, Kenya titled much of the common land in the semi-arid regions to individual owners, usually in 5 to 10 hectare plots for small holders growing maize and other market crops, especially in Kajiado and Narok districts	[11]
High potential land on the mountain slopes was allocated to prominent individuals as Individual Ranches (IR), and most were quickly subdivided and sold to immigrant farmers.	[32]
The majority of the Maasai remained in the savanna lowlands where Group Ranches (GRs) were created that were based on traditional grazing areas and boundaries drawn to enclose sufficient wet and dry season water and grazing resources	[32]
Privatization into smaller individual holdings is for the registered members of the group ranches. Registration was stopped in the early 1980s, when most of the registers were closed	[36]
Rich herders were against subdivision - large herds could not be sustained under smaller sized parcels	[12]
Subdivision was expected to favor poor herders - they would lease excess pastures to the rich and milk their animals	[12, 17]
In the whole of Narok District, over 50,000 hectares of the subdivided	[36]

land has already been sold to peasant farmers	
corridors to water point /salt licks/ utilities (dips) were privatized after land individualization	[36]
The trend in 2000 was greater mobility in both subdivided and communal group ranches, but movement was towards unfragmented areas - importance of maintaining these “intact” areas for people and livestock within the system.	[10]
Conversion from Communal to individual land tenure (Land privatization)	[12], [14], [10]
Official division of swamp areas into private parcels	[10]
Inordinate expenses of individual parcel management	[12]
Masai fear that ranch establishment is more for the purpose of land grabbing than for efficient land management	[12, 38]
Right to ownership usually have adult married men, but sometimes woman might have some rights as well. Although woman might not be the owner, she might have control of resources (i.e. the stock)	[9]
Power relates to accessing resources, and resources are largely in the control of the adult married man	[9]
Woman and moran are less powerful in the Maasai society, because they do not control resources	[9]
private tourism and conservation groups lease land from pastoralists who have recently received individual title deeds from the privatization of former communal land (i.e., group ranches)	[17]
Conservation areas are often predicated on the assumption (implicit or explicit) that land is to be exclusively used for wildlife conservation and tourism purposes (Thompson et al. 2009). Payments are disbursed to pastoralists if the land is not used by domestic livestock.	[17]
that pastoralists around Protected Areas are negotiating a new, indeed transformed, pastoral landscape	[17]

Soil- Land, Land characteristics, and Land formations

Swamps, mountains, hills and rivers suggest key functional system and spatial perceptiveness components. The quality of the land and the soil types are included in the current model as well, since they provide different potentials to natural resources availability and consequently to land use potential [15, 31, 32]. The potential of land use, especially as a grazing land, determines the movements of the Maasai pastoralists and therefore the locations that are going to be used as permanent residences.

Table 18. Terms related to land and soil, with the relevant explanation, and the sources: Dictionary A (A), Dictionary B (B), sketches (C), and literature

TERMS - Land - Soil			
Term	Explanation	Source	Other Comments
en-kop	ground - earth - soil, land, field	A, B	B – en-gop (land - earth)
en-derit	ground	B	
en-kulukuoni	soil	A	

en-kuruma	plot of land	A	
e-dupo	plot	B	
o-sanyai	sand	B	
em-boliei em-bulioi	Clay soil	A	
	Volcanic soils	[32]	

Table 19. Concepts related to land and soil, and the sources: Dictionary A (A), Dictionary B (B), sketches (C), and literature

OTHER CONCEPTS - Land - Soil	
Concept	Source
Volcanic soils very fertile	[32]

Table 20. Terms related to land characteristics, with the relevant explanation, and the sources: Dictionary A (A), Dictionary B (B), sketches (C), and literature

TERMS – Land characteristics			
Term	Explanation	Source	Other Comments
paga	communal restricted land	A	
orpora	degraded restricted land	[40]	
orkojta	non-degraded grazing land	[40]	
ngulupo	heavily grazed areas	[40]	
lanata	flat country - treeles, plane-desert	A	
anata	Plain, desert, flat country	A	
onata	Plain, flat open country, wilderness	A	
n-kisiacata	trees plain	A	
mula	Treeless plain, esp. where there is salt up to several centimeters deep on the ground	A	
nakurro	Bare grassless place	A	
orng'arua	swampy area - The soils are greyish in color with high salt content	[40]	
En-kusero	swampy ground	A	
l-kees	Arid land, desert	A	
Ol-purkel	Arid land, desert	A	
natet	Semi-arid land	A	
l-kárjáj	desert	A	
em-pusel	desert	B	
Il-mwateni	desert	B	
e-or / i-ori	dry plot	B	
en-atini eng-atini	stony	B	

Table 21. Terms related to land formations, with the relevant explanation, and the sources: Dictionary A (A), Dictionary B (B), sketches (C), and literature

TERMS - Land formations			
Term	Explanation	Source	Other Comments
endonyo nadosoito	red mountain - for grazing in wet	A, C	

	period		
en-doinyo n-dónyío	hill	A, B, C	3 – the concept of hills exists also in sketches but without local term, however, there is a local term for the mountains (oldonyo)
ol-melíl	Small spur or range of hills	A	
e-marti	cliff	B	
ol-dóinyío	mountain	A, B, C, [15]	3- oldonyo:mountains odonyo orok? oldoinyo orok? ordonyo orok?
lo-doinyo le'ngima	volcano	B	
ol-manie	Surroundings - Perimeter; of a dam, river, mountains (ie. foot of mountains)	A	
ebalbal	crater - grazed in wet period	[40]	
fanya juu	natural terracing structures	[41]	
ololukoti	The name means a high table land – High mountain flat on top. The landscape is used both for grazing and settlement. Indigenous vegetation includes: Tondoluan and Esisinet	[40]	
enk-ashepani	small ravine or gully	A	
ol-baata	crack - gully	A	
ol-buaa	swamp - artificial or natural depression on the ground	A	
ol-are	swamp	A	
l-orrian	swamp	A	
ol-corro	dam		
ol-duroto	dam	B	
esilante	Swamps /marshland	C	
ol-baan	dry riverbed - seasonal river	A	
ol-keju	Small river, brook – river either permanent or seasonal	A, B, C, [10], [20]	B – ol-geju – river C – orkeju C – enkeju
e-guaso, ol-geju o-riet ol-mwipo ewaso	river	B, [15]	[15]– ewaso-water ways
l-baa	Stream of water, rivulet	A	
nk-apune	cave	A	
ol-baata	A long narrow depression in a surface; crack, eroded gully , ditch, channel	A	

n-damata	Slope of a mountain, hillside, face (of mountain)	A	
enk-oshoke	Slope of a hill	A	
l-mari	Slope of a hill	A	
osopuko	highlands	[15]	
e-marti	Upwards sloping land	A	
ol-dama	hillside	A	
	Open location with no tree or house to hide in		
l-dankal		A	
en-dapdapoi	rock	A	
o-soit	rock	A	
n-doroto	Bare ground	A	
ol-pura	Bare ground		
shenai opir	Rocky outcrops	A, [15]	
en-gumotisho	Land depression: valley, ditch	A	
en-gumoto	Hole, esp. in the ground	A	
oyarata oyerata agarata	Valley	A, [15]	[15] – agarata or oyarata - marshes
olpurkel	Dry lowlands	[15]	
em-pukuroto	valley	A	
en-nongoto			
ongata	valley	A, B, [15]	[15] - ongata-plains
negum	valley	A	
e-ululu	Cave (or valley)	A	
l-karjaj	Wasteland, desert	A	
l-karrkarri	Stony place, gravelly area	A	
l-kuran	island	A	
	High ground, as between watercourses; watershed, divide		
l-orúko		A	
olosho onyokie	Plateau which is red	A	
o-subugo	plateau	B	
e-uluku			
ol-lumwa	pit	B	
em-bout	trench	B	

Homestead and homestead components

The nomadic way of living of the Maasai pastoralists gives the homestead a very particular role. Different kinds of permanent or temporary homesteads based on the used material but also based on the role they serve and the family member that resides in them, were enlisted in current ontological model. Characteristics of the human and animal homesteads, animal enclosures, as well as their main components provide important spatial information and were incorporated into the ontological model.

Table 22. Terms related to homestead, with the relevant explanation, and the sources: Dictionary A (A), Dictionary B (B), sketches (C), and literature

TERMS - Homestead			
Term	Explanation	Source	Other Comments
boma*	Households, small collections of huts, homestead	A, C, [7, 26, 28, 36, 42], [19], [14, 17]	C – homestead [42]– boma (Swahili) = enkanj (Maa)=domestic settlement
kraal*	Settlement surrounded by thorn bush fences	A, B, [28]	[28] - ‘kraal camp’ for permanent or semi-permanent settlements.
enkanj*	for people and cattle	A, B, [11, 28, 42] [9]	B – eng-ang – ing-agitie (kraal) – home [42] – boma (Swahili) = enkanj (Maa)=domestic settlement [9] - village, settlement, home [11] - engang – homestead [28] - boma = enkanj
ol-campa	ranches	A, C, [11], [39], [4, 41], [12]	A - A parcel of land that an individual owns and has a title deed for. [12] - only the term ranch
ol-kaji	huge house	A	VS enkanj (?)
Enkanj / enkanjiji	house for wife [4] - in polygamous families each wife has her own house	A, B, C, [4]	B – eng-agi (house or hut) B - e’ngaji C – enji (?) /enkanj - enkanjiji
house-top en-topij em-barnat e’ngaji	house	B	
olalasho	house for girls (?)	C	
	workers’house	C	
emanyata (pl. imanyat)	kraal for warriors	B, C, [28], [36, 39], [9]	C - manyattas (houses) [28] - Manyatta’ is the Maasai word for the (generally unfenced) settlements of the warriors (Maa pl.: il-murrani), but has reached common usage to refer to any Maasai settlements with permanent or semi-permanent huts. [9] – emanyata: ceremonial village
	Youth house	C	
olmarei	normally means family but has also the meaning of household	A, [4, 5, 8]	[8]- household
enlwji	house made of dung and mud mixture	A	
mabati	building with iron roof	A, C, [39]	

im-barnati	House out of stone (permanent)	B, [12]	
ol-ngobori	Hut out of skins	B	
en-gitagata	hut where elders meet	B	
osinkira	hut built <i>in emanyata at eunoto</i>	[9]	
	Temporary, Seasonal camps	[5, 20, 42]	

Table 23. Concepts related to homestead, and the sources: Dictionary A (A), Dictionary B (B), sketches (C), and literature

OTHER CONCEPTS - Homestead	
Concept	Source
The internal arrangement of houses also suggests variation between the sections. From the data available, the relative positioning of the beds to each other, and the orientation of the house relative to the central area of enkang' (village; pl. inkang'itie) appears to vary by section (clan)	[9]
Temporary camps , distant from permanent settlements are used to host herders and livestock during drought. [20] -These areas are usually close to National Parks and Protected Areas	[5, 20]
Each Maasai family builds a circular corral or boma of thorny branches from acacia trees and locates the huts around the inner perimeter	[28, 38]
Multi-generational households	[10]
in Kenya, enkangs might have a mean size of 2.6 households.... The household in physical terms refers to the collection of houses about a communal gate . The gate carries the name of the man and a separate gate is a symbol of his autonomy as a cattle owner and founder of a family	[4]
Several polygamous extended families (3–12 households, 10–50 people) live together in domestic settlements in order to share labor for herding and to protect the herds	[42]
Number of houses per settlement tends to decline	[10]
Larger settlements reflect larger traditional social and labor-sharing units (e.g., Lenkisiim, Emeshenani and southern Eselenkei)	[10]
Temporary settlements (seasonal cattle camps, warrior encampments, meat-feasting sites)	[42]
In typical settlements houses are circularly arranged around a central cattle enclosure. The entire settlement is ringed with thorn fence. Central enclosure is surrounded by smaller livestock enclosures.	[42]
Each adult male has his own gate in the perimeter fence and the house of his first wife is to the right of this gate.	[42]
Wife's house has average 6x3x1.5 m. In this house live the woman, her children and young livestock	[42]
Wives' houses are made of a mixture of ash, cattle dung, and mud over a wooden frame	[42]
Men's house is usually under a shady tree, within 15m from the settlement.	[42]
manyattas are more widely distributed in the lower parts of the Mara region. There are more manyattas observed in Siana, followed by Koiyaki and Olkinyei where pastoralism is still strongly practiced	[39]
more grass-thatched houses in Oloirien group ranch where people are more sedentary	[39]

Table 24. Terms related to homestead components, with the relevant explanation, and the sources: Dictionary A (A), Dictionary B (B), sketches (C), and literature

TERMS - Components of homestead			
Term	Explanation	Source	Other Comments
en-gishomi in-gishomi	door, gate	B, C, [42]	C - kishomi (gate)
ol-gerenget – il- gerengeti en-gikatata – in- gikatata	fence	B, C, [9], [7, 10, 15, 42]	C - en-kikarata
	Wind break	[9]	
ol-lengati	yard	B	
ol-tiren en-geberi	roof	B	
ol-gelata ol-pasne ol-marei	room	B	
e-hima	tent	B	
ol-ohurie en-gitagata	shelter	B	
en-guruma – in- gurman en-kurma ol-cjambai - il- chamba	garden	A, B, [9]	A - en-kurma: garden-field A- ol-campa: cultivated garden-field B - en-guruma – in-gurman ol-cjambai - il-chamba [9] – <i>enkurma</i> : fenced area for cultivation, flour.
	Fireplace	C	
	Father's bed	C	
	Mother's bed	C	
	Place for firewood	C	
oldiret	a packing frame closing the entrance of the woman house	[9]	
boo	area inside fence of enkang but outside the house	[9]	
oltiren	central area in house	[9]	

Table 25. Concepts related to homestead components, and the sources: Dictionary A (A), Dictionary B (B), sketches (C), and literature

OTHER CONCEPTS - Components of homestead	
Concept	Source
Oldiret is a packing frame closing the entrance of the woman house, indicating that she is sleeping - it is placed on a donkey when a household moves	[9]
Thorn fences enclose animals in the temporary residence, during dry period	[7]
Small thorns are used for internal fencing (<i>Acacia mellifera</i>), large thorns are used for defensive external fence surrounding the whole settlement (<i>Acacia tortilis</i>)	[42]
Two types of gates wide ones for livestock, and narrow ones used for people, and can be characterised as main or secondary	C, [42]

Table 26. Terms related to materials, with the relevant explanation, and the sources: Dictionary A (A), Dictionary B (B), sketches (C), and literature

Materials			
Term	Explanation	Source	Other Comments
e-munui	sediment	B	
eng-are	water	B	
	mud	A, [42]	
	wood	A, [42]	

Table 27. Concepts related to materials, and the sources: Dictionary A (A), Dictionary B (B), sketches (C), and literature

OTHER CONCEPTS - Materials	
Concept	Source
house made of dung and mud mixture	A
Wives' houses are made of a mixture of ash, cattle dung, and mud over a wooden frame	[42]

Table 28. Terms related to enclosures for animals, with the relevant explanation, and the sources: Dictionary A (A), Dictionary B (B), sketches (C), and literature

TERMS - Enclosures for animals			
Term	Explanation	Source	Other Comments
	Permanent enclosures – built constructions	[20]	
	Temporary livestock enclosures	[28], [20]	
Boma*		A, C	C-cattle boma
Kraal*	*fenced enclosures for animals (Settlement	A, B	

	surrounded by thorn bush fences)		
ormwati	thorn bush fence	[7, 28], [20]	
	Electric fences	[36]	
olopololi	Grazing field	A, C,[12]	
Oloasingo*	Cattle shed	C, [8]	[8] – oloshon: largest grazing unit
	Milking shed	C	
olokeri	for sick animals or restricted area near the homestead for calves to graze [6, 39] - small family-owned pastures	A, [6, 24, 39]	
ol-girrar	where calves sleep	A	
Ol-aleli	enclosure for calves to graze	A, C, [9]	C- olale (grasses) C-olale (young cattle shed) [9] - Olale – calf pen inside house
olalili ololucoti	calf pasture reserve	A, [40]	
enkang oontare	where sheep and goats stay	A	
ol-muaate	calf pen	A, C, [9]	C-emuataa (goat shed) C- omuatata [9] – emuatata: small-stock pen
omwaiaia	Goat and sheep pen (?)	C	
m-perit	Sheep pen	A	
sum	Sheep pen	A	
em-watata	Young goat shed	C	
	Young cattle/calf shed	C	
	Chicken house /chicken coop	C	
	kennel	C	

Table 29. Concepts related to enclosures for animals, and the sources: Dictionary A (A), Dictionary B (B), sketches (C), and literature

OTHER CONCEPTS - Enclosures for animals	
Concept	Source
Temporary livestock enclosures are used during dry period - they are mainly thorn-fenced enclosures	[20]
Ormwati is a thorn bush fence created for animal protection during the wet grazing period- away from the boma, in the temporary herder residences	[28], [7, 20]
Ormwati - temporary livestock camps constructed when grazing takes place far away from the boma	[28]
Olaleli is an enclosure set aside for calves to graze. This is outside of the enk-áj, and is enclosed by thorn bushes. It may be 1 x 6 km or bigger	A
During evening and night the animals (in Shompole) are kept in the boma , i.e. the place where the people and livestock live . Cattle are kept within the circle of huts and sheep and goats within the inner enclosure .	[19]
Electric fences exist between Mara Game Reserve and individual croplands	[36]

Olopololi is a grazing area used only by ranchers in dry period	[12]
Olokeri is a small circular grassy family-owned area, immediately outside the cattle gate, which belongs to the family as long as its members reside in the specific homestead and use it. It is grazed by calves or sick animals. Family has the exclusive temporary privilege to use it.	[6, 39]
Olokeri is a traditional private enclosures for sick animals	[24]
Olalili ololucoti is a calf pasture reserve for settlements located at the bottom of the western Rift wall. The landscape is set aside for calf grazing during the dry season	[40]

Landmarks, Vegetation, and Infrastructure

Landmarks and infrastructures, mainly related to water and transportation are distinct characteristics that can provide valuable information related to land recording, and thus were incorporated into the ontological model. Trees and vegetation have also a special role as meeting places (landmarks) or boundaries, while public buildings, such as hospitals, schools or police stations, suggest special constructions which can be used as spatial reference points.

Table 30. Terms related to landmarks, with the relevant explanation, and the sources: Dictionary A (A), Dictionary B (B), sketches (C), and literature

TERMS - Landmarks			
Term	Explanation	Source	Other Comments
ol-polosie	Landmark (boundary)	B	
ol-joro – il-joroi en-gitokitok	fountain	B	
o-balbal en-aiposha	lake	B	
ol-balbal en-duroto	pond	B	
ol-are	watering place	B	
En-naiuroo	waterfall	B	
o-singira en-nemirishoreiki	market	B	
ol-duka	shop	B	
ol-tanki	tank	B, C	3 – the concept of tank exists also in sketches but without local term
oiti	Tree – meeting point for women	C	
oltepesi	Main tree – meeting point for men	C, [42]	[42]- the tree locates usually 15 m away from the settlement
mugumo tree	Tree specie meeting place tree	C	
	Maasai Mara National Reserve	[20]	
	Talek River (perennial river - in	[20, 26]	

	the MMNR)		
	Amboseli'S swamps	[21]	
	Tsavo National Park	[21]	
	Kilimanjaro Moutain	[12], [10]	
	Chyulu Hills	[10]	
	Amboseli National Park	[21]	
	Namelok swamp	[32]	
	Isinet swamp	[32]	
	Kimana swamp	[32]	
	Rombo perennial stream	[32]	
	Livestock Markets	[10]	

Table 31. Concepts related to landmarks, and the sources: Dictionary A (A), Dictionary B (B), sketches (C), and literature

OTHER CONCEPTS - Landmarks	
Concept	Source
Livestock Markets were vital to Maasai livelihoods	[10]

Table 32. Terms related to vegetation, with the relevant explanation, and the sources: Dictionary A (A), Dictionary B (B), sketches (C), and literature

TERMS - Vegetation			
Term	Explanation	Source	Other Comments
oit ekituma	Acacia forest	[9, 40]	
	forest	C	
omeserani	Baobab plants grazed all year	[40]	
markhamia lutea	plant used as boundary marker - living fence	[41]	
terminalia catappa	soil-conservation structures	[41]	
commiphora hedge	used as plant fence - secure cattle enclosure	[41]	
croton megalocarpus	used as hedge	[41]	
commiphora zimmermannii	used for permanent boundaries	[41]	
tamarindus indica	boundary marker	[41]	
grevillea robusta	for constructions	[40]	
eucalypts	for constructions	[40]	
albizia gummifera	meeting place	A	
en-guruma – in-gurman	garden	B	
ol-cjambai - il-chamba	garden	B	
en-gojit – in-gojita			
o-seyai – i-seya	grass	B	
ol-paiki	maize	B	
ol-piro	palm tree	B	
en-gurma	plantation	B	

en-gwashi	potato	B	
ol-kirataata	shrub	B	
ol-jani	tree	B	
ol-jata	tree	B	
il-gek	tree	B	
en-gurma	vineyard	B	
ol-oikilepo	willow	B	
ol-oirien	wild olive	B	
en-dabogai	vegetable	B	
en-jata			
en-dim	wood	B	
oltim, oltiki	dead tree set outside the enkang	C	
oltepesi	meeting place tree for men	C	
oiti	meeting place tree for women	C	
mugumo tree	Species of tree used as meeting place	C	
	Shady tree	C	
olaisai	Sericocomopsis hildebrandtii	[40]	
	Medical trees	[29]	

Table 33. Concepts related to vegetation, and the sources: Dictionary A (A), Dictionary B (B), sketches (C), and literature

OTHER CONCEPTS - Vegetation	
Concept	Source
Vegetation is used for multiple purposes and plays an important role in traditional Maasai communities	[18], [5, 7, 9, 40-42], [10], [20]
Dominant Vegetation - broad leaf, dry tropical forests and woodlands, grasslands and seasonally flooded plains, riverine forests, halophytic grass and scrubland in the Amboseli Basin, and scattered Commiphora and Acacia woodlands.	[10]
Oit ekituma is Acacia forest grazed in dry period	[9, 40]
Omeserani are Baobab plants grazed all year	[40]
Markhamia lutea is a plant used as boundary marker - living fence	[41]
Acacia woodland is a dominant plant in the study area	[18], [5, 7, 10, 42], [20]
Acacia xanthoploea woodlands within Amboseli National Park collapse	[10]
The pods of Acacia tortilis are some of the most important sources of fodder for sheep and goats in the dry season	[7]
Savannah woodland can be grazed all year round	[9]
Commiphora and Acacia woodlands surrounding the park increased as a result of livestock grazing in the absence of elephants	[10]
Vegetation is used for erosion protection, spatial arrangements (define paths or land parcel boundaries), wind breaks, protection from wild animals, or landmarks (meeting places, teaching areas)	[41]
Terminalia catappa is a plant used for soil-conservation structures	[41]
Commiphora hedge is a plant used as living fence in order to secure cattle enclosure	[41]
Croton megalocarpus is a plant used as hedge	[41]
Commiphora zimmermannii is a plant used for permanent boundaries	[41]
Tamarindus indica is a plant used for soil-conservation structures	[41]

Grevillea robusta is a plant used for constructions	[40]
Eucalypts is a tree used for constructions	[40]

Table 34. Terms related to constructions and infrastructure, with the relevant explanation, and the sources: Dictionary A (A), Dictionary B (B), sketches (C), and literature

TERMS - Constructions - Infrastructure			
Term	Explanation	Source	Other Comments
	Shop/store	C, [9]	
	Office	C	
	Car parking	C	
hospitali	Hospital	B	
	Dispensary	[9]	
	Police department	[9]	
	Governmental building	[9]	
o-sikul	School (primary school, secondary school, government school)	B, C, [9]	C - the concept of school exists also in sketches but without local term
	Primary school	C	
e'sikul eng-aji	schoolhouse	B	
	church	C, [15]	
eng-oitoi e'segenge EsekenkeiEngarriEnkim a	rail road	B	
	trash pits	[42]	
eng-oitoi e-regie	Road	B, C, [12], [10]	C - the concept of road exists also in sketches but without local term
	Tarmac road	C	
	Corridor to water point /salt licks/ utilities (dips)	[36]	
	Home road	C	
	Small path	C	
	Foot path	C	
	Dust road used by neighbors	C	
e-udoto	tunnel	B	
	Infrastructure for water (dams, boreholes, wells)	[12], [10]	
ol-tanki*	Tank water reservoirs /water tank	B, C	C – Water tank for domestic use and animals
	Water base	C	
oltinga /oltinga	Borehole well – common water point for watering animals	C, [5]	
	Cattle dip	[9], [10]	
	Irrigation canals	[10]	

	Tap	C	
	Pipelines	C	
	Electricity cables	C	
	Beacon	C	
	Kitchen	C	
	Toilet /bathroom	C	

Table 35. Concepts related to constructions and infrastructure, and the sources: Dictionary A (A), Dictionary B (B), sketches (C), and literature

OTHER CONCEPTS - Constructions - Infrastructure	
Concept	Source
Herders are increasingly constrained by a fragmenting landscape of physical and socially constructed barriers	[15]
Dams provide the opportunity for intensive grazing	[9]
Livestock infrastructure - stock dip tanks, water points (cattle dip)	[10], [9]
Cattle dip is among the most important infrastructure - people bring their cattles from long distances	[9]
Infrastructure system seems to be still poor in the Amboseli region	[10]
Access of household to services (shools, medical facilities, markets) and infrastructure (roads, boreholes etc) differs, depending on settlement location	[10]
Trash pit (about 1x1 m) are located near the inhabited boma. Every woman's house has its own trash pit, which she uses as long as she lives in the boma	[42]
Wealthier households may be better able to afford investments that improve the quality of herding (Turner 1999a), as well as having sufficient financial reserves to purchase infrastructure or fodder that helps alleviate the effects of drought (Scoones 1992).	[17]
Land privatization has caused access limitation issues to several infrastructure	[10]

Table 36. Terms related to spatial information, with the relevant explanation, and the sources: Dictionary A (A), Dictionary B (B), sketches (C), and literature

Other words for spatial information			
Term	Explanation	Source	Other Comments
e-weji*	place / position	B	
e-weji i-wejitin	location/place	B	
en-gidanyata in-gidanyat	fracture	B	
ol-mongoite em-danyidanyata	fragment	B	
te'dokoya	front	B	
ti atwa	inner/inside	B	
ol-gerera	line	B	
en-topiz	point	B	

ol-otoni	omnipresent	B	
ti aulo	outdoors	B	
ti aulo te'ta	outside	B	
te shumata	over	B	
erisio	parallel	B	
en-gitashoto	perpendicular	B	
e-matwa	quarter	B	

Climate

The climatological conditions and the seasonality prevailing in Kenya, and consequently in the specific study region, are the dominant factor controlling human behavior related to nomadic way of living and the land use [9, 10, 17, 27, 37, 38]. Water availability is a limiting factor for the ecosystem functionality, tightly connected to the local population survival. Consequently, the concepts of **dry season** and **wet season**, as well as climatic concepts related to **drought** and **rain** were considered as critical for the ontological model.

Table 37. Terms related to climate, with the relevant explanation, and the sources: Dictionary A (A), Dictionary B (B), sketches (C), and literature

TERMS - Climate			
Term	Explanation	Source	Other Comments
orpukel lengoloi	hot arid	[40]	
olameyu	dry season	[9]	
olari	wet season	[9]	
orpukel le-supuko	semi-arid	[40]	
osupuko	cool sub-humid	[40]	
en-deem enoguring	hail	B	
ol-odalu	summer	B	
ol-oirujuruj	winter	B	
en-jan	winter	B	
en-joro			
ol-oitokitok	spring	B	
en-gisuisui	wind	B	
ol-limwa	wind	B	
en-can	rain	B	
eng-ai	rain	B	
ol-oirag le'ngare	flood	B	
	Drought	[12]	

Table 38. Concepts related to climate, and the sources: Dictionary A (A), Dictionary B (B), sketches (C), and literature

OTHER CONCEPTS - Climate	
Concept	Source
Climatic variability significantly affects human life in the study area	[12, 37, 38],

	[14], [10]
Olameyu sapuk is the big drought, when land becomes very dry and water resources become scarce	[9]

Sketches

Spatial organizations		
Term	Explanation	Sketch ID
Enkang	City – area where a family resides	F4, F5
<i>Homestead</i> <i>/home area</i>		F8, F15, F16, F17, F18, F23, F24, F25
boma		F2, F4, F5, F6, F11
Oloshon	Largest grazing unit	F6
Words for homestead		
Term	Explanation	Sketch ID
House /home		F3, F6, F10, F11, F16, F24, F26, F27, F28, F34, F28, F29, F31, F33
ol-campa	ranches	F15, F16, F20
Enkaji / enkajiji	house for wife	F4?, F20
olalasho	house for girls (?)	F4
	workers' house	F35
e-manyata – i-manyat	kraal for warriors	F6, F7, F9, F13, F16, F17, F18, F19, F23, F24
	Youth house	F35
mabati	building with iron roof	F7
Components of a homestead		
Term	Explanation	Sketch ID
en-gishomi	door, gate	F6, F7, F9, F10, F11, F13, F15, F16, F20, F25, F26, F27, F29, F30, F31, F32, F33, F34, F35
in-gishomi		
kishomi	main-small gate	
	Cattle gate	F27, F29, F35
ol-gerenget – il-gerengeti en-gikatata – in-gikatat enkikarata	Fence Boundary fence – Rounding fence	F6, F7, F10, F11, F12, F14, F15, F16, F17, F18, F19, F21, F22, F23, F24, F25, F26, F27, F28, F29, F30, F31, F34, F35
	Fireplace	F13
	Father's bed	F13
	Mother's bed	F13
	Place for firewood	F13
Enclosures For Animals		
Term	Explanation	Sketch ID
olopololi	Grazing field	F2, F9, F14, F20
Olosingo	Cattle shed	F4, F6, F9, F10, F11, F17, F18, F20, F23, F24 F25, F26, F27, F30, F31, F33, F35
	Milking shed	F35
Ol-aleli	enclosure for calves to graze	F4, F6, F8, F9, F14, F15,

olale		F16, F18, F20, F24, F30
omwaiaia	Goat and sheep pen	F4, F7, F25, F26, F29, F35
ol-muaate	calf pen	
em-watata emuatata	Young goat shed	F6, F9, F13, F17, F20, F25, F30
	Young cattle/calf shed	F7, F9, F10, F11, F17, F18
	Chicken house /chicken coop	F28, F29, F31, F32, F34, F35
	kennel	F31
Other Grazing-related Areas		
Term	Explanation	Sketch ID
	pasture	F34
Agricultural Areas		
Term	Explanation	Sketch ID
Shambas	cultivated plots	F35
	farming land /farm	F11, F25, F34
em-paret	field – garden	
en-kurma	garden field	F31, F33
Land formations		
Term	Explanation	Sketch ID
endonyo nadosoito	red mountain - for grazing in wet period	
en-doinyo n-dónyío	hill	
ol-dóinyío	mountain	F1, F5, F6, F8, F9, F15, F16, F17, F18, F23
ol-keju orkeju	Small river, brook – river either permanent or seasonal	F3, F6, F8, F9, F11, F15, F16, F17, F18, F26
Esilante	Swamps /marshland	F15, F17, F18
Landmarks		
Term	Explanation	Sketch ID
ol-tanki *	Tank /water tank	F15, F19, F25, F30, F31, F33, F34, F35
	dam	F6, F15, F16, F25, F27?, F33, F35
mugumo tree	Tree species / meeting place	F25
Constructions other than homesteads and enclosures for animals		
Term	Explanation	Sketch ID
	kitchen	F10, F11, F26, F29, F30, F31, F33
	Shop/store	F10, F11, F28, F31, F32?
	office	F11
	Toilet /bathroom	F18, F26, F29, F30, F31, F33, F35
	Car parking	F33
o-sikul	School	F1, F3, F9, F11, F25

enyarta	Primary school	
	church	F3, F9, F11, F25
eng-oitoe-regie	Road	F3, F5, F8, F11, F18, F25, F31, F33, F35
	Tarmac road	F8
	small path foot path	F3, F8, F9, F3, F29
	Home road	F25
	Dust road used by neighbors	F34
ol-tanki*	tank water reservoirs /water tank	F10, F11, F12, F19, F25, F30, F31, F34, F35
	water base	F35
oltinga /oltinka ontinka	borehole – also common water point for watering animals (?) well	F3, F5, F6, F8, F9, F15, F17, F18, F22, F24
	Tap (?)	F16, F26, F27
	pipelines	F26
	Electricity cables	F35
	Beacons	F1, F2, F14, F15, F22
Vegetation		
Term	Explanation	Sketch ID
	forest	F3, F14, F15, F16, F17, F18, F21, F22, F23
	Tree / shady tree	F10, F19, F26, F29, F32
oiti	Tree – meeting point for women	F8, F9, F18, F20
oltepesi	Main tree – meeting point for men	F5, F8, F9, F12, F20
mugumo tree	Species of tree used as meeting place	F25
Oltim	dead tree set outside the enkang	F5, F7, F9, F20, F35
oltiki		F4
Ikiku inkiku	Small trees-branches kept inside enkang, used to close the main door at night	F7, F9, F20
Orkongil Entipiliwa orngosua	Medical trees	F12
Society		
Term	Explanation	Sketch ID
ol-morani moran ilmuran	warrior	F6
<i>Olkiyioi</i>	<i>Olkiyioi</i>	F6
Activities		
Term	Explanation	Sketch ID
	Washing cattle	F11

Ontologies

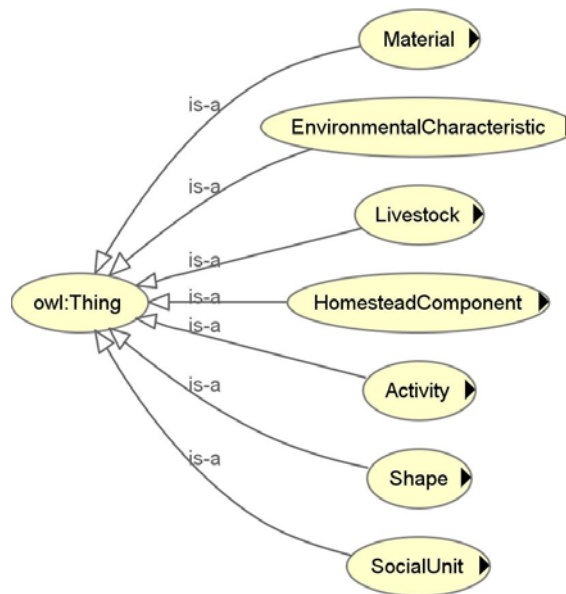
In an attempt to develop a system of land recording services, web of concepts related to the spatial features, structures, landscapes and social life of the Maasai communities, was developed. The entities and the relations between the entities of this web are described through the concept of Ontologies, with the Maasai society being the domain ontology.

For the web of ontologies, the used concepts were identified in the Maa language, literature and after direct contact with locals.

Ontologies are consisted of three main components, the Individuals (or instances), the Properties (binary relations among individuals) and the Classes (the concrete representations of concepts) [43].

A class hierarchy is developed always based on the needs of the study. Initially, were created seven main super classes (Figure 1), which were enriched as shown in the following figures.

Figure 9. Initial super-classes



The class “Environmental characteristics” is subdivided in three subclasses “Climatic characteristics”, “Land characteristics” and “Vegetation characteristics” (**Figure 2**), each of which has a number of subclasses as well (**Figure 3**). The climate is an important concept since social behavior and activity of the Maasai is based on it [20]. The vegetation capital and the characteristics of the land provide significant spatial information about Maasai communities and land tenure as well.

Figure 10. Super-class “Environmental Characteristics” and its three subclasses



Figure 11. Sub-class “Vegetation Characteristics” and its subclasses

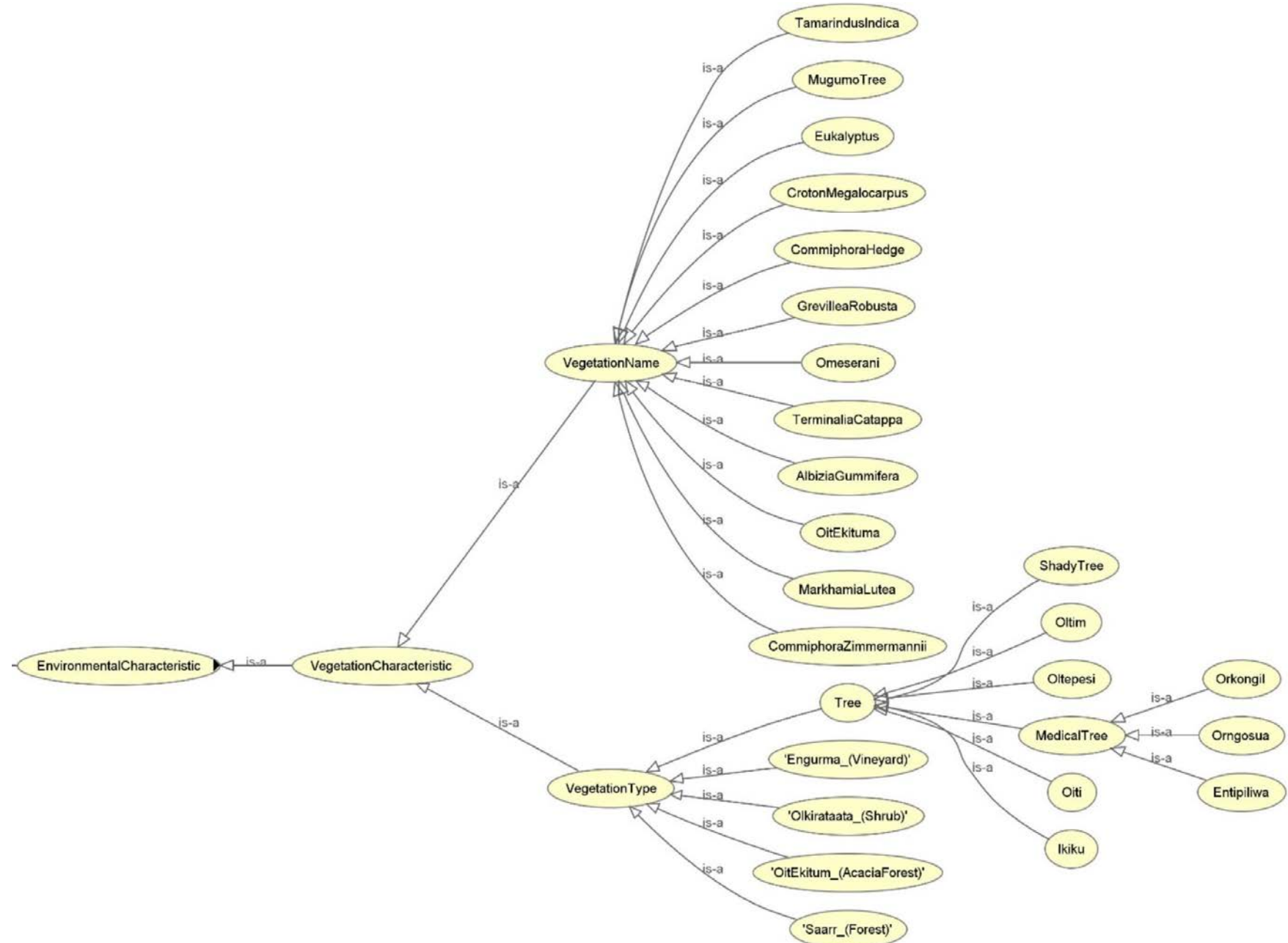


Figure 12 . Sub-class “Land Characteristics” and its subclasses.

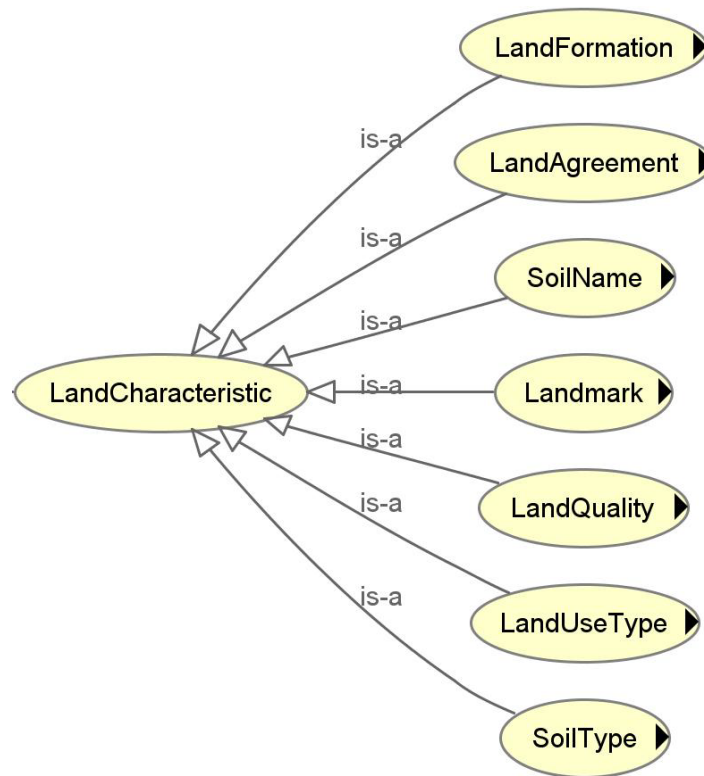


Figure 13. Sub-class “Land Formation” and its subclasses.

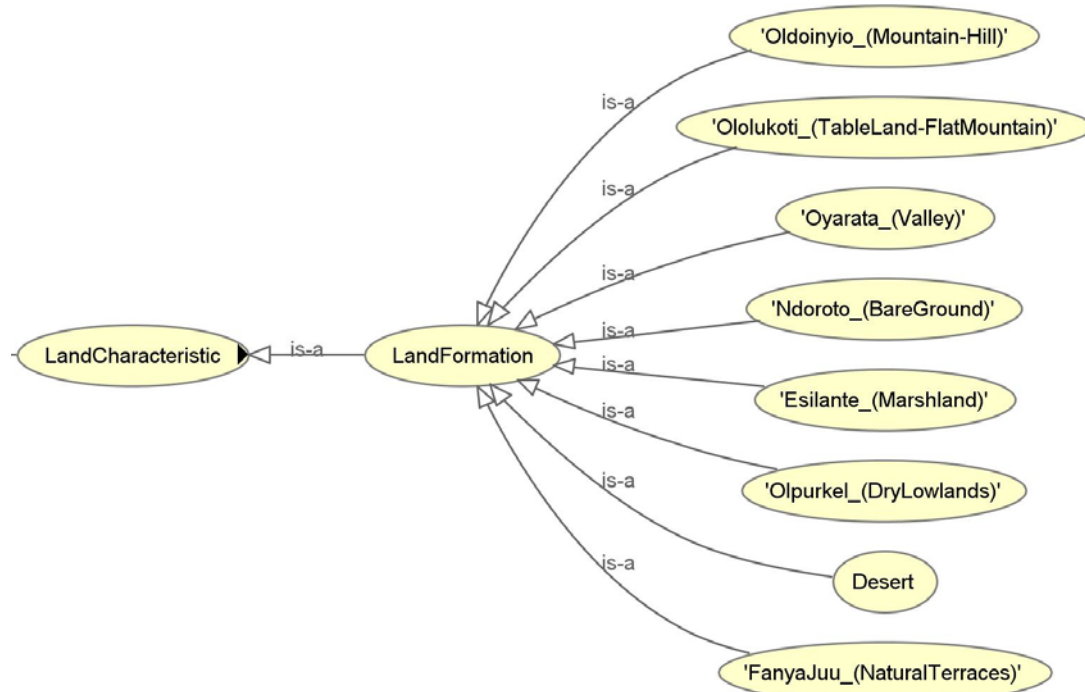


Figure 14. Sub-class “Land Agreement” and its subclasses.

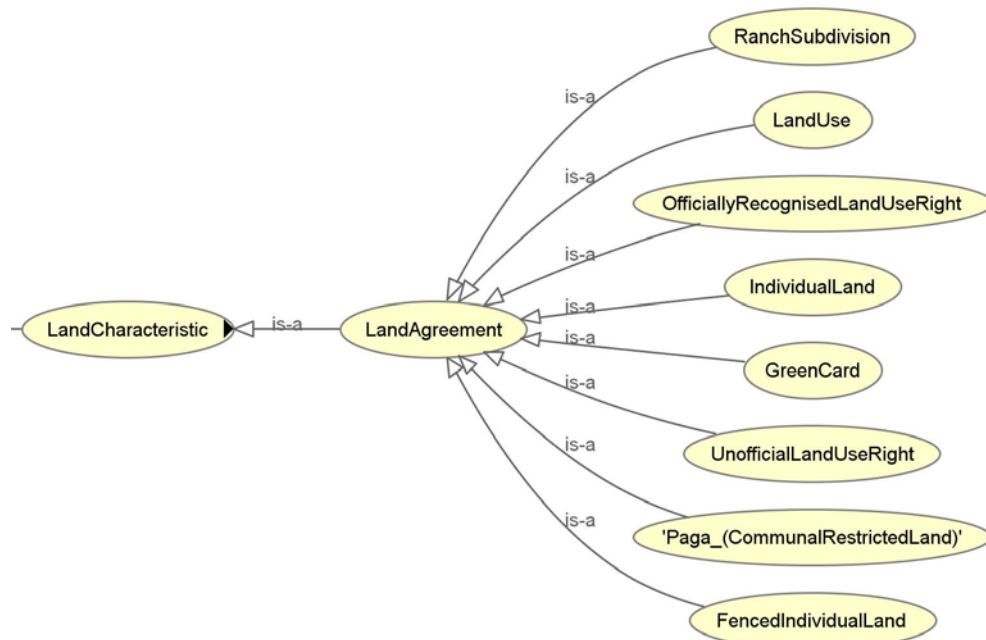


Figure 15. Sub-class “Landmark” and its subclasses.



Figure 16. Sub-class “Land Quality” and its subclasses.

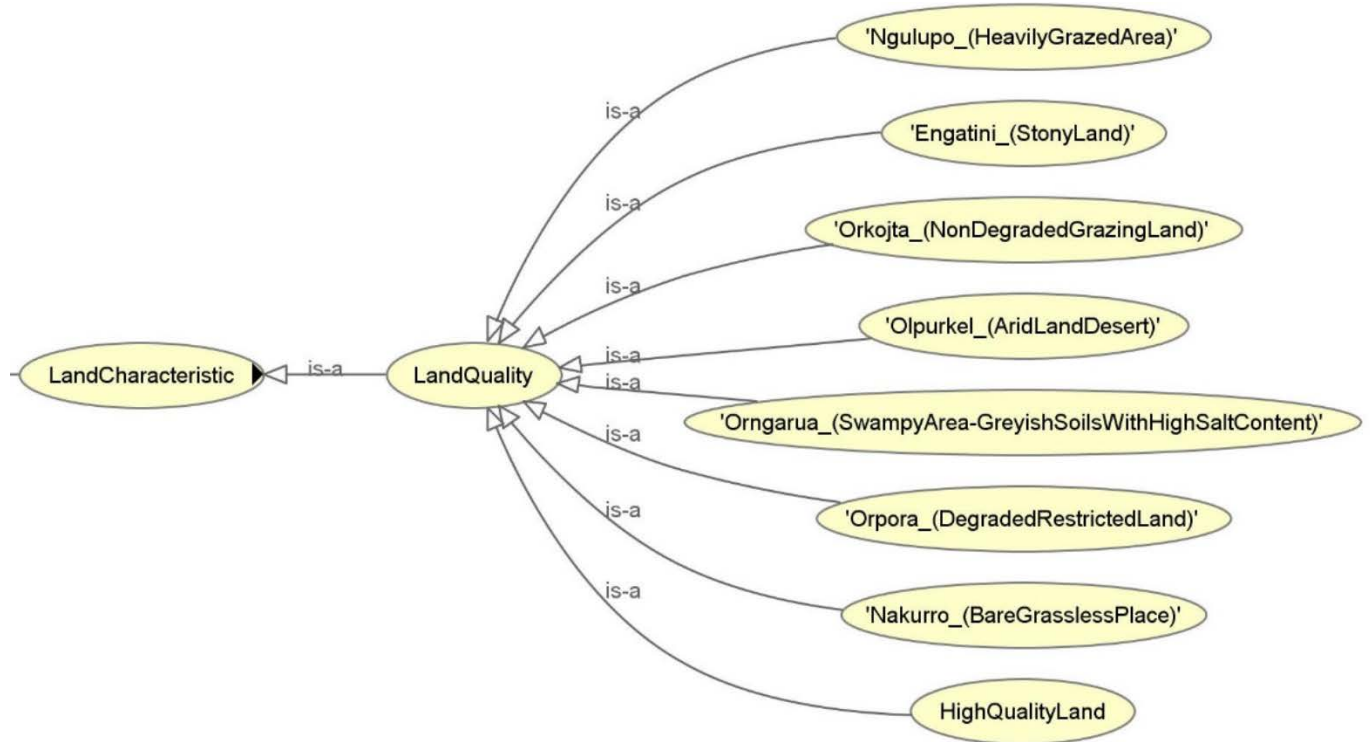


Figure 17. Sub-class “Soil Name” and its subclasses.

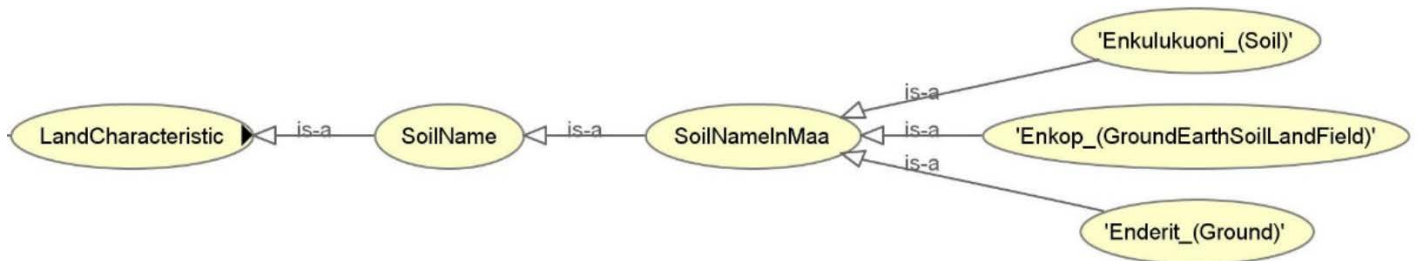


Figure 18. Sub-class “Soil Type” and its subclasses.

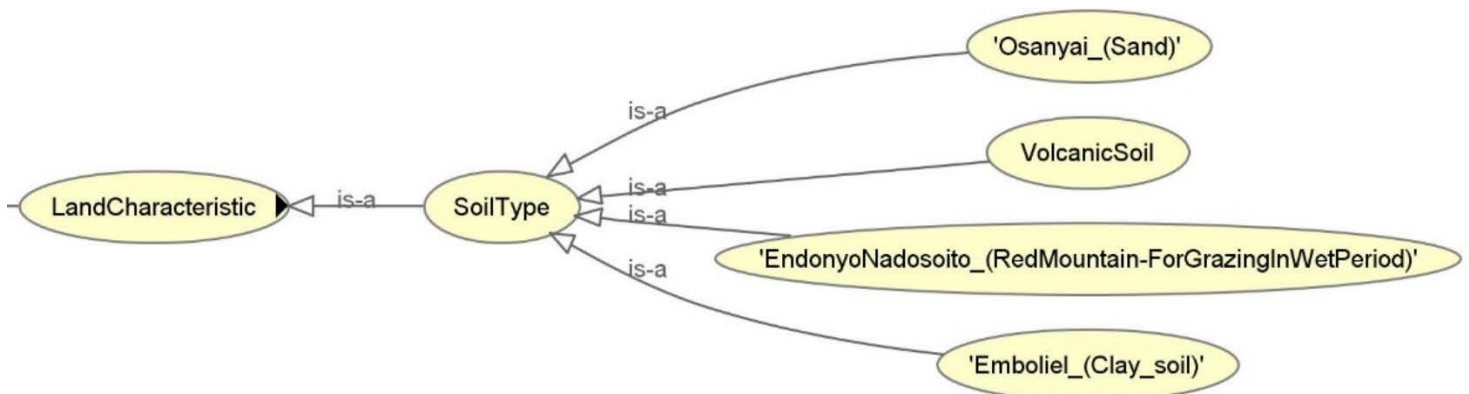


Figure 19. Sub-class “Land Use Type” and its subclasses.

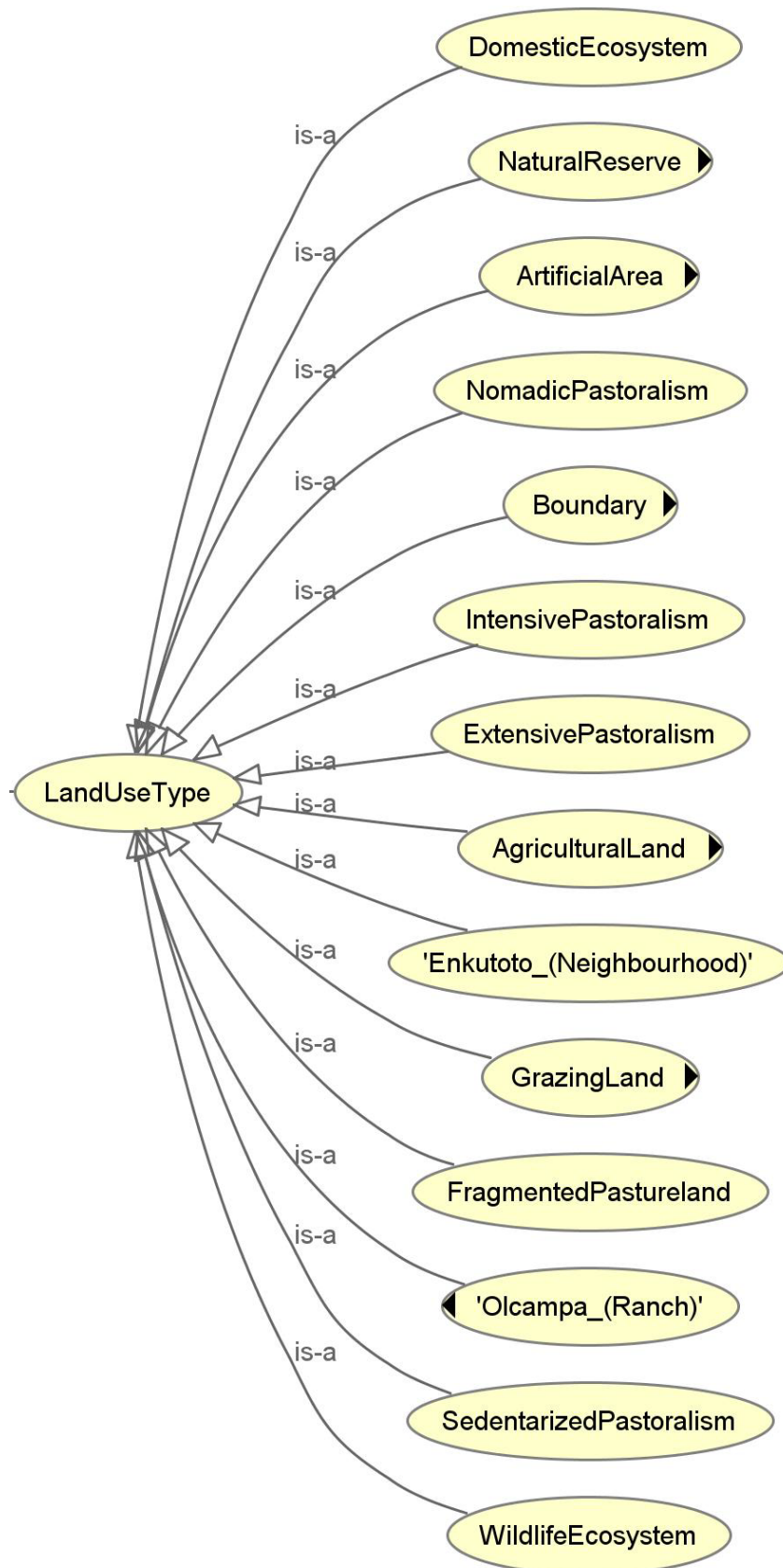


Figure 20. Sub-class “Agricultural Land” and its subclasses.

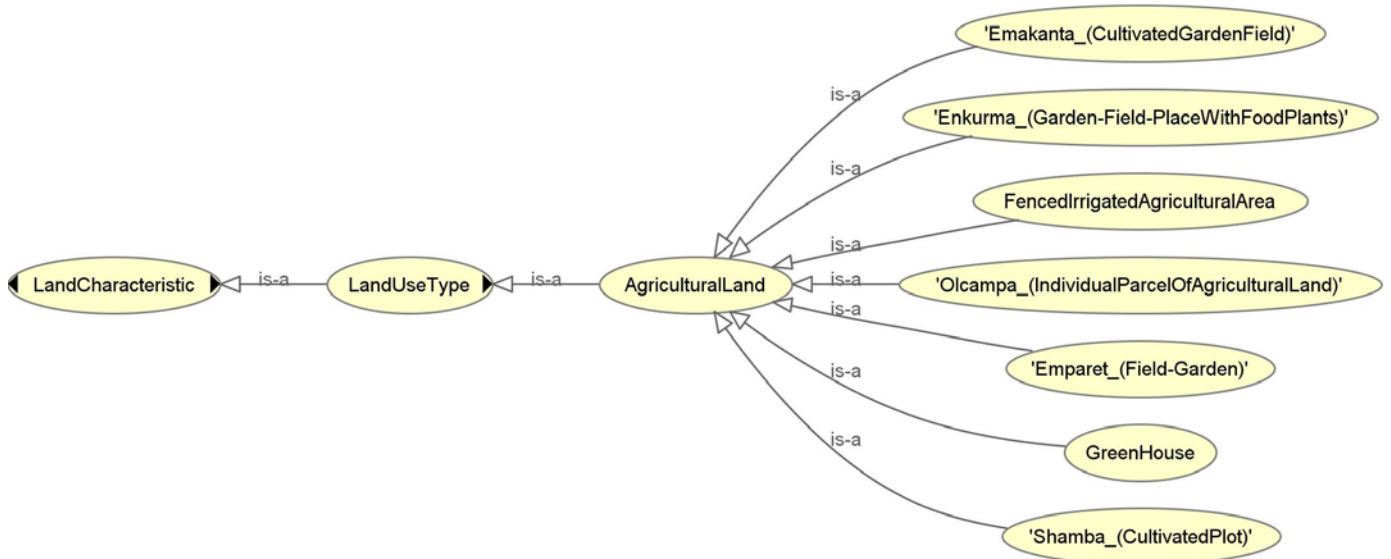


Figure 21. Sub-class “Boundary” and its subclasses.



Figure 22. Sub-class “Natural Reserve” and its subclasses.

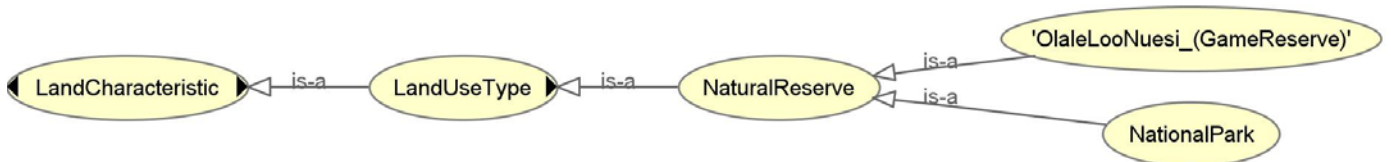


Figure 23. Sub-class “Grazing Land” and its subclasses.

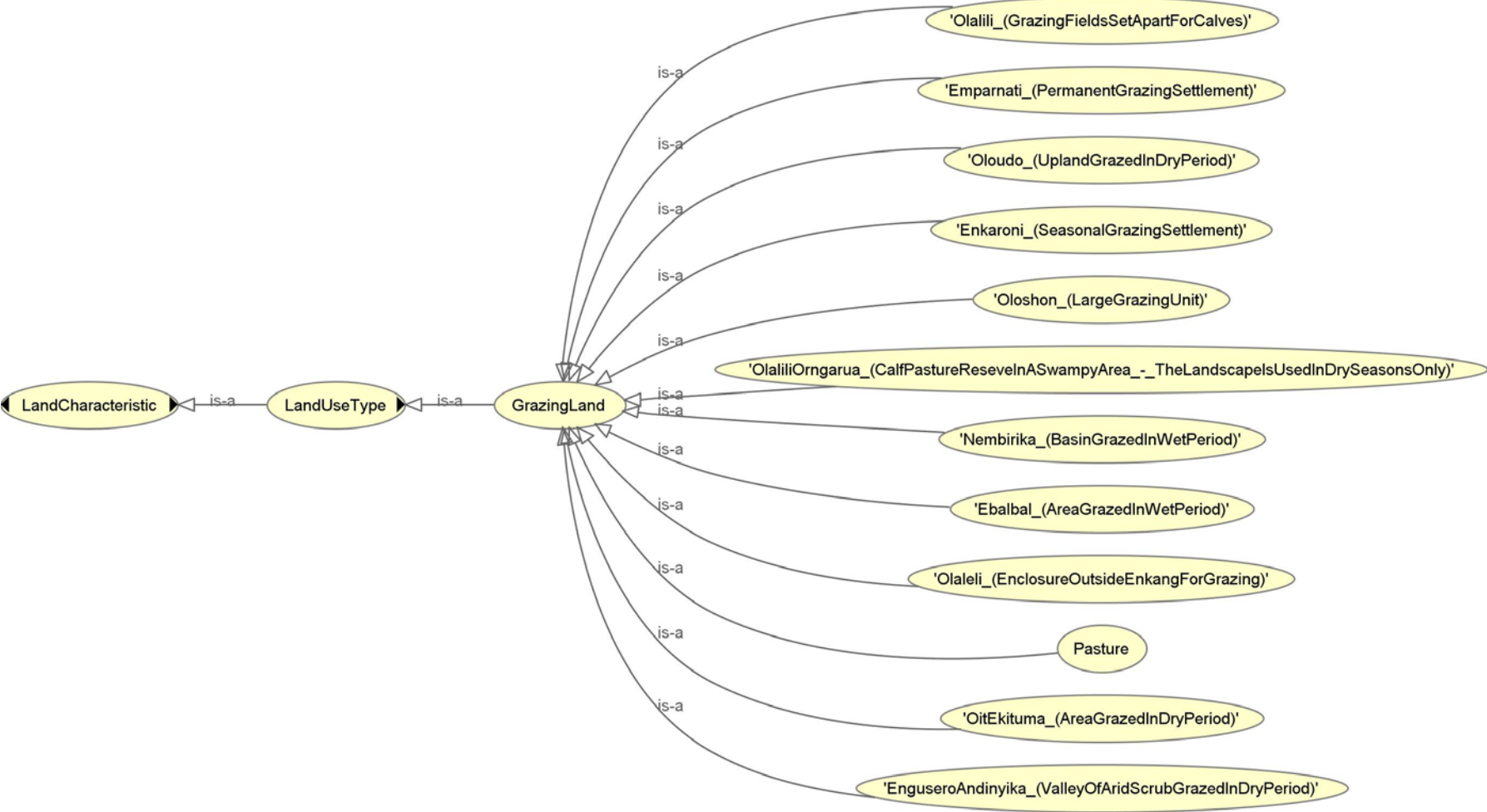


Figure 24. Sub-class “Artificial Land” and its subclasses.

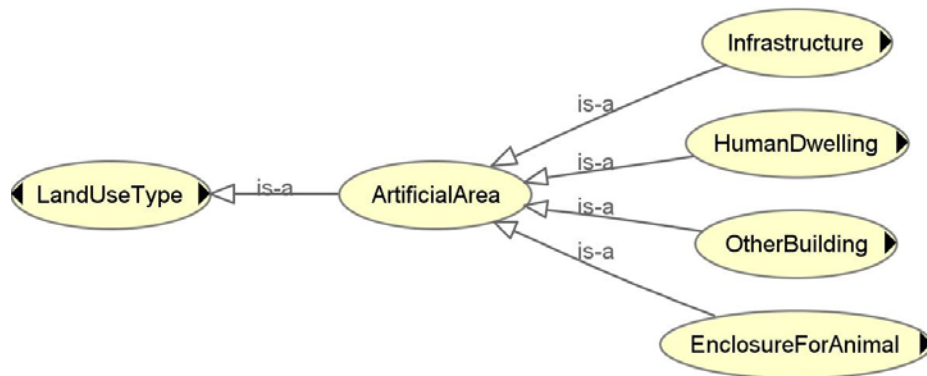


Figure 25. Sub-class “Human Dwelling” and its subclasses.

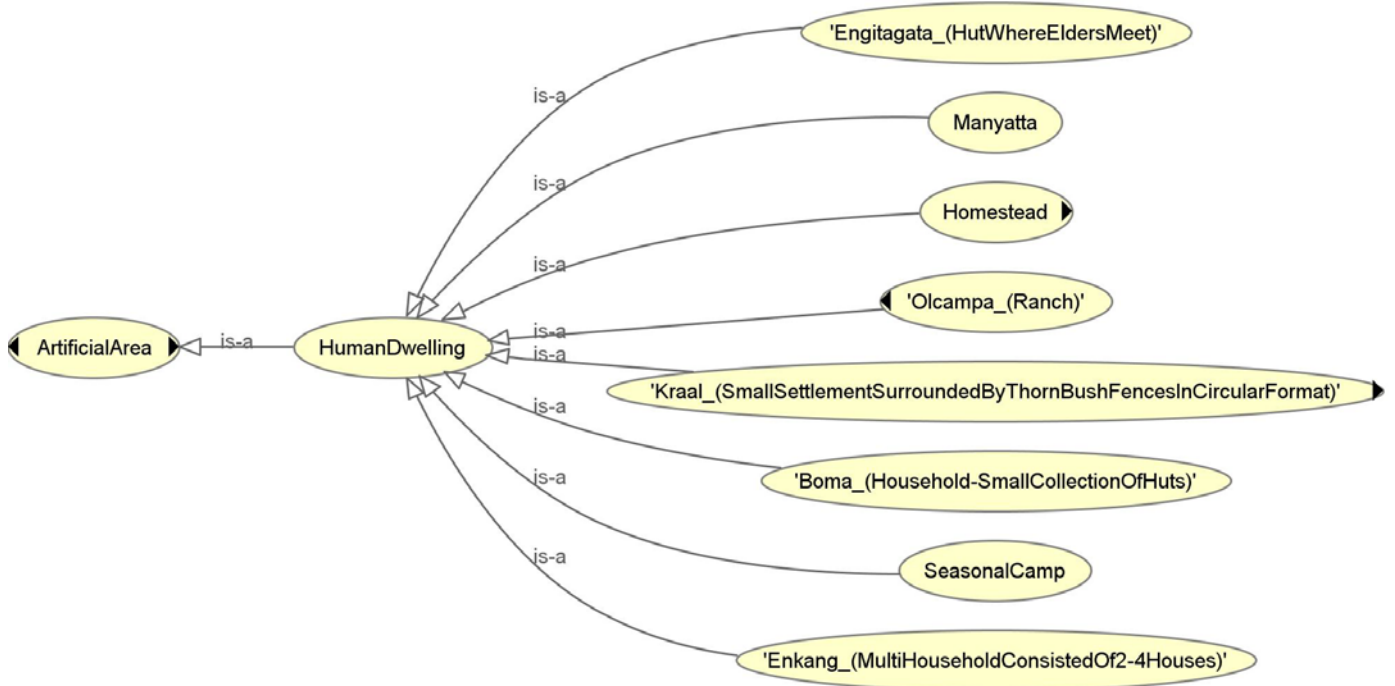


Figure 26. Sub-class “Kraal” and its subclasses.

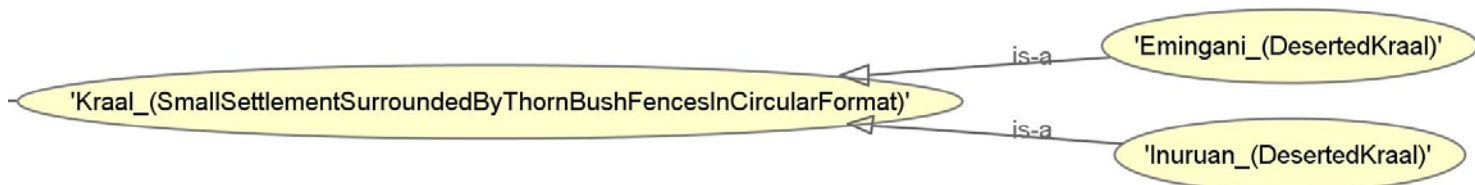


Figure 27. Sub-class “Homestead” and its subclasses.



Figure 28. Sub-class “Enclosure for Animals” and its subclasses.

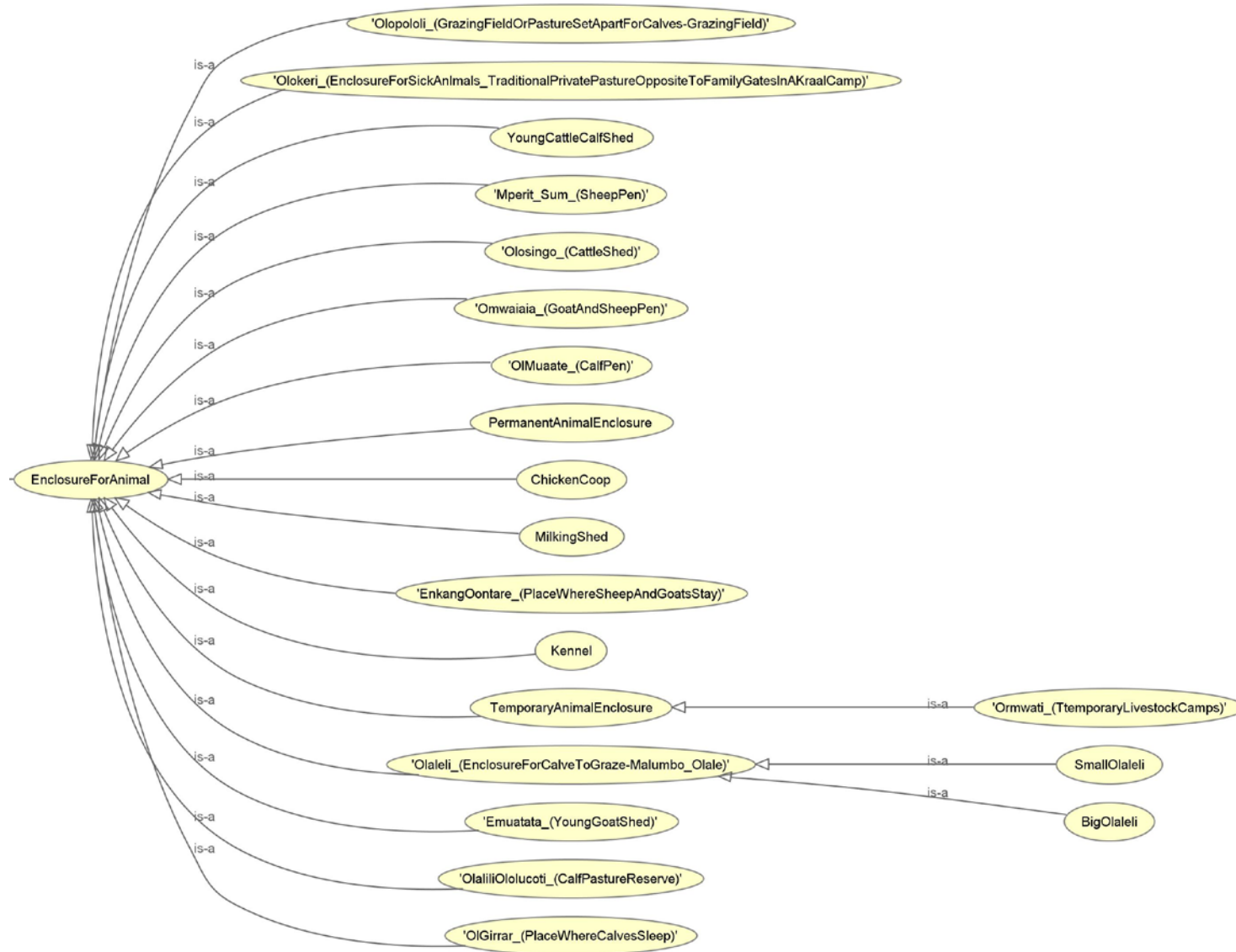


Figure 29. Sub-class “Infrastructure” and its subclasses.

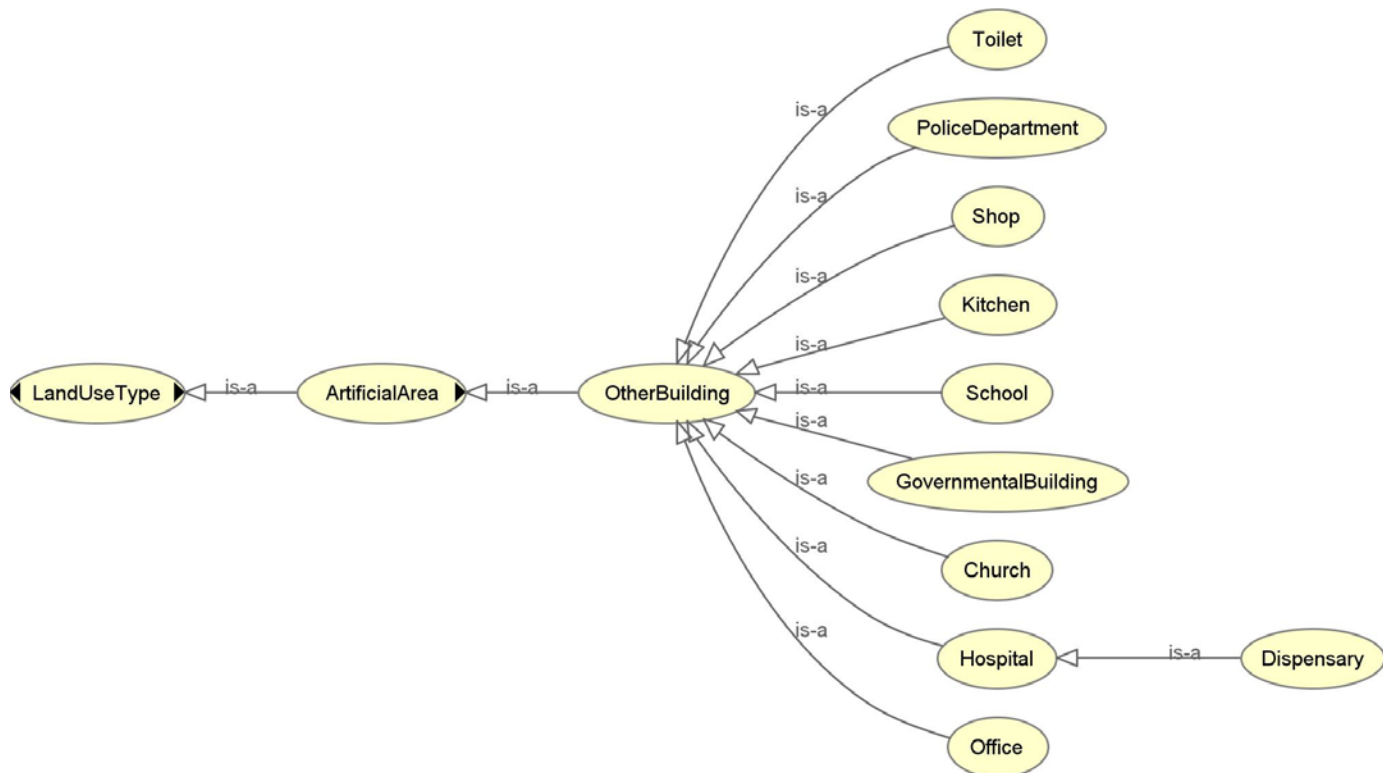
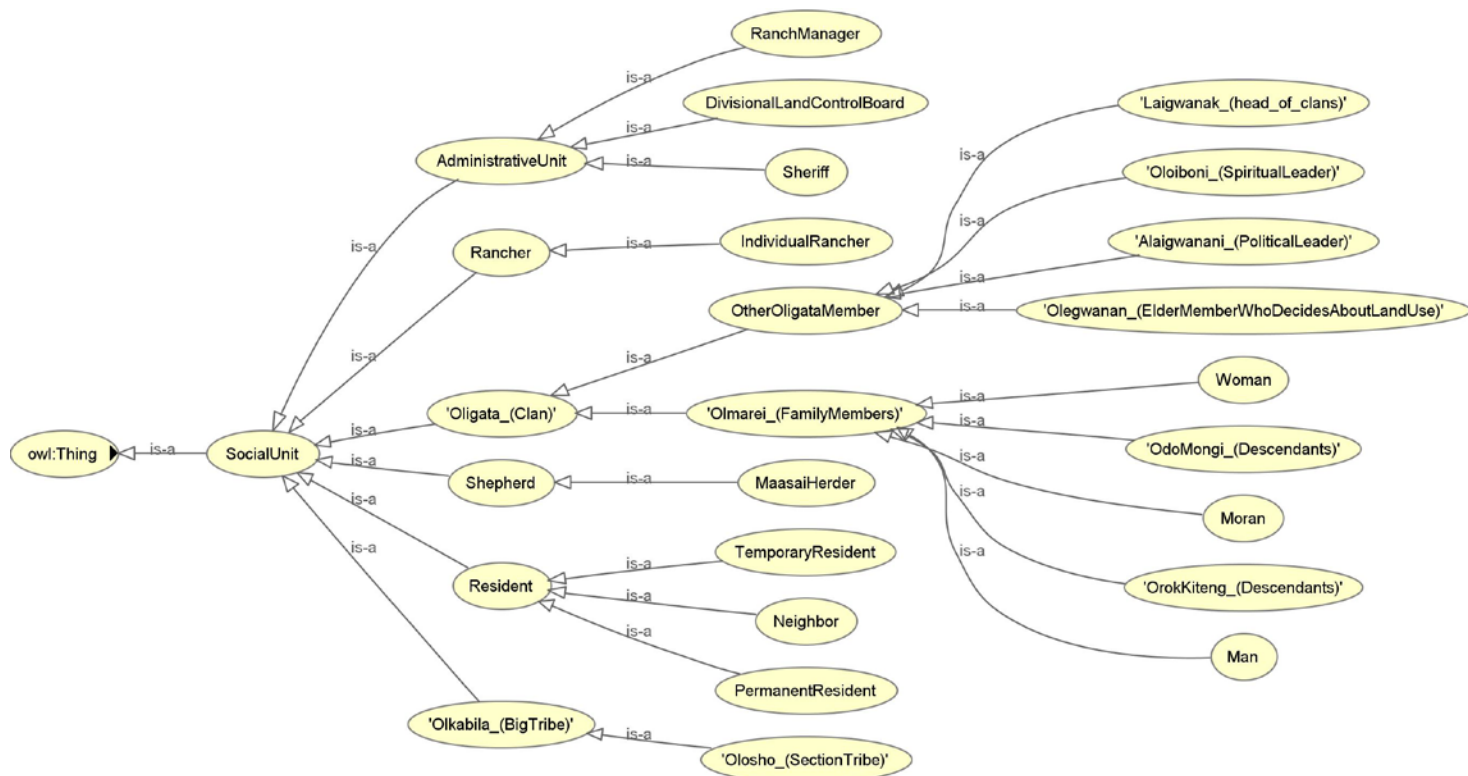
Figure 30. Sub-class “Other Building” and its subclasses.**Figure 31.** Sub-class “Social Unit” and its subclasses.

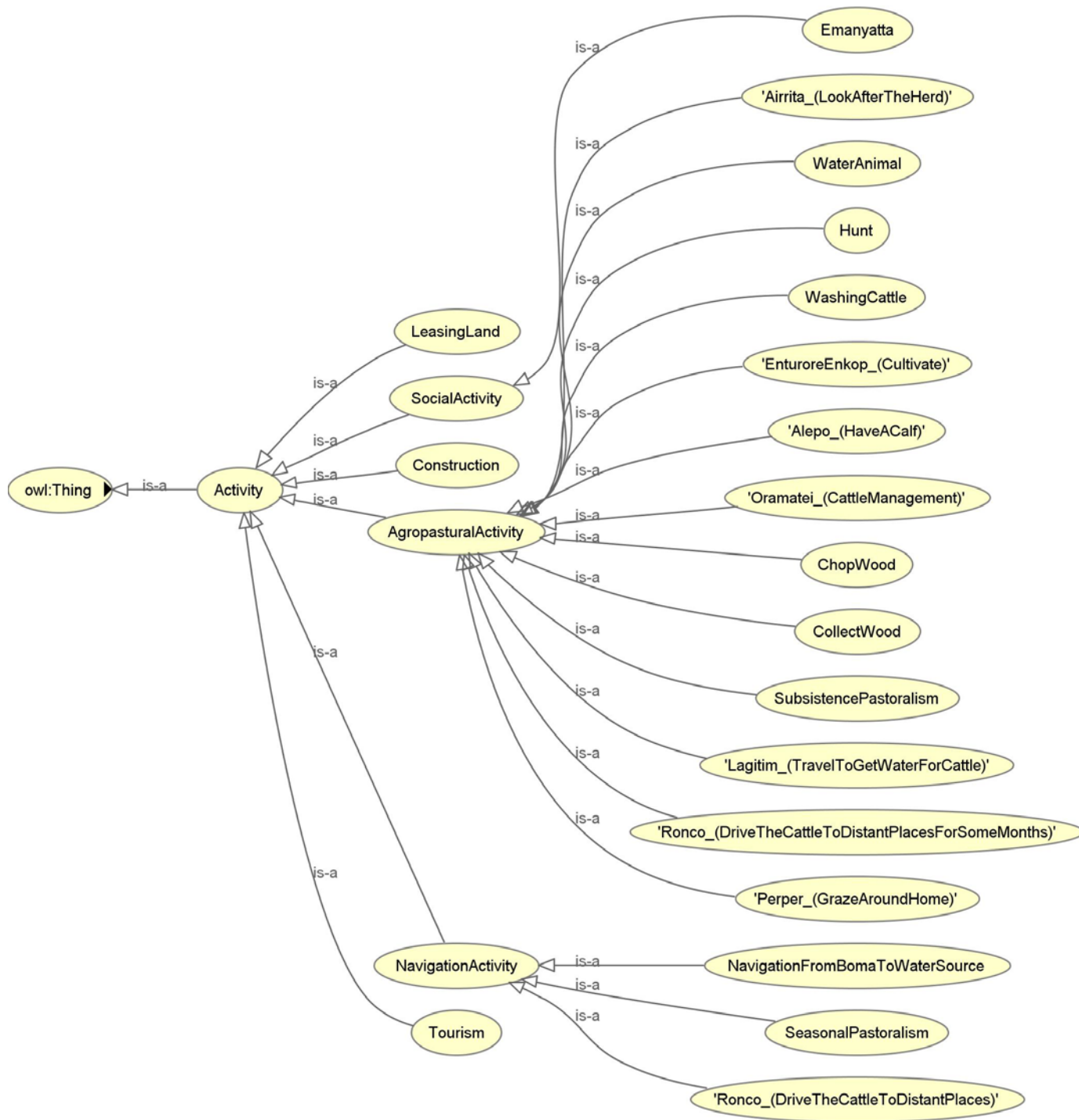
Figure 32. Sub-class “Activity” and its subclasses.

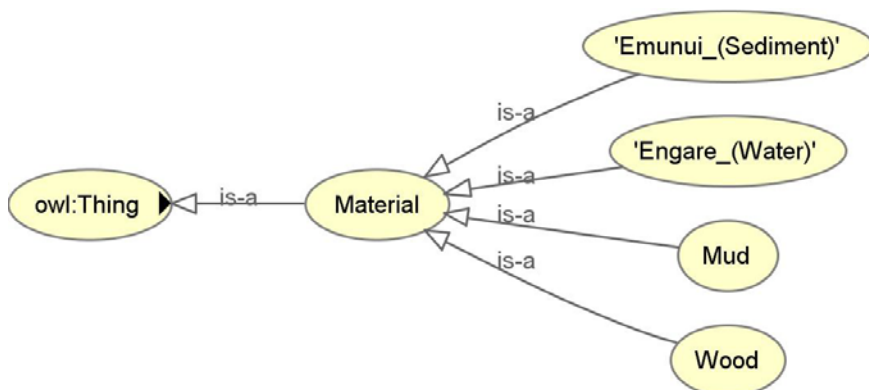
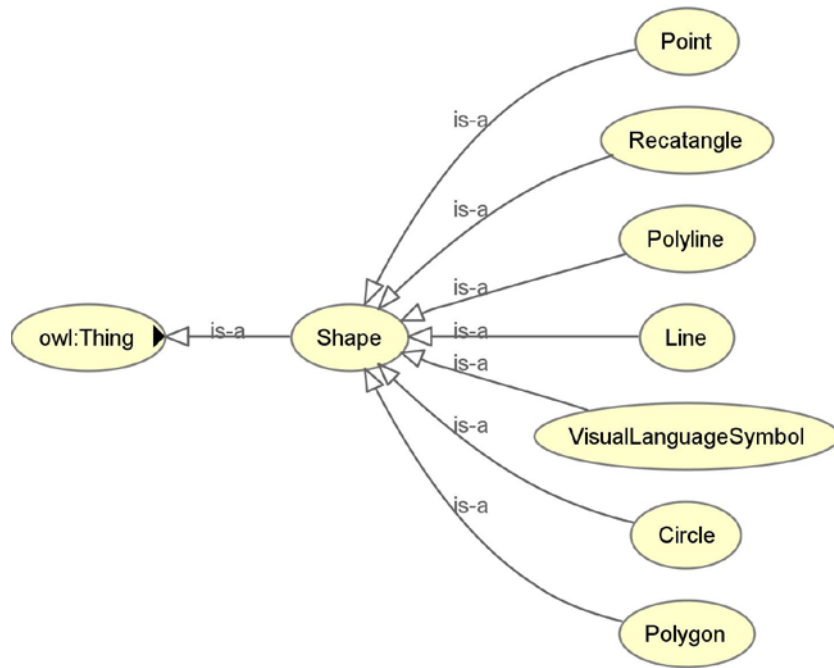
Figure 33. Sub-class “Homestead Component” and its subclasses.**Figure 34.** Sub-class “Material” and its subclasses.

Figure 35. Sub-class “Shape” and its subclasses.

References

1. Lacasta, J., J. Nogueras-Iso, R. Béjar, P.R. Muro-Medrano, and F.J. Zarazaga-Soria, *A Web Ontology Service to facilitate interoperability within a Spatial Data Infrastructure: Applicability to discovery*. Data & Knowledge Engineering, 2007. **63**(3): p. 947-971.
2. Payne, D.L. and L. Ole-Kotikash, *Maa Dictionary*. 2008, Maasai (IlKeekonyokie, IlPurko, IlWuasinkishu) and Samburu. <http://www.uoregon.edu/~maasai/Maa%20Lexicon/index-english/main.htm> [A web-site of Maasai language].
3. Richmond, C., *Maasai Dictionary*. 2016, Archives & Reprint Series (imprint). 2. <http://digitalcommons.humboldt.edu/reprint/2>.
4. Coast, E., *Maasai socioeconomic conditions: a cross-border comparison*. Human ecology, 2002. **30**(1): p. 79-105.
5. Miller, B.W., P.W. Leslie, and J.T. McCabe, *Coping with natural hazards in a conservation context: resource-use decisions of maasai households during recent and historical droughts*. Human ecology: an interdisciplinary journal, 2014. **42**(5): p. 753.
6. Galaty, J.G., *Land and Livestock among Kenyan Masai: Symbolic Perspectives on Pastoral Exchange, Change and Inequality*. Journal of Asian and African Studies, 1981. **16**(1): p. 68.
7. Wangui, E.E., *Development interventions, changing livelihoods, and the making of female Maasai pastoralists*. Agriculture and Human Values, 2008. **25**(3): p. 365-378.
8. Bekure, S., *Maasai herding: an analysis of the livestock production system of Maasai pastoralists in eastern Kajiado District, Kenya*. Vol. 4. 1991: ILRI (aka ILCA and ILRAD).
9. Knowles, J.N., *Power, influence and the political process among Iloitai Maasai*. 1993, Durham University.
10. Galvin, K.A., R.S. Reid, R. Behnke, and N.T. Hobbs, *Fragmentation in semi-arid and arid landscapes. Consequences for Human and Natural Systems*. Dordrecht, The Neth.: Springer, 2008.
11. Fratkin, E., *East African pastoralism in transition: Maasai, Boran, and Rendille cases*. African Studies Review, 2001. **44**(3): p. 1-25.
12. Mwangi, E., *The transformation of property rights in Kenya's Maasailand: Triggers and motivations*. 2005: CGIAR Systemwide Program on Collective Action and Property Rights, International Food Policy Research Institute.
13. Kimani, K. and J. Pickard, *Recent trends and implications of group ranch sub-division and fragmentation in Kajiado District, Kenya*. Geographical Journal, 1998: p. 202-213.
14. Butt, B., *Herding by Mobile Phone: Technology, Social Networks and the "Transformation" of Pastoral Herding in East Africa*. Human Ecology, 2015. **43**(1): p. 1.
15. Jandreau, C. and F. Berkes, *Continuity and change within the social-ecological and political landscape of the Maasai Mara, Kenya*. Pastoralism, 2016. **6**(1): p. 1.
16. Butt, B., *Commoditizing the safari and making space for conflict: Place, identity and parks in East Africa*. Political Geography, 2012. **31**(2): p. 104-113.
17. Butt, B., *Coping with uncertainty and variability: The influence of protected areas on pastoral herding strategies in East Africa*. Human Ecology, 2011. **39**(3): p. 289-307.
18. Butt, B., *Seasonal space-time dynamics of cattle behavior and mobility among Maasai pastoralists in semi-arid Kenya*. Journal of Arid Environments, 2010. **74**(3): p. 403-413.
19. Jonsson, H., *Foraging behaviour of cattle, sheep and goats on semi-arid pastures in Kenya*. 2011.
20. Butt, B., A. Shortridge, and A.M. WinklerPrins, *Pastoral herd management, drought coping strategies, and cattle mobility in southern Kenya*. Annals of the Association of American Geographers, 2009. **99**(2): p. 309-334.
21. Bulte, E., R. Boone, R. Stringer, and P. Thornton, *Wildlife conservation in Amboseli, Kenya: Paying for nonuse values*. 2006.
22. Wade, C., *Strengthening Food Security in Africa: A Case for Supporting Pastoralism in East Africa*, 2016.
23. Hazzah, L., S. Dolrenry, D. Kaplan, and L. Frank, *The influence of park access during drought on attitudes toward wildlife and lion killing behaviour in Maasailand, Kenya*. Environmental conservation, 2013. **40**(3): p. 266-276.
24. Kibet, S., M. Nyangito, L. MacOpiyo, and D. Kenfack, *Tracing innovation pathways in the management of natural and social capital on Laikipia Maasai Group Ranches, Kenya*. Pastoralism, 2016. **6**(1): p. 16.

25. Raizman, E., H.B. Rasmussen, L. King, F. Ihwagi, and I. Douglas-Hamilton, *Feasibility study on the spatial and temporal movement of Samburu's cattle and wildlife in Kenya using GPS radio-tracking, remote sensing and GIS*. Preventive veterinary medicine, 2013. **111**(1): p. 76-80.
26. Butt, B., *Pastoral resource access and utilization: quantifying the spatial and temporal relationships between livestock mobility, density and biomass availability in southern Kenya*. Land Degradation & Development, 2010. **21**(6): p. 520-539.
27. Schrepfer, N. and M. Caterina, *On the margin: Kenya's pastoralists*. From displacement to solutions, a conceptual study on the internal displacement of pastoralists. Internal Displacement Monitoring Centre Norwegian Refugee Council, 2014.
28. Lamprey, R.H. and R.S. Reid, *Expansion of human settlement in Kenya's Maasai Mara: what future for pastoralism and wildlife?* Journal of Biogeography, 2004. **31**(6): p. 997-1032.
29. Kiringe, J.W., *A survey of traditional health remedies used by the Maasai of Southern Kajiado District, Kenya*. Ethnobotany Research and applications, 2006. **4**: p. 061-074.
30. Rutten, M.M.E.M., *Selling wealth to buy poverty: the process of the individualization of landownership among the Maasai pastoralists of Kajiado district, Kenya, 1890-1990*. 1992: Saarbrücken [etc.]: Breitenbach.
31. BurnSilver, S.B., J. Worden, and R.B. Boone, *Processes of fragmentation in the Amboseli ecosystem, southern Kajiado District, Kenya*, in *Fragmentation in semi-arid and arid landscapes*. 2008, Springer. p. 225-253.
32. Campbell, D.J., D.P. Lusch, T.A. Smucker, and E.E. Wangui, *Multiple methods in the study of driving forces of land use and land cover change: a case study of SE Kajiado District, Kenya*. Human Ecology, 2005. **33**(6): p. 763-794.
33. Raini, J.A., *Impact of land use changes on water resources and biodiversity of Lake Nakuru catchment basin, Kenya*. African Journal of Ecology, 2009. **47**(s1): p. 39-45.
34. Mondiale, B., *Principles for Responsible Agricultural Investment that Respects Rights, Livelihoods and Resources*. 2010, Washington, DC: Banque Mondiale.
35. Abbink, J., K. Askew, D.F. Dori, E. Fratkin, E.C. Gabbert, J. Galaty, S. LaTosky, J. Lydall, H.A. Mahmoud, and J. Markakis, *Lands of the future: transforming pastoral lands and livelihoods in eastern Africa*. 2014.
36. Nyariki, D., *Land-use change and livestock production challenges in an integrated system: the Masai-Mara ecosystem, Kenya*. 2009.
37. McClain, M.E., *Balancing water resources development and environmental sustainability in Africa: a review of recent research findings and applications*. Ambio, 2013. **42**(5): p. 549.
38. Maloiy, G.M. and H.F. Heady, *Grazing conditions in Kenya Masailand*. Journal of Range Management, 1965: p. 269-272.
39. Seno, S.K. and W. Shaw, *Land tenure policies, Maasai traditions, and wildlife conservation in Kenya*. Society & Natural Resources, 2002. **15**(1): p. 79-88.
40. Oba, G. and L. Kaitira, *Herder knowledge of landscape assessments in arid rangelands in northern Tanzania*. Journal of Arid Environments, 2006. **66**(1): p. 168-186.
41. Tengnäs, B., *Agroforestry extension manual for Kenya*. 1994: World Agroforestry Centre.
42. Shahack-Gross, R., F. Marshall, K. Ryan, and S. Weiner, *Reconstruction of spatial organization in abandoned Maasai settlements: implications for site structure in the Pastoral Neolithic of East Africa*. Journal of Archaeological Science, 2004. **31**(10): p. 1395-1411.
43. Horridge, M., S. Jupp, G. Moulton, A. Rector, R. Stevens, and C. Wroe, *A practical guide to building owl ontologies using protégé 4 and co-ode tools edition 1. 2*. The university of Manchester, 2009. **107**.