



BSI Standards Publication

Geographic information — Classification systems

Part 3: Land Use Meta Language (LUML)

National foreword

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A list of organizations represented on this committee can be obtained on request to its committee manager.

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English Version

**Geographic information - Classification systems - Part 3:
Land Use Meta Language (LUML) (ISO/TS 19144-3:2024)**

Information géographique - Systèmes de classification -
Partie 3: Métalangage d'affectation des sols (LUML)
(ISO/TS 19144-3:2024)

Geoinformationen - Klassifizierungssysteme - Teil 3:
Land Use Meta Language (LUML) (ISO/TS 19144-
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European foreword

This document (CEN ISO/TS 19144-3:2024) has been prepared by Technical Committee ISO/TC 211 "Geographic information/Geomatics" in collaboration with Technical Committee CEN/TC 287 "Geographic Information" the secretariat of which is held by BSI.

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Endorsement notice

The text of ISO/TS 19144-3:2024 has been approved by CEN as CEN ISO/TS 19144-3:2024 without any modification.

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO document should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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This document was prepared by Technical Committee ISO/TC 211, *Geographic information/Geomatics*, in collaboration with the European Committee for Standardization (CEN) Technical Committee CEN/TC 287, *Geographic Information*, in accordance with the Agreement on technical cooperation between ISO and CEN (Vienna Agreement), and in collaboration with the Food and Agriculture Organization of the United Nations (UN FAO).

A list of all parts in the ISO 19144 series can be found on the ISO website.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

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](#).

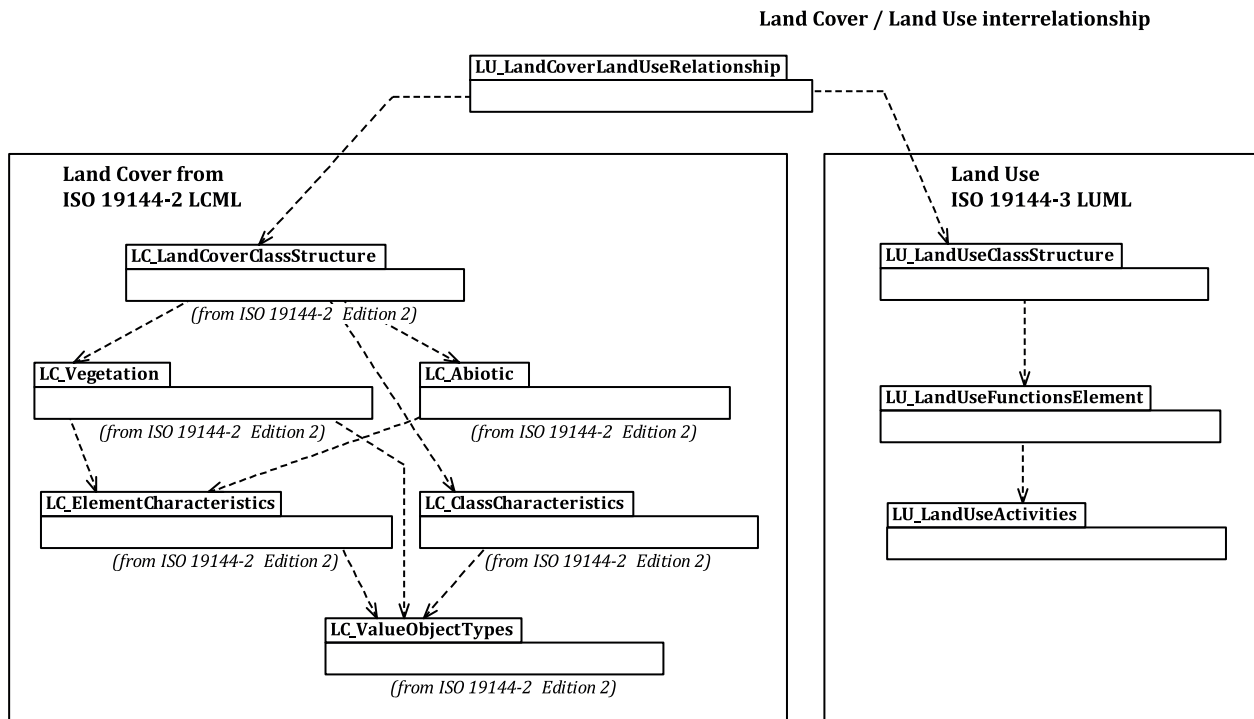


Figure 1 — LUML packages

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.

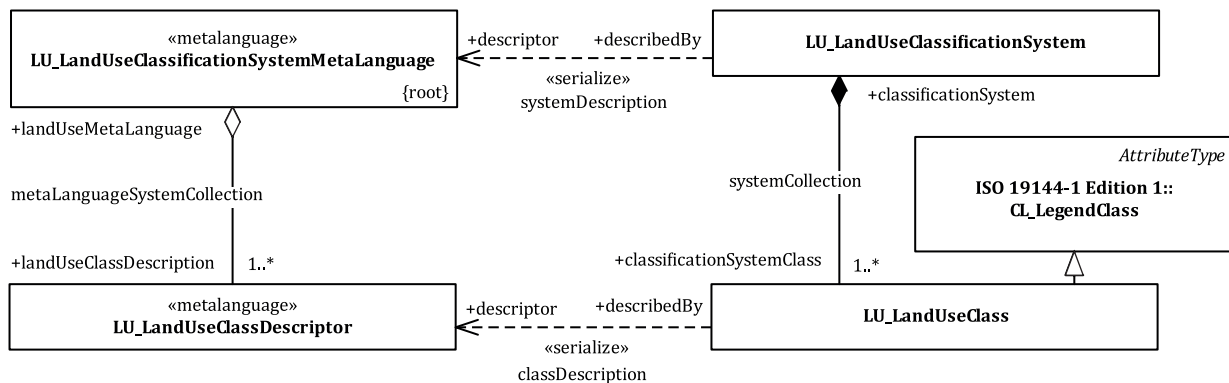


Figure 2 — High level structure of the Land Use Classification Model

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.

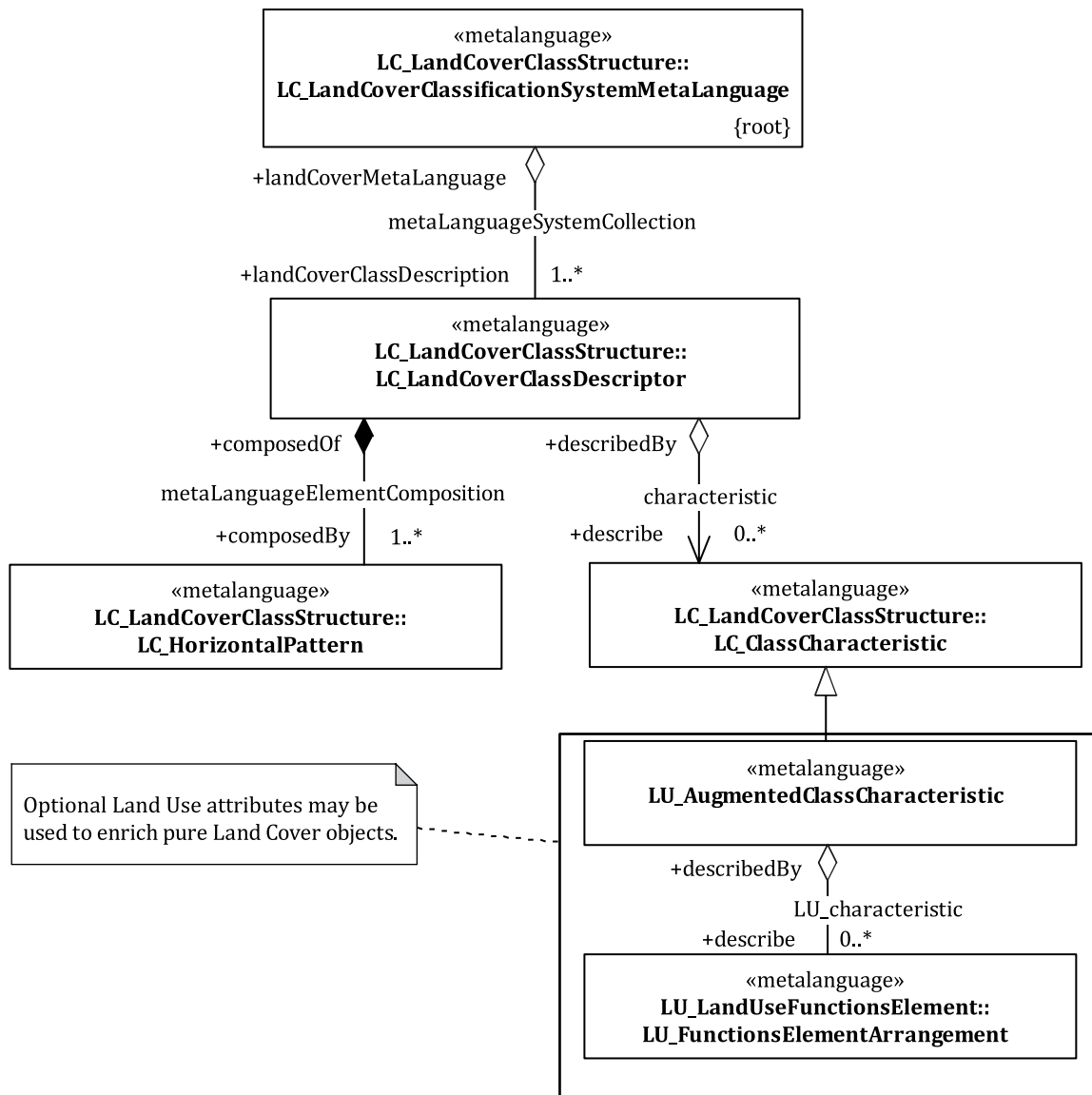


Figure 3 — High level structure of the Land Cover and Augmented Land Cover, Description Type 1

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](#).

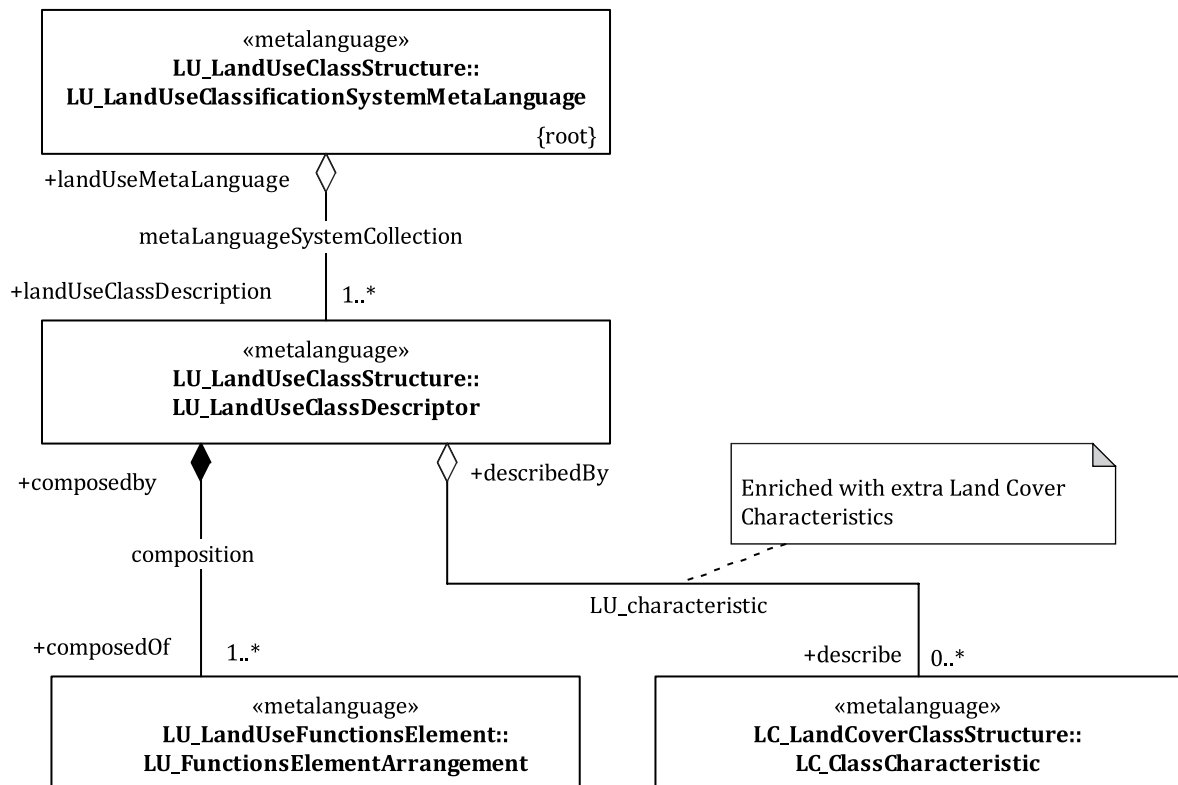


Figure 4 — High level structure of Land Use and Augmented Land Use, Description Type 2

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 used 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*.

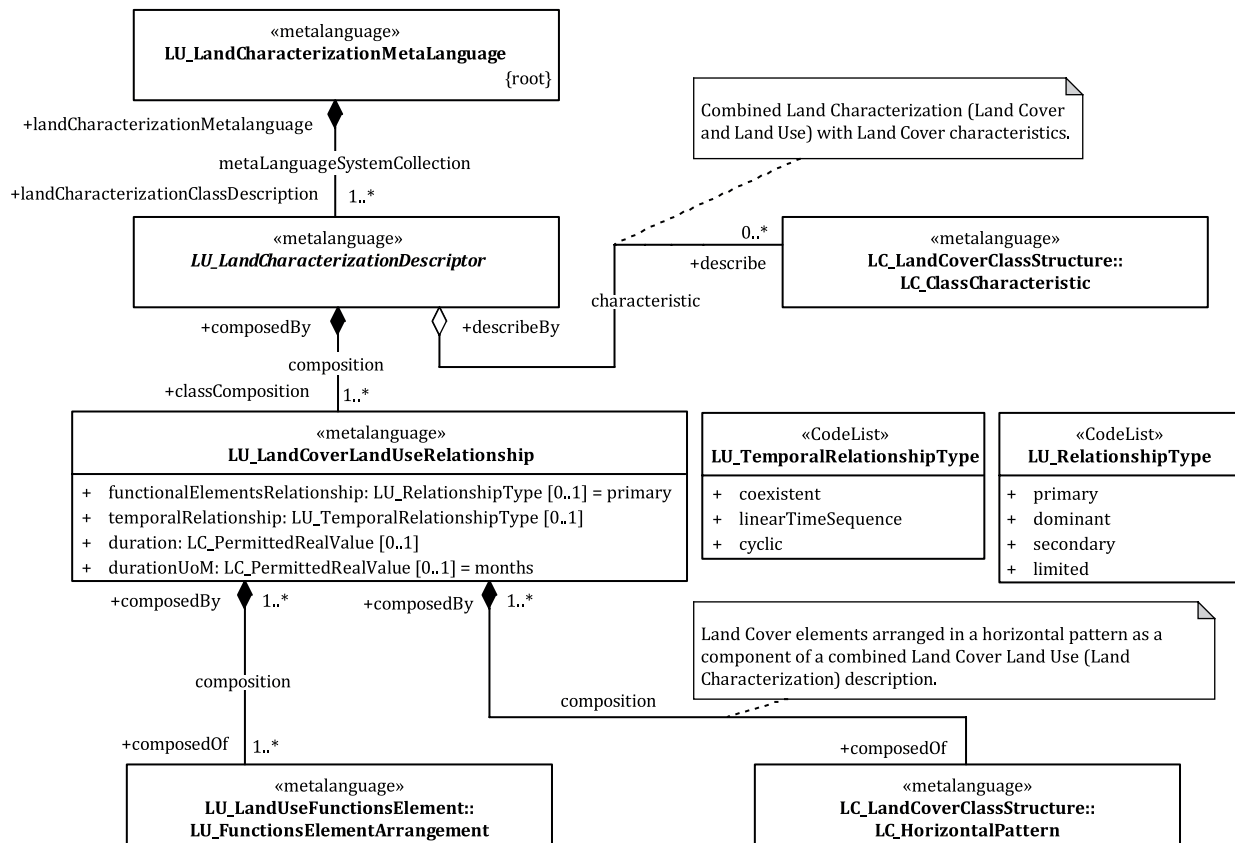


Figure 5 — Combined Land Cover and Land Use, Description Type 3

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:

- coexistent — 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 Land Use 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`.

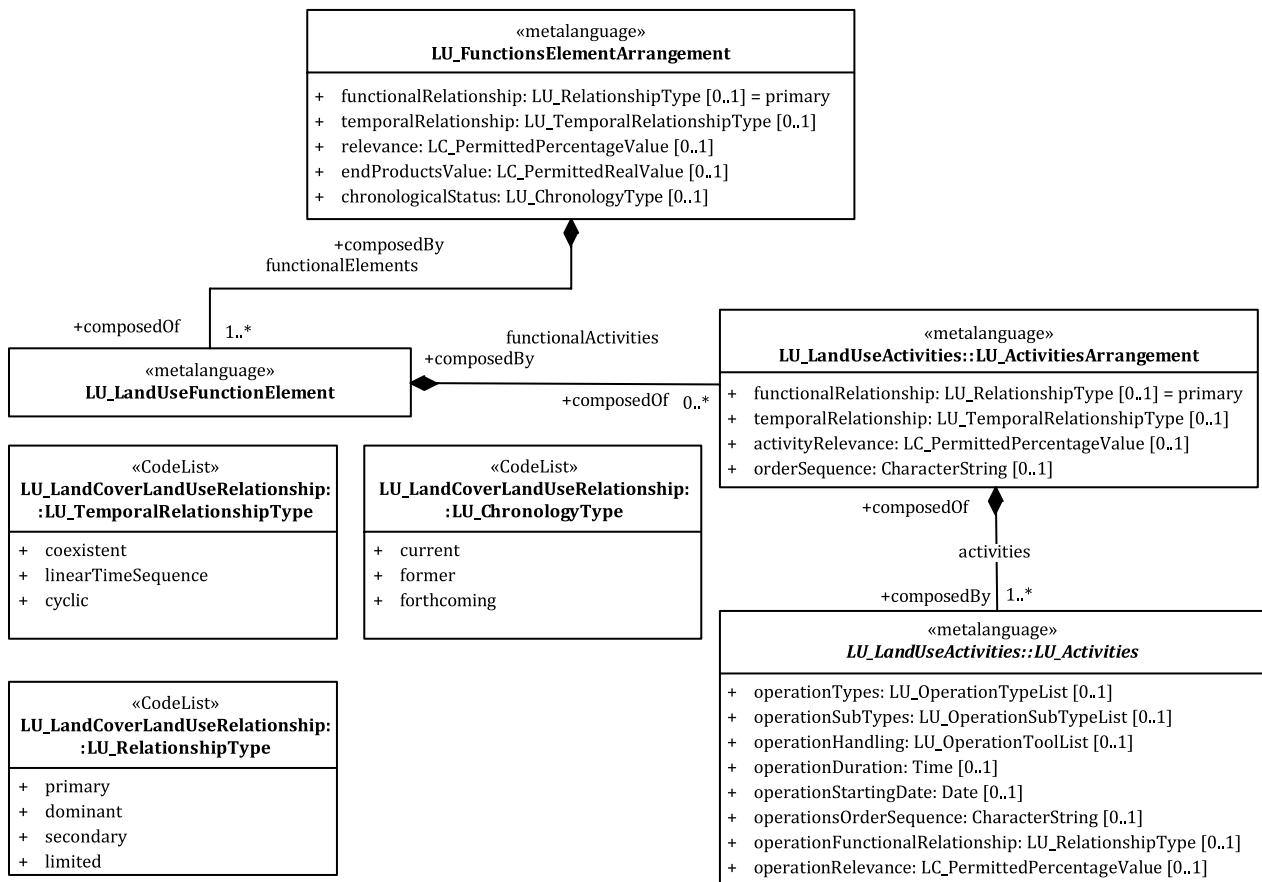


Figure 6 — Functions element arrangement

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.