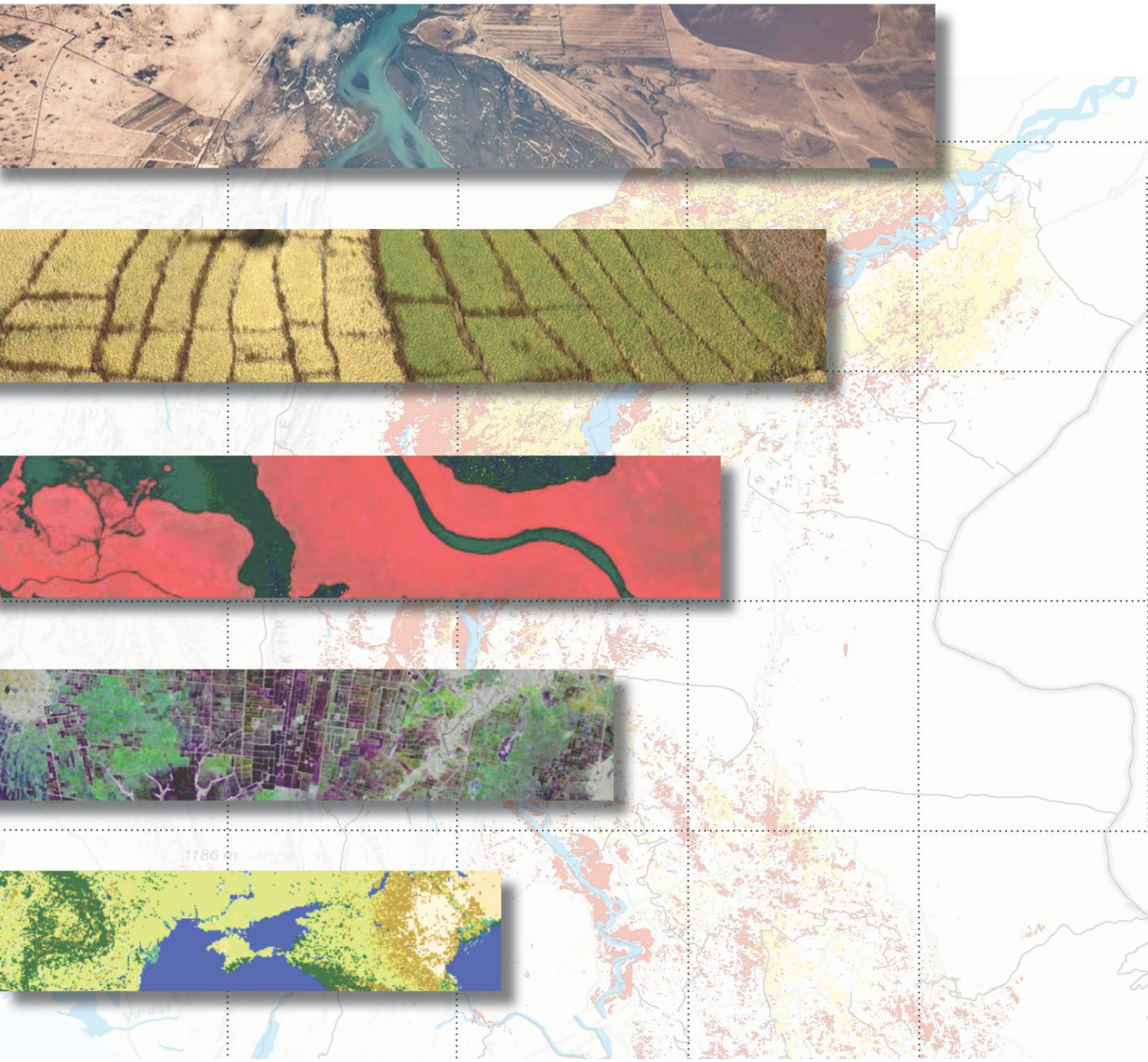
Food and Agriculture Organization of the United Nations

Geographic information — Classification systems: Land Use Meta Language (LUML)

Part 3: ISO 19144-3:2024 (Edition 1)



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Part 3: ISO 19144-3:2024 (Edition 1)

Food and Agriculture Organization of the United Nations
Rome, 2025

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Foreword

Since 2003, the Food and Agriculture Organization of the United Nations (FAO) and the International Organization for Standardization (ISO) have built a strong and strategic partnership aimed at addressing the critical need for standardized approaches to land cover and land use. This collaboration has been a key enabler of global efforts to harmonize geospatial information and contribute to the consistency of land cover and land use data across countries and regions.

Recognizing that land is an essential component of achieving the Sustainable Development Goals (SDGs), FAO and ISO have been working on the ISO 19144 series of standards. The series provides a flexible and robust foundation for defining the structure of geographic classification systems, establishing meta languages to describe land cover and land use features, and defining a registration system and its implementation aspects.

This collaboration is grounded in practical experience, the fast-paced development of the geographic information sector, and the changing needs of countries. It ensures that the resulting standards are scientifically robust, adaptable, and practical for real-world applications. Incorporating these standards into land monitoring efforts – such as national systems – empowers users to manage land resources more sustainably, effectively and accurately. Moreover, it enhances the ability to meet international reporting needs and obligations, including those under global frameworks like the Rio Conventions, the Paris Agreement, the Sendai Framework for Disaster Risk Reduction 2015–2030, and the 2030 Agenda for Sustainable Development.

The ISO 19144-3 – land use meta language (LUML) was prepared jointly by FAO, Technical Committee of ISO i.e., Technical Committee 211 (TC211) on Geographic information/Geomatics, and European Committee for Standardization (CEN) Technical Committee CEN/TC 287.

FAO acknowledges with deep appreciation the exceptional permission granted by ISO to continue republishing the current editions of the ISO 19144 series as FAO publications. This unique arrangement underscores the spirit of mutual trust and collaboration between the two organizations, ensuring wider and equitable access to these essential standards by Member Nations, technical partners and practitioners around the world.

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Acknowledgements

We gratefully acknowledge the longstanding collaboration between the Food and Agriculture Organization of the United Nations (FAO) and the International Organization for Standardization (ISO), particularly through ISO Technical Committee 211, in advancing international standards for land cover and land use classification.

This partnership has been instrumental in the development and promotion of ISO 19144 series 'Geographic information — Classification systems'. These standards have significantly enhanced consistency, interoperability, and utility of geospatial data across national and international initiatives.

We extend our appreciation to the FAO and ISO experts who contributed to the development of these standards, with special recognition to **Antonio Di Gregorio** for his pioneering work in conceptualizing and developing the Land Cover Meta Language (LCML) - ISO 19144-2 standard and Land Use Meta Language (LUML) - ISO 19144-3 standard and to **C Douglas O'Brien** for his leadership in land cover land use classification and sustained contributions to the ISO 19144 series. Their expertise and dedication have been central to bridging operational needs with standardization efforts, enabling broader adoption and practical application of these frameworks worldwide.

We also acknowledge the work of **Matieu Henry** as Convenor of ISO TC211 Advisory Group 13 on land cover and land use and **Fatima Mushtaq,** Land Cover Monitoring Specialist at FAO, for their role in facilitating this publication process.

Special thanks to **John Latham** for his role as project lead of the ISO 19144 series, providing guidance throughout the development of these standards.

Introduction

There is a tremendous diversity in how people establish a built infrastructure on land or over water, or otherwise make use of the surface of the earth. This diversity in use also means that there is a great diversity in how Land Use is described. Land Use data (even more so than Land Cover) are closely linked to national and regional customs, legislation, or economic factors, and are therefore necessarily quite different from one country or region to another. Within one country or region there can also be different Land Use classifications in operation, serving different administrative and management purposes. It is not meaningful to try to standardize this multitude of classifications, but it is meaningful to develop a meta-language that can assist in the comparison of systems, assist translation between the systems and help international and other organizations when they need to extract comparable data from many different data sources.

The aim of this document is to enable the comparison of information from existing classification systems in a meaningful way without replacing them. The aim is to complement the development of future classification systems that can offer more reliable collection methods for particular national or regional purposes by allowing them to be described in a consistent manner.

A critical factor in implementing such global activities is the availability of a common, umbrella Land Use classification system structure. This then provides a reliable basis for interaction without replacing the increasing number of national, regional and global Land Use mapping and monitoring activities. This enables comparisons of Land Use classes to be made regardless of mapping scale, Land Use type, data collection method or geographic location.

This document provides a metalanguage expressed as a UML model that allows different Land Use classification systems to be described. This document establishes a metalanguage for a set of objects and rules (language) to describe Land Use features that can be part of different Land Use legends (nomenclature). This provides a framework for comparing different systems and nomenclatures. This document is not a description of a nomenclature nor is it a description of a specific set of classes.

The design concepts are described as follows.

— A classification process deals with the structuring of a specific knowledge domain in order to create consistency, stability and common understanding in communication between the users, therefore its main function is the capability to be a valid reference system for a larger community of users.

— However, a classification is a dynamic process. Definitions can change over time and in relation to the prevalence of other cultures, evolving user needs and new scientific advances.

— No classification system can fully reflect either the social or the natural world completely accurately.

— There are always multiple ways to conceptualize and communicate knowledge, thus there can be an inherent ambiguity in any categorization.

— The way to create consistency in this complex and dynamic domain is the establishment of a metalanguage that defines the framework of elements and rules with which any user can define their own specific ontology.

— The system needs to be documented through a rigorous definition of a generative grammar explicated using a graphic modelling language (UML class diagram).

The metalanguage needs to ensure migration from “human language” to a “machine representation” of the “elements, rules and conditions” with which a particular category (or set of categories) has been generated.

Additional parts of the ISO 19144 series are defined to describe the classification of other aspects of the environment, such as Land Cover (ISO 19144-2). These other parts appear in separate documents, but may be

used in conjunction with classifications systems described using the Land Use Meta-Language specified in this document.

There is a requirement for registration of some characteristics and code lists to be used with the classes in this metalanguage and in any instantiation of this metalanguage. Registration is also desirable for a set of instantiated schemas that correspond to the many existing Land Use classification systems in broad use. A section on registration existed in the previous edition of ISO 19144-2:2012. This content has now been separated into another part of the series, in order to generalize the registration process, allowing it to support Land Use as well as Land Cover and any other future parts of the ISO 19144 series. In addition, this new part on registration will also address implementation issues.

The present document (ISO/TS 19144-3) is a new part of the ISO 19144 series. Some of the content of this document addressing Land Use was originally contained in ISO 19144-2:2012. The description of these Land Use elements has been moved to this document. In addition, there have been changes to the classes LC_GrowthFormCharacteristic, LC_CultivatedAndManagedVegetation, and LC_BuiltUpSurfaces to clarify the differences between Land Cover and Land Use. Details relating to backward compatibility are described in Annex C.

There is a need amongst some users of this document for an expression of Land Cover and or Land Use information in XML, as well as a need for an XML Schema (XSD). This document describes a reference metamodel for the description and comparison of classification systems. Any classification system described using this metamodel is not implicitly an ISO standardized classification system. An XML expression of this document is an XML expression of a metamodel and therefore such an XML Schema is a metaschema. An XML expression of Land Cover and/or Land Use information needs to be at the Application Schema level, which is one level of instantiation lower than the metaschema and defined in terms of a particular classification system. The use of metamodels and the subsequent instantiation into models, including the instantiation into an XML Schema that can be used to encode data is an implementation issue that is not addressed in this document.

Appropriate references to externally managed lists or listed items established particularly for the ISO 19144 series can be registered. In addition, whole classification systems described using the Land Cover or Land Use parts of the ISO 19144 series can be registered. The name and contact information of the maintenance agency for this document can be found at www.iso.org/maintenance_agencies.

This document is a joint deliverable with the UN Food and Agriculture Organization (UN FAO). Permission has been granted to ISO by the UN FAO to make a derived work based on any material developed or copyright UN FAO. The EAGLE concept has also provided input to the process of developing this document.[21]

In this document UML attributes names are given in *italics*.

In accordance with the ISO/IEC Directives, Part 2, 2018, Rules for the structure and drafting of International Standards, in International Standards the decimal sign is a comma on the line. However, the General Conference on Weights and Measures (Conférence Générale des Poids et Mesures) at its meeting in 2003 passed unanimously the following resolution:

“The decimal marker shall be either a point on the line or a comma on the line.”

In practice, the choice between these alternatives depends on customary use in the language concerned. In the technical areas of geodesy and geographic information it is customary for the decimal point always to be used, for all languages. That practice is used throughout this document.

Geographic information — Classification systems —

Part 3:
Land Use Meta Language (LUML)

1 Scope

This document specifies a Land Use Meta Language (LUML) expressed as a UML metamodel that allows different Land Use classification systems to be described. This document recognizes that there are a number of Land Use classification systems in existence. It provides a common reference structure for the comparison and integration of data for any generic Land Use classification system, but does not intend to replace those classification systems. This document complements ISO 19144-2 on Land Cover Meta Language (LCML) and can be used independently to describe Land Use or together with ISO 19144-2 to describe a combined Land Cover Land Use.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 19103, *Geographic information — Conceptual schema language*

ISO 19123-1, *Geographic information — Schema for coverage geometry and functions — Part 1: Fundamentals*

ISO 19144-1, *Geographic information — Classification systems — Part 1: Classification system structure*

ISO 19144-2, *Geographic information — Classification systems — Part 2: Land Cover Meta Language (LCML)*

3 Terms, definitions and abbreviated terms

3.1 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 19144-1 and ISO 19144-2 and the following apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/

NOTE The term "class" is used in the ISO 19144 series to represent a construct in a classification system. However, the term has several meanings in other contexts, including in the UML modelling language. Where possible, attributes or other identifiers are needed to distinguish between the various uses of the term "class".

3.1.1
class
<UML> classifier of a set of objects

Note 1 to entry: Adapted from UML 2.5.1, 11.8.3.1.[22]

[SOURCE: ISO 19103:—,[1] 3.14]

3.1.2
coverage
function which returns values from its range for any direct position within its domain

[SOURCE: ISO 19123-1:2023, 3.1.9]

3.1.3
discrete coverage
coverage that returns value for the direct positions within its domain

Note 1 to entry: Discrete coverages have values only for their direct positions, whereas continuous coverages can be interpolated, thereby providing values between direct positions in addition.

[SOURCE: ISO 19123-1:2023, 3.1.15]

3.1.4
feature
abstraction of real world phenomena

Note 1 to entry: A feature can occur as a type or an instance. Feature type or feature instance will be used when only one is meant.

[SOURCE: ISO 19101-1:2014, 4.1.11]

3.1.5
register
set of files containing identifiers assigned to items with descriptions of the associated items

[SOURCE: ISO 19135-1:2015, 4.1.9]

3.2 Abbreviated terms

ATS	abstract test suite
IUCN	International Union for the Conservation of Nature
LCML	Land Cover Meta Language
LUML	Land Use Meta Language
NLUD	UK National Land Use Database
UML	unified modelling language
UNEP	United Nations Environment Programme
UN FAO	United Nations Food and Agriculture Organization
UN FCCC	United Nations Framework Convention on Climate Change
XML	Extensible Markup Language
XSD	XML Schema

[1] Under preparation. Stage at the time of publication: ISO/FDIS 19103:2024.

4 Conformance

4.1 Conformance requirements and testing

Conformance to this document consists of alignment with the requirements established in 4.2, 4.3, 4.4, 10.2 and 10.3. The abstract test suite (ATS) given in Annex A describes a methodology which shall be applicable for testing conformance to these requirements.

4.2 Conformance classes

Two conformance classes are identified in this document, one for the description of a land characterization classification system and the other for the comparison between two or more land characterization classification systems.

4.3 Conformance class 1 — Description of a land characterization classification system

Requirement 1: The description of Legends or Land characterization Application Schema using this document shall consist of a set of UML classes with associated attributes that correspond to instantiations of the metalanguage classes described in Clause 8 or the combined Land Cover Land Use combinations identified in 7.7, or both.

4.4 Conformance class 2 — Comparison of land characterization classification systems

Requirement 2: The process of comparison of two land characterization classification systems shall be performed by developing descriptions of the two land classification systems, each in accordance with Requirement 1, and then identifying the differences on a class-by-class basis. This can be repeated for more than two land characterization classification systems under comparison.

NOTE The level of detail of the comparison is dependent on the type of description.

5 Notation

The conceptual schema specified in this document is described using the Unified Modelling Language (UML), in accordance with ISO 19103.

Several model elements used in this schema are defined in other ISO geographic information standards. By convention within ISO/TC 211, names of UML classes, with the exception of basic data type classes, include a two-letter prefix that identifies the standard and the UML package in which the UML class is defined. This provides a global unique name for the class. UML classes defined in this document have the two-letter prefix "LU". Examples in this document and ISO 19144-2 have the two-letter prefix EL. Table 1 lists the other International Standards and packages in which UML classes used in this document have been defined.

Table 1 — Sources of externally defined UML classes

Prefix	International Standard	Package
CL	ISO 19144-1	Classification system structure
LC	ISO 19144-2	Land Cover Meta classes
EL	ISO 19144-2 & ISO/TS 19144-3	Examples in the ISO 19144 series
CV	ISO 19123-1	Coverage geometry

The stereotype <<metalanguage>> is used throughout this document to identify metalanguage objects that compose the LC_LandCoverClassDescriptor, LU_LandUseClassDescriptor or

LU_LandCharacterizationClassDescriptor. As illustrated in 7.3, LU_LandCoverLandUseRelationship and its components are at a higher level of abstraction than the LU_LandUseClass that form a Land Use Classification System, which are at the Application Schema level. A Legend as described in ISO 19144-1 is the simplest type of Application Schema.

The stereotype <<metalanguage>> applies to a class whose instances are other classes that are described by the metalanguage class.

The term "class" is an English word with a dictionary definition. However, it also has several meanings within the ISO 19144 series, dependent upon context. Classification is a process and the result of a classification process is a “class”. The term "class" (<classification>) is used in the ISO 19144 series to represent a construct in a classification system. However, the term "class" has several other meanings in other contexts. A classification system consists of a set of classes subdividing the concepts within a given topic area. There is an unavoidable conflict with the terminology when a modelling language such as UML is used to describe a classification system metalanguage such as the LCML. The UML modelling language uses the term "class" (<UML>) as a construct in an object-oriented programming or data modelling paradigm, as the template for an object. That is, a UML class describes the properties associated with the instances of the class called objects. The term "class" is used in normal practice in both modelling and classification, and it is unreasonable for either modelling or classification to avoid the term. The term “Item Class” is also used in the process of registration, identifying the item that is registered. This term occurs in other parts of the ISO 19144 series. Adjectives have been used in this document where possible to reduce this confusion. For example, UML classes can be called “UML classes” and classification system classes can be called “classification classes” or “legend classes”. At times, a UML class describes a classification class and it is possible to dispense with the adjective since both meanings of "class" are equivalent in the context. The conflict results from the fact that there is a deep relationship between data modelling and classification as used in other domains.

There is a similar related potential conflict with the associated terms "attribute" and "object". Adjectives have been used where possible, but at times it is necessary to derive the meaning from the context. Other terms where there is a potential for confusion are the terms “element”, “component”, “characteristic” and especially “attribute”. The use of these terms is potentially confusing as they have different meanings in different contexts. These terms come from different places and all that can be controlled is their usage in the ISO 19144 series. Care is taken to use adjectives with these terms to help to clarify their meaning.

Certain classes that are common to both this document and to ISO 19144-2 are defined once. The classes that describe how permitted numeric values at the metalanguage level may be instantiated to the basic number types at the type level represented by LC_ValueObject or its subtypes are described in ISO 19144-2. The basic number types defined in ISO 19103 shall apply.

Classes related to the Land Cover Land Use Relationship are defined in this document in the package LU_LandCoverLandUseRelationship.

6 Context

The purpose of this document is to define a common reference structure for the comparison and integration of data for any generic Land Use classification system.

The majority of today's global biosphere is occupied by human-modified landscapes of agricultural, urban and other Land Uses. Due to the extent of the human impact, it is of fundamental importance to understand the extent and effects of human use of ecosystems, such as urban development, deteriorating environmental quality, changes in the extent and types of agricultural systems, and loss of fragile ecosystems (e.g. wetlands and steep lands) or of ecosystems with a high value in terms of biodiversity (e.g. humid tropical forests). These processes and problems need to be understood and documented in order to manage biodiversity, water security and human health. In other words, an understanding of Land Use and Land Cover is necessary if living conditions and standards are to be improved or at least maintained at the current level. For regional to national extents, Land Use is typically measured and mapped at a coarse spatial resolution (e.g. state or county

unit) and for only broad categories of use (e.g. urban vs. agriculture). No unified or detailed worldwide Land Use classification exists. Some Land Cover maps depict ‘‘developed’’ or built-up Land Cover types that are directly related to human activities. However, that information cannot represent the full extent and complexity of human use of the land. Since every Land Use classification system is highly dependent on the purpose of the classification itself, there is a great diversity between Land Use classification systems.

In the past, many Land Use classification authors had different purposes and the result was an amalgam of classification methods to describe Land Use. As a result, today, comparison across time and space of Land Use has become very arduous. There is no agreement on any of the common classificatory principles. The metalanguage presented in this document accommodates this diversity and provides a way to describe and compare different systems. A Land Use or combined Land Cover Land Use system, described using the metalanguage specified in this document, should be able to re-examine and then make interoperable existing land-use data sets to make realistic comparisons within and between the systems used in different countries or application areas. It should also be able to collect time series information with which to analyse the dynamics of Land Use changes and therefore detect and predict trends.

7 Conceptual basis

7.1 Domain of interest

The term “Land Use” has different meanings across different disciplines and is consequently identified with a wide range of different parameters (for instance, those determined by natural, economic, institutional, cultural and legal factors). In order to develop a consistent approach to view Land Use is it easiest to start with the broad concept of “Land”.

The term “Land” is inclusive of all physical elements, bestowed by nature, to a specific area. This includes fields, forests, minerals, inland water and in a broader sense, environment. Land Cover has been defined in this context in ISO 19144-2. In contrast, Land Use is defined with respect to different types of human activities that maintain or produce change to the land.

There is a clear relationship between Land Cover and Land Use. In fact, many existing older Land Use classifications are based on Land Cover information. However, the two are necessarily separate concepts. Land Cover can be considered the result of some aspects of Land Use at a certain moment in time. In this sense some Land Cover is the direct visible consequence of certain Land Use activities humans make to the bio-physical cover of the Earth. Land Use is determined by the human activities over certain periods of time, while Land Cover is determined at one moment including temporal aspects.

7.2 Model based approach

The “Object Based” ontology approach detailed in UML class diagrams represents one of the most efficient ways to represent the complexity and variety of land features.

This approach offers the following advantages:

— No predefined fixed list of categories exists, but an almost unlimited possibility of combination of well-defined attributes is allowed.

— Each Land Feature class is described or characterized by a specific UML model. This is an efficient way to represent complex land dynamics.

— The system is flexible and copes well with the advance of science in many different sectors. For instance, the use of Mark Up languages (XSD, XML) can be used to represent the instantiation of the information content.

— As the Land Use system component is built up with same "object oriented" logic of the ISO 19144-2 LCML, it is straightforward and effective to model a functional relationship between the Land Biophysical component (Land Cover) with the functions and activities (Land Use) that outline it.

Both the Land Cover and Land Use classification systems described in ISO 19144-2 and this document make use of a building block approach to the description of a classification system. Detailed elements are defined which can be combined to create a precise description of any Land Cover or Land Use class. This is described in more detail in ISO 19144-2:2023, 8.1. The background theory is given in Reference [6].

7.3 Packages

The UML model of each of the Land Use metalanguage-elements is given in Clause 8. The metalanguage objects are organized into several packages.

The package LU_LandUseClassStructure contains the definition of the basic Land Use classes. The LU_LandUseClassStructure package also relates to the LU_LandUseFunctionsElement package which is related to the LU_LandUseActivities package. The LU_LandCoverLandUseRelationship package contains classes that define the relationship to the Land Cover classes defined in ISO 19144-2. All of these classes contain numerical attributes related to the LC_ValueObjectTypes package that is defined in ISO 19144-2. This is represented in Figure 1.

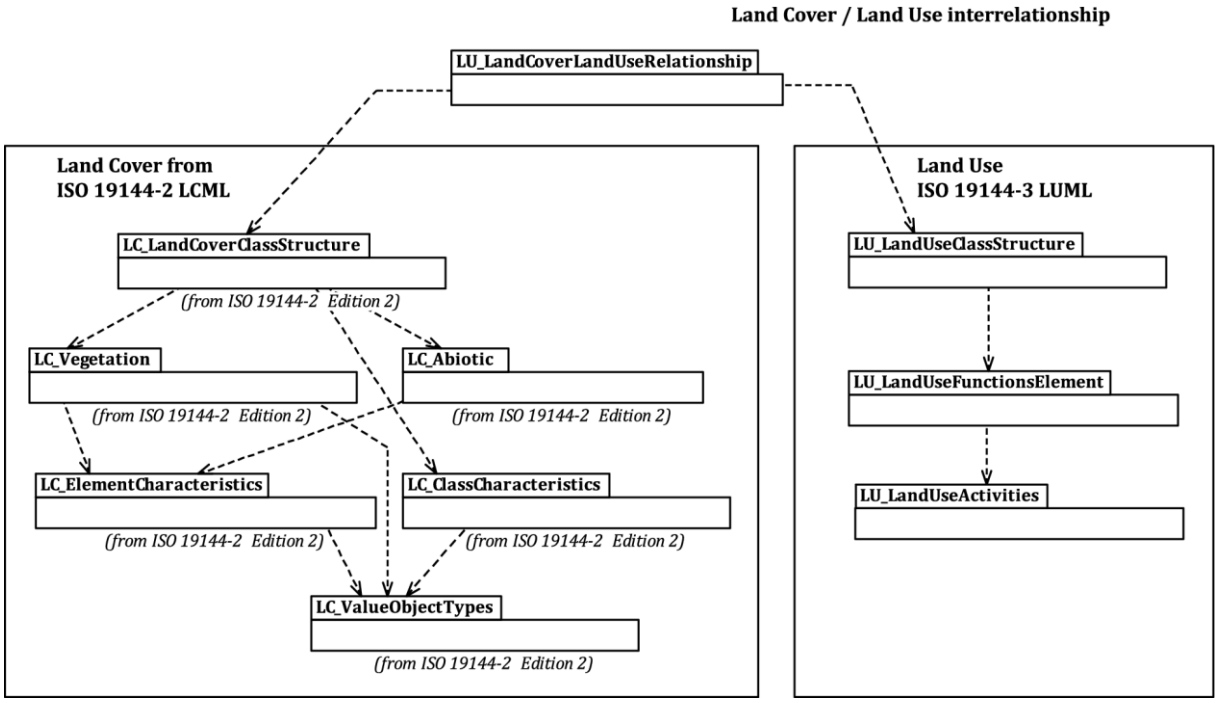

Figure 1 — LUML packages

7.4 Relation to ISO 19144-1

The LUML metalanguage is used to describe a Land Use classification system which is itself a UML model of classes that is then used to generate a legend (or nomenclature) or schema.

A classification system consists of a set of Land Cover or Land Use Classes that are established to exhaustively represent a particular aspect of the reality. The totality or a subset of these classes can be selected to describe a particular geographic area establishing a legend or nomenclature. The Land Use metalanguage described in this document has the same relationship to ISO 19144-1 as ISO 19144-2. The relationship between a classification system and legend is described in ISO 19144-1.

There are two separate semantic levels of abstraction involved. A legend (or nomenclature) is concrete in that it defines legend classes, instances of which can exist within a particular geographic area. A classification system is a semantic level of abstraction above a legend that characterizes the functional relationship of a set (finite or infinite) of possible classes and defines their descriptive criteria. The LUML metalanguage is another semantic level of abstraction higher. The metalanguage provides the structure so that a classification system can be described.

As indicated in ISO 19144-1, a classification system subdivides any geographic area into smaller units that have a unique type, and that result is represented as a "discrete coverage". The definition of coverages provided in ISO 19123-1 shall apply. This approach is used as the basis for both ISO 19144-2 and this document (see ISO 19144-2:2023, 7.2).

In a similar manner to ISO 19144-2, the high-level structure consists of the relationships between the LU_LandUseClassificationSystemMetaLanguage object and the aggregation of a set of LU_LandUseDescriptor objects. These are metalanguage objects that can be used to describe Land Use Classification systems which are composed of individual Land Use classes.

The LU_LandUseClassificationSystemMetaLanguage object is a description of a Land Use classification system as represented by the UML class LU_LandUseClassificationSystem. The individual LU_LandUseDescriptor objects can be serialized to produce LU_LandUseClass(s) which correspond to individual classes in a Land Use classification system. LU_LandUseClass is a subtype of CL_LegendClass as defined in ISO 19144-1.

Figure 2 shows that there is a parallel relationship between the descriptors that compose the metalanguage and the Land Use classes that compose a Land Use classification system. The descriptors are used to describe each classification class in a Land Use classification system, and the whole metalanguage is used to describe the whole classification system.

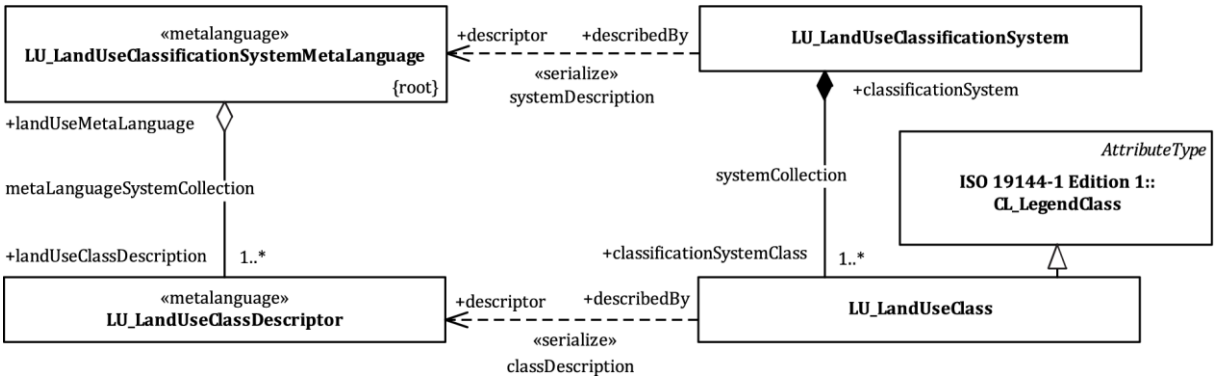

Figure 2 — High level structure of the Land Use Classification Model

7.5 High level structure classes

7.5.1 LU_LandUseClassificationSystemMetaLanguage

The LU_LandUseClassificationSystemMetaLanguage object is composed of all the Land Use elements that when serialized describe the classes that make up a classification system as given by LU_LandUseClassificationSystem.

The LU_LandUseClassificationSystemMetaLanguage object has one relationship: MetaLanguageSystemCollection. LU_LandUseClassificationSystemMetaLanguage is an aggregation of the Land Use objects LU_LandUseDescriptor.

The diagram in Figure 2 shows that there is a parallel relationship between the descriptors that compose the metalanguage and the Land Use classes that compose a Land Use classification system. The descriptors are

used to describe each classification class in a Land Use classification system, and the whole metalanguage is used to describe the whole classification system. The LU_LandUseClass is a subtype of the more general CL_LegendClass described in ISO 19144-1.

The LU_LandUseClassificationSystem object is described by the components of the LU_LandUseClassificationSystemMetaLanguage object. It corresponds to a Land Used classification system. It consists of all the Land Use classes in a Land Use classification system.

This object has the relationship systemCollection. It is an aggregation of LU_LandUseClass objects. It is also related to LU_LandUseClassificationSystemMetaLanguage by the dependency relation that indicates a LU_LandUseClassificationSystem described by the serialization of the metalanguage objects that compose the LU_LandUseClassificationSystemMetaLanguage.

7.5.2 LU_LandUseClassDescriptor

The LU_LandUseClassDescriptor object is the metalanguage level template for a Land Use class in a Land Use classification system. The LU_LandUseClassDescriptor object is used to describe the LU_LandUseClass.

This UML class is an element in the aggregation in the metaLanguageSystemCollection relationship with the LU_LandUseClassificationSystemMetaLanguage object. It is also related to LU_LandUse by the dependency relation which indicates that the LU_LandUseClass is described by the serialization of the metalanguage objects that compose the LU_LandUseDescriptor.

7.5.3 LU_LandUseClass

The LU_LandUseClass metalanguage object is the result of the serialization of the LU_LandUse object; that is, it is related to LU_LandUseDescriptor by a dependency relationship that indicates that the LU_LandUseClass is described by the serialization of the metalanguage objects that compose the LU_LandUseDescriptor. It corresponds to a single Land Use class in a Land Use classification system.

This object has a relationship systemCollection with the object LU_LandUseClassificationSystem.

This object is a subtype of the UML class CL_LegendClass as defined in ISO 19144-1: it is a specialization of a general classification system Legend Class for the use of Land Use.

7.6 Connection with Land Cover

This document defines Land Use as arrangements, activities and inputs people undertake in a certain Land Cover type to maintain it or produce change. This allows for a direct link between Land Cover and the description of Land Use. The combined use of Land Cover and Land Use will be called Land Characterization.

Land Cover and Land Use information are important parameters in most of the studies related to the natural environment, ecosystem services and other disciplines. However, despite the importance of data harmonization and the many efforts made towards achieving this, there does not exist an accepted model on how to link and functionally correlate these two information concepts. On the contrary, there is often an inclusion of Land Use terms in many Land Cover nomenclatures, for example in Anderson,[17] Corine,[18],[19] etc. Some Land Cover terms are also found certain Land Use classifications (UN FCCC, NLUD, etc.). Even when the two information types are kept correctly clearly distinct (for example in the EU Inspire spatial data infrastructure),[10] no effort has been made to model or describe their functional relationship.

The close relationship between Land Cover and Land Use concepts is well acknowledged, and there is a broadly accepted understanding of the necessity to maintain a clear separation between these two aspects of the land. In practice, in many instances of Land Cover and Land Use, concepts are so closely interrelated that often the meaning of terms becomes interchangeable. This interrelation becomes more and more evident when one endeavours to show a more dynamic representation of the land. With time series, it is possible to

more comprehensively capture and analyse the phenomena and associated processes occurring on land. Parts of these dynamics (excluding the recurrent natural vegetation phenology) are direct consequences of human activities or are strongly related to them. The close and important relationship between the pure aspect of the "land biophysical features" and the "human activities" is evident.

The historical use of hybrid ontologies where Land Cover and Land Use terms are interchangeable and coexist in the same system are unable to describe or explain these more complex relationships.[9] A portion of the land includes both Land Cover and Land Use information. In a modern and efficient system, one cannot be substituted for the other.

It is not efficient to create independent Land Cover and Land Use systems and later attempt to build a kind of artificial connection between them. It is much more logical to develop a framework that should be able to dynamically integrate and incorporate both Land Cover and Land Use information together. This framework should respect the most recent technical advances in information systems that characterize modern ontologies. This paradigm should define a system which is:

a) simple — the determining factors or diagnostic criteria should be the most logical and accepted ones;

b) stable (as far as possible) — the diagnostic criteria relate to characteristics of Land Cover and Use that are universal and relevant in longer terms;

c) comprehensive — able to characterize all aspects of Land Cover and Land Use;

d) scientifically sound — strongly related to the definition of natural vegetation and human activities.

Observing the land from this perspective highlights that a strong triadic relationship exists between "Land Objects", "Land Events" and "Land Functions" (or "Socio-Economic Purposes").

— Land Objects relate to the (bio)physical entities of natural or artificial origin fixed to the Earth's surface. They are a collection of matter within a defined contiguous boundary in three-dimensional space. Land objects are present as a whole at each moment of their existence. Instances of Land Objects are discrete, non-divisible and countable individuals.[11]

— Land Events are the results of a natural (bio)physical process or disturbance, or of human activity, framed within a given time interval, and involving one or many land objects. They have a start and an end, and therefore a duration. Regardless of how long the duration is, there will always be a temporal granularity at which the land event appears as instantaneous. Instances of Land Events are discrete, non-divisible and countable individuals.[11]

— Land Functions are related to the economic, cultural, social and climate-environmental value that a piece of land has. This is fully related to the behavioural interaction of individuals or communities of individuals.

7.7 Land Cover Land Use functional link

7.7.1 Types of descriptions

The Land Use Meta Language can be used alone or in combination with the Land Cover Meta Language in accordance with ISO 19144-2. Each of these modelling description types are allowed in different circumstances. Three main types of outputs can be generated.

— **Description Type 1 — Land Cover land description:** This characterization is based on the use of the physiognomic/structural description of the land objects as addressed in ISO 19144-2. Optionally, the land objects can be enriched with functions or activities or both, incorporated from the Land Use component.

— **Description Type 2 — Land Use land description:** This characterization addresses only Land Use and uses both Functions and Activities. Optionally, Land Use objects can be enriched with additional attributes from the physiognomic or structural component of Land Cover as described in ISO 19144-2.

— **Description Type 3 — Functional Land Cover Land Use land description:** This last possibility provides a full, functional integration of physiognomic or structural elements with Land Use Functions and Activities. This is called Land Characterization.

The description of pure Land Cover (Description Type 1) is contained in ISO 19144-2 with an optional reference by attribute to this document. This document contains the description of Land Use and Land Cover/Land Use combinations, as represented in Description Types 2 and 3. Examples of the LUML used to produce a Land Use classification system or a combined Land Use Land Cover classification system are given in Annex B.

7.7.2 Description Type 1 — Land Cover

The description of pure Land Cover (Description Type 1) is addressed in ISO 19144-2 and is illustrated in ISO 19144-2:2023, Figure 3. It is also illustrated in Figure 3 of this document. Land Cover can be enriched with Land Use attributes through the use of optional attributes. The class LU_AugmentedClassCharacteristics is a subtype of the LC_ClassCharacteristics class defined in ISO 19144-2. The optional composition relationship links LU_FunctionalElementArrangement to the LU_AugmentedClassCharacteristic.

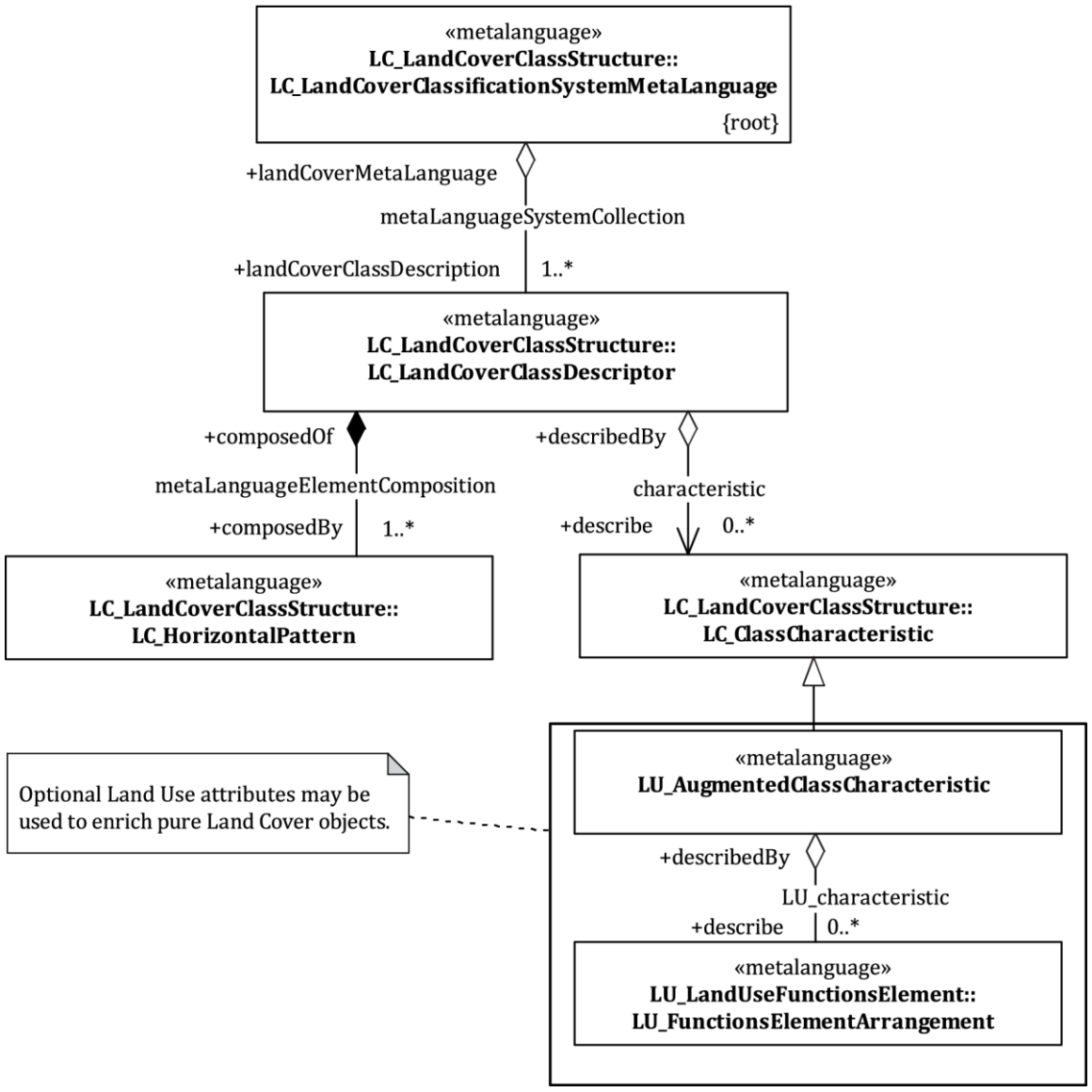

Figure 3 — High level structure of the Land Cover and Augmented Land Cover, Description Type 1

7.7.3 Description Type 2 — Land Use

The description of pure Land Use is addressed by the combination of Land Use functions and activities as described in Clauses 8 and 9. The functions and activities are integrated in the class LU_FunctionalElementArrangement. Description Type 2 describes a classification system metalanguage and a set of class descriptors for Land Use. This can be enhanced by Land Cover class characteristics from LC_ClassCharacteristics (from ISO 19144-2). This is a minimum enhancement of only characteristics. A full integration is described in Description Type 3, 7.7.4.

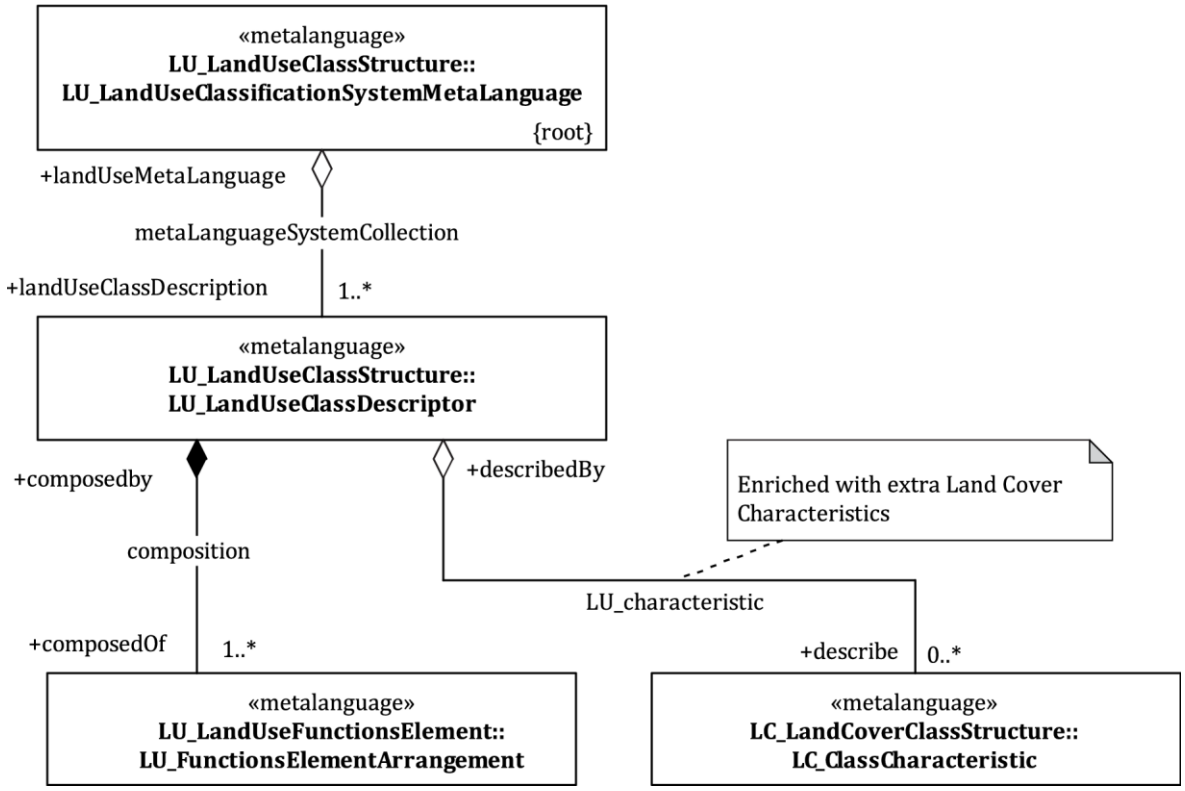

Figure 4 — High level structure of Land Use and Augmented Land Use, Description Type 2

7.7.4 Description Type 3 — Combined Land Cover Land Use – Land Characterization

The description of a combined Land Cover and Land Use metalanguage (Description Type 3) is illustrated in Figure 5. This is termed Land Characterization.

The enhanced Land Use metalanguage in Figure 4 shows Description Type 2, where Land Cover Characteristics can be a component of a Land Use Class Descriptor. This is parallel to Description Type 1 in Figure 3 where Land Use functional elements can be used as additional attributes to augment Land Cover. These two cases, where some Land Cover characteristics are use in a Land Use description or where some Land Use functional elements are used in a Land Cover description are not full land characterization descriptions in a combined ontology. Rather they are special cases where a few additional attributes are added to Land Cover or Land Use using the elements from the other schema. However, it is important to ensure that this is used sparingly. To properly describe a combination of Land Cover and Land Use, a combined Land Characterization ontology should be used.

The combined Land Cover Land Use (Land Characterization) structure allows for the relationship between Land Cover elements, arranged through strata and horizontal patterns, and Land Use Functions and Activities arranged through the class LU_FunctionalElementsArrangement to be combined. Specific attributes may be applied to these combinations as specified using the attributes in LU_LandCoverLandUseRelationship. These attributes are: *functionalElementRelationship* taking on the datatype LU_RelationshipType, *temporalRelationship* taking on the datatype LU_TemporalRelationshipType and *timelength* related to the temporal relationship. The attribute *timelengthUoM* describes the units of measure for *timelength*.

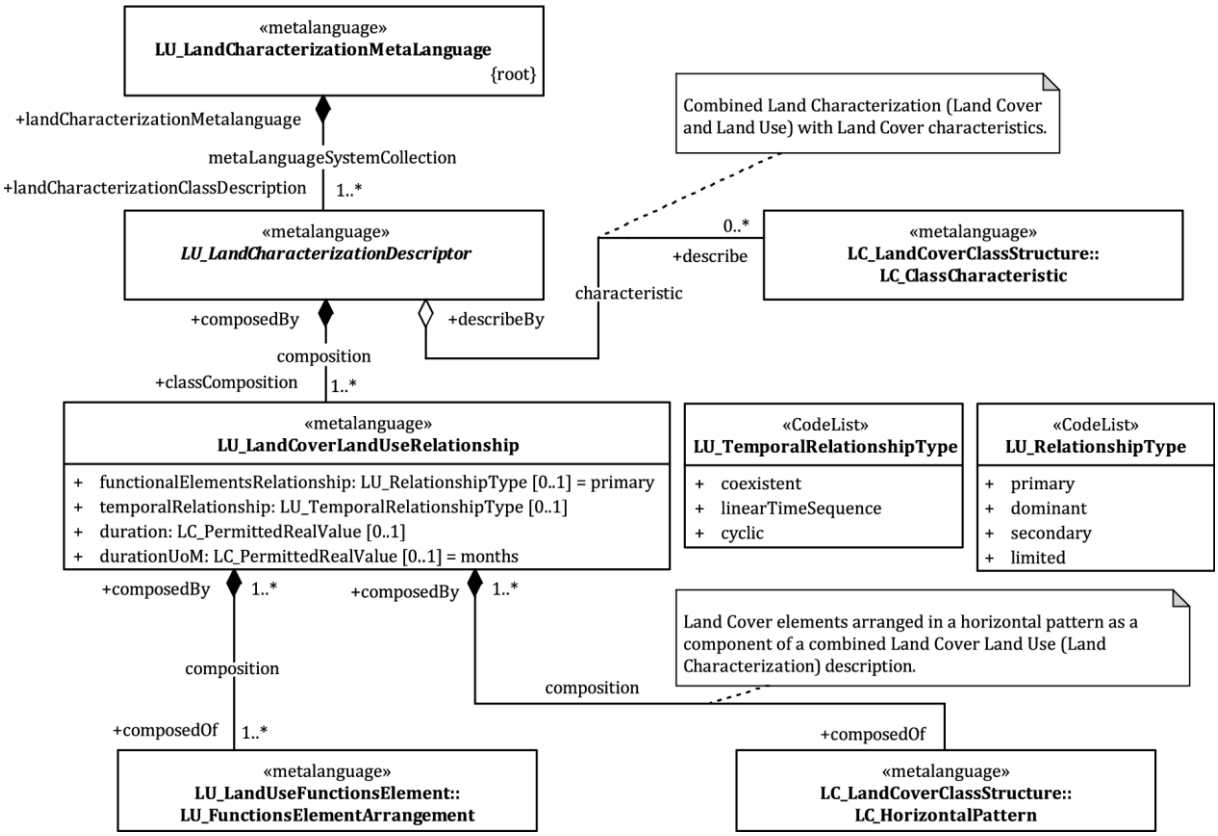

Figure 5 — Combined Land Cover and Land Use, Description Type 3

7.7.5 Descriptive Overview of the functional link

The Land Cover Land Use Relationship structure provides a functional relationship between the “Biophysical” and “Land Use” characterization of the land. The structure utilizes three different “relationship types”:

1) functional relationship,

2) temporal relationship,

3) duration (this aspect describes the length of time of the relationship.)

The model ensures a full functional interconnection of the Land Cover and Land Use components. They are not separate entities and it is necessary to consider them as a full integrated system when used together to fully describe land.

The class LU_LandCoverLandUseRelationship integrates Land Cover descriptions organized as horizontal patterns according to LC_HorizontalPattern with LU_FunctionalElementArrangement(s). This relationship is the principle correlation that assures a functional relationship between an extensive “Biophysical” and “Land Use” characterization of the land.

— Functional Relationship: models the “functional” relationship between the physiognomic or structural components of the schema with the function or activities. The “relationship types” are:

  — primary,

  — dominant,

  — secondary,

  - limited.

- Temporal Relationship: models the temporal aspect of the relationship. The types are:
  - coexistant,
  - time sequence (linear),
  - cyclic.
- Time Length: duration of the temporal aspect.
  - The time length units of measure describes the units of measure for the time length with the default being months.

7.7.6 Land Characterization class description

7.7.6.1 LU_LandCharacterizationMetaLanguage

The LU_LandCharacterizationMetaLanguage object is composed of all the Land Cover, Land Use and combined Land Cover Land Use (land characterization) elements that when serialized describe the classes that make up a classification system.

7.7.6.2 LU_LandCharacterizationDescriptor

The LU_LandCharacterizationDescriptor object is the metalanguage level template for a Land Use or Land Cover class in a combined Land Use Land Cover classification system.

This UML class is an element in the aggregation in the metaLanguageSystemCollection relationship with the LU_LandCharacterizationMetaLanguage object.

This object is composed of all the Land Cover, Land Use (Land Characterization) elements that describe a particular class in a combined Land Cover Land Use system. Some class descriptors in a combined system can describe pure Land Use, others can describe pure Land Cover and others can be a combination.

The LU_LandCharacterizationDescriptor object has three relationships. The first is the composition relationship metaLanguageSystemCollection. LU_LandCharacterizationMetaLanguage is an aggregation of the Land Cover Land Use objects represented by LU_LandUseDescriptor through the LU_LandCoverLandUseRelationship class. The second relationship is an aggregation relationship from the Land Cover LC_ClassCharacteristics where the Land Cover class characteristics are used in part to describe the combined Land Cover Land Use class. The third relationship is a composition relationship from LU_LandCoverLandUseRelationship that allows both Land Use elements through the LU_FunctionalElementsArrangement and Land Cover elements through LC_HorizontalPattern to be incorporated.

7.7.7 LU_LandCoverLandUseRelationship

7.7.7.1 General

The LU_LandCoverLandUseRelationship object is a collection class that describes the composition relationship of elements from the Land Use LU_FunctionsElementArrangement class and the Land Cover classes arranged in a horizontal pattern from the LC_HorizontalPattern class. A horizontal pattern can be used for a complex Land Cover object composed by two or more distinct Land Cover features that will be handled as a “unicum”.

This class has three attributes: *functionalElementRelationship*, *temporalRelationship* and *timeLength*; and two relations: a composition relationship with Land Use functional elements from LU_FunctionalRelationshipArrangement and a composition relationship with Land Use elements from LC_HorizontalPattern.

7.7.7.2 LU_LandCoverLandUseRelationship attributes and relations

7.7.7.2.1 functionalElementRelationship attribute

This attribute specifies the functional relationship between the physiognomic or structural components of the schema with the function or activities. The relationship types are given in the code list LU_RelationshipType.

7.7.7.2.2 temporalRelationship attribute

This attribute specifies the temporal aspect of the relationship. The temporal aspect types are given in the code list LU_TemporalRelationshipType. This attribute is optional and by default there is no temporal relation specified.

7.7.7.2.3 duration attribute

This attribute describes the temporal relationship value of the temporal relationship. The temporal aspect takes on the value type of a real number as represented by "LC_PermittedRealValue". This attribute is optional and is conditional upon the attribute *temporalRelationship*. The attribute name *timeLength* is an alias to the name *duration*.

7.7.7.2.4 durationUom attribute

This attribute describes the units of measure used with respect to the *duration* attribute, providing options (days, weeks, months, years). This attribute is optional and is conditional upon a *duration* attribute being expressed. The default value is "months". The attribute name *timeLengthUom* is an alias to the name *durationUom*.

7.7.7.2.5 Composition relationship to LU_FunctionalElementArrangement

The composition relationship links the LU_FunctionalElementArrangement with the LU_LandCoverLandUseRelationship class. This supports the establishment of a combined Land Cover Land Use (Land Characterization) descriptor as part of a Land Characterization metalanguage.

7.7.7.2.6 Composition relationship to LC_HorizontalPattern

The composition relationship links the LC_HorizontalPattern with the LU_LandCoverLandUseRelationship class. This supports the establishment of a combined Land Cover Land Use (Land Characterization) descriptor as part of a Land Characterization metalanguage.

7.7.7.2.7 LU_RelationshipType

The code list LU_RelationshipType contains a list of types of relationships. This list contains four types primary, dominant, secondary and limited. This list may be extended through registration.

The code list values are:

— primary — (default value) a direct relationship exists between one physiognomic/structural component and one function (with related activities);

— dominant — a relationship exists and is "dominant" with respect to others;

— secondary — a relationship exists but is not dominant (another dominant relationship exists);

— limited — the relationship is limited to a few situations.

7.7.7.2.8 LU_TemporalRelationshipType

The code list LU_TemporalRelationshipType contains a list of types of temporal relationships. This list contains three types: coexistent, linearTimeSequence and cyclic. This list may be extended through registration.

The code list values are:

— coexistant — the relationship is consistent all the time;

— linearTimeSequence— the relationship is partial for some periods;

— cyclic — the relationship is regularly repeated in time.

7.7.7.2.9 LU_FunctionalElementArrangement

The class LU_FunctionalElementArrangement describes the arrangement and combination of the Land Use functions. See 8.2.3.1.

8 LUML design concepts

8.1 Overview of LUML design

The LUML is a metalanguage which can be used to describe a wide variety of Land Use classification systems. The LUML operates by describing each class in a Land Use classification system in terms of a set of basic elements that when combined describe each aspect of the Land Use classification system class. That is, each class in a Land Use classification system may be modelled using the basic element objects defined in the LUML. This structure is analogous to the parallel structure defined in ISO 19144-2 for Land Cover.

Any set of basic elements that fully describe a topic area could be chosen as the basic vocabulary to establish a metalanguage. It is possible to establish other metalanguages based on different criteria. However, in order to do a comparison and to integrate data from different Land Use systems it is necessary to standardize one metalanguage. This structure matches the one defined in ISO 19144-2 so that Land Cover and Land Use classes can be used together to describe complex cases that have both Land Cover and Land Use aspects.

8.2 Elements of the LUML metamodel

8.2.1 General description

Land Use and Land Cover describe complementary aspects of land. Different groups can consider that Land Cover or Land Use or both are under the “responsibility” of different organizations. From a management point of view this can potentially be true in many cases, but when a structure is created that describes all aspects of land, it is necessary to build a logical bridge. The ISO 19144 series includes both Land Cover and Land Use and the bridging relationships between them. This document can be used to describe existing Land Use classification systems, for example, the American Planning Association Land-Based Classification Standards (LBCS),[6] the Australian Land Use and Management system (ALUM),[7] or the European INSPIRE Land Use system.[10]

Functions can be defined by the sequence of specific actions on a given type of Land Cover. For example, the same action (e.g. tree planting) could contribute to different functions if exerted on short rotation coppice (production) or on forest (regulative).

There is another aspect of land that is almost entirely separate. That is the legal rights associated with land such as ownership and restrictions legally imposed on that land. This is expressed in the ISO 19152 series, which describes the Rights, Restrictions and Responsibilities and associated Parties that apply as special legal (or official) attributes to “Basic Administrative Units”. These Basic Administrative Units (BAUnits) are composed of multiple “Features”, where a geographic feature is equivalent to a “Land Object”. In terms of the ISO/TC 211 Reference Model, these “features” are each an “abstraction of a Real World phenomena” in accordance with ISO 19101-1, the ISO Geographic Information Reference Model.

The Land Use Meta-Language creates a functional link between Land Use and Land Cover. The relation between Land Use and Land Cover is described in 7.5.

The composite model ensures a full functional inter-connection of the two components. In fact, they are not separate entities, but it is necessary to consider them as a full integrated system. To allow this integration, the composite model provides many different interconnections.

8.2.2 Land Use Meta Language object structure

The Land Use component of the schema is based on a functional interaction between “functions” and “activities”:

— "function" refers to the specific purpose that a particular piece of land serves and the specific output it provides;

— "activities" refer to what actually takes place in physical or observable terms or both on the land defined under a specific function.

A Land Use class descriptor LU_LandUseClassDescriptor is composed of one or more Land Use arrangements methods. These functional arrangements can have a relation to Land Cover classes through a LandCoverLandUseRelationship or can serve as a component of a LC_LandCoverClassDescriptor as additional information that augmented the description. A LandUse arrangement is composed of Land Use functional elements LU_LandUseFunctionalElements together with Land Use activities through LU_ActivitiesArrangement

This is illustrated in Figure 6 where LU_LandUseFunctionElement and LU_ActivitiesArrangement are shown as components of LU_FunctionsElementsArrangement. LU_Activities is shown as a component of LU_ActivitiesArrangement.

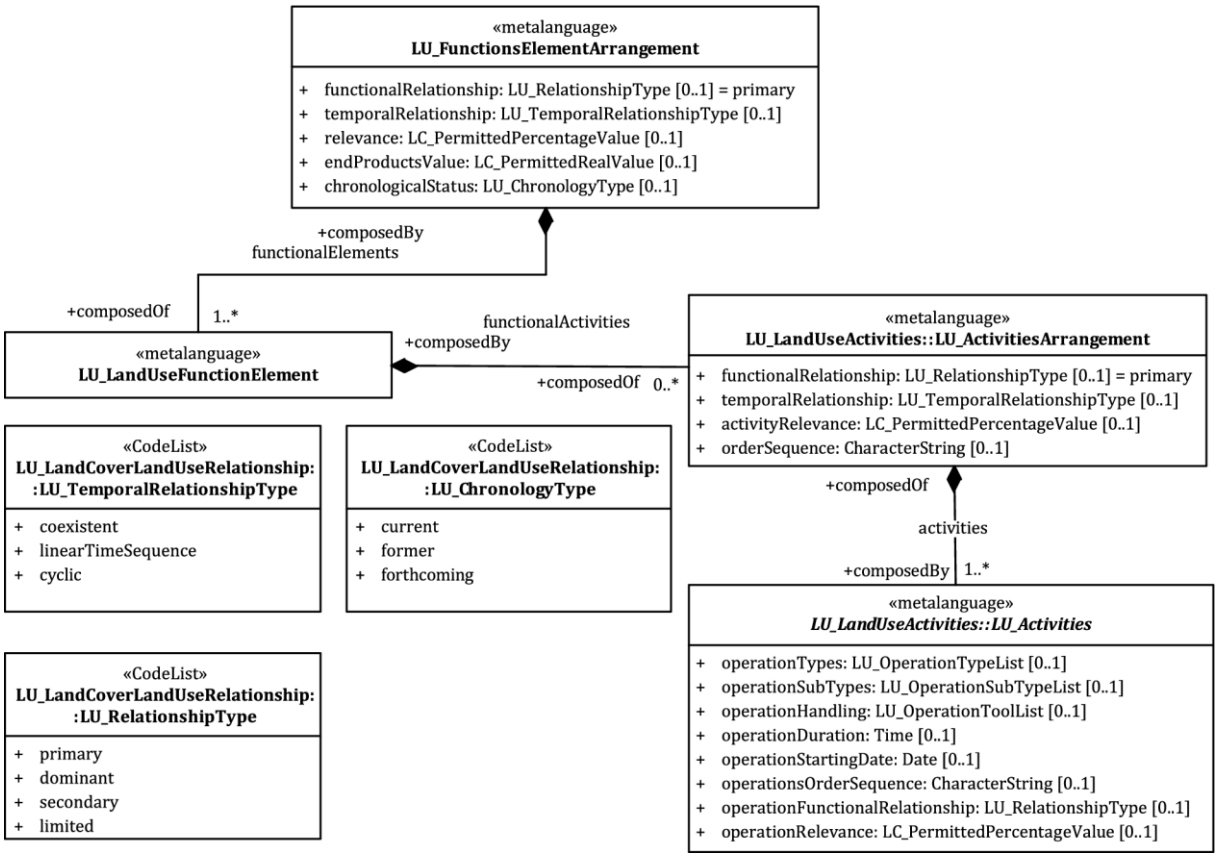

Figure 6 — Functions element arrangement

8.2.3 Land Use function and activities

8.2.3.1 LU_FunctionsElementArrangement

The class LU_FunctionsElementArrangement describes the arrangement and combination of the Land Use functions. A Land Use arrangement is composed of Land Use functional elements LU_LandUseFunctionElements together with LU_ActivitiesArrangements as a component of LU_LandUseFunctionalElements (i.e. optionally with activities linked to particular elements). Functions and activities components are complementary. Without this subdivision into functions and activities there would be a very large number of single Land Use entities. This subdivision provides structure.

This class has five attributes: *functionalRelationship*, *temporalRelationship*, *relevance*, *endProductsValue*, and *chronologicalStatus*.

8.2.3.2 LU_FunctionsElementArrangement attributes and relationships

8.2.3.2.1 functionalRelationship attribute

This attribute specifies the functional relationship between the physiognomic or structural components of the schema with the function or activities. The relationship types are given in the code list LU_RelationshipType. The default of this optional attribute is “primary”.

8.2.3.2.2 temporalRelationship attribute

This attribute specifies the temporal aspect of the relationship. The temporal aspect types are given in the code list LU_TemporalRelationshipType. This attribute is optional and by default there is no temporal relation specified.

8.2.3.2.3 relevance attribute

This attribute describes significance expressed as the relative weight between two or more functions. This attribute is optional. The data type is a percentage value as represented by LC_PermittedPercentageValue.

8.2.3.2.4 endProductValue attribute

This attribute describes the end product produced from a Land Use production activity using a consolidated product classification. This attribute is optional. The code list and attribute values used to fill this attribute field are established through registration. Any list or set of values established by a particular user of the document may be employed. Reference [16] can be used as a default list. References [14] and [12] can also be used.

8.2.3.2.5 chronologicalStatus attribute

This attribute describes the chronological time sequence of each function. This attribute is optional. The chronology types are given in the code list LU_ChronologyType.

8.2.3.2.6 functionalElements composition relationship

The functionalElements composition relationship indicates that LU_FunctionsElementArrangement is composed, in part, of LU_LandUseFunctionsElement classes.

8.2.3.2.7 functionalActivities composition relationship

The functionalActivities composition relationship indicates that LU_FunctionsElementArrangement is composed, in part, of LU_ActivitiesArrangement classes.

8.2.3.3 LU_LandUseFunctionElement

The class LU_LandUseFunctionElement describes particular Land Use functions. "Function" refers to the specific purpose that a particular piece of land serves and the specific output it provides. These are described in more detail in their subtypes.

8.2.3.4 LU_ActivitiesArrangement

The class LU_ActivitiesArrangement describes what actually takes place in physical or observable terms on the land defined under a specific function. This class allows multiple activities to be aggregated and arranged in accordance with five attributes. These attributes are: *functionalRelationship*, *temporalRelationship*, *activityRelevance*, *orderSequence* and *activitiesComposition*.

8.2.3.5 LU_ActivitiesArrangement attributes and relationships

8.2.3.5.1 functionalRelationship attribute

This attribute specifies the functional relationship between the physiognomic or structural components of the schema with the function or activities. The relationship types are given in the code list LU_RelationshipType. The default of this optional attribute is “primary”.

8.2.3.5.2 temporalRelationship attribute

This attribute specifies the temporal aspect of the relationship. The temporal aspect types are given in the code list LU_TemporalRelationshipType. This attribute is optional and by default there is no temporal relation specified.

8.2.3.5.3 activityRelevance attribute

This attribute describes the significance expressed as the relative weight between two or more activities. This attribute is optional. The value is given with a range from (1 to 100) %. The data type is a percentage value as represented by LC_PermittedPercentageValue.

8.2.3.5.4 orderSequence attribute

This attribute describes the sequential order, if present, linking different activities, i.e. the order of different activities (for example, seeding comes before harvesting). This attribute is optional. The data type is a CharacterString.

8.2.3.5.5 activities composition relationship

The activities composition relationship indicates that LU_ActivitiesArrangement is composed of LU_Activities classes.

8.2.4 LU_ChronologyType

The code list LU_ChronologyType contains a list of types of chronology relationships. This list contains three types: current, former and forthcoming.

The code list values are:

— current — at the present time;

— former — at a previous time;

— forthcoming — at a future time.

8.3 Land Use structure

8.3.1 Overview of the Land Use structure

Land Use components are based on a functional interaction or connection between “functions” and “activities”. These may also be called "Land Use types". Functions refer to purpose and output, realized through a sequence of actions taking place on given Land Cover.

Five main functions are shown in Figure 7 and are listed below. Each function is subdivided into different subfunctions.

The main five functions are:

— production — the process of growing, harvesting or making goods; it refers both to the growing of plants or animals and the process and methods used to transform tangible raw materials into goods. The purpose is the production of goods and the output are the goods produced;

— provision — the action/process of providing or supplying of intangible products for other business or consumers; it refers to the provision of services, utilities, transport or logistic. The purpose is the provision of intangible products and the output are the services, utilities or other intangible products produced;

— residential — the action or state of providing housing, including both single and multifamily houses when not linked to direct and secondary production. The purpose is the provision of housing and the output is the housing provided;

— regulative — the action, process or state of managing through specific normative rules (controlling, directing, monitoring or managing) or principles including both conservation/protection of environmental areas, conservation/protection archaeological sites, restriction rules to access particular areas to permit, promote, prohibit or restrict. For example, a regulated activity can require that if the environmental status is degraded then particular actions are enacted to restore good environmental status. The purpose is the management and the output is the environmental, educational and cultural benefit to people. Regulation is only briefly addressed in this document in order to provide a link to an external specification. The detailed rights, restrictions and responsibilities and parties associated with a "Regulative" function may be described separately in an external document or in accordance with the Land Administrative Domain Model specified in ISO 19152-1;

— insubstantial other — not evident, undetermined, undecided or irrelevant use.

Figure 7 illustrates the five main functions. The list of functions can be extended by registration of addition functional elements.

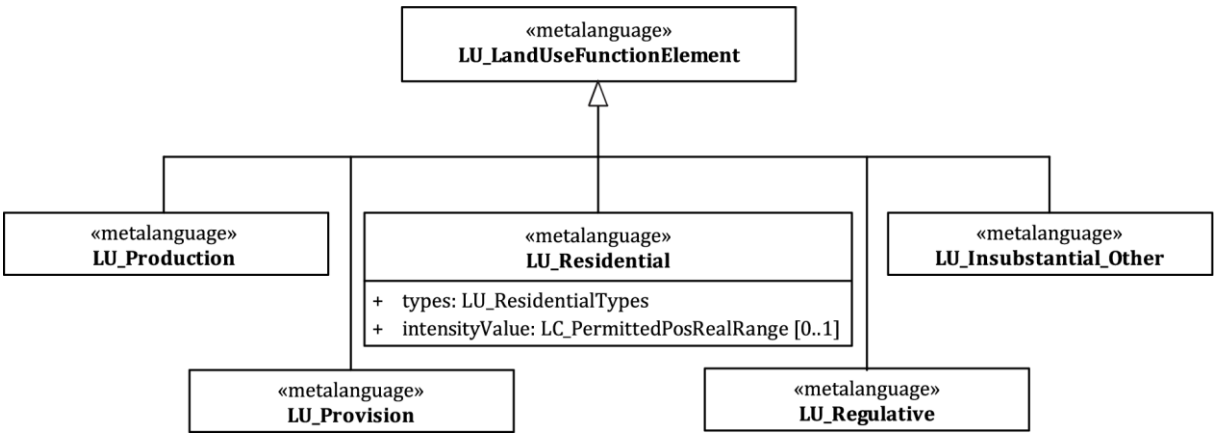

Figure 7 — The five main functions for Land Use

8.3.2 Description of the Land Use function classes

8.3.2.1 LU_Production

The class LU_Production describes the process of growing, harvesting or making goods; it refers both to the growing of plants or animals and the process and methods used to transform tangible raw materials into goods.

8.3.2.2 Subtypes of LU_Production

The "Production" function is subdivided into two subcategories:

— direct (or primary) production — the production of basic material or crops;

— secondary production — manufacturing of goods.

The direct production is further subdivided into different subcategories and sub-subcategories. Similarly, secondary production is further subdivided into different subcategories and sub-subcategories. The high-level decomposition tree of classes is shown in Figure 8.

8.3.2.3 Subtypes of LU_DirectProduction

8.3.2.3.1 LU_DirectProduction

The class LU_DirectProduction describes the production of basic material or crops. LU_DirectProduction may also be called by its alias LU_BasicMaterialProduction. This class has five subtypes and many sub-subtypes as illustrated in Figure 8.

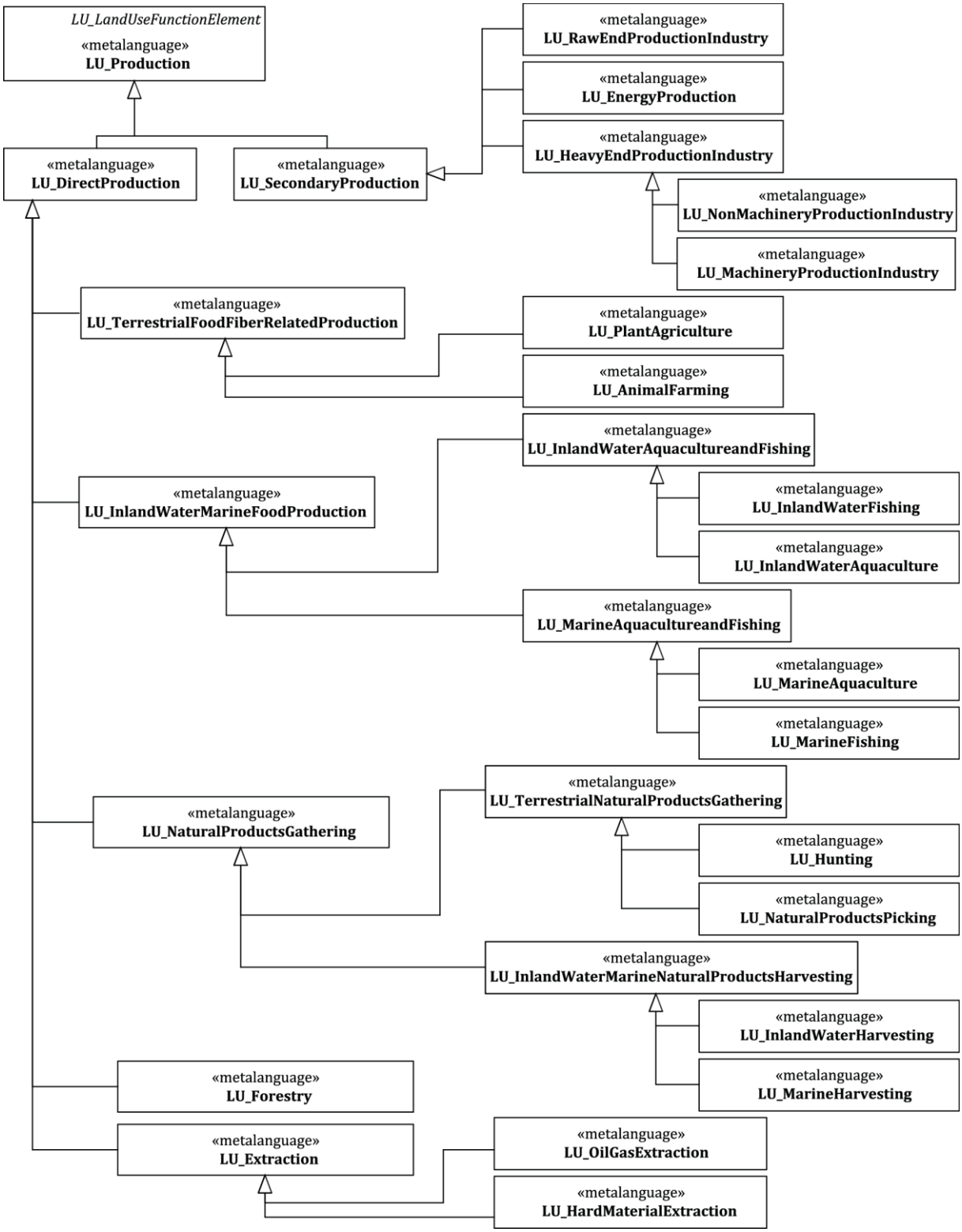

Figure 8 — Subtypes of LU_Production

The subclasses of LU_Production are shown in detail in Figures 9, 10, 11, 12 and 13 with attributes.

8.3.2.4 LU_TerrestrialFoodFiberRelatedProduction

The class LU_TerrestrialFoodFiberRelatedProduction is a subtype of LU_DirectProduction. This class may also be called by its alias LU_FoodFiberRelatedProduction. It describes to the production of crops and animal products for food consumption and commercial purposes. The function is further sub–divided into two different categories: plant agriculture and animal farming. This is illustrated in Figure 9.

8.3.2.5 LU_PlantAgriculture

The class LU_PlantAgriculture is a subtype of LU_TerrestrialFoodFiberRelatedProduction. It refers to the growing of crops both in open fields and green houses. The function is defined by three different "plant agriculture types" as expressed in the optional attributes *exploitationType*, *intensity* and *scale*. These attributes take on values from the code lists LU_DegreeOfCommercializationTypes, LU_IntensityTypes, and LU_FarmScaleRelatedTypes. These code lists are shown in Figure 14.

8.3.2.6 LU_AnimalFarming

The class LU_ AnimalFarming is a subtype of LU_TerrestrialFoodFiberRelatedProduction. It refers to the branch of agriculture related to animals raised for food consumption or other products. This class is a sub-subtype of LU_Production. Several LU_Production classes can be aggregated to describe a LU_LandUseClassDescriptor. For example, in a mixed farming situation consisting of beef cattle and dairy cattle, two different farming types are combined. The class has the optional attributes *type*, *species, intensity* and *productionSystem*. These attributes take on values from the code lists LU_AnimalFarmingTypes, a character string for *species*, LU_IntensityTypes, and LU_ProductionSystemTypes. These code lists are shown in Figure 14.

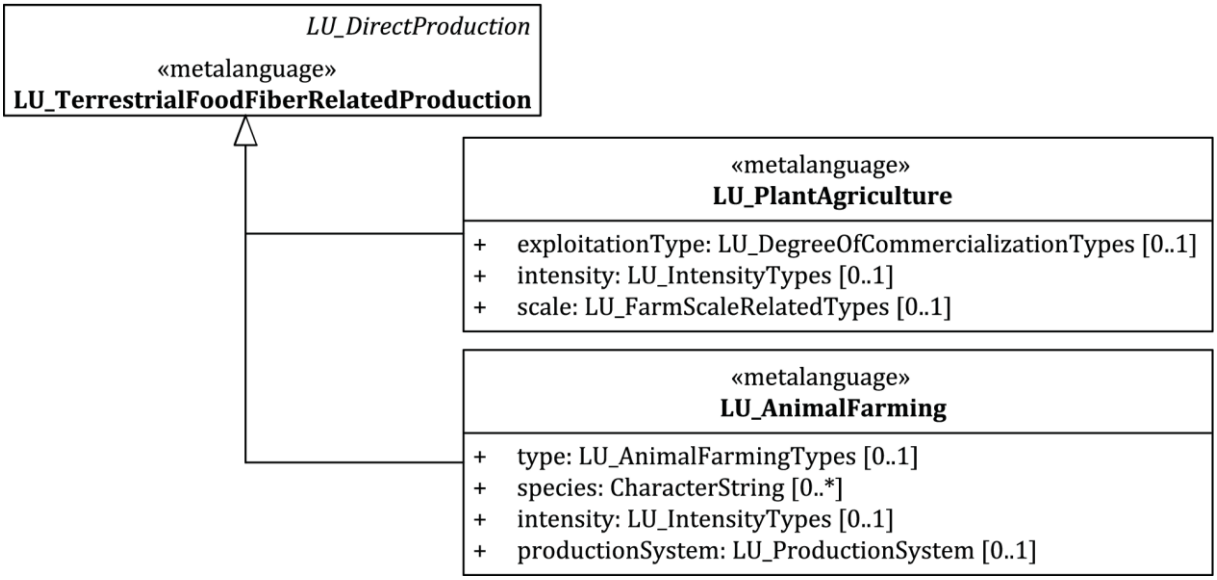

Figure 9 — Terrestrial food fibre related production element

8.3.2.7 LU_InlandWaterMarineFoodProduction

The class LU_InlandWaterMarineFoodProduction is a subtype of LU_DirectProduction. It refers to the fishing or aquaculture both on inland water and sea. It is further divided into: inland water aquaculture and fishing, and marine aquaculture and fishing. This is illustrated in Figure 10.

8.3.2.8 LU_InlandWaterAquacultureandFishing

The class LU_InlandWaterAquacultureandFishing is a subtype of LU_InlandWaterMarineFoodProduction. It has subtypes of both “aquaculture” and “fishing” in inland waters.

8.3.2.9 LU_InlandWaterAquaculture

The class LU_InlandWaterAquaculture is a subtype of LU_InlandWaterAquacultureandFishing. It refers to “aquaculture” in inland waters. The class has the optional attribute *type* which takes on values from the code list LU_InlandWaterAquacultureTypes. This code list is shown in Figure 14.

8.3.2.10 LU_InlandWaterFishing

The class LU_InlandWaterFishing is a subtype of LU_InlandWaterAquacultureandFishing. It refers to “fishing” in inland waters. The class has the optional attribute *type* which takes on values from the code list LU_InlandWaterFishingTypes. This code list is shown in Figure 14.

8.3.2.11 LU_MarineAquacultureandFishing

The class LU_MarineAquacultureandFishing is a subtype of LU_InlandWaterMarineFoodProduction. It has subtypes of both “aquaculture” and “fishing” at sea.

8.3.2.12 LU_MarineAquaculture

The class LU_MarineAquaculture is a subtype of LU_MarineAquacultureandFishing. It refers to “aquaculture” at sea. The class has the optional attribute *type* which takes on values from the code list LU_MarineWaterAquacultureTypes. This code list is shown in Figure 14.

8.3.2.13 LU_MarineWaterFishing

The class LU_MarineWaterFishing is a subtype of LU_MarineAquacultureandFishing. It refers to “fishing” at sea. The class has the optional attribute *type* which takes on values from the code list LU_MarineFishingTypes. This code list is shown in Figure 14.

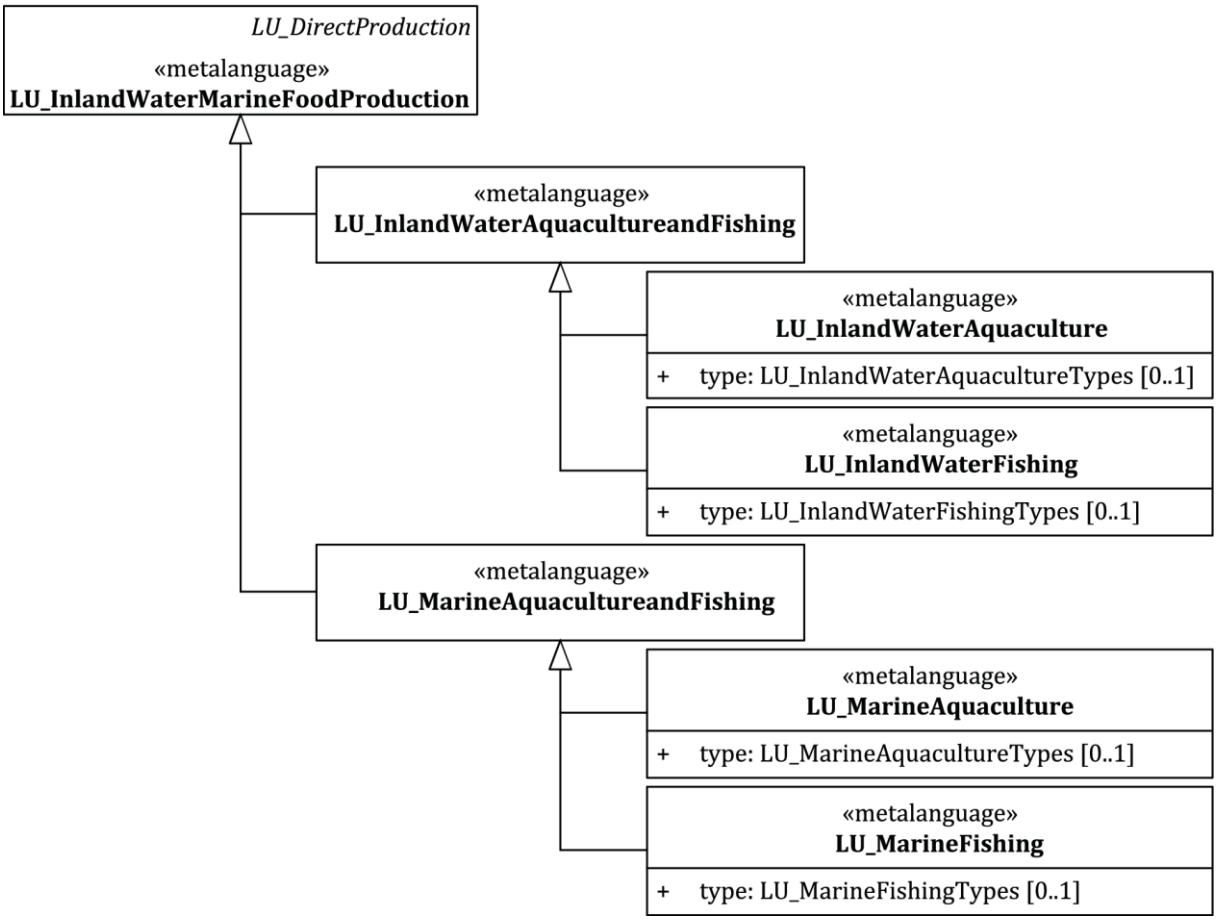

Figure 10 — Inland water marine food production element

8.3.2.14 LU_NaturalProductsGathering

The class LU_NaturalProductsGathering is a subtype of LU_DirectProduction. the collection of natural products like hunting animals, collection of wild growing non-wood forestry products, etc. It is further divided into: terrestrial natural product gathering and inland water and marine natural product harvesting. This is illustrated in Figure 11.

8.3.2.15 LU_TerrestrialNaturalProductsGathering

The class LU_TerrestrialNaturalProductsGathering is a subtype of LU_ NaturalProductsGathering. It refers to gathering on a terrestrial environment and is further subdivided into “hunting” and “natural products piking”.

8.3.2.16 LU_Hunting

The class LU_Hunting is a subtype of LU_TerrestrialNaturalProductsGathering. It refers to “hunting” in terrestrial environment. It takes on the optional attributes *type* and *species*. The attribute *type* takes on values from the code list LU_AnimalHuntingTypes, and the attribute *species* has a character string for its value type. These code lists are shown in Figure 14.

8.3.2.17 LU_NaturalProductsPicking

The class LU_NaturalProductsPicking is a subtype of LU_TerrestrialNaturalProductsGathering. It refers to “gathering” in terrestrial environment.

8.3.2.18 LU_InlandWaterMarineNaturalProductsHarvesting

The class LU_InlandWaterMarineNaturalProductsHarvesting is a subtype of LU_NaturalProductsGathering. It refers to gathering on inland water or sea and is further subdivided into “inland water product harvesting” and “marine water product harvesting”

8.3.2.19 LU_InlandWaterHarvesting

The class LU_InlandWaterHarvesting is a subtype of LU_InlandWaterMarineNaturalProductsHarvesting. It refers to “gathering” in inland waters.

8.3.2.20 LU_MarineHarvesting

The class LU_MarineHarvesting is a subtype of LU_InlandWaterMarineNaturalProductsHarvesting. It refers to “gathering” at sea.

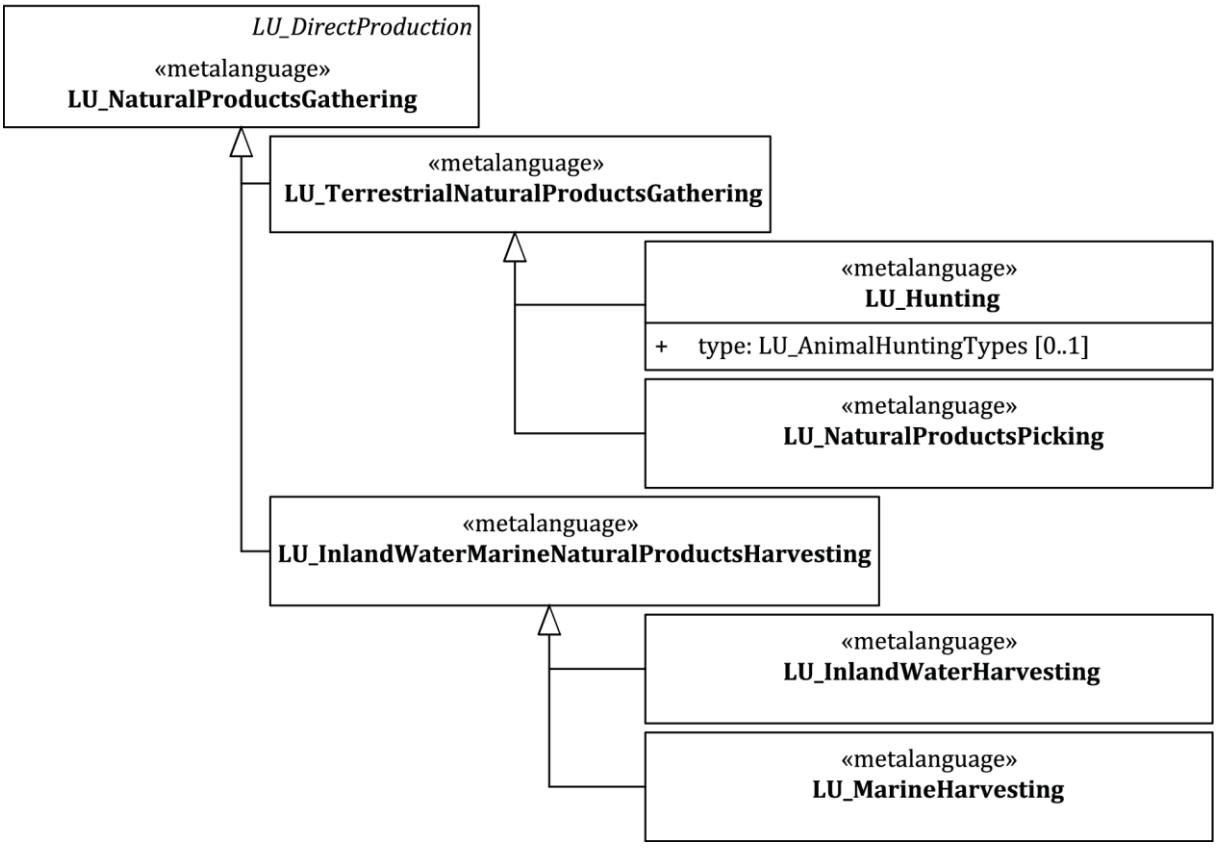

Figure 11 — Natural products gathering element

8.3.2.21 LU_Forestry

The class LU_Forestry is a subtype of LU_DirectProduction. It is the practice of planting, managing and caring for areas with trees defined as forest. This is illustrated in Figure 12. It takes on the optional attribute *type* which takes on values from the code list LU_ForestryTypes. This code list is shown in Figure 14.

8.3.2.22 LU_Extraction

The class LU_Extraction is a subtype of LU_DirectProduction. It describes the extraction of minerals and materials present in nature as solid, liquid or gasses. It is further subdivided into: hard material extraction and oil gas extraction. This is illustrated in Figure 12.

8.3.2.23 LU_HardMaterialExtraction

The class LU_HardMaterialExtraction is a subtype of LU_Extraction. It refers to the mining or extraction of hard materials. The class takes on the optional attributes *position*, *miningTypes* and *materialTypes*. These code lists are shown in Figure 14.

8.3.2.24 LU_OilGasExtraction

The class LU_OilGasExtraction is a subtype of LU_Extraction. It refers to the extraction of liquid or gasses materials or both. The class takes on the optional attributes *extractedMaterialTypes* and *extractionTypes.* These code lists are shown in Figure 14.

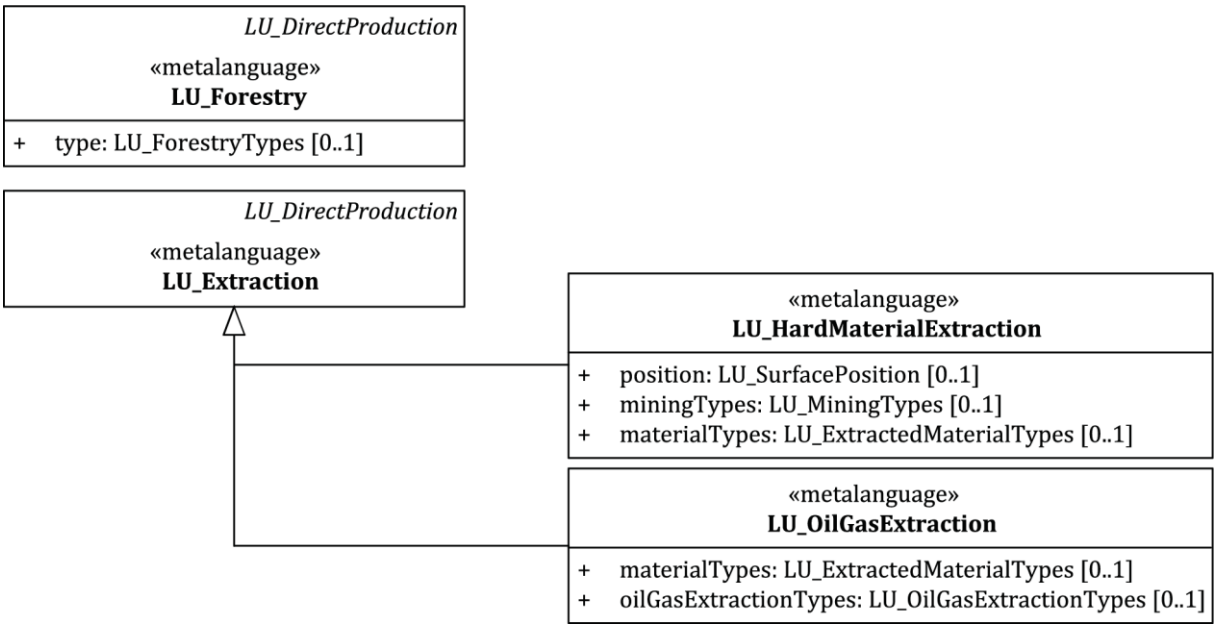

Figure 12 — Forestry and extraction functional elements

8.3.2.25 Subtypes of LU_SecondaryProduction

8.3.2.25.1 LU_SecondaryProduction

The class LU_SecondaryProduction describes the manufacturing of goods. This class has three subtypes and two sub-subtypes as illustrated in Figure 8 and Figure 13.

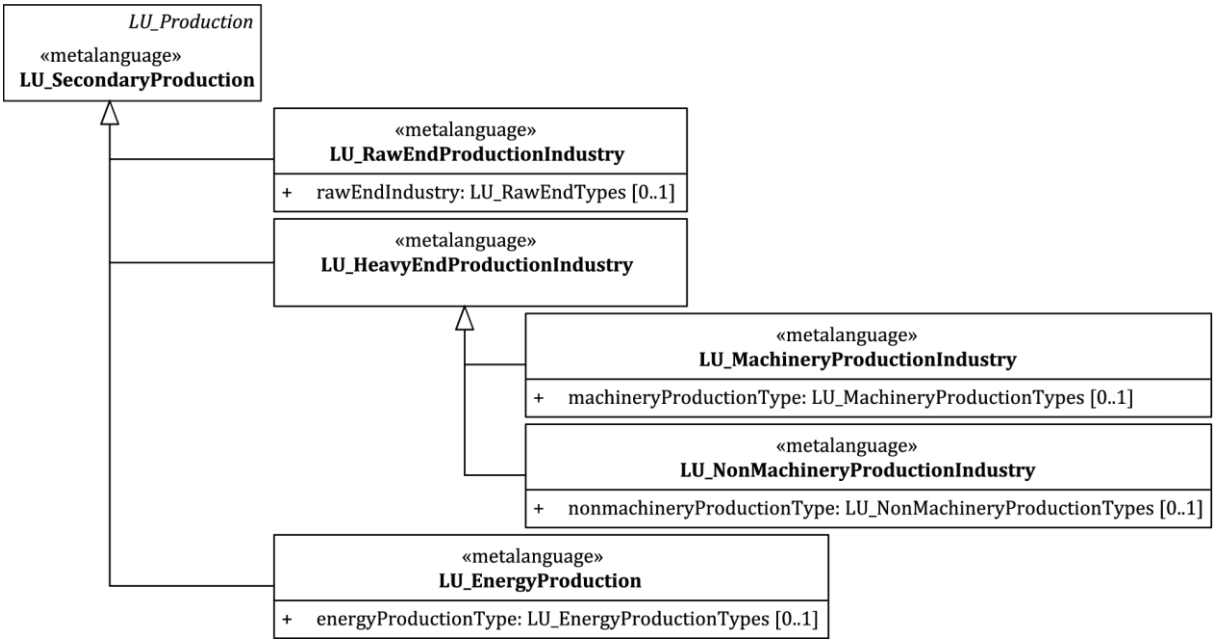

Figure 13 — Secondary production functional element

8.3.2.26 LU_Provision

The class LU_ Provision describes the action or process of providing or supplying of intangible products for other business or consumers; it refers to the provision of services, utilities, transport or logistic.

8.3.2.27 LU_Residential

The class LU_Residential describes an area used mainly for housing, including both single and multifamily houses when not linked to direct and secondary production.

8.3.2.28 LU_Residential attributes

8.3.2.28.1 type attribute

This attribute specified the type of residential housing. The types are given in the code list LU_ResidentialTypes.

8.3.2.28.2 intensityValue attribute

This attribute specifies intensity or density of residential housing. This attribute is optional. The data type is a positive real range. A unit of measure needs to be established.

8.3.2.29 LU_Regulative

The class LU_Regulative describes the set of management principles under specific normative rules to ensure, among others: the conservation, protection or restoration of areas important for environment and climate; the conservation or protection of archaeological sites; and the preservation of the aesthetic character of valuable environmental spaces.

The detailed rights, restrictions and responsibilities and parties associated with a “Regulative” function may be described separately in an external document in accordance with the Land Administrative Domain Model specified in ISO 19152-1.

8.3.2.30 LU_Insubstantial_Other

The class LU_Insubstantial_Other describes an area that is not evident, irrelevant or of negligible use or of other use.

8.3.2.31 LU_RawEndProductionIndustry

The class LU_RawEndProductionIndustry is a subtype of LU_SecondaryProduction. It describes all the industrial activities that are devoted to the transformation (including packaging) of the outputs of the direct (or primary) products into assembled or manufactured basic raw products. It is further defined by a list of "raw end production industry". It has the optional attribute *rawEndIndustry* which takes on values from the code list LU_RawEndIndustryTypes. This code list is shown in Figure 14.

8.3.2.32 LU_HeavyEndProductionIndustry

The class LU_HeavyEndProductionIndustry is a subtype of LU_SecondaryProduction. It describes all the industrial activities that are devoted to the transformation of raw manufactured products into machinery and other “heavy” materials. It is further subdivided into “machinery” and “non-machinery” products.

8.3.2.33 LU_MachineryProductionIndustry

The class LU_MachineryProductionIndustry is a subtype of LU_HeavyEndProductionIndustry. It refers to industrial activities that transform products of direct production into different types of machinery. It has the optional attribute *machineryProductionType* which takes on values from the code list LU_MachineryProductionTypes. This code list is shown in Figure 14.

8.3.2.34 LU_NonMachineryProductionIndustry

The class LU_NonMachineryProductionIndustry is a subtype of LU_HeavyEndProductionIndustry. It refers to industrial activities not related to machinery. It has the optional attribute *nonMachineryProductionType* which takes on values from the code list LU_NonMachineryProductionTypes. This code list is shown in Figure 14.

8.3.2.35 LU_EnergyProduction

The class LU_EnergyProduction is a subtype of LU_SecondaryProduction. It describes areas that are used for the production of any form of energy (electric, fuel, gas, biogas, nuclear, etc.). It has the optional attribute *energyProductionType* which takes on values from the code list LU_EnergyProductionTypes. This code list is shown in Figure 14.

8.3.3 Code lists and support classes for LU_Production

8.3.3.1 LU_Production general

The code list "code lists and support classes related to LU_Production" is illustrated in Figure 14.

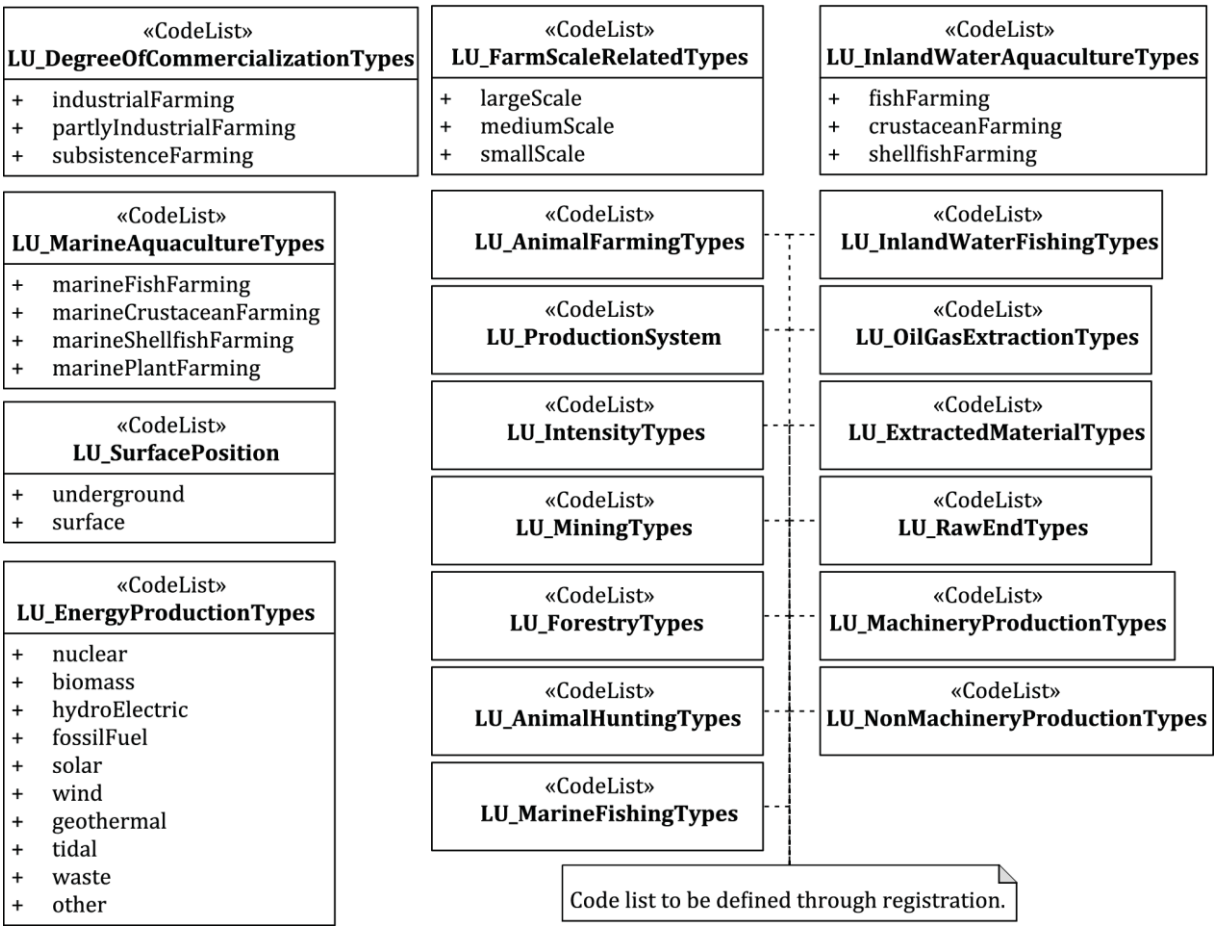

Figure 14 — Code lists and support classes

8.3.3.2 LU_DegreeOfCommercializationTypes

The code list LU_DegreeOfCommercializationTypes describes the degree of commercial exploitation involved in the practice of plant agriculture. The code list values are:

— industrialFarming — a type of mechanized agriculture where crops are grown for industrial or commercial use only. It is an intensive agriculture in one or more sectors. It generally includes increased use of fertilizer, plant growth regulator and pesticides;

— partlyIndustrialFarming — a type of mechanized agriculture where crops are grown both for personal and industrial or commercial use. They are intensive farms usually smaller than those of the previous class and with more sustainable intensive cultivation methods;

— subsistenceFarming — a type of agriculture which is mainly a self-sufficient farming system in which the products are mainly used to provide for the basic needs of the farmer. The output is mostly used for local requirements with limited or negligible surplus trade. However, for goods that are not necessary for survival, many farmers participate in trade for some degree.

This code list may be extended through registration.

8.3.3.3 LU_IntensityTypes

The code list LU_IntensityTypes defines the amount of inputs of one form or another for increasing productivity on a per unit area basis.

This code list may be defined through registration.

The method of describing agricultural intensity in terms of yield per land area and per input unit[15] or as the sum of different categories of input costs and the total usable agricultural area[13] are defined in the referenced sources. Either output-oriented (production) or, input-oriented (utilization) measures can be used to describe agricultural intensity.

8.3.3.4 LU_FarmScaleRelatedTypes

The code list LU_FarmScaleRelatedType contains a list of types that define the general character of the business unit know as a farm. The major discriminate is the type of labour supply. It is defined by three types: large scale, medium scale, and small scale. The code list values are:

— largeScale — any kind of farming were the manager does not do the manual work but confines activity mainly to the work of superintendence;

— mediumScale — any kind of farming were the farmer does some part of the work but not entirely;

— smallScale — any kind of farming were the farmer (and members of a family) does the whole part of the work.

This code list may be extended through registration.

8.3.3.5 LU_AnimalFarmingTypes

The code list LU_AnimalFarmingTypes describes types of animal farming.

This code list may be defined through registration.

8.3.3.6 LU_ProductionSystem

The code list LU_ProductionSystem describes the production system used for animal farming.

This code list may be defined through registration.

8.3.3.7 LU_InlandWaterAquacultureTypes

The code list LU_InlandWaterAquacultureTypes describes inland aquaculture types. The types are:

— fishFarming — raising fish commercially in tanks or fish ponds in fresh water for food production;

— crustaceanFarming — raising crustaceans in fresh water for food production;

— shellfishFarming — raising of shellfish in fresh water.

This code list may be extended through registration.

8.3.3.8 LU_MarineAquacultureTypes

The code list LU_MarineAquacultureTypes refers to “aquaculture” at sea. The code list values are:

— marineFishFarming — raising of fish in the ocean for food production;

— marineCrustaceanFarming — raising of crustaceans in the ocean for food production;

— marineShellfishFarming — raising of shellfish in the ocean;

— marinePlantFarming — farming of different species of algae, kelp or other flora in the ocean.

This code list may be extended through registration.

8.3.3.9 LU_MarineFishingTypes

The code list LU_MarineFishingTypes describes the types of fishing at sea.

This code list may be defined by registration.

8.3.3.10 LU_AnimalHuntingTypes

The code list LU_AnimalHuntingTypes describes types of animal hunting.

This code list may be defined by registration.

8.3.3.11 LU_ForestryTypes

The code list LU_ForestryTypes describes the types of planting, managing and caring for areas with trees defined as forest.

This code list may be defined by registration.

8.3.3.12 LU_SurfacePosition

The code list LU_SurfacePosition describes the position on which the extraction activities take place. The code list values are:

— underground — excavation of material under land surface;

— surface — category of mining in which soil and rock deposits overlaying the minerals are removed.

This list may be extended through registration.

8.3.3.13 LU_MiningTypes

The code list LU_MiningTypes describes the types of hard material extraction.

This code list may be defined by registration.

8.3.3.14 LU_ExtractctedMaterialTypes

The code list LU_ExtractctedMaterialTypes describes the types of materials extracted through hard material extraction.

This code list may be defined by registration

8.3.3.15 LU_OilGasExtractionTypes

The code list LU_OilGasExtractionTypes describes the methods of oil and gas extraction.

This code list may be defined by registration.

8.3.3.16 LU_RawEndTypes

The code list LU_RawEndTypes describes industrial activities that are devoted to the transformation (including packaging) of the outputs of the direct (or primary) products into assembled or manufactured basic raw products.

This code list may be defined by registration.

8.3.3.17 LU_MachineryProductionTypes

The code list LU_MachineryProductionTypes describes the types of industrial activities that transform products of direct production into different types of machinery.

This code list may be defined by registration.

8.3.3.18 LU_NonMachineryProductionTypes

The code list LU_MachineryProductionTypes describes the types of industrial activities that transform products of direct production into different types of machinery.

This code list may be defined by registration.

8.3.3.19 LU_EnergyProductionTypes

The code list LU_EnergyProductionTypes describes the types of the production of energy. The code list values are as follows:

— nuclear — nuclear-based energy production;

— fossilFuel — fossil fuel combustion-based energy production;

— biomass — biomass combustion-based energy production;

— hydroElectric — water-based energy production;

— solar — solar-based energy production;

— wind — wind-based energy production;

— geothermal — geo-thermal based energy production;

— tidal — tidal-based energy production;

— waste — waste combustion-based energy production;

— other — other energy production.

This code list may be extended through registration.

8.3.4 LU_Provision function

The “Provision” function is subdivided into two subcategories:

— services and utilities — refers to all types of services (commercial, financial, commercial, cultural, recreational, etc.) and utilities (infrastructures related to energy distribution services, water distribution, sewage treatment, etc.). This subfunction is further subdivided into sole “services” and sole “utilities”;

— transport and logistic — refers to all types of infrastructures related to transport and logistics. This sub–function is further subdivided into sole “transport” and sole “logistics”.

The services and utilities and transport and logistic are further subdivided into different subcategories. The decomposition tree of classes is shown in Figure 15.

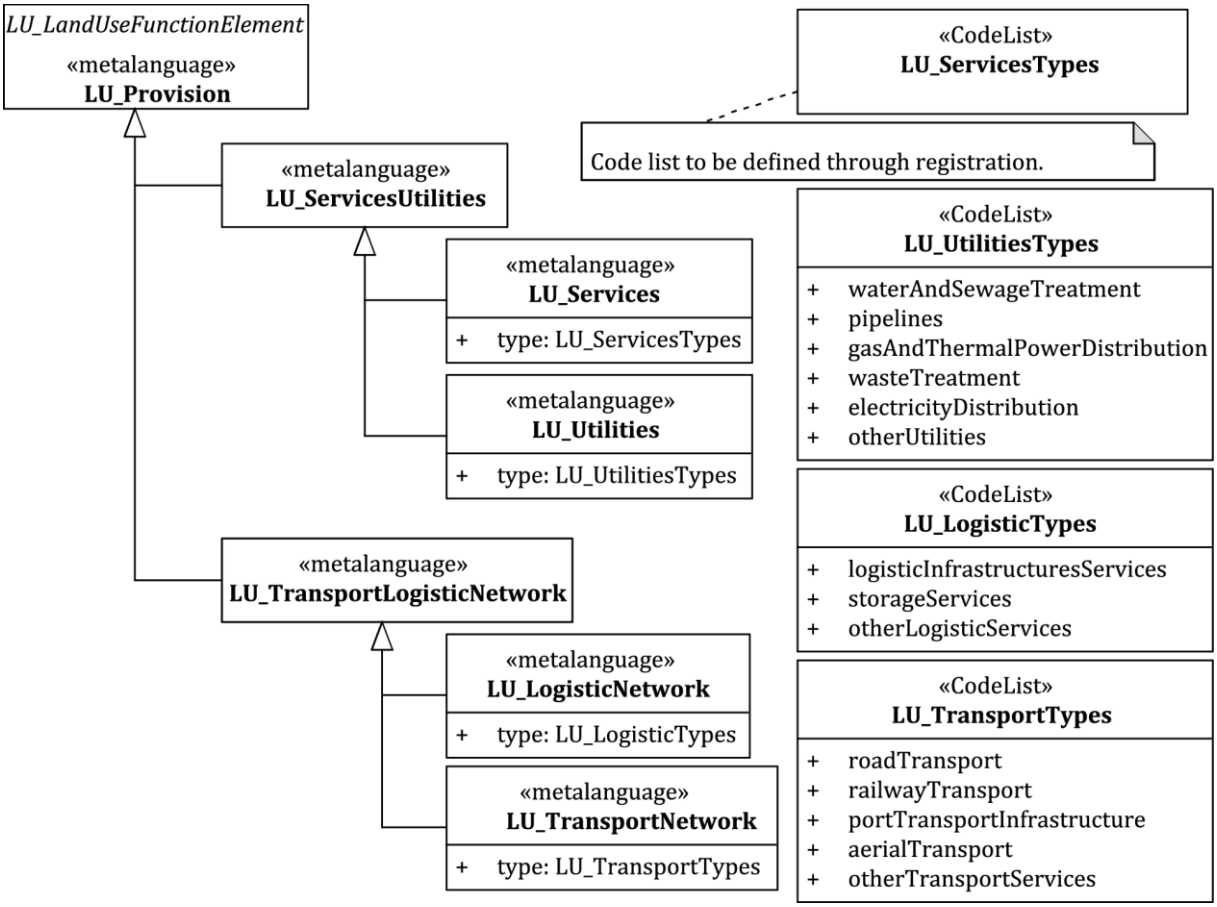

Figure 15 — Subtypes of LU_Provision

8.3.5 Subtypes of LU_ Provision

8.3.5.1 LU_ServicesUtilities

The class LU_ServicesUtilities describes types of services (commercial, financial, commercial, cultural, recreational, etc.) and utilities (infrastructures related to energy distribution services, water distribution, sewage treatment, etc.). This subfunction is further subdivided into sole “services” and sole “utilities” as illustrated in Figure 15.

8.3.5.2 LU_Services

The class LU_Services is a subtype of LU_ServicesUtilities. It describes types of services. It has one attribute, *types*, which makes use of the code list LU_ServiceTypes.

8.3.5.3 LU_Utilities

The class LU_Utilities is a subtype of LU_ServicesUtilities. It describes types of utilities. It has one attribute, *type*, which makes use of the code list LU_UtilitiesTypes.

8.3.5.4 LU_TransportLogisticNetwork

The class LU_TransportLogisticNetwork describes types of infrastructures related to transport and logistics. This subfunction is further subdivided into sole “transportation network” and “logistic network” as illustrated in Figure 15.

8.3.5.5 LU_TransportationNetwork

The class LU_TransportationNetwork is a subtype of LU_TransportLogisticNetwork. It describes types of transportation networks. It has one attribute, *type*, which makes use of the code list LU_TransportTypes.

8.3.5.6 LU_LogisticNetwork

The class LU_LogisticNetwork is a subtype of LU_TransportLogisticNetwork. It describes types of logistic networks. It has one attribute, *type*, which makes use of the code list LU_LogisticTypes.

8.3.5.7 LU_ServicesTypes

The code list LU_ServicesTypes contains a list of types of service provisions. Examples are food services, administrative services, personnel care services.

This code list may be defined by registration.

8.3.5.8 LU_UtilitiesTypes

The code list LU_UtilitiesTypes contains a list of types of utilities provisions.

The code list values are:

— waterAndSewageTreatment — water and sewage treatment: areas devoted to the provision of water and sewage treatment including collection extraction and purification;

— pipelines — pipelines for oil or gas: areas devoted to the transport of oil or gas;

— wasteTreatment — waste treatment: areas devoted to the different types of treatment of waste;

— electricityDistribution — electricity distribution services: areas and infrastructures devoted to the distribution of electricity;

— gasAndThermalPowerDistribution — gas and thermal power distribution services: areas and infrastructures devoted to the storage and distribution of gas and thermal power;

— otherUtilities — other utilities.

This code list may be extended through registration.

8.3.5.9 LU_LogisticTypes

The code list LU_LogisticTypes contains a list of types of utilities provisions.

The code list values are:

— logisticInfrastructuresServices — logistic infrastructures services: any type of infrastructure used for logistic service;

— storageServices — storage services: any utility and infrastructure used for storage of goods;

— otherLogisticServices — other logistic types.

This code list may be extended through registration.

8.3.5.10 LU_TransportTypes

The code list LU_TransportTypes contains a list of types of utilities provisions.

The code list values are:

— roadTransport — roads and related infrastructures;

— railwayTransport — railways and related infrastructures;

— portTransportInfrastructure — ports, docks and any other related infrastructure;

— aerialTransport — areas and infrastructures devoted to the air transportation;

— otherTransportServices — other transport services.

This code list may be extended through registration.

8.3.6 LU_ResidentialTypes

8.3.6.1 LU_ResidentialTypesDescription

The *type* attribute in the class LU_Residential takes on the code list LU_ResidentialTypes. This is shown in Figure 16. The code list LU_ResidentialTypes contains a list of types of residential dwellings. The code list values are:

— household — all households except the ones used for special provisions and services;

— accommodation — hotels, motels and other accommodation services for lodging and short-term accommodation;

— otherResidential — other residential housing.

This code list may be extended through registration.

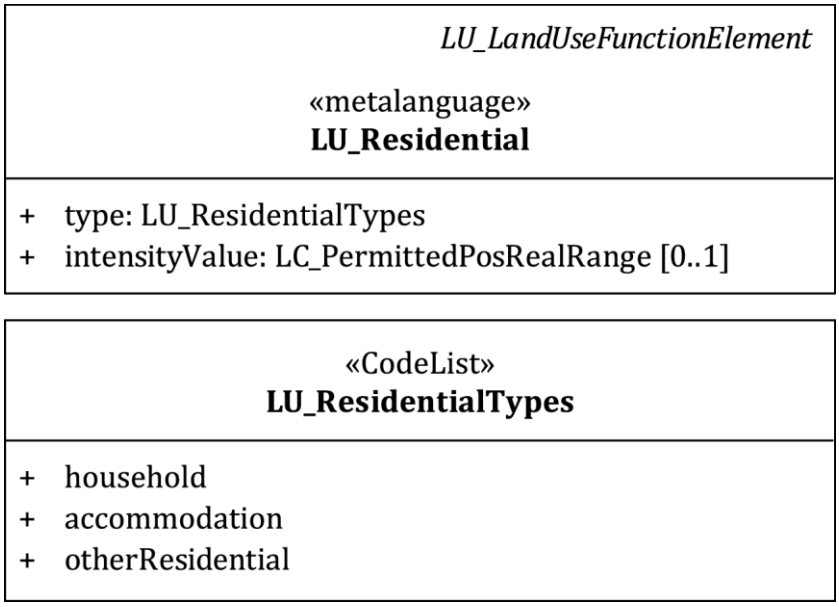

Figure 16 — Residential types

8.3.7 LU_Regulative

The “Regulative” function is subdivided into four major groups:

— conservation/protection/restoration — areas under specific restoration measures or conservation or protection rules or both;

— heritage — areas having cultural, historical significance and therefore having some form of protection;

— restricted — areas were the access is restricted due to some specific risk exposure (technological, natural, etc.);

— buffering and shielding — controlled zones designated to defend against or protect from specific hazard (flooding, contamination, etc.). It is further divided into “buffering” and “shielding”.

The detailed rights, restrictions and responsibilities and parties associated with a “Regulative” function may be described separately in an external document in accordance with the Land Administrative Domain Model specified in ISO 19152-1.

The Regulative function is shown in Figure 17 including subtypes and the associated code lists are shown in Figure 18.

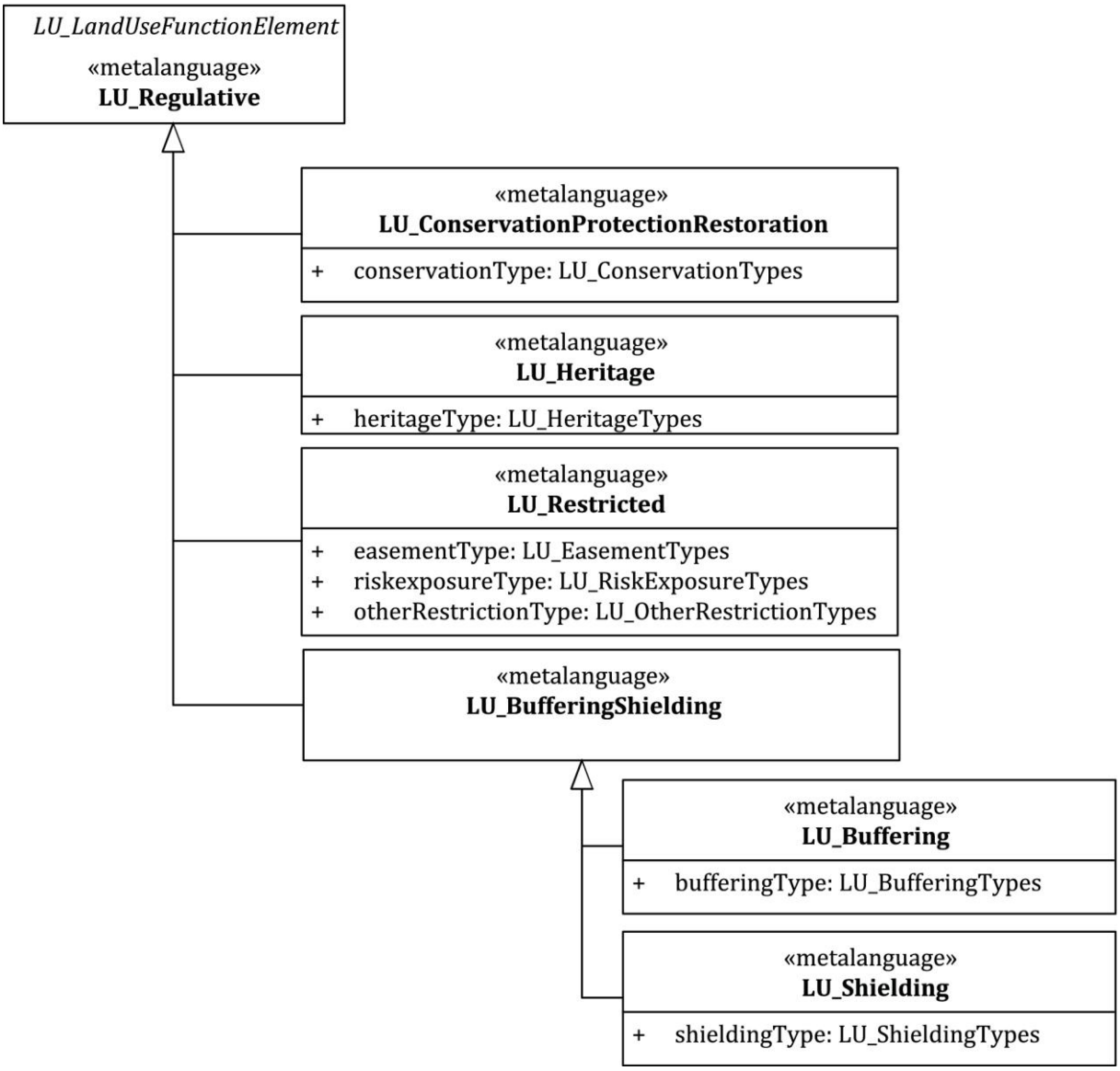

Figure 17 — Subtypes of LU_Regulative

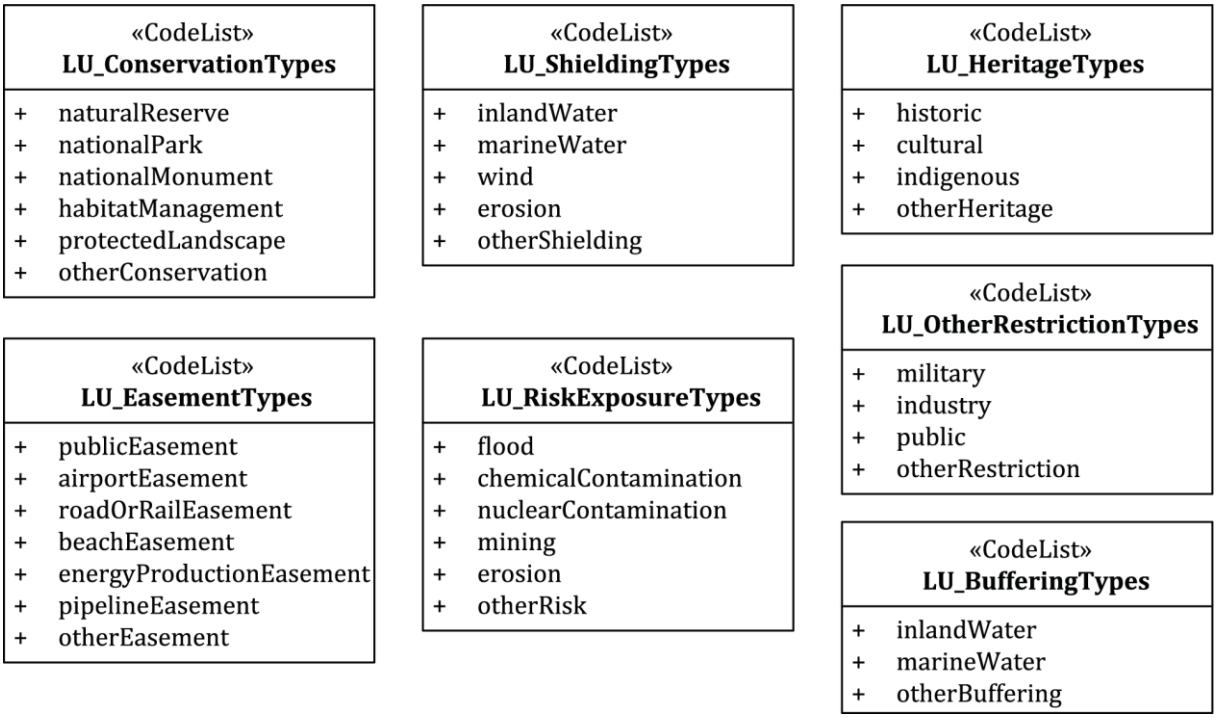

Figure 18 — Subtypes of LU_Regulative code lists

8.3.8 Subtypes of LU_Regulative

8.3.8.1 LU_ConservationProtectionRestoration

The class LU_ConservationProtectionRestoration is a subtype of LU_Regulative which describes areas under specific restoration measures or conservation or protection rules or both. It has the attribute *conservationTypes* which takes the value LU_ConservationTypes.

8.3.8.2 LU_Heritage

The class LU_Heritage is a subtype of LU_Regulative which describes areas having cultural, historical significance and therefore having some form of protection. It has the attribute *heritageType* which takes the value LU_HeritageTypes.

8.3.8.3 LU_Restricted

The class LU_Restricted is a subtype of LU_Regulative which describes areas were the access is restricted due some specific risk exposure (technological, natural, etc.). It has the attributes *easementType, riskExposureType*, and *restrictionType* which take the values LU_EasementTypes, LU_RiskExposureTypes, and, LU_OtherRestrictionTypes respectively.

8.3.8.4 LU_BufferingShielding

The class LU_BufferingShielding describes controlled zones designated to defend against or protect from specific hazards (flooding, contamination, etc.). It is further divided into the subtypes LU_Buffering and LU_Shielding.

8.3.8.5 LU_Buffering

The class LU_Buffering is a subtype of LU_BufferingShielding which describes controlled zones designated to defend against or protect from specific hazards by the use of a buffer area. It has the attribute *bufferingTypes* which takes the value LU_BufferingTypes.

8.3.8.6 LU_Shielding

The class LU_Shielding is a subtype of LU_BufferingShielding which describes controlled zones designated to defend against or protect from specific hazards by the use of a shield. It has the attribute *shieldingTypes* which takes the value LU_ShieldingTypes.

8.3.9 Code lists for LU_Regulative

8.3.9.1 LU_ConservationTypes

The code list LU_ConservationTypes describes the types of conservation or protection rules.

The code list values are:

— naturalReserve — strict natural reserve and wilderness area with protection of a large unmodified, or slightly modified area retaining its natural character and influence, without permanent or significant human habitation, which is protected and can serve as reference for scientific research and monitoring;[20]

— nationalPark — national park with protection of large natural or near natural areas set aside to protect large scale ecological processes;[20]

— nationalMonument — natural monument or features with protection of specific areas (generally small) containing a distinct natural monument (landform, sea mount, submarine cavern, any other geological feature);

— habitatManagement — habitat management areas: protection and conservation of areas that are habitats of particular species;

— protectedLandscape — protected landscape or seascape: protection and conservation of areas of peculiar distinct character due to the interaction of peoples and nature over time;

— otherConservation — other conservation protection.

This code list may be extended through registration.

8.3.9.2 LU_HeritageTypes

The code list LU_HeritageTypes describes areas having cultural, historical significance and therefore having some form of protection.

The code list values are:

— historic — normative rules for particular places of significance to peoples on account of historical values;

— cultural — normative rules for particular places of significance to peoples on account of cultural values;

— indigenous — normative rules for particular places of significance to peoples that are native to an area or who naturally belong to it;

— otherHeritage — other historic significance.

This code list may be extended through registration.

8.3.9.3 LU_EasementTypes

The code list LU_EasementTypes describes the types of easement.

The code list values are:

— publicEasement — easement of a public area;

— airportEasement — easement of airport infrastructure;

— roadOrRailEasement — easement of roads or rail and related areas;

— beachEasement — easement of beaches and related infrastructures;

— energyProductionEasement — easement of energy production infrastructures;

— otherEasement — other easement.

This code list may be extended through registration.

8.3.9.4 LU_RiskExposureTypes

The code list LU_RiskExposureTypes describes the types of risk exposure types for areas were the access is restricted due to a specific risk.

The code list values are:

— flood — flood risk exposure;

— chemicalContamination — chemical contamination risk exposure;

— nuclearContamination — nuclear contamination risk exposure;

— mining — mining risk exposure;

— erosion — erosion risk exposure;

— otherRisk — other risk exposure.

This code list may be extended through registration.

8.3.9.5 LU_OtherRestrictionTypes

The code list LU_OtherRestrictionTypes describes other types of restriction.

The code list values are:

— military — military restriction;

— industry — industrial restriction;

— public — public restriction;

— otherRestriction — other restriction type.

This code list may be extended through registration.

8.3.9.6 LU_BufferingTypes

The code list LU_BufferingTypes describes the types of buffer used to protect from specific hazards.

The code list values are:

— inlandWater — an area of inland water as a buffer zone;

— marineWater — an area of marine water (sea) as a buffer zone;

— otherBuffering — other buffering area.

This code list may be extended through registration.

8.3.9.7 LU_ShieldingTypes

The code list LU_ShieldingTypes describes the types of shielding used to protect from specific hazards.

The code list values are:

— inlandWater — an area of inland water as a shield;

— marineWater — an area of marine water (sea) as a shield;

— wind — wind as a shield;

— erosion — erosion as a shield;

— otherShield — other shielding.

This code list may be extended through registration.

8.3.10 Subtypes of LU_Insubstantive_Other

8.3.10.1 LU_ Insubstantive_Other structure

The class LU_Insubstantial_Other describes an area that is not evident, undetermined, undecided, or irrelevant use or has another use. It has two subtypes: LU_OtherUse and LU_NotUnderDistinctUse. This is illustrated in Figure 19.

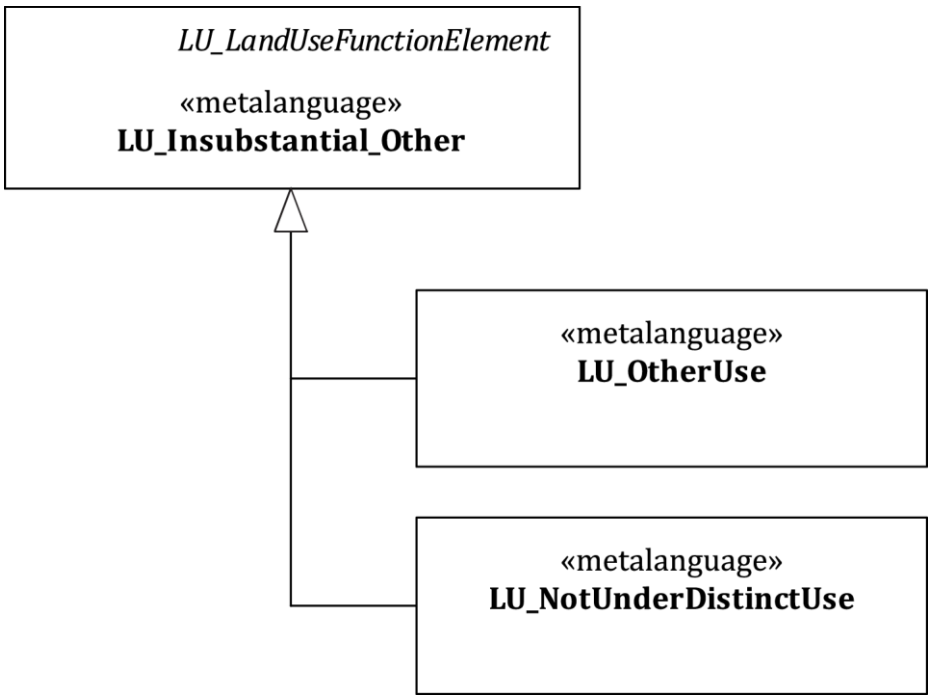

Figure 19 — Subtypes of LU_Insubstantive_Other

8.3.10.2 LU_OtherUse

The class LU_OtherUse is a subtype of LU_Insubstantial_Other. It describes an area that has another use.

8.3.10.3 LU_NotUnderDistinctUse

The class LU_NotUnderDistinctUse is a subtype of LU_Insubstantial_Other. It describes an area that has is not evident, irrelevant or of negligible use.

9 Land Use activities

9.1 Land Use activities arrangement structure

A list of activities is defined for each of the main functions. The activities are correlated to the functions element through the activity arrangement structure.

The activity arrangement tool is defined by four different types:

— functional relationship — models the functional relationship of the activities belonging to each activity function group. It is generated by three types:

  1) dominant,

  2) secondary,

  3) equivalent;

— temporal relationship — models the temporal relationship between the activities belonging to each activity function group. It is generated by three types:

  1) coexistent,

2) sequential,

3) cyclic;

— activity relevance — models the significance of the activities of each function expressed as the relative weight between two or more of the functions. The significance of different activities will depend on the specific context. The value is given with a range from (1 to 100) %. The data type is a percentage value as represented by LC_PermittedPercentageValue;

— order sequence — models the logical succession of each activity with each other.

This is illustrated in Figure 20. This figure shows the activities arrangement including the composition of individual LU_Activities. Class characteristics from Land Cover may also be included to augment the description of an activity.

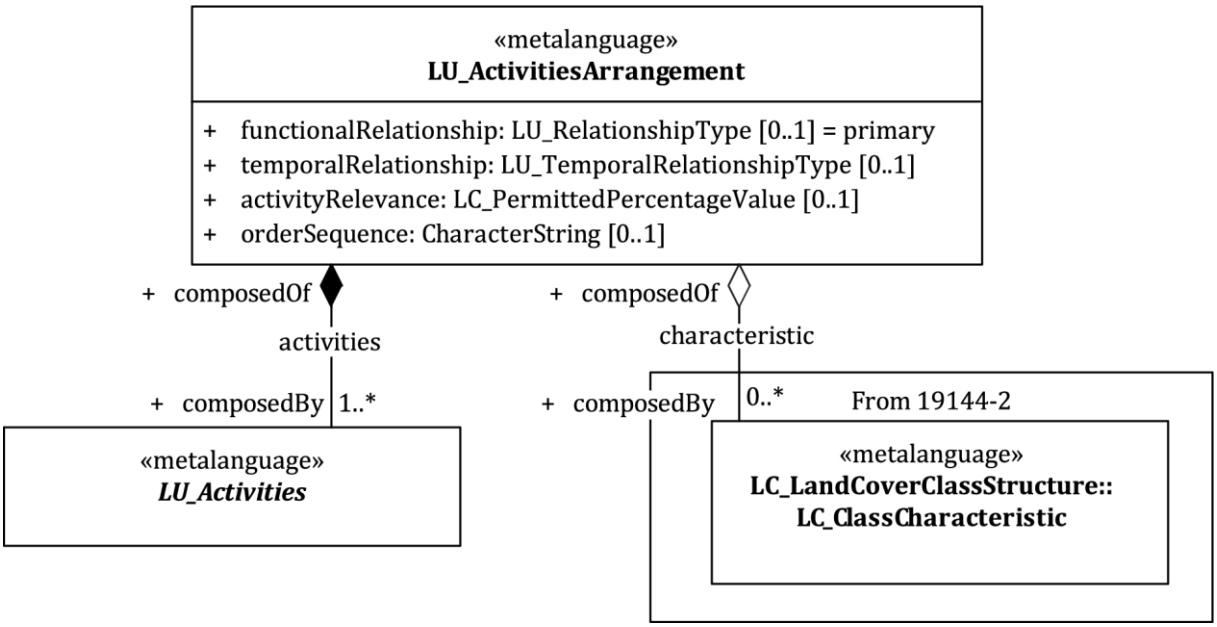

Figure 20 — Activity arrangement structure

9.2 Land Use activities structure

There are eight subtypes of LU_Activities that each correspond to a function type. Figure 21 shows the subtypes of LU_Activities. These classes are abstract. Each of the subtypes is further subdivided into many specific activities.

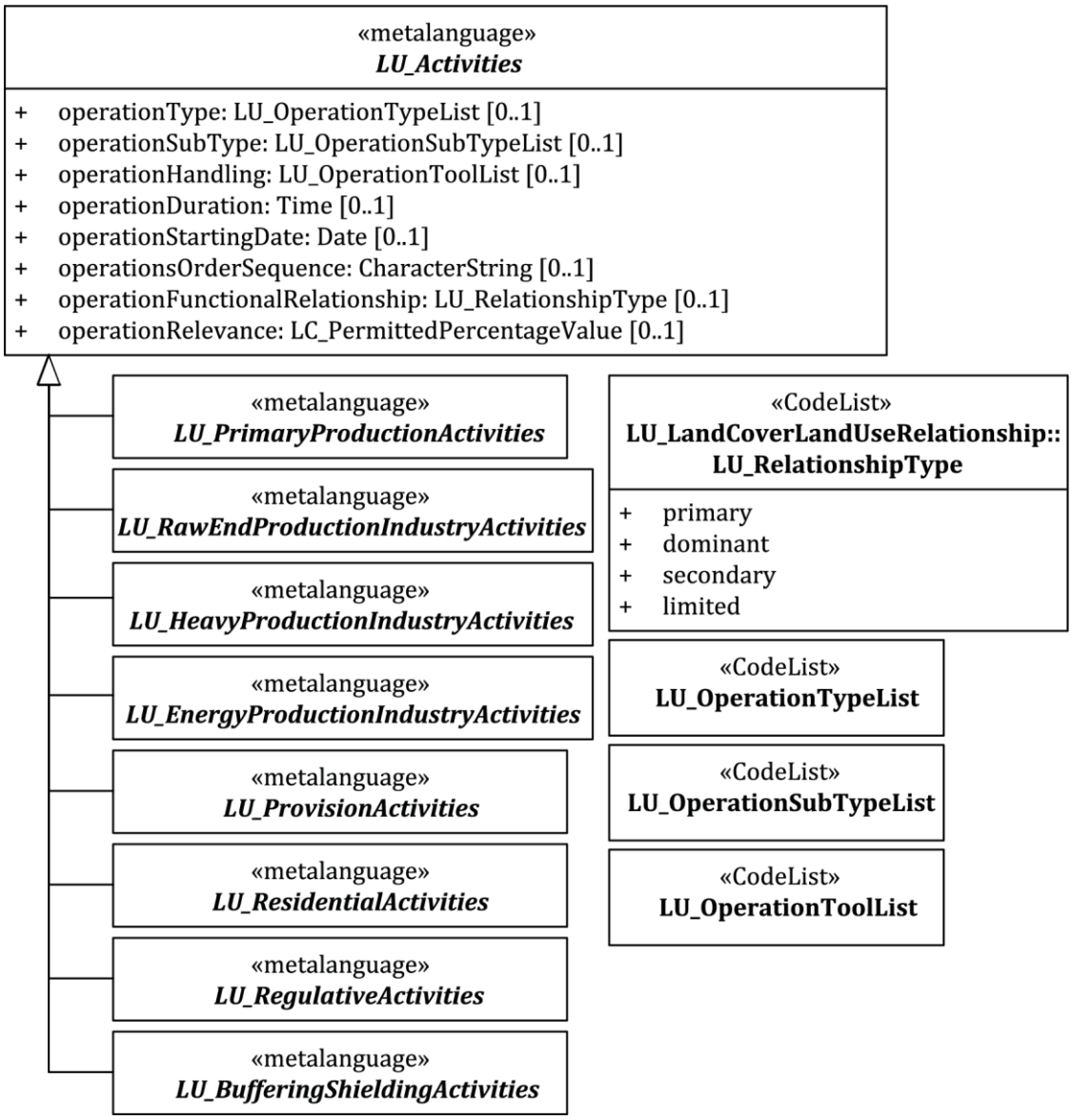

Figure 21 — Subtypes of LU_Activities

9.3 Land Use activities description

9.3.1 LU_Activities attributes and support classes

9.3.1.1 operationType attribute

The attribute *operationType* specifies the type of specific action or process that will define a specific activity. The types are given in the code list LU_OperationTypeList.

9.3.1.2 operationSubType attribute

The attribute *operationSubType* describes the type of specific sub-action or sub-process that will define a specific operation type. There is an implicit interrelationship between an operation and sub-operations. The values are given in the code list LU_OperationSubTypeList.

9.3.1.3 operationHandling attribute

The attribute *operationHandling* describes the tools used to perform a specific operation (or sub-operation). Each operation (or sub-operation) type has a list of tools that is enumerated. The values are given in the code list LU_OperationToolList.

9.3.1.4 operationDuration attribute

The attribute *operationDuration* specifies the duration of a specific operation. It takes on the datatype "Time".

9.3.1.5 operationStartingDate attribute

The attribute *operationStartingDate* specifies the date on which a specific operation (or sub-operation) starts. It takes on the datatype "Date".

9.3.1.6 operationsOrderSequence attribute

The attribute *operationsOrderSequence* specifies the sequence of the different operations (or sub-operations). The sequence is expressed as a characterString datatype.

9.3.1.7 operationFunctionalRelationahip attribute

The attribute *operationsFunctionalRelationship* specifies the functional correlation between the different operations when there are two or more operations. The relative significance of different operations depends on the specific context. The values are given in the code list LU_RelationshipType.

9.3.1.8 operationRelevance attribute

The attribute *operationRelevance* specifies the significance of a specific operation expressed as the relative weight between two or more operations. The value is given with a range from (1 to 100) %. The data type is a percentage value as represented by LC_PermittedPercentageValue.

9.3.1.9 LU_OperationTypeList

The code list LU_OperationsTypeList contains a list of types of operations applicable to Land Use activities.

This list may be defined through registration.

9.3.1.10 LU_OperationSubTypeList

The code list LU_OperationsSubTypeList contains a list of types of operations applicable to Land Use activities.

This list may be defined through registration.

9.3.1.11 LU_OperationToolsList

The code list LU_OperationToolList contains a list of the tools used to perform a specific operation (or sub-operation).

This list may be defined through registration.

9.3.2 LU_Activities subtypes

9.3.2.1 LU_PrimaryProductionActivities

The class LU_PrimaryProductionActivities describes activities related to the primary production function of growing, harvesting or making goods. The related function class is LU_DirectProduction, and its subtypes.

9.3.2.2 LU_RawEndProductionIndustryActivities

The class LU_RawEndProductionIndustryActivities describes activities related to the secondary production function of raw end production, which corresponds to the industrial activities that are devoted to the transformation of the outputs of the direct (or primary) products into assembled or manufactured basic raw products. The related function class is LU_RawEndProductionIndustry.

9.3.2.3 LU_HeavyProductionIndustryActivities

The class LU_HeavyProductionIndustryActivities describes activities and processes related to industrial activities that are devoted to the transformation of raw manufactured products into machinery and other "heavy" materials. The related function class is LU_HeavyEndProductionIndustry and its subtypes.

9.3.2.4 LU_EnergyProductionIndustryActivities

The class LU_EnergyProductionIndustryActivities describes activities related to the production of any form of energy (electric, fuel, gas, biogas, nuclear, etc.). The related function class is LU_EnergyProduction.

9.3.2.5 LU_ProvisionActivities

The class LU_ProvisionActivities describes activities related to the action or process of providing or supplying intangible products for other business or consumers, including the provision of services, utilities, transport or logistics. The related function class is LU_Provision and its subtypes.

9.3.2.6 LU_ResidentialActivities

The class LU_ResidentialActivities describes activities related to residential housing of various types. The related function class is LU_Residential.

9.3.2.7 LU_RegulativeActivities

The class LU_RegulativeActivities describes an area under specific normative rules or principles including both conservation and protection of environmental areas, archaeological sites and restriction of access. The related function class is LU_Regulative and its subtypes.

9.3.2.8 LU_BufferingShieldingActivities

The class LU_BufferingShieldingActivities describes activities related to controlled zones designated to defend against or protect from specific hazards. The related function class is LU_BufferingShielding and its subtypes.

9.4 Land Use activities details

9.4.1 LU_PrimaryProductionActivities subtypes

The set of activities related to the primary production function is shown in Figure 22. The class LU_PrimaryProductionActivities inherits eight attributes from LU_Activities; these are inherited by all of its subtypes.

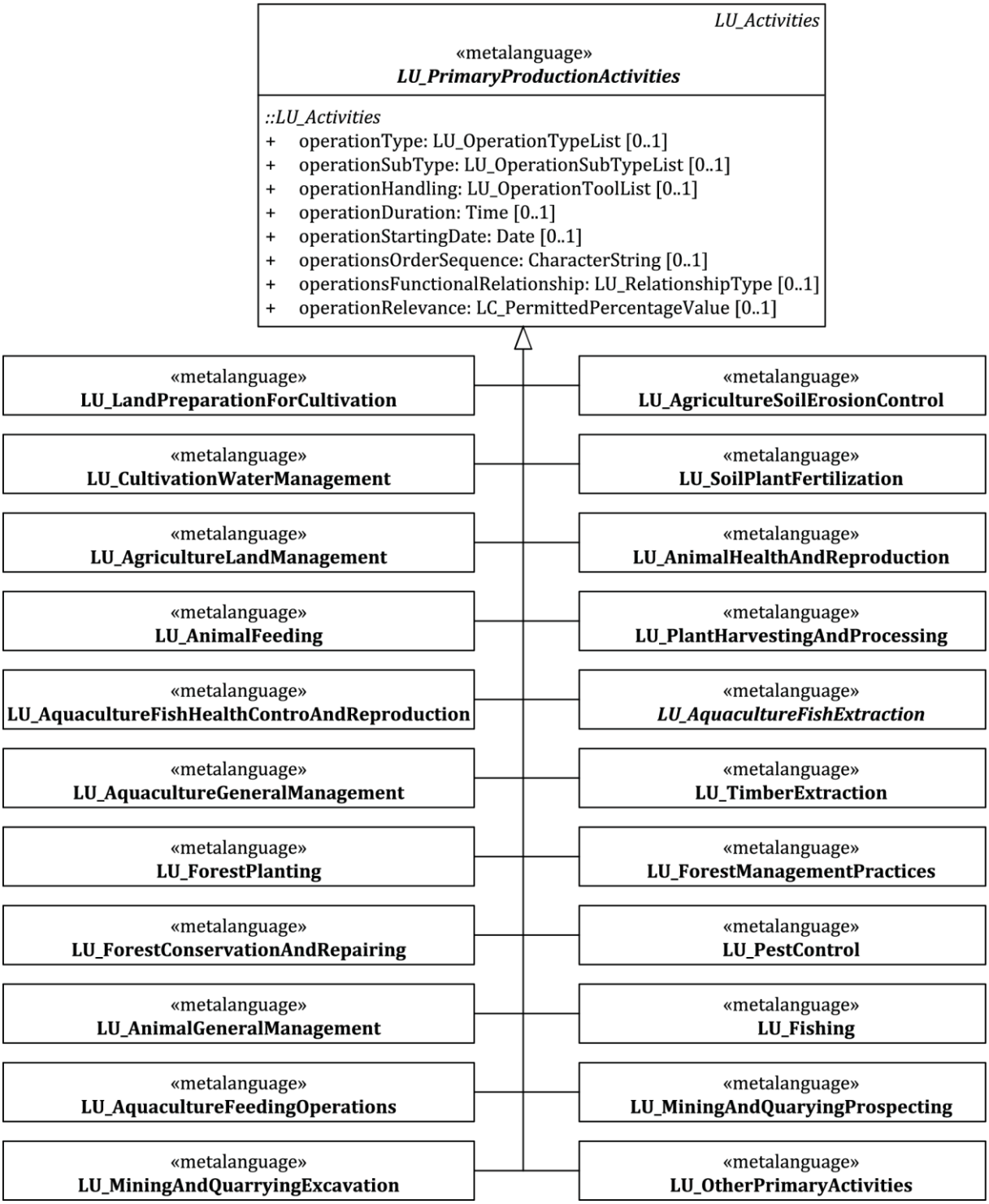

Figure 22 — Subtypes and attributes of LU_PrimaryProductionActivities

9.4.2 LU_PrimaryProductionActivities subtypes and attributes

9.4.2.1 LU_LandPreparationForCultivation

The class LU_LandPreparationForCultivation describes the activities on the field to make it suitable for crop establishment such as ploughing, harrowing or levelling.

9.4.2.2 LU_CultivationWaterManagement

The class LU_CultivationWaterManagement describes the water management activities on the field to optimize crop development such as irrigation, drainage, sprinkling or flooding.

9.4.2.3 LU_AgricultureSoilErosionControl

LU_AgricultureSoilErosionControl describes the activities on the field to limit soil erosion such as no tillage, embankment, terracing or crop rotation.

9.4.2.4 LU_SoilPlantFertilization

The class LU_SoilPlantFertilization describes the activities on the field to improve plant fertilization such as fertilizer spraying, manure incorporation, green manuring or crop rotation.

9.4.2.5 LU_AgricultureLandManagement

The class LU_AgricultureLandManagement describes the process of managing the use and development of land resources for the purpose of agriculture.

9.4.2.6 LU_AnimalHealthAndReproduction

The class LU_AnimalHealthAndReproduction describes the process of managing animal health and supporting or managing animal reproduction.

9.4.2.7 LU_AnimalFeeding

The class LU_AnimalFeeding describes the process of providing or managing the provision of feed as part of animal agriculture.

9.4.2.8 LU_PlantHarvestingAndProcessing

The class LU_PlantHarvestingAndProcessing describes the process of gathering crops from land and the processing of these crops to transform them to agricultural products or food.

9.4.2.9 LU_AquacultureFishHealthControlAndReproduction

The class LU_AquacultureFishHealthControlAndReproduction describes the process of managing health and supporting or managing reproduction in aquaculture.

9.4.2.10 LU_AquacultureFishExtraction

The class LU_AquacultureFishExtraction describes the process of gathering fish or other species as part of aquaculture.

9.4.2.11 LU_AquacultureGeneralManagement

The class LU_AquacultureGeneralManagement describes the general process of managing aquaculture.

9.4.2.12 LU_TimberExtraction

The class LU_TimberExtraction describes the process of cutting, processing and moving trees to a location for transport. It can include on-site processing and loading of trees or logs onto trucks or other transport means.

9.4.2.13 LU_ForestPlanting

The class LU_ForestPlanting describes the process of transplanting tree seedlings for forestation of new forests or reforestation of previously cut forests.

9.4.2.14 LU_ForestManagementPractices

The class LU_ForestManagementPractices describes the administrative, legal, economic and other management of forests including management for timber, aesthetics, recreation, urban values, water, wildlife, inland and nearshore fisheries, wood products, plant genetic resources, and other forest resources.

9.4.2.15 LU_ForestConservationAndRepairing

The class LU_ForestConservationAndRepairing describes the planning and maintaining of forested areas for sustainability and future benefits including the upkeep of the natural resources within a forest and maintenance of the ecosystem.

9.4.2.16 LU_PestControl

The class LU_PestControl describes the regulation or management of any animal, plant or fungus that impacts adversely on activities or environment.

9.4.2.17 LU_AnimalGeneralManagement

The class LU_AnimalGeneralManagement describes the administrative, legal, economic and other management of animals.

9.4.2.18 LU_Fishing

The class LU_Fishing describes the activity of harvesting fish, including those caught as wildlife from the natural environment and those from stocked bodies of water.

9.4.2.19 LU_AquacultureFeedingOperations

The class LU_AquacultureFeedingOperations describes the operation of providing feed to aquaculture fish farms, including management of the timing and of the volume or weight of feed.

9.4.2.20 LU_MiningAndQuarryingProspecting

The class LU_MiningAndQuarryingProspecting describes the process of geological survey and analysis for the development of mining and quarrying.

9.4.2.21 LU_MiningAndQuarryingExcavation

The class LU_MiningAndQuarryingExcavation describes the process of extraction of rocks or minerals from a mine or quarry.

9.4.2.22 LU_OtherPrimaryActivities

The class LU_OtherPrimaryActivities describes primary production activities not addressed in the preceding categories.

9.4.3 LU_RawEndProductionIndustryActivities subtypes and attributes

The set of activities related to the raw end production function is shown in Figure 23. The class LU_RawEndProductionIndustryActivities inherits eight attributes from LU_Activities; these are inherited by all of its subtypes.

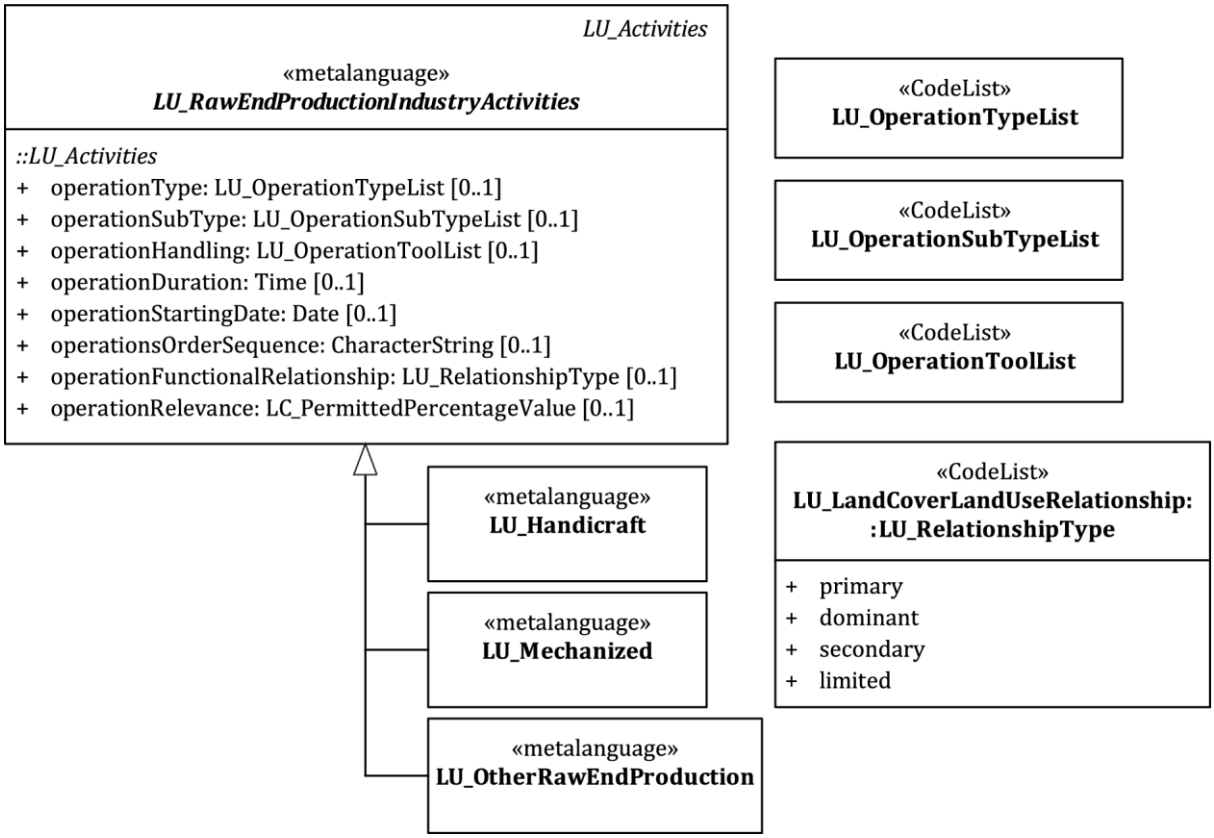

Figure 23 — Subtypes and attributes of LU_RawEndProductionIndustryActivities

9.4.4 LU_RawEndProductionActivities subtypes

9.4.4.1 LU_Handicraft

The class LU_Handicraft describes craftwork.

9.4.4.2 LU_Mechanized

The class LU_Mechanized describes mechanized production.

9.4.4.3 LU_OtherRawEndProduction

The class LU_OtherRawEndProduction describes other production activities.

9.4.5 LU_HeavyProductionIndustryActivities subtypes and attributes

The set of activities related to the heavy production function is shown in Figure 24. The class LU_HeavyProductionIndustryActivities inherits eight attributes from LU_Activities; these are inherited by all of its subtypes.

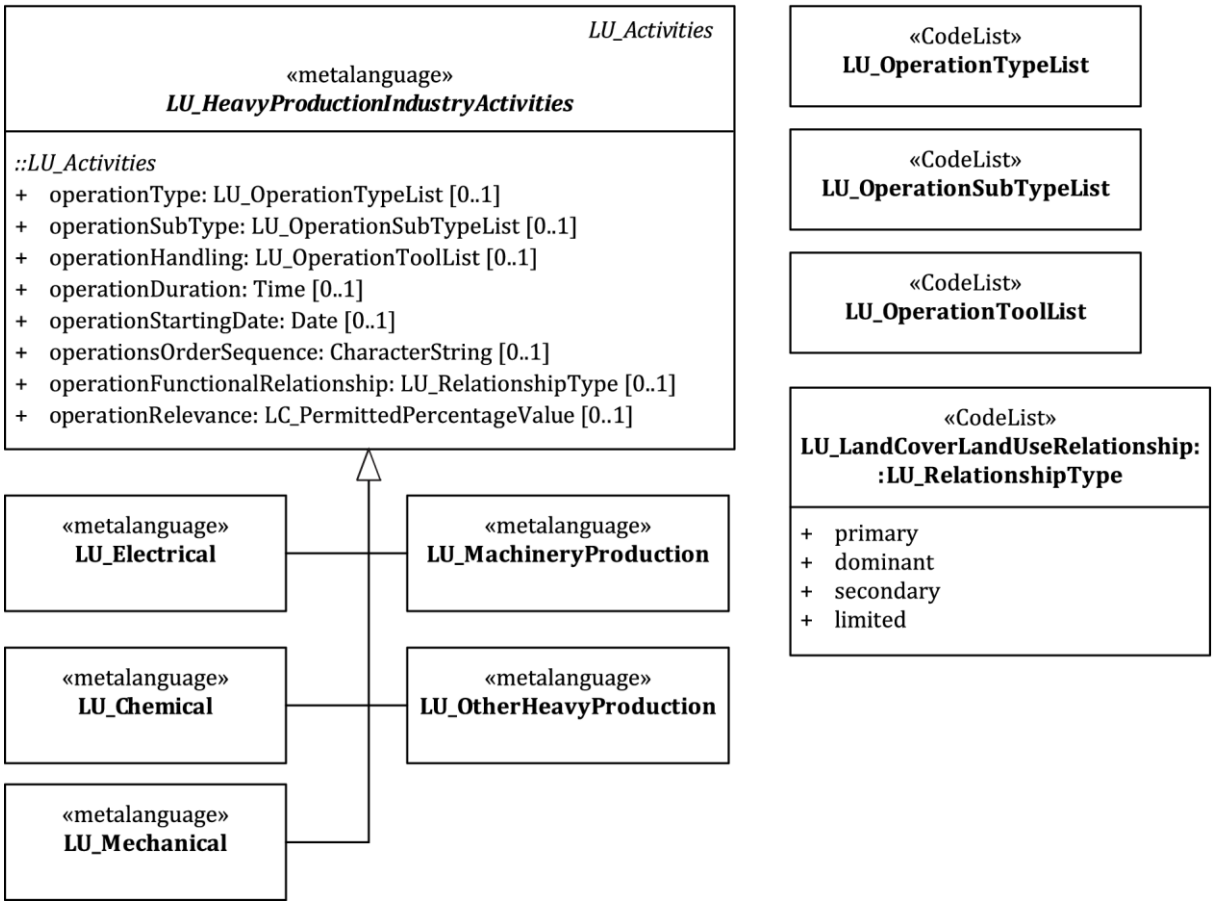

Figure 24 — Subtypes and attributes of LU_HeavyProductionIndustryActivities

9.4.6 LU_HeavyProductionActivities subtypes

9.4.6.1 LU_MachineryProduction

The class LU_MachineryProduction describes heavy machinery processes such as earth movers or other large machinery-based production.

9.4.6.2 LU_Electrical

The class LU_Electrical describes electricity production.

9.4.6.3 LU_Chemical

The class LU_Chemical describes chemical production.

9.4.6.4 LU_Mechanical

The class LU_Mechanical describes mechanical equipment production.

9.4.6.5 LU_OtherHeavyProduction

The class LU_OtherHeavyProduction describes other large scale production activities.

9.4.7 LU_EnergyProductionIndustryActivities subtypes and attributes

The set of activities related to the energy production function is shown in Figure 25. The class LU_EnergyProductionIndustryActivities inherits eight attributes from LU_Activities; these are inherited by all of its subtypes.

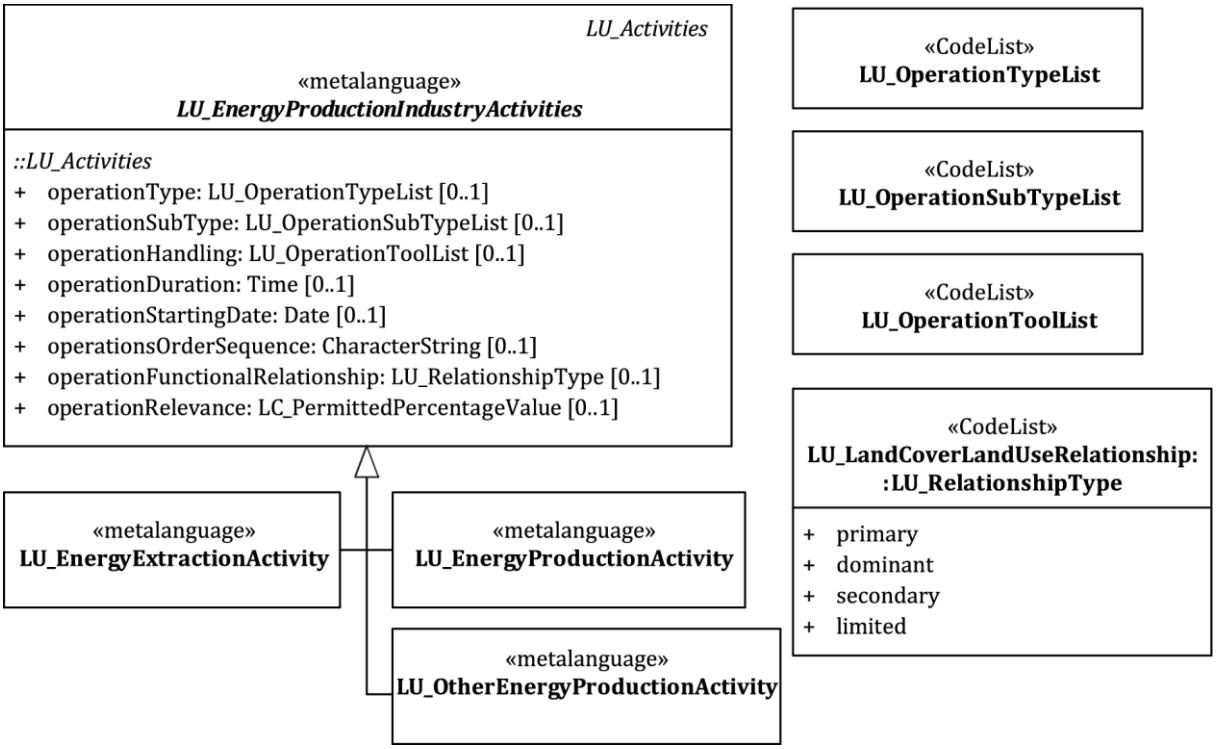

Figure 25 — Subtypes and attributes of LU_EnergyProductionIndustryActivities

9.4.8 LU_EnergyExtraction subtypes

9.4.8.1 LU_EnergyExtractionActivity

The class LU_EnergyExtractionActivity describes the activity of extracting energy from a source, such as the extraction of fossil fuels, geothermal, wind, solar or other energy.

9.4.8.2 LU_EnergyProductionActivity

The class LU_EnergyProductionActivity describes the production of energy from an energy source such as the combustion of fossil fuels, or the generation of electricity from a hydroelectric dam, or the generation of electricity from nuclear.

9.4.8.3 LU_OtherEnergyProductionActivity

The class LU_OtherEnergyProductionActivity describes other forms of energy production.

9.4.9 LU_ProvisionActivities subtypes and attributes

The set of activities related to the provision function is shown in Figure 26. The class LU_ProvisionActivities inherits eight attributes from LU_Activities; these are inherited by all of its subtypes.

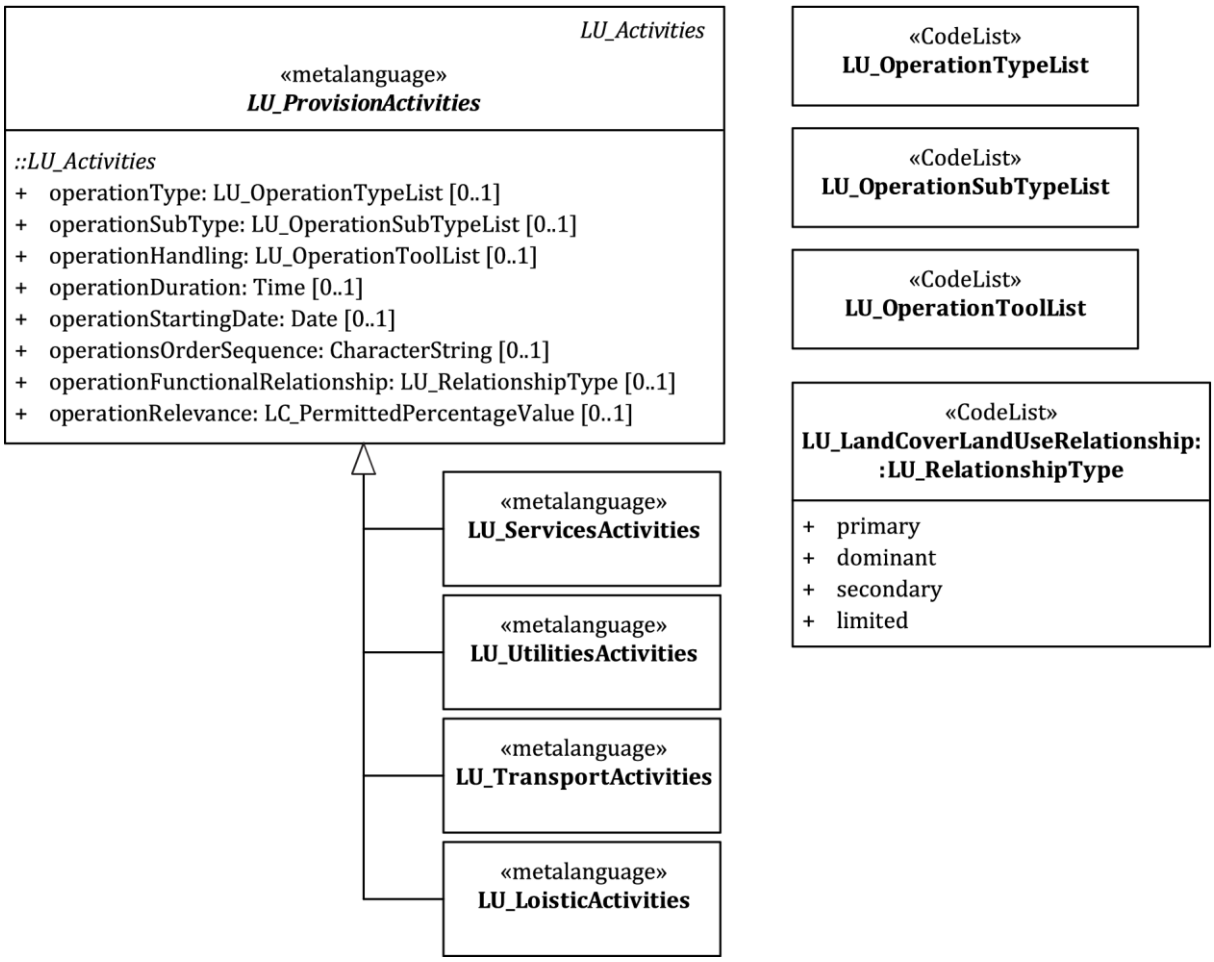

Figure 26 — Subtypes and attributes of LU_ProvisionActivities

9.4.10 LU_ProvisionActivities subtypes

9.4.10.1 LU_ServicesActivities

The class LU_ServicesActivities describes activities related to the provision of services.

9.4.10.2 LU_UtilitiesActivities

The class LU_UtilitiesActivities describes the activities related to the provision or distribution of utilities such as gas, electric or water distribution.

9.4.10.3 LU_TransportActivities

The class LU_TransportActivities describes the activities related to transportation or the moving or persons or goods.

9.4.10.4 LU_LogisticActivities

The class LU_LogisticActivities describes the management of systems for the coordinated production or transportation or storage of goods.

9.4.11 LU_ResidentialActivities subtypes and attributes

The set of activities related to the residential activities function is shown in Figure 27. The class LU_ResidentialActivities inherits eight attributes from LU_Activities; these are inherited by its subtype.

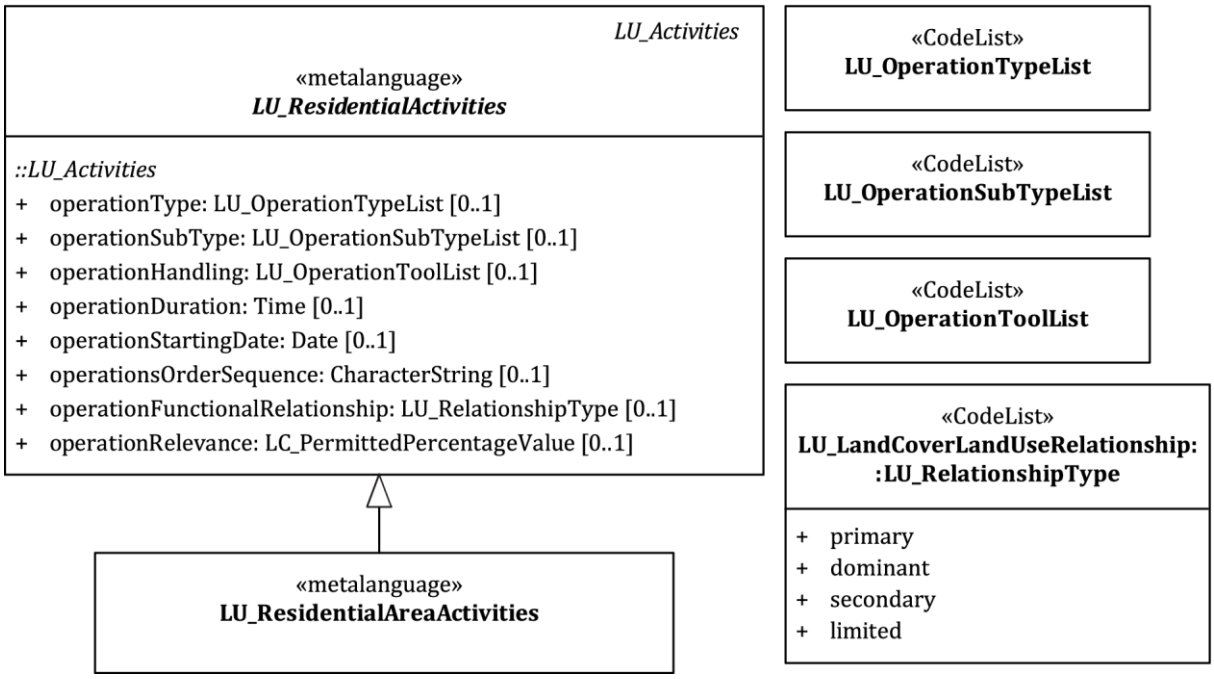

Figure 27 — Subtypes and attributes of LU_ResidentialActivities

9.4.12 LU_ResidentialActivities subtypes

9.4.12.1 LU_ResidentialAreaActivities

The class LU_ResidentialAreaActivities describes the provision of housing.

9.4.13 LU_RegulativeActivities subtypes and attributes

The set of activities related to the regulative activities function is shown in Figure 28. The class LU_RegulativeActivities inherits eight attributes from LU_Activities; these are inherited by all of its subtypes.

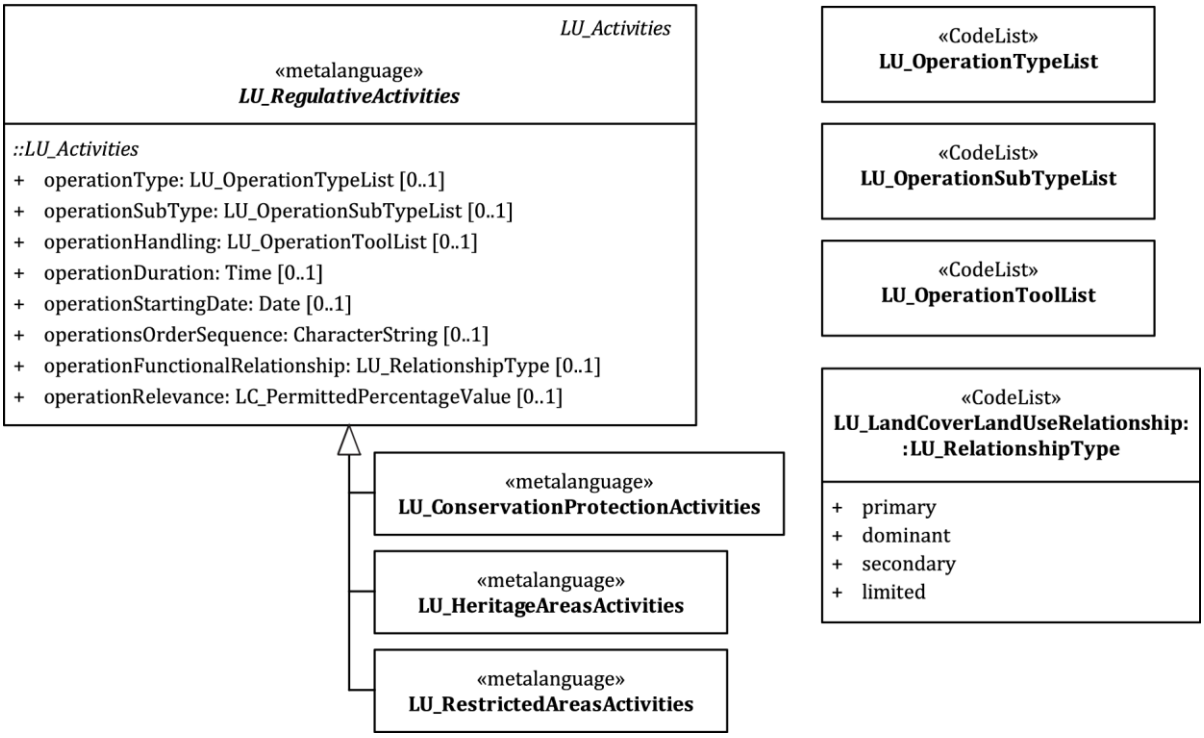

Figure 28 — Subtypes and attributes of LU_RegulativeActivities

9.4.14 LU_RegulativeActivities subtypes

9.4.14.1 LU_ConservationProtectionActivities

The class LU_ConservationProtectionActivities describes areas under specific conservation or protection rules or both.

9.4.14.2 LU_HeritageAreaActivities

The class LU_HeritageAreaActivities describes areas having cultural, historical significance and therefore as having some form of protection.

9.4.14.3 LU_RestrictedAreasActivities

The class LU_RestrictedAreasActivities describes areas where the access is restricted due to some specific risk exposure.

9.4.15 LU_BufferingShieldingActivities subtypes and attributes

The set of activities related to the buffering and shielding activities function is shown in Figure 29. The class LU_BufferingShieldingActivities inherits eight attributes from LU_Activities; these are inherited by all of its subtypes.

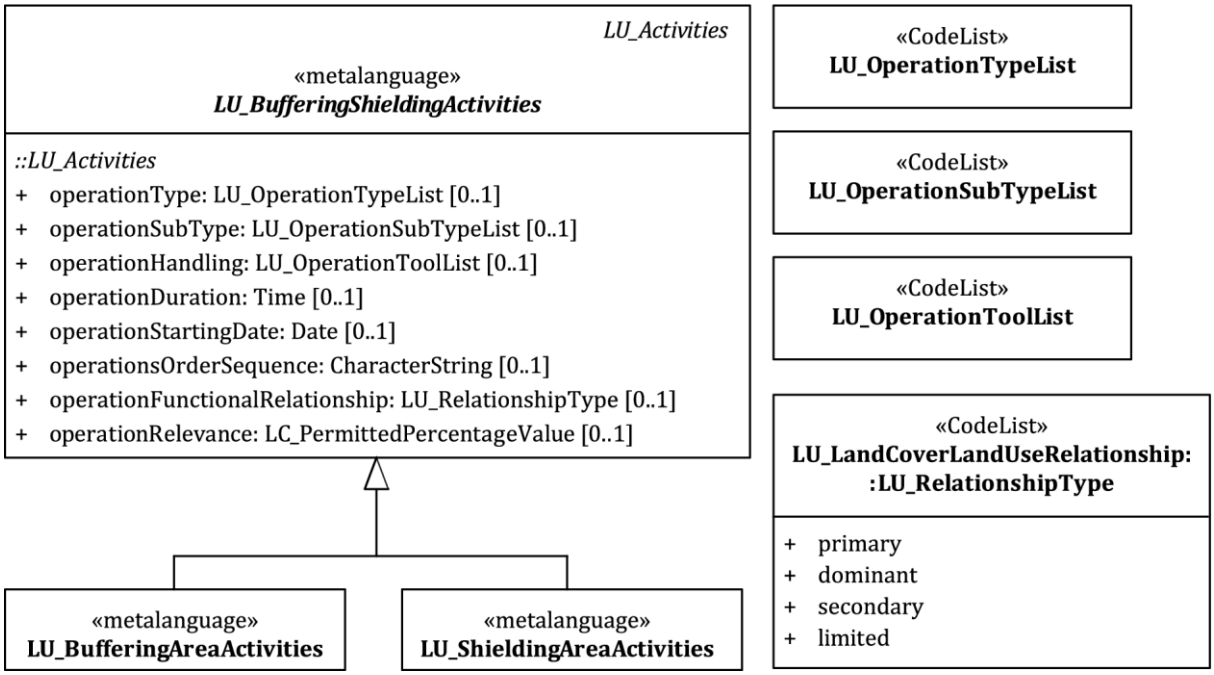

Figure 29 — Subtypes and attributes of LU_BufferingShieldingActivities

9.4.16 LU_BufferingShieldingActivities subtypes

9.4.16.1 LU_BufferingAreaActivities

The class LU_BufferingAreaActivities describes the activity of using buffering as a technique for the defence or protection against specific hazards.

9.4.16.2 LU_ShieldingAreaActivities

The class LU_ShieldingAreaActivities describes the activity of using shielding as a technique for the defence or protection against specific hazards.

10 Extension of the LCML

10.1 Extension process

The LUML and LCML contain a set of fixed metalanguage elements that are the basic vocabulary for describing different Land Use and Land Cover classification systems. It is necessary for this vocabulary to be stable in order for descriptions of different Land Use and Land Cover classification systems to be comparable. ISO 19144-2 describes a method of extending the set of Land Cover elements. This document describes a similar method for extending the set of Land Use elements. The subtypes of the UML class LU_LandUseFunctionalElement in the model used to express the metalanguage may only be changed by amendment of this document. This allows for a route to extend the language that is well controlled by the standardization process.

10.2 Registration of extensions

Changes to the Land Use activities as expressed through the class LU_Activities may be made by registration according to the rules laid out in a future part of the ISO 19144 series (ISO 19144-4:—)[2]. This provides a

[2] Under preparation. Stage at the time of publication: ISO/NP TS 19144-4:2024.

simple route to extend the descriptive aspects of the Land Use activities associated with the metalanguage without changing the basic metalanguage elements. It also permits the associated code lists to be extended.

Additions can also be made to the subtypes of the UML class LU_LandUseFunctionalElement or the components, attributes or code lists associated with these metalanguage objects by registration. This is considered an addition to the subtypes of LU_LandUseFunctionalElement, not a change.

The separate part of the ISO 19144 series (ISO 19144-4) is intended to define the structure of the register, not its contents. The contents can be established by a national body or other user who would establish their own instance of the register. A user of the register could make a perfect description of their national Land Cover classification system using the elements defined in this document plus additional registered extensions. A comparison of two Land Cover and Land Use classification systems using the LCML and LUML would be based on the common elements defined in this document and the elements defined in ISO 19144-2 and on a comparison of the additional extensions nationally registered.

The responsibility for a register to extend the LCML and or LUML by registration rests with the national body or organization which wishes to do the extension. The national body or organization would set up their own register. Other national bodies or organizations can also set up other equivalent registers for their own use. A comparison of two Land Cover and or Land Use classification systems using the common portion of the LCML and LUML, as defined in this document together with ISO 19144-2, will only be to the level of detail addressed by the metalanguage objects and attributes that have been standardized. To do a comparison to a more detailed level would require an examination of the Land Cover and Land Use classification system in terms of the registered items in one or both registers.

NOTE The register for extension of the metalanguage is different in purpose from the register identified in ISO 19144-1. The register identified in ISO 19144-1 is used to record the legend classes produced from a Land Cover, Land Use or other classification system. The register for extension of the metalanguage is at a different level. It is used to manage any extensions to the metalanguage objects in the LCML or changes to the characteristics.

Requirement 3: Extensions to the metalanguage by the subtyping of UML class LU_LandUseFunctionalElement or the components, attributes or code lists associated with these metalanguage objects, or extension to the properties of Land Cover element characteristics or Land Cover class characteristics or both shall be carried out through a registration process.

10.3 Backward compatibility through registration

Since one of the primary purposes of the LUML (possibly in conjunction with the LCML) is to allow for comparison between different Land Use and Land Cover classification systems, it is important that any changes to the vocabulary of the metalanguage be well controlled and be backward compatible. None of the metalanguage objects can be deleted from the model. They can be extended with additional UML attributes. If a sub-object needs to be altered, an additional sub-object can be defined to replace that sub-object, leaving the old sub-object in place for backward compatibility as a deprecated sub-object. This is in accordance with the procedures for registration as described in ISO 19135-1.

EXAMPLE If a code list is extended, the old version of the code list is superseded with a new object containing the new list. The old list remains in the register with an old identifier and date. In order for the comparative aspect of the language to work, the relationship between the new registered item class and the deprecated registered item class needs to be described.

The maintenance of backward compatibility in the LUML and LCML is required both in the basic metalanguage elements that are the subtypes of LU_LandUseFunctionalElement, which can only be changed by amendment to this document, and for changes to the metalanguage objects which can be done by registration.

Requirement 4: Any extension or change to the metalanguage shall be backward compatible with the published edition of this document.

Annex A
(normative)

Abstract test suite

A.1 Overview of abstract test suite

This annex presents the abstract test suite for evaluating conformance to this document. The abstract test suite contains a test module for a Land Use or combined Land Cover Land Use classification system (Clause A.2), and a test module for the comparison of two Land Cover or combined Land Cover Land Use classification systems (Clause A.3).

A.2 Conformance of a Land Use or Land Cover classification system

a) Test purpose: Verify that a Land Use or combined Land Cover Land Use classification system can be described in terms of the LUML and LCML in accordance with Requirement 1.

b) Test method: Inspect the generated model of the Land Use or Land Cover classification system or both by composing Land Use and Land Cover metaclasses (LU_LandUseClassDescriptor or LC_LandCoverClassDescriptor or both) for each UML class from the Land Use and Land Cover classification system and then instantiating each UML class to form the Land Use or Land Cover (or both) classification system model. Each UML class in the Land Use or combined Land Use Land Cover classification system is to be expressed in terms of LU_LandUseFunctionElement(s), LU_Activities, LC_Elements, LC_LandCoverElementCharacteristic(s) and LC_ClassCharacteristic(s) organized into LU_LandUseClassDescriptor or LC_LandCoverClassDescriptor classes, or both.

c) Reference: Clause 8, including the Land Use high level UML class structure as defined in 8.2.2, and the definition of the LU_LandUseFunctionalElement as defined in 8.3 including all of the subtypes of LU_LandUseFunctionalElement defined in 8.3.2-8.3.13, and the applicable activities as defined in Clause 9.

d) URI: https://standards.isotc211.org/19144/-3/1/LandUseSystem.

e) Test type: Capability.

A.3 Conformance of a comparison process of two Land Use or combined Land Cover Land Use classification systems

a) Test purpose: Comparison of two Land Use or combined Land Cover Land Use classification systems to identify the differences in accordance with Requirement 2. This will enable the development of a mapping between the two systems.

b) Test method: Generate a model for each of the Land Use or combined Land Cover Land Use classification systems by composing Land Use and Land Cover metalanguage objects (LU_LandUseClassDescriptor or LC_LandCoverClassDescriptor or both) for each UML class from each of the two Land Use or combined Land Cover Land Use classification systems and then instantiating each UML class to form two separate Land Use Land Cover classification system models. Each UML class in each of the two the classification systems is to be expressed in terms of LU_LandUseFunctionElement(s), LU_Activities, LC_Elements, LC_LandCoverElementCharacteristic(s) and LC_ClassCharacteristic(s) organized into LU_LandUseClassDescriptor classes or LC_LandCoverClassDescriptor classes or both in accordance with the LUML and LCML. Examine each of the classes between each of the two classification systems identifying:

1) which are identical because they have the same description using the LUML/LCML metalanguage objects;

2) which are generalizations or specializations of each other because they share the same root description using the LUML LCML metalanguage objects, but one or the other classes uses additional metalanguage object descriptor elements or characteristics; and

3) which ones are similar because they share many of the same LUML LCML metalanguage object descriptor elements or characteristics but differ on specific metalanguage object descriptor elements or characteristics.

c) From the comparison, generate a mapping between the two classification systems.

d) Reference: Clause 8, including the Land Cover high level UML class structure as defined in 8.2.2, and the definition of the LU_LandUseFunctionalElement as defined in 8.3 including all of the subtypes of LU_LandUseFunctionalElement defined in 8.3.2-8.3.13, and the applicable activities as defined in Clause 9.

Clause 8, including the Land Use high level UML class structure as defined in 8.2.2, and the definition of the LU_LandUseFunctionalElement as defined in 8.3 including all of the subtypes of LU_LandUseFunctionalElement defined in 8.3.2 - 8.3.13, and the applicable activities as defined in Clause 9.

e) URI: https://standards.isotc211.org/19144/-3/1/LU_Comparison.

f) Test type: Capability.

A.4 Extension of the Land Cover Meta Language

a) Test purpose: Verify that extensions to the metalanguage are done through a registration process in accordance with Requirement 3.

b) Test method: Inspect the classes, attributes and code lists used in the generated model of the Land Use or Land Cover classification system to ensure that any extensions are documented in a manner so that they can be registered.

c) Reference: 10.2. The details of registration are intended to be described in a separate part of the ISO 19144 series.

d) URI: https://standards.isotc211.org/19144/-3/1/MetaLanguageExtension.

e) Test type: Capability.

A.5 Backward compatibility of the Land Use Meta Language

a) Test purpose: Verify that any extension or change to the metalanguage is backward compatible with the published edition of this document in accordance with Requirement 4.

b) Test method: Inspect any extensions to the metalanguage to ensure that extensions to classes are done by subtyping or the development of new independent classes, and that extensions to other components, such as attributes or code lists associated with these metalanguage objects, or extension to the properties of Land Cover element characteristics are done without changing the meaning of existing elements.

c) Reference: 10.3.

d) URI: https://standards.isotc211.org/19144/-3/1/MetaLanguageBackwardCompatibility.

e) Test type: Capability.

Annex B
(informative)

Examples

B.1 Descriptive examples

This annex presents a number of descriptive examples of the LUML used to produce a Land Use classification system or a combined Land Use Land Cover classification system and subsequently a nomenclature or legend. It is not possible to show an entire Land Use or combined Land Use Land Cover classification system or the metalanguage objects that are used to define an entire classification system.

NOTE For the examples in this annex the UML instance object names begin with the two-letter code EL to distinguish them from any other UML instance objects in the ISO/TC 211 harmonized model and to avoid any inadvertent clashes with names that can be generated in other documents. A detailed UML instance object by object description is only given in the example of agroforestry parkland (Clause B.2), because such a detailed description for some of the other examples would be too long and obscure the meaning of the example.

B.2 Base of example of agroforestry parkland

The base example considers a typical agroforestry system in Sub-Sahara Africa called “agroforestry parkland” (see Figure B.1). It is broadly defined as an area where scattered multipurpose trees occur in farmlands as result of farmer selection and protection. These parklands include a long-term cultivation.

Figure B.1 — A typical agroforestry parkland area in Sub-Sahara Africa

B.3 Example 1 — Pure Land Cover description of an agroforestry parkland

This example presents a pure Land Cover description of an agroforestry parkland system in accordance with ISO 19144-2. The model can be used to describe the sole physiognomic or structural aspect of the area (see Figure B.2). Two major elements are considered: “Trees” and “Herbs”. The information about these two elements, organized in different layers, is then enriched with a series of different types of attributes (defined in the model as properties and characteristics). For instance, the herbs are defined as cultivated, the crop type is Sorghum and the size of the fields are small. On the other hand, the trees are defined as broadleaved

deciduous, scattered (cover 5 % to 20 %), and floristic type "*Parkia biglobosa*". The information that can be derived from a satellite image and is reported in a normal Land Cover legend.

The model illustrated in Figure B.2 shows a UML instance object example of an agroforestry parkland class which makes use of only the LCML Land Cover metalanguage classes from ISO 19144-2.

The model shows that the two major elements are "Trees" and "Herbs" represented in two layers. The first layer is composed by the element "Tree". The second layer is composed of "Herbaceous Vegetation". A class characteristic of climate is a descriptor of the entire Parkland Agroforestry class. The class characteristic EL_Climate:LC_ClimateCharateristic describes the overall climatic conditions. Climate is a description of a climate system. At the metalanguage level this list is empty. The different methods of describing climate are user-defined. In this example there are two user-defined climate attributes: *climateType* and *thermalZone*.

There is one instance of EL_HorizontalPattern:LC_HorizontalPattern that has been built up with a layer of Herbaceous Vegetation and by a layer consisting of the element Tree.

The LC_HorizontalPattern object allows the ordering of LC_Stratum objects consisting of single or groupings of LC_Elements. The object LC_HorizontalPattern has three optional attributes: *patternType*, *patternCoveragePercentage* and *patternOccurrence*. In this example all of these optional attributes are not used.

The class EL_Stratum_1:LC_Stratum has the attribute *presenceType* = Fixed, meaning that the element is not a conditional relationship and the attribute *onTop* = Baseline, meaning that the element is with respect to the base level of the stratum, not on top of any other stratum. This is not shown in the example because these are the default values for the attributes. A stratum may be named and in this example the attribute *name* = tree.

EL_Stratum_1:LC_Stratum (tree) is composed of the LCML element EL_AgForestry:LC_Tree. The components of LC_Tree are instantiated as attributes. The leafPhenology relationship is handled as the attribute *leafPhenology* = deciduous and the leafType relationship is handled as the attribute *leafType* = broadleaved. The cover of the trees is a rather open layer (cover between 5 % to 20 %). The height is in the range of 5 m to 8 m. The characteristics EL_AgForestryVegetation:LC_NaturalOrSeminaturalVegetation and EL_AgFloristicName:LC_FloristicAspectsCharacteristic further refine the class EL_AgForestry:LC_Tree.

The metalanguage class LC_FloristicAspectsCharacteristic has the optional attribute *speciesName*. At the metalanguage level this list is empty, but it may be populated by the user. In this example the attribute *speciesName* = ParkiaBiglobosa.

EL_Stratum_2:LC_Stratum (herbaceous vegetation) is composed of the LCML element Herbaceous Vegetation. The attributes *presenceType* = Fixed, and *onTop* = Baseline are not shown in the model because they are the default values for these attributes. The attribute *name* = herbaceous vegetation.

The class EL_Stratum_2:LC_Stratum (herbaceous vegetation) is composed of the LCML element EL_AgForestry:LC_HerbaceousGrowthForm with the characteristics LC_CultivatedAndManagedVegeationCharacteristic, LC_FloristicAspectsCharacteristic, and LC_FieldSizeChracteristic. No subtypes are shown or attributes are expressed for the class characteristic EL_AgCultivatesManagedVegetation:LC_CultivatedAndManagedVegeationCharacteristic. The metalanguage class LC_FloristicAspectsCharacteristic has the optional attribute *speciesName*. At the metalanguage level this list is empty, but it may be populated by the user. In this example the attribute *speciesName* = Sorgum. The characteristic EL_AgFieldSize:LC_FieldSizeCharacteristic has the optional attribute *size*. The permitted values of the attribute *size* are described by the value object LC_PermittedPosRealRange.

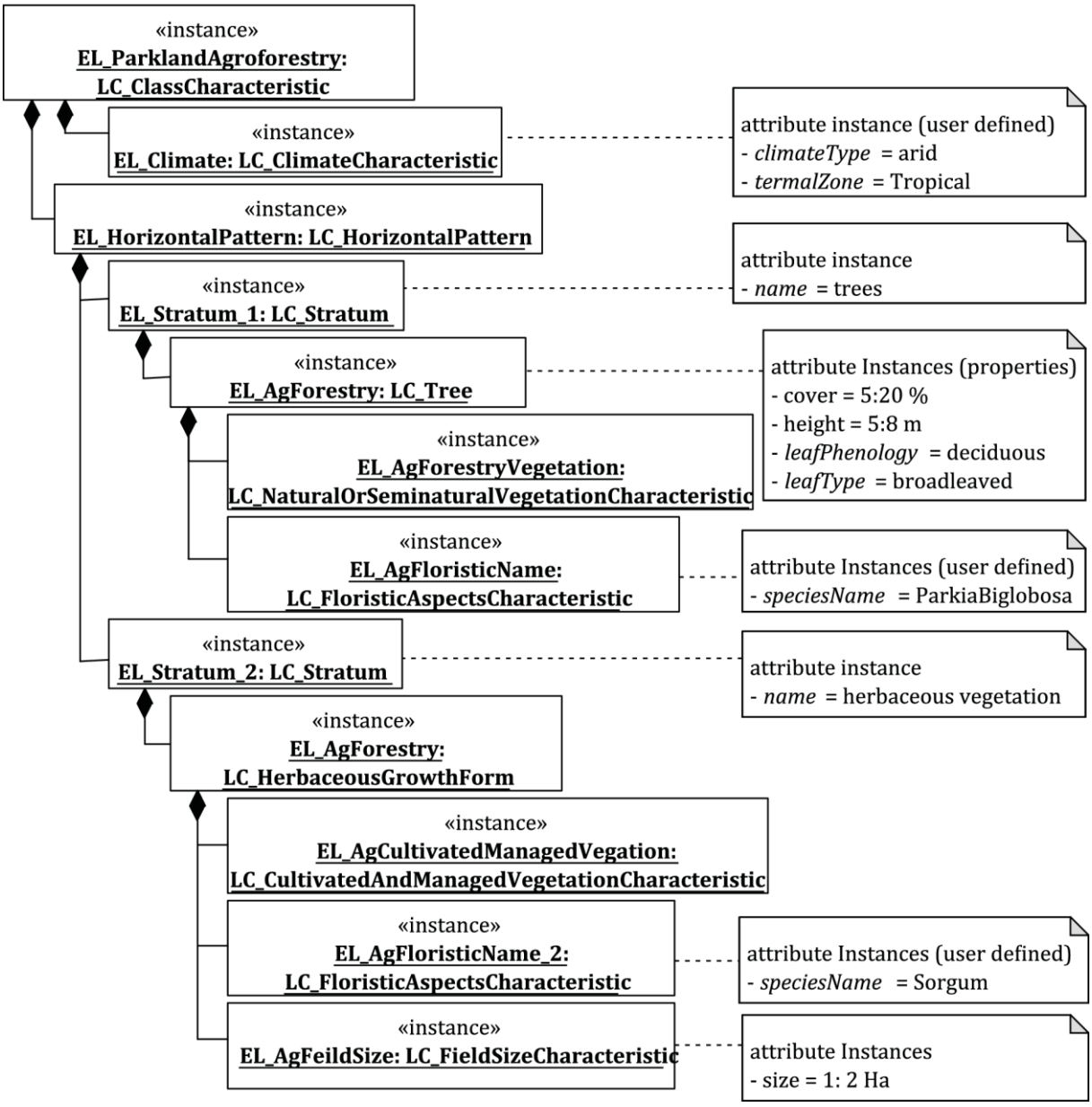

Figure B.2 — Example of an agroforestry parkland from a pure Land Cover point of view

B.4 Example 2 — Land Cover description of an agroforestry parkland system with additional Land Use information

This example presents a Land Cover description of a parkland agroforestry system (as described in Example 1, Clause B.3) with additional Land Use information. This is still Description Type 2 (7.7.3) but augmented by some Land Use information. The model allows the user to further improve the basic Land Cover information with a description of the Land Use purpose (LU_Function) of the land and the activities peoples are undertaking on it. In this case, the model still has the Land Cover component as its central structure but this main component is further enriched with specific Land Use attributes. In the example, the LU_Functions are simply attached as class characteristics to the class, while the LU_Activities are linked to the main physiognomic objects of the class (Trees and Herbs).

The model illustrated in Figure B.3 shows a description of an agroforestry parkland that makes use of the LCML Land Cover metalanguage classes augmented by Land Use functions and activities as characteristics. The description of the Land Cover classes is given in Example 1. The additional Land Use information is

described in this clause. Some of the details of the activities are user-defined for this example. Figure B.4 shows the details of the Land Use classes and associated attributes used to augment a Land Cover description of Parkland Agroforestry.

The class characteristic EL_LandUseFunctionsClassCharacteristic:LU_FunctionalElementArrangement describes the arrangement and combination of the Land Use functions and serves as a component of a LC_AugmentedLandCoverClassDescriptor as additional information that augmented the description. In this example there are two Land Use functions identified: LU_PlantAgriculture and LU_Forestry. EL_LandUseFunctionalElement_1:LU_Forestry refers to the practice of planting, managing and caring for areas with trees defined as forest. No attributes are expressed in this example to further refine the practice of forestry. The Land Use functional element EL_LandUseFunctionalElement_2:LU_PlantAgriculture refers to the growing of crops both in open fields and green houses. In this example there are three attributes: *exploitationTypes* = Subsistance, *intensityTypes* = LowIntensity (user defined value), and *scaleTypes* = SmallScale.

The element characteristic EL_LandUseFunctioalElementCharacteristic_1:LU_ForestManagementPractices describes the activity of forest management. In this example, there are two Land Use activities identified: pruning and pollarding. The operational handling is identified as "ManualMechanicalPruningTools".

The element characteristic EL_LandUseFunctioalElementCharacteristic_2:LU_CultivationWaterManagement describes the activity of cultivation water management. In this example there is one Land Use activity identified, indicating that the cultivation water management method is "rainfed" and that the duration is 100 %.

The element characteristic EL_LandUseFunctioalElementCharacteristic_3:LU_SoilPlantFertilization describes the activity of soil and plant fertilization practices. In this example, there is one Land Use activity identified: organic fertilization. The handling is described as “animalAndPlantManure” and the operational starting dates is “2 (year month)” and the duration is “10 to 20 days".

The element characteristic EL_LandUseFunctioalElementCharacteristic_4:LU_LandPreperationForCultivation describes the activity of preparation for cultivation. In this example, there are three Land Use activities identified: AnimalPloughing, HumanPloughing, and ManualSeeding. The handling is described as “WoodenAnimalPloughs” and “Hoe” and the operational starting dates are “5,6 (year month)” and the duration “1,3 days” and “3,5 days”. The operational order sequence is “1-2,3 days” and the operationalFunctionalRelationship is “AndOr 1,2”.

The element characteristic EL_LandUseFunctioalElementCharacteristic_5:LU_PlantHarvestingAndProcessing describes the activity of harvesting and processing.

In this example there is one Land Use activity identified: ManualHarvesting. The handling is described as Sikle and the operational starting dates are “9,10 (year month)” and the duration “2,5 days”.

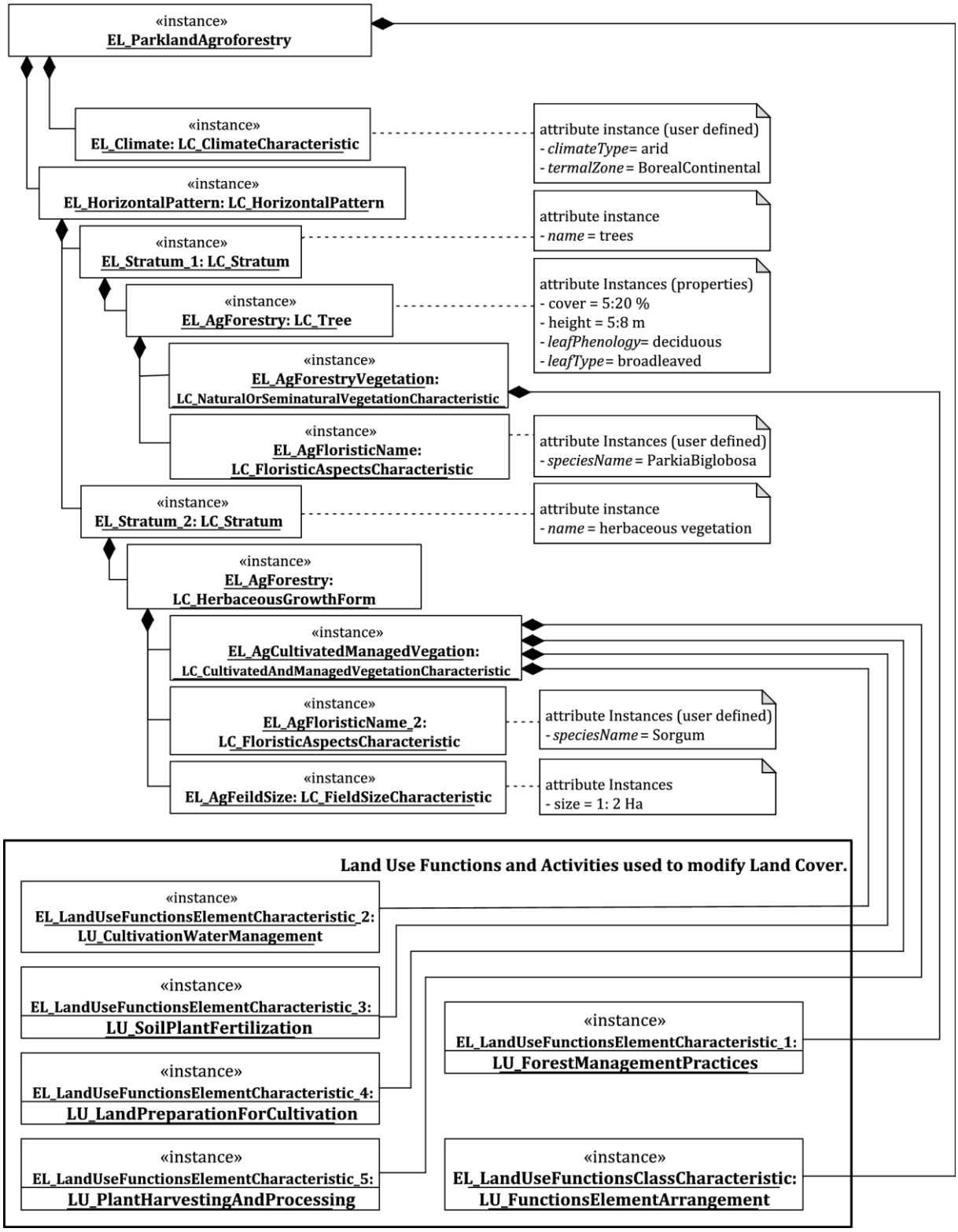

Figure B.3 — Example of an agroforestry parkland from the Land Cover point of view enriched with extra Land Use attributes

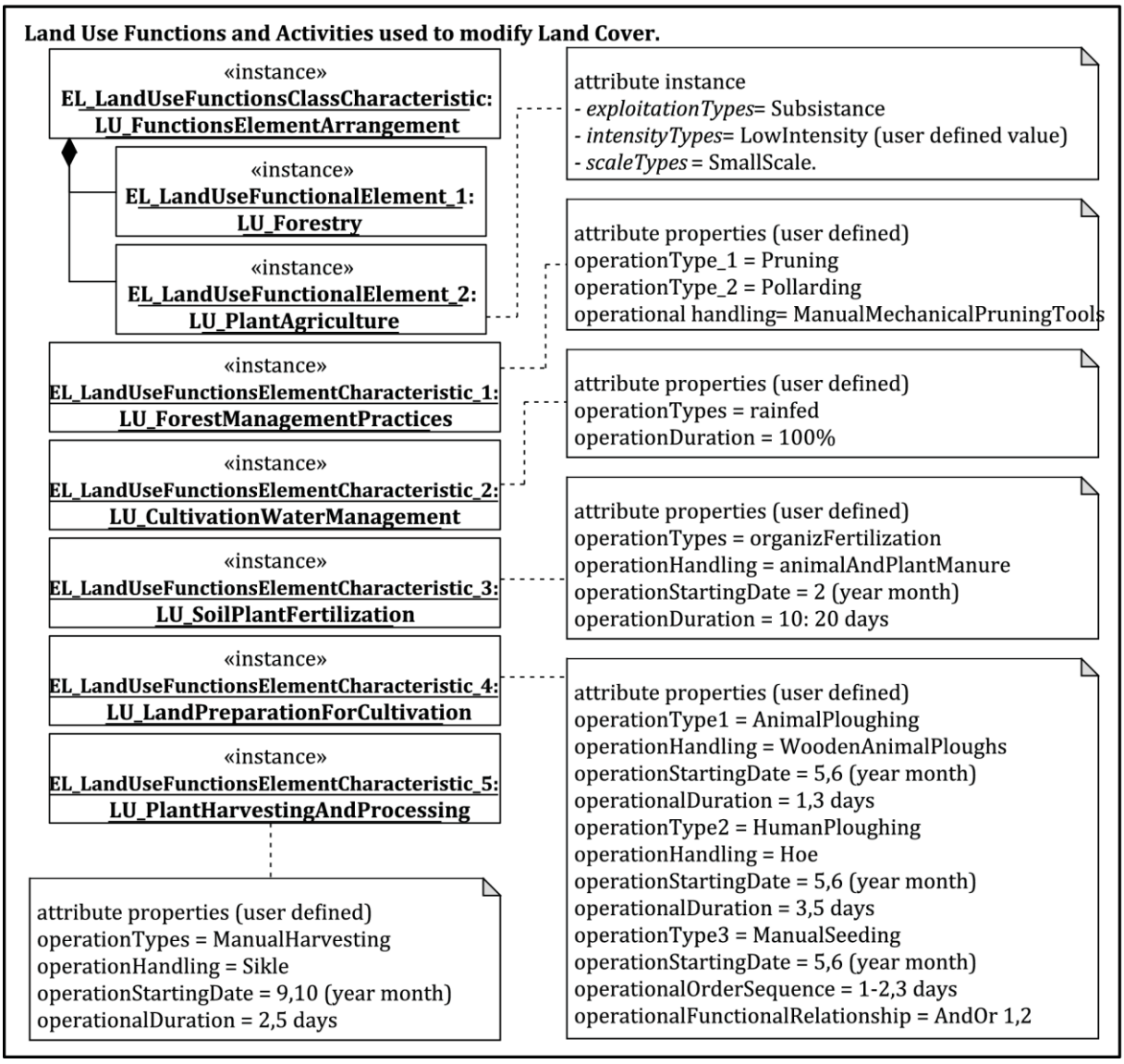

Figure B.4 — Land Use classes and associated attributed used to augment a Land Cover description of Parkland Agroforestry

B.5 Example 3 — Land Use description of an agroforestry parkland

This example illustrates a Land Use description of an agroforestry parkland. The model can be used to describe the area purely from the LU point of view, which means the description of the main purposes (LU Functions) that characterize this specific land and the different activities peoples are undertaking on it. Both "functions" and "activities" are further characterized within and between themselves with specific types of relationship.

The model illustrated in Figure B.5 shows an agroforestry parkland which makes use of only the LUML Land Use metalanguage classes. The model shows the two major functions which are "Forestry" and "Plant Agriculture" represented by two functional elements. LU_FunctionalElementArrangement describes the arrangement and combination of the Land Use functions and serves as a component of a LC_LandCoverClassDescriptor.

The Land Use functional element EL_LandUseFunctionalElement_1:LU_Forestry refers to the practice of planting, managing and caring for areas with trees defined as forest. No attributes are expressed in this example to further refine the practice of forestry.

The Land Use functional element EL_LandUseFunctionalElement_2:LU_PlantAgriculture refers to the growing of crops both in open fields and green houses. In this example there are three attributes: *exploitationTypes*, *intensityTypes* and *scaleTypes* = SmallScale.

LU_ActivitiesArrangement describes the arrangement and combination of the Land Use activities and serves as a component of an LC_LandCoverClassDescriptor through the LU_FunctionalElementsArrangement class. In this example, there are four Land Use activities related to the two Land Use functions: LU_ForestryManagementPractices, LU_CultivationWaterManagement, LU_SoilPlantFertilization and LU_PlantHarvestingAndProcessing.

The element EL_LandUseActivity_1:LU_ForestManagementPractices describes the activity of forest management. In this example there are two Land Use activities identified, pruning and pollarding, and the operational handling is identified as "ManualMechanicalPruningTools".

The element EL_LandUseActivity_2:LU_CultivationWaterManagement describes the activity of cultivation water management. In this example there is one Land Use activity identified, indicating that the cultivation water management method is "rainfed" and that the duration is 100 %.

The element EL_LandUseActivity_3:LU_SoilPlantFertilization describes the activity of soil and plant fertilization practices. In this example there is one Land Use activity identified, Organic Fertilization, and the handling is “animalAndPlantManure”, the operational starting date is “2 (year month)” and the duration “10 to 20 days".

The element EL_LandUseActivity_4:LU_LandPreperationForCultivation describes the activity of preparation for cultivation. In this example there are three Land Use activities identified: AnimalPloughing, HumanPloughing, and ManualSeeding. The handling is described as: “WoodenAnimalPloughs” and “Hoe”, the operational starting dates are “5,6 (year month)” and the duration “1,3 days” and “3,5 days”. The operational order sequence is “1-2,3 days” and the operationalFunctionalRelationship is “AndOr 1,2”.

The element EL_LandUseActivity_5:LU_PlantHarvestingAndProcessing describes the activity of harvesting and processing. In this example there is one Land Use activity identified, ManualHarvesting. The handling is described as Sikle and the operational starting dates are “9,10 (year month)” and the duration “2,5 days”.

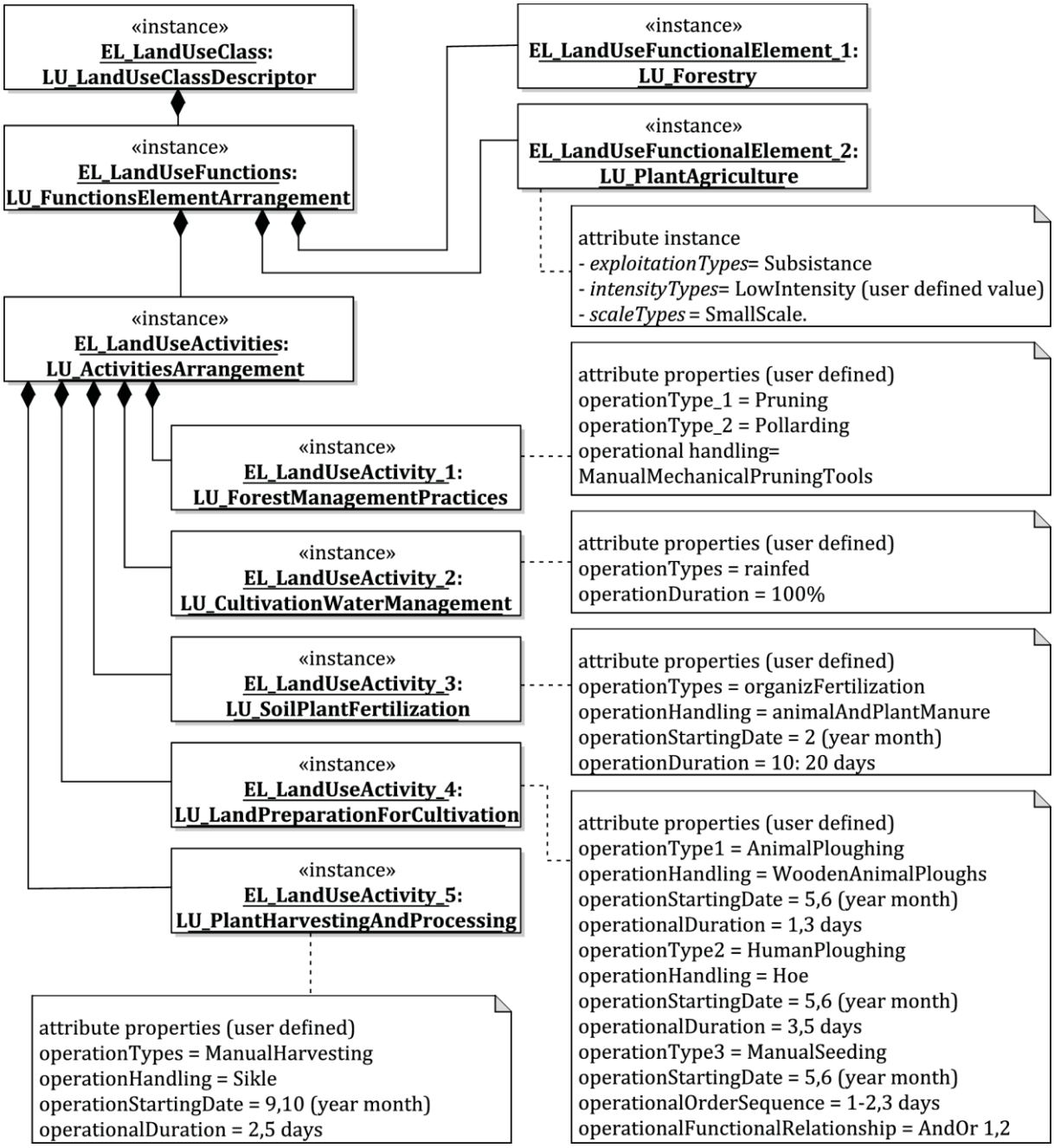

Figure B.5 — Example of an agroforestry parkland from the Land Use point of view

B.6 Example 4 — Land Use description of an agroforestry parkland area with additional information on basic Land Cover attributes

This example illustrates Land Use description of a parkland agroforestry area with additional information on basic Land Cover attributes. In this case, the model allows the user to further improve the LU description that is the main component of the model, with further information on the physiognomic or structural aspect of the natural objects (trees and herbs) present in the area. This LC information is attached to the Land Use class through a specific LC attribute element.

The model illustrated in Figure B.6 shows a description of an agroforestry parkland which makes use of the LUML Land Use metalanguage classes LU_Forestry and LU_PlantAgriculture, represented by two functional elements, augmented by two Land Cover classes, LC_AgTrees and LC_AgHerbacaeousVegetation, acting as characteristics. Figure B.7 shows the Land Cover classes and associated attributes used to augment the Land

Use classes which describe Parkland Agroforestry. The description of the Land Use elements is the same as in Example 3 (Clause B.5). The description of the Land Cover classes LC_AgTrees and LC_AgHerbacaeousVegetation and their representation in Strata_1 and Strata_2 are the same as in Example 1 (Clause B.3).

The class characteristic EL_LandCoverClassCharacteristic:LC_ClassCharacteristic augments the description of the base LU_AugmentedLandUseClassDescriptor with Land Cover information. In this example there are two Land Cover elements, “Trees” and “Herbaceous Growth Form”, represented in two strata.

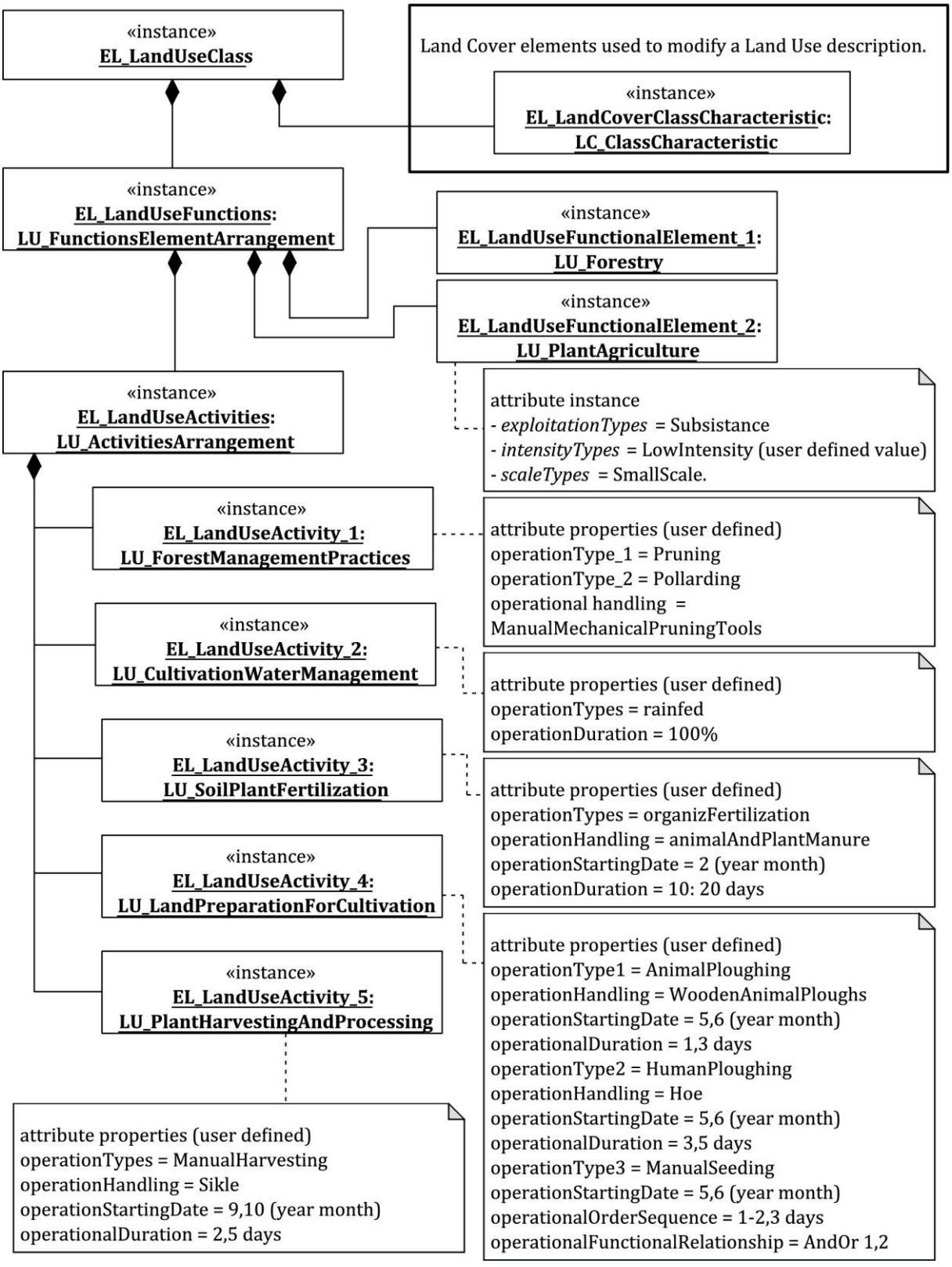

Figure B.6 — Example of an agroforestry parkland from the Land Use point of view enriched by Land Cover attributes

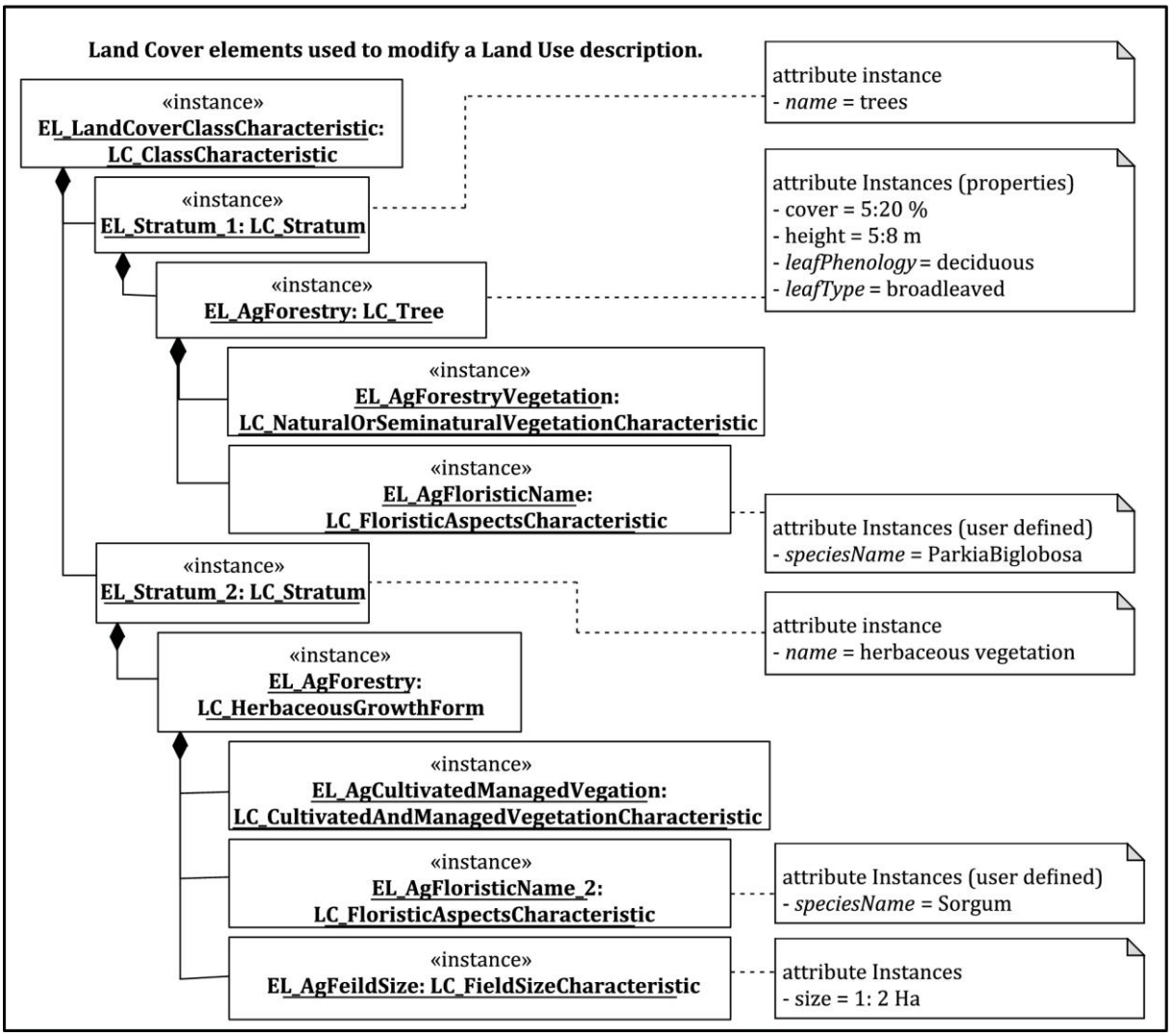

Figure B.7 — Land Cover classes and associated attributes used to augment the Land Use classes which describe Parkland Agroforestry

B.7 Example 5 — Comprehensive representation of the parkland agroforestry

This example illustrates comprehensive representation of the parkland agroforestry area. In this case both Land Cover and Land Use information are the main components of the model. The user can give a full description of the area using the physiognomic structural description of the basic objects (Land Cover description) and the purposes (functions) for which the land is used together with the activities which people are undertaking on it (Land Use description). All of these different Land Cover and Land Use elements are linked through specific model procedures that ensure a full efficient and functional relationship of them. This ensures the capability to describe a specific aspect of the land trying to model the complex and intricate relationship the different elements have between themselves.

This full characterization of agroforestry parkland, as illustrated in Figure B.8, makes use of the LUML Land Use metalanguage classes LU_Forestry and LU_PlantAgriculture represented by two functional elements together with two Land Cover classes, LC_Trees and LC_HerbacaeousVegetation. In addition, there is a class characteristic of LC_ClimateCharacteristic. Figure B.9 shows the details of the Land Cover classes and associated attributes and Figure B.10 shows the details of the Land Use classes and associated attributes.

The LU_LandCoverLandUseRelationship object is a collection class that describes the composition relationship of elements from the Land Use LU_FunctionsElementArrangement class and the Land Cover

classes arranged in a horizontal pattern from the LC_HorizontalPattern class. A horizontal pattern may be used for a complex Land Cover object composed by two or more distinct Land Cover features that will be handled as a "unicum". This class has three attributes: *functionalElementRelationship* (default primary), and optional *temporalRelationship* and *timeLength*, and two relations, a composition relationship with Land Use functional elements from LU_FunctionalRelationshipArrangement and a composition relationship with Land Cover elements from LC_HorizontalPattern. In this example these attributes are not shown because the default applies for the *functionalElementRelationship* attribute and the other attributes are optional.

The description of the Land Use elements is the same as in Example 3. The description of the Land Cover classes LC_AgTrees and LC_AgHerbacaeousVegetation and their representation in Strata_1 and Strata_2 are the same as in Example 1 (Clause B.3). A class characteristic of climate is a descriptor of the entire Parkland Agroforestry class. The description of the class characteristic EL_Climate is the same as in Example 1 (Clause B.3).

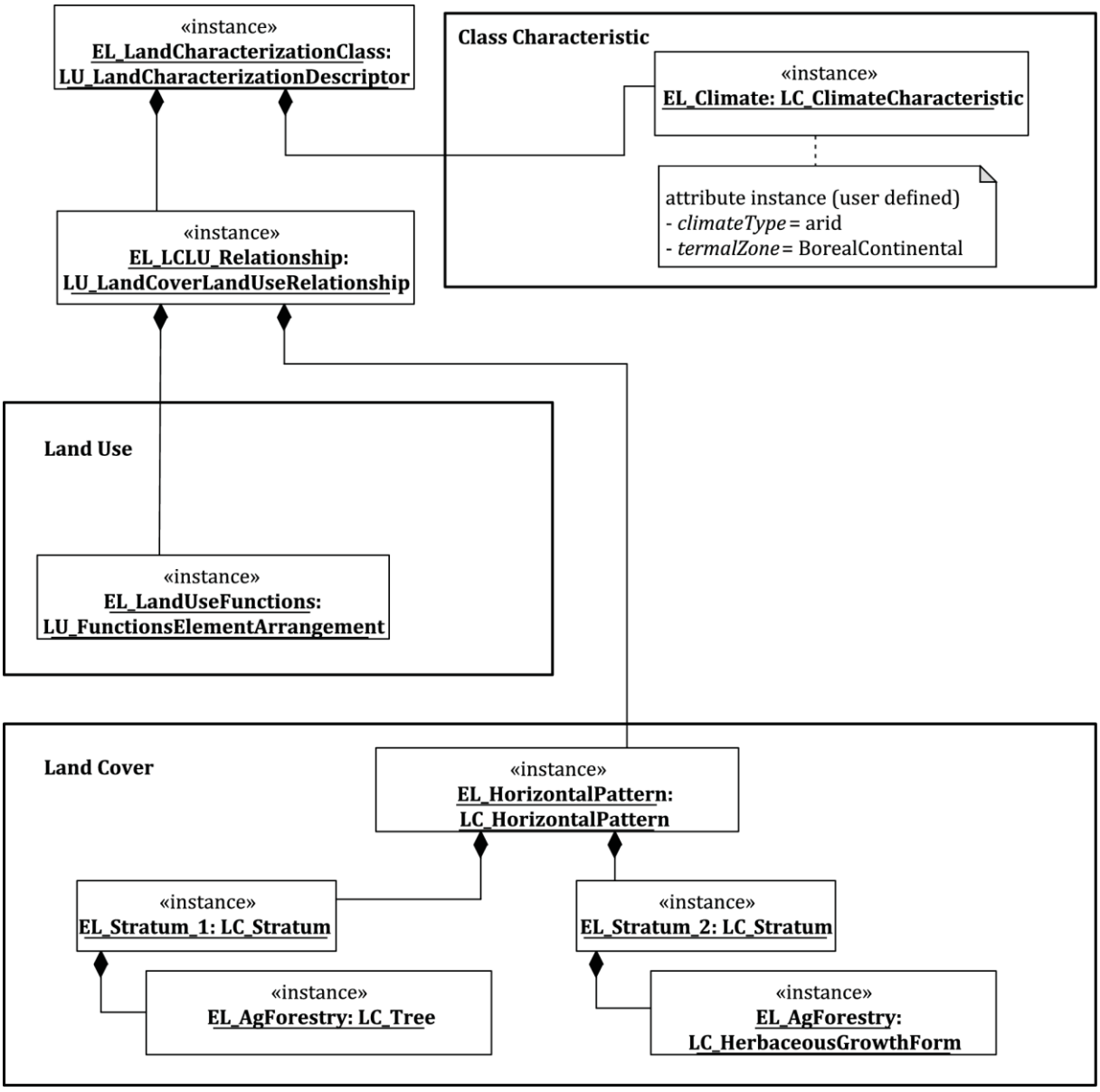

Figure B.8 — Example of an agroforestry parkland from both the Land Use and Land Cover point of view

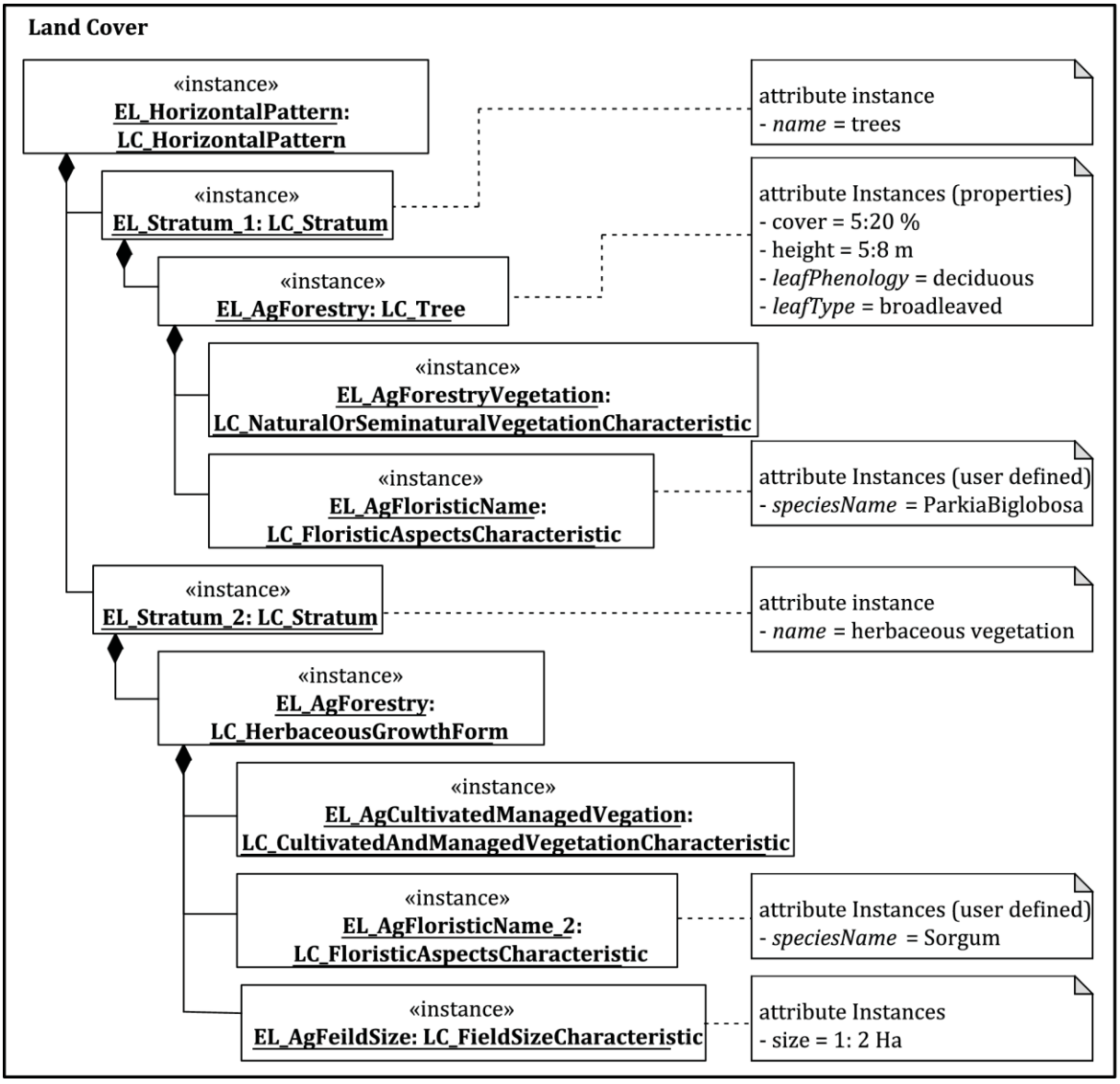

Figure B.9 — Land Cover classes and associated attributes used as part of a combined Land Cover Land Use description

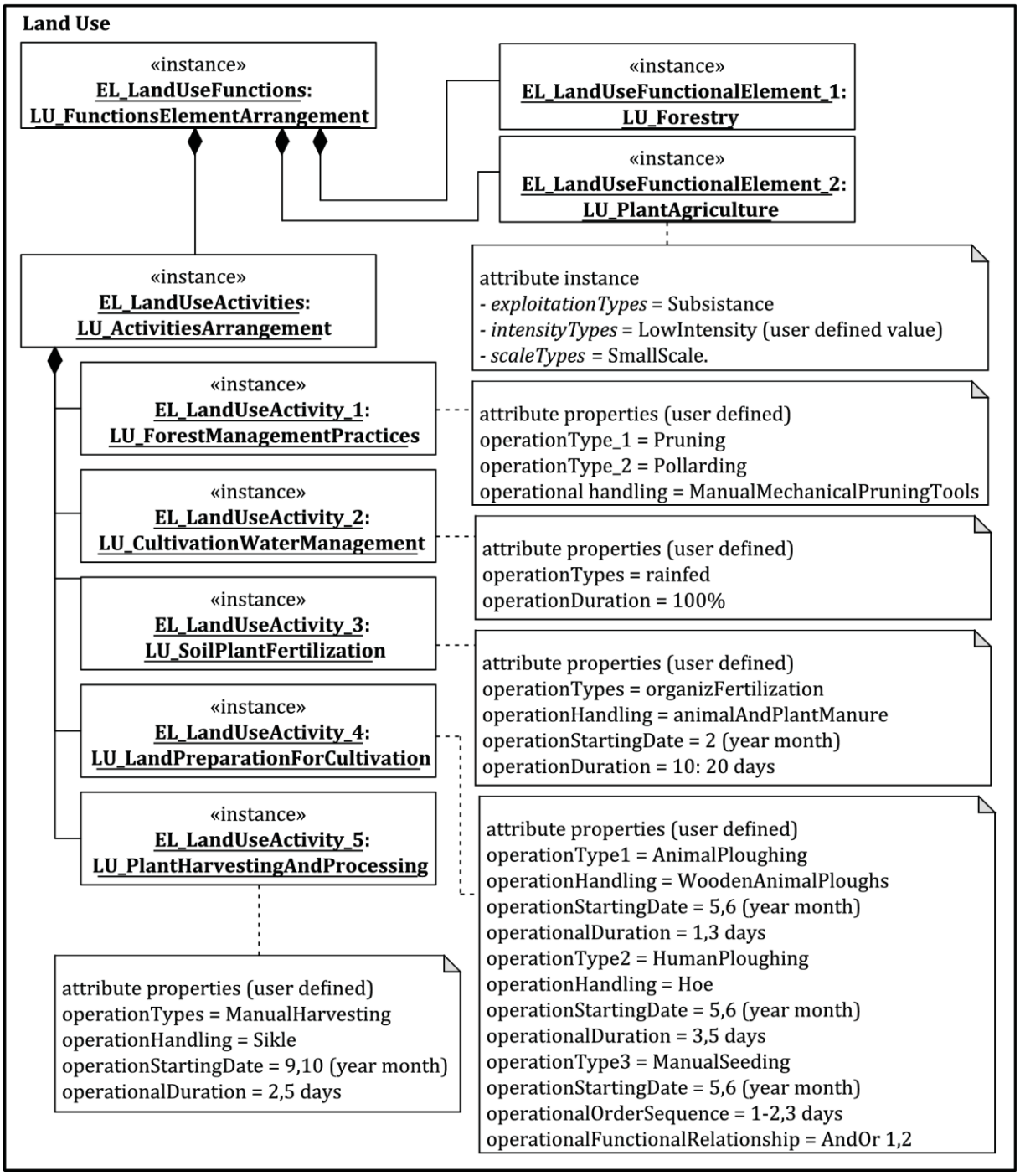

Figure B.10 — Land Use classes and associated attributes used as part of a combined Land Cover Land Use description

Annex C
(informative)

Backward compatibility

C.1 Revision of the ISO 19144 series on classification systems

This document is a new part of the ISO 19144 series on classification systems. However, the previous editions of the standards in the series have been reorganized and some material has been moved from ISO 19144-2:2012 to this new document, ISO/TS 19144-3. This annex presents an overview of the overall changes that have been made to the ISO 19144 series and in particular the information moved from the previous edition of ISO 19144-2 to this document. Complementary information related to the changes that have occurred in ISO 19144-2 are documented in ISO 19144-2:2023, Annex E.

In order to be able to aggregate and fuse data from multiple sources that have been collected using different collection criteria and structured in different manners, there is a need to establish a high-level metalanguage addressing both Land Cover and Land Use in order to describe such data and determine the common elements. Stability of this metalanguage is important. All changes that have been made to the ISO 19144 series have been fully backward compatible.

ISO 19144-1 was first published in 2009 and ISO 19144-2 was first published in 2012. In 2018, based on a systematic review, a (Stage 0) Preliminary study was undertaken to "study the integration of specific Land Cover classifications with ISO 19144-2 and how to address Land Use classifications". A Review Summary report was submitted to TC211 in 2019 which recommended a revision of ISO 19144-2 and the development of two new documents, one (ISO/TS 19144-3, this document) on a Land Use Meta Language, and another (ISO 19144-4) on Registration and implementation aspects.

As a result of the Review Summary report, revisions were made to ISO 19144-2, all of which are backward compatible. Material on registration has been moved and is intended to appear in the new International Standard in the ISO 19144 series on Registration and Implementation Aspects. Material related to Land Use has been moved to this document.

C.2 Movement of Land Use elements

C.2.1 General

There were a number of Land Use elements described in ISO 19144-2:2012. These have been moved and placed in this document, ISO/TS 19144-3. The following are the elements that have been moved. These elements remain the same, but they shall now be referenced through a different path. Some of the code lists have been generalized, and are therefore left for registration.

C.2.2 LU subtype of LC_GrowthFormCharacteristic and associated code lists

C.2.2.1 LC_GrowthFormCharacteristic

Moved to this document:

— LC_TreeAreaManagementPractices and converted to LU_ForestManagementPractices

— LC_Grazing and converted to be a part of LU_AnimalFeeding

— LC_Mowing and converted to be a part of LU_PlantHarvestingAndProcessing

The characteristics LC_Grazing and LC_Mowing have been changed to LC_GrazedCharacteristic and LC_MowedCharacteristic in ISO 19144-2 to make it clear that only the Land Cover effects of mowing and grazing are considered as Land Cover. The activities themselves are considered as Land Use.

C.2.2.2 LC_Associated code lists

Moved to this document:

— LC_TreeAreaManagementPracticesType: a list of tree management practice types has been left for future development and registration.

— LC_GrazingAnimalType: a list of grazing types as part of general animal feeding has been left for future development and registration.

C.2.3 LU subtype of LC_CultivatedAndManagedVegetation and associated code lists

C.2.3.1 LC_CultivatedAndManagedVegetation

Moved to this document:

— LC_PestControl

— LC_CropFertilization and converted to LU_SoilPlantFertilization

— LC_Ploughing and converted to LU_LandPreparationForCultivation

C.2.3.2 LC_Associated code lists

Moved to this document:

— LC_PestControlType: a list of pest control types has been left for future development and registration.

— LC_CropFertilizationType: a list of types of crop fertilization types has been left for future development and registration.

— LC_PloughingType:a list of ploughing types has been left for future development and registration.

C.2.4 LC_BuiltUpSurface classes related to Land Use

The LC_BuiltUpSurface class was simplified in ISO 19144-2 to remove the subtypes of LC_Road, LC_Railway, LC_CommunicationAndOther. These can be described as a linear surface (LC_LinearSurface) and a Land Cover description given through a new attribute, *LC_LinearSurfaceType*. A Land Use description can be given through the ISO/TS 19144-3 Land Use Meta Language.

C.3 Registration

The use of registration to define and extend code lists was originally specified in ISO 19144-2:2012. This flexibility also occurs in this document. However, the methodology of registration has been moved to the future document ISO 19144-4 (see 10.3).

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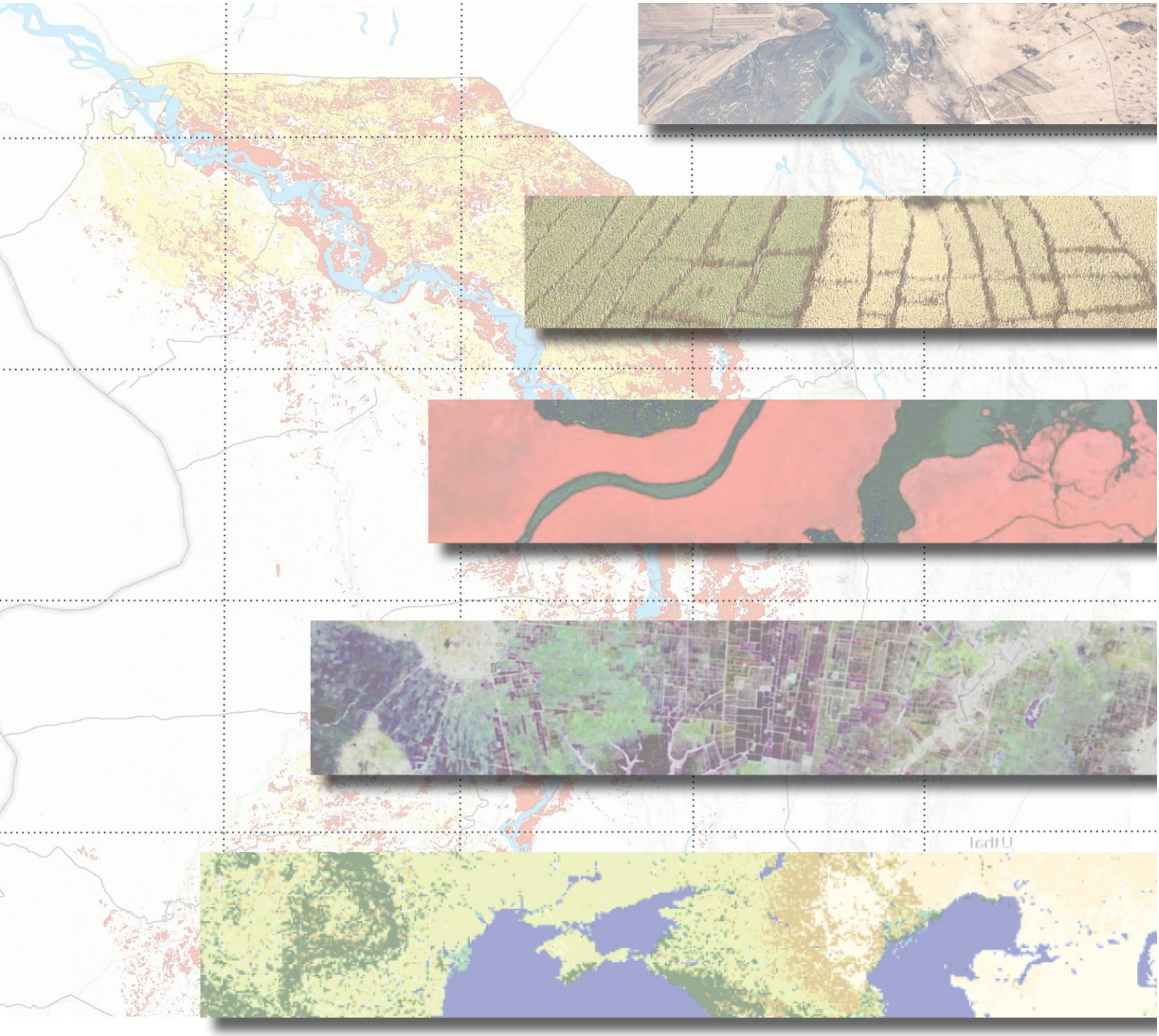
Geographic information – Classification systems: Land Use Meta Language (LUML)

Part 3: ISO 19144-3:2024 (Edition 1)



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